Community Built Environment and Multilevel Social Determinants of Obesity in China

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Abstract

Social determinants of obesity and effects of the community built environment remain poorly understood in developing nations. We synthesized literature on socio-economic (SES) gradients and income inequality effects on health and analyzed data from China Health and Nutrition Survey (N=9,586) to understand how multilevel social determinants of obesity varied by built environments assessed by fast food restaurants and sports facilities. We found that at the individual-level, obesity was positively associated with income and wealth but negatively associated with education and manual occupation. At the community-level, obesity was negatively associated with income inequality in north regions. SES effects on obesity varied across built environmental contexts; inequality effects on obesity remained significant and consistently negative across contexts. All these social determinants effects were pronounced in communities with the presence of fast food but absence of sports facilities. SES and inequality effects on obesity in China are different from those in developed countries.

Introduction

Obesity, a health condition characterized by excessive amount of body weight, is a risk factor for major chronic diseases including cardiovascular disease and cancer. The global obesity epidemic (WHO 2010) has brought about alarming health care and economic burdens worldwide, not merely in developed countries but also in developing countries such as China, Mexico, and Thailand, where obese rates rival those in high-income nations (Popkin 2004) and continue to rise. Despite recent scholarly and policy attention on diagnosis, treatment and prevention of obesity within social contexts, differencing multilevel social determinants of obesity in the developing countries remains a challenge, largely due to limited conceptual frameworks and available data. Further, despite growing attention on the relationship between the built environment and neighborhood-based obesity prevention and current knowledge of biological, behavioral social and environmental risk factors of obesity, little is known in developing countries about how the built environment influences obesity and their social determinants.

In this paper, we draw from major conceptual frameworks studying social determinants of health and focus on how multilevel socioeconomic status (SES) and income inequality independently and jointly influence obesity among adults in China, the world's largest and most populace country. Using the China Health and Nutrition Survey data (CHNS) and the China General Social Survey (CGSS) data, we identify and evaluate multilevel social determinants in China, including individual and community SES, geographic and urban/rural disparities, and regional income inequality that may put people at risk, and further study how obesity rates and their social determinants vary by different built environment contexts. Our multilevel study provides a case study on the patterns of SES and inequality effects on obesity in China, with its distinct social-economic contexts and its on-going nutrition transition, and discusses how they differ from those observed in Western societies and other developing countries.

Background and Aims

The impact of the built environment on obesity

The built environment, a term relative to the natural environment, has long been of interest to population health studies, including mental health (Weich et al. 2002), mortality (Pope et al. 2002), and obesity (Morland, Wing, Diez Roux, and Poole 2002). Pathways that the built environment could influence health included “the direct pathological impacts of various chemical, physical, and biologic agents” as well as “factors in the broad physical and social environment, which include housing, urban development, land use, transportation, industry, and agriculture” (CDC 2010).

A majority of epidemiological evidence supports that the built environment affects risk of obesity through individual-level physical activity and diet (Feng et al. 2010). Contemporary built environments in the Western nations tend to increase the risk of obesity (Papas et al. 2007) largely due to decreased physical activity and increased unhealthy diets related with the built environment. The direction of association between the built environment and obesity depends on the type of built environment. For example, in New York City, BMI was significantly associated with the built environment after adjusting for SES (Rundle et al. 2007). An Atlanta-based study found that more walkable environment may result in higher levels of physical activity and lower obesity prevalence (Frank et al. 2007). Urban sprawl is positively associated with overweight and obesity among US adults (Lopez et al. 2000; Ewing et al. 2008).

The burden of the built environment on obesity has been more detrimental for lower SES groups and minority populations (Cummins and Macintyre 2006). Similarly, communities with higher proportions of minority races were associated with less physical activity facilities (Powell et al. 2004). Health disparities associated with the built environment may be interpreted by a "deprivation amplification" process: individual disadvantages arising from exposure to poorer quality environment were amplified and detrimental to health (Macintyre and Ellaway 2003; Macintyre 2007). A number of studies have supported this "deprivation amplification" argument: in more deprived neighborhoods, environmental disadvantages, such as lack of access to nutritious, affordable food are compounded by individual disadvantages associated with poor health outcomes (Chung and Myers 1999; Morland, Wing, Diez Roux, and Poole 2002).

Although studies on the built environment in developed countries have generally shown that highly available local fast food is positively related to obesity, and that local sports facilities promote physical activity and hence are associated with lower obesity prevalence, little is known how the community built environment is associated with adult obesity and its social determinants in China.

Theoretical Perspectives

Social scientists study health disparities with distinct theoretical frameworks that originated from two major research traditions. One tradition examines the relationship between SES and health (Antonovsky 1967; Faris 1965; Link et al. 1998); the key question is whether higher SES positions should lead to better health outcomes. Research of this strand has reported mixed findings on socioeconomic disparities in health at the individual level. The second tradition, proliferated by Wilkinson and colleagues' work, focuses on income inequality effects on population health (Wilkinson 1996, 1997; Wilkinson and Pickett 2006) , uses aggregate-level or multilevel data, and generates mixed findings on the impact of the income distribution (measured by indices, e.g. the Gini coefficient) and population health (e.g. life expectancy and mortality) or individual-level health outcomes. The two traditions view the mechanism that social factors are related to health through distinctive perspectives: The first claims that poorer SES lead to poor health, hence disadvantaged SES is to blame. The second emphasizes an independent, detrimental effect of income inequality on health after adjusting for individual income, possibly through pathways including defragmented human and social capital, social cohesion and socio-psychological mechanisms. Hence, reducing income inequality is necessary for elevating population health in industrialized societies. Derived from the two traditions are three competing hypotheses on income-health associations: the absolute income hypothesis, the relative income hypothesis, and the income inequality hypothesis (Wagstaff and van Doorslaer 2000). The absolute income hypothesis suggests that health improves with the increase of the absolute individual income, and population health improves as the average income in society increases. The relative income hypothesis argues that one's income relative to his reference group, rather than absolute material standards, is positively related to health. The income inequality hypothesis proposes that population health is negatively associated with ecological income inequality; therefore, the less unequal a society is, the better the population health will be. Although the two conceptual frameworks and related income hypotheses are widely seen in health literature, few have incorporated them spontaneously in a single study of health outcomes (for an exception, see Li and Zhu

2006) and to the best of our knowledge, none have examined social determinants of obesity in a developing country bringing together both conceptual frameworks.

SES and Obesity among Adults

Many studies reported an inverse SES-obesity association in Western societies. Sobal and Stunkard (1989) and McLaren (2007) summerized 144 and 333 published studies, respectively, and suggested a higher obesity prevalence in low income, less educated and minority population of Western countries. A systematic review on obesity in the U.S. reported that obesity among low-SES groups increased between 1990 and 2006 (Wang and Beydoun 2007). Roskam et al. (2010) observed inverse educational gradients of overweight and obesity in many European countries, implying potential effect of ecological socio-economic development on the strength and direction of these associations. In addition, ecological GDP was inversely associated with BMI among European adults (Peytremann-Bridevaux et al. 2007). Explanations of mechanism largely attribute to these factors: individual-level healthy lifestyle behaviors (such as diet, smoking, alcohol intake, physical exercises), psychological characteristics (such as depression and stress) (Adler et al. 1994) and social support (Kawachi and Berkman 2001; Steinbach 1992) that favor high SES groups in health outcomes. However, related mechanisms could vary by life courses and across generations, as well as by social and economic context (House, Kessler, and Herzog 1990; Link and Phelan 1995), causing the relationship between SES and obesity in Western societies being specific to different dimensions of SES conditions and the period variations (Chang and Christakis 2005; Mokdad et al. 2001; Robert and Reither 2004; Schoenborn et al. 2004). For example, the inverse SES-obesity association is less consistent among men than women, and over time, an inverse SES-obesity association is weakened among the high-SES individuals from 1971 to 2000 (Zhang and Wang 2004), and in recent years1999-2008 (Flegal, Carroll, Ogden, and Curtin 2010).

By contrast, research on non-Western countries suggests a positive SES-obesity association, exactly opposite to what was observed in Western societies (McLaren 2007; Sobal and Stunkard 1989). From less developed to more developed countries, the SES-obesity association turns from positive to negative (Mokdad et al. 2003). Likewise, as the country's gross national product (GNP) increased, the burden of obesity shifted from higher SES towards lower SES groups, according to a systematic review of adult obesity in developing countries (Monteiro, Moura, Conde, and Popkin 2004). Recently, new evidence reported shifting burdens of obesity from urban to rural areas, from the wealthy to the poor. For example, low-income Brazilian women were significantly more susceptible to obesity than high-income Brazilian women in the recent decade (Monteiro, Conde, and Popkin 2007). However, the underlying mechanisms of SES and obesity in developing countries are not readily available.

Inequality and Obesity among Adults

Although adult SES is commonly addressed in obesity disparity research, cross-national comparison studies have shown that the income inequality is a contextual factor independently associated with obesity, although the strength of the association may vary in different societies. In Europe, Picket and colleagues (2005) reported a positive correlation between income inequality and waist circumstances in both genders in a study of 17 European Union countries and Australia, Canada, Japan, and the U.S. This association was independent of average calorie intake. A study based on 31 member countries in the Organization for Economic Co-operation and Development (OECD) reported a positive correlation between income inequality and obesity (Su et al. 2012). Evidence from within-country comparisons remains mixed. Robert and Reither (2004) showed that the U.S. community income inequality had an independent positive association with BMI. However, the HUNT study in Norway reported a very small effect of income inequality on BMI; only 1% of the unexplained variance on neighborhood and municipality levels (Sund et al. 2010).

In developing countries, the literature of income inequality effect on obesity is inclusive. A multilevel study in India reported an increased risk of overweight of 9% by each standard deviation increase in state income inequality (Subramanian, Kawachi, and Smith 2007). In a study of seniors in China, Ling (2009) found income inequality was positively associated with waistline, negatively associated with overweight, but not associated with obesity. However, Chen and Meltzer (2008) observed a significant and positive association between the community income inequality and obesity in rural China. Building on inconclusive findings, our study intends to go beyond the literature by testing simultaneously the three income-health hypotheses on adult obesity in China.

General Limitations in the current literature

The consistency and robustness of effects of SES and income inequality on health outcomes continue to generate controversies. By controlling for different covariates and confounding factors, these social determinant effects could be weakened and even eliminated, and are specific to cohorts and periods (Fiscella and Franks 1997). In addition, most studies only used single level data, but either the aggregate-level or the individual-level study had methodological limitations, hence multilevel studies becomes more desirable (Lynch et al. 2004; Wagstaff and van Doorslaer 2000). To date, such multilevel studies are yet to be conducted in developing countries. Piece-wise evidence from Argentina (Fernando 2008), China (Chen et al. 2010; Li and Zhu 2006) and India (Subramanian et al. 2007) are inconsistent and different from those in Western societies. No published study has spontaneously addressed the three income hypotheses on obesity issues in developing societies or explained obesity differentials at multilevel. Further, the multi-dimensionality of SES is not well addressed in empirical investigations of obesity. Our study stems from these literature gaps by examining the three income-related hypotheses on the relation between SES gradient, income inequality and obesity in China.

China: the Study Setting

National survey showed that China's combined rates of overweight and obesity increased from 14.6 to 21.8% between 1992 and 2002 (Zhao et al. 2008), showing an alarming increase quite comparable to the U.S. Obesity prevalence in China was observed in all age and gender groups nationwide (Wang et al. 2007).

Among developing countries, China's unique social context offers a fertile ground for studying social determinants of obesity. Over the past four decades, China has experienced profound social and economic developments, including institutional market economy transition (Bian and Logan 1996; Nee 1989), a per capita GDP of $ 3,744 (World Bank 2009), the massive urbanization and population migration (Chen 2006; He and Pooler 2002; Kasarda and Crenshaw 1991; Shaoquan et al. 2004; Zhao 1999), deep regional development disparities and a Gini coefficient over 4.0 (Human Development Report 2006), and the westernization of lifestyle (high fat/caloric intake dietary patterns and sedentary lifestyles) that resulted in multiple health concerns (Cockram et al. 1993;

Miao et al. 2008; Popkin 1999). However, quite limited investigations have been conducted into patterns social determinants of obesity in China, and few have been published in the English literature that discusses the patterns in the context of relevant studies based on data from other developing or developed countries.

Compared with China's 5,000-year-old culinary tradition, fast food from Western-style outlets is young, yet it has brought about a significant expansion of chain restaurants and profoundly changed the food market in China (Miu and Leung 1994). Because fast food in China is a relatively new phenomenon, research on the association between access to fast food and obesity in the Chinese population is limited.

Our specific objectives are: (1) to examine the multilevel social determinants of obesity in China; (2) to examine the association between the built environment assessed by community fast food and sports environment as measured by presence or absence of fast food restaurants and sports facilities; (3) to examine whether effects of social determinants of obesity are amplified by access to (or lack of) different local built environment contexts, and (4) to examine whether effects of social determinants of obesity vary by different local built environment contexts in China.

Hypotheses

Hypothesis 1 *(the education hypothesis):* Chinese adults with higher educational attainment are less likely to be obese.

This hypothesis is developed from the inverse SES-obesity association found in developed countries and some transitional developing world. As Sobal (1989) and McLauren (2007) reported, in developed countries and developing countries in transition, higher educational attainment was related to lower risk of obesity. This could be a result that health literacy translates into healthy behaviors for a healthy weight (Sobal 1991). However, education-obesity association is mixed in lower-middle-income developing economies (Monteiro, Moura, Conde, and Popkin 2004), and is mostly positive in the developing world. Since China is a medium-income developing country in the economic and nutritional transition, we make the inverse education-obesity hypothesis such that people with higher educational attainment have more resources for a healthy lifestyle which prevents them from being obese.

Hypothesis 2 *(the occupation hypothesis):* Chinese adults in manual occupations are less likely to be obese.

Very few studies have examined the relationship between occupation and obesity outcome. Occupation may affect obesity outcome by the intensity of physical activity required by job characteristics (Ng, Norton, and Popkin 2009). Manual workers have more intense physical activity than any other occupation types, but the association between occupation and obesity remains unresolved.

Hypothesis 3 *(the absolute income hypothesis):* Chinese adults with more income and household wealth are more likely to be obese.

A positive SES-obesity association prevails the non-Western world. Evidence from Cebu, Philippines suggested household income was positively associated with childhood and early adulthood weight status (Schmeer 2010). However, mixed patterns of the income-obesity association still exist, due to the complex effect of income on diet quantity and quality (Du et al. 2004). In general, we hypothesize a positive income/wealth-obesity association independent of other factors.

Hypothesis 4 *(the relative income hypothesis*): Chinese adults with a higher relative income are more likely to be obese.

There is no ready relative income hypothesis on obesity, so we derive one from the relative income hypothesis on health, controlling for the absolute income (Wagstaff and van Doorslaer 2000). Studies from Western societies debated about whether a low relative income in comparison to one's reference group may cause poor health (Kawachi and Kennedy 1999; Marmot 2005; Mellor and Milyo 2002; Subramanian and Kawachi 2004; Wilkinson and Pickett 2006). A few studies of the relative deprivation effect in China found minimal relative deprivation effects on one's self-reported health (Li and Zhu 2006). According to literature, we make this relative income hypothesis.

Hypotheses 1 – 4 focus on individual-level factors that affect obesity. However, contextual determinants may have independent effects. The most important macro-social contextual factors include income inequality (at the national, state or community level) and community characteristics such as community SES or deprivation. We then make the following hypotheses:

Hypothesis 5 *(the community SES hypothesis):* After adjusting for individual-level SES, Chinese adults living in a more deprived community are less likely to be obese.

Community SES, or individuals' socioeconomic composition, is the most commonly investigated neighborhood characteristics in social research (Bird et al. 2010; Diez Roux 2001; Fotso and Kuate-Defo 2005). Deprived communities are characterized by under-investment in the social and physical infrastructure; literature shows that living in communities with a low socioeconomic profile negatively affects health-promoting attitudes and behaviors (Robert 1999). Mechanisms include short-term influences on behaviors, attitudes, and health-care utilization, or a longer-term process of "weathering" (Ellen et al. 2001). Similarly, community SES may affect one's exposure to obesity risk factors, such that living in a more deprived neighborhood is associated with a higher probability of being obese in the U.S. (Robert and Reither 2004), Sweden (Sundquist et al. 1999), other factors being equal. Assuming that during China's nutrition transition, residents of a more deprived community have less exposure to Western diets and sedentary lifestyles, we suggest an opposite association compared with the developed world.

Hypothesis 6 *(the income inequality hypothesis):* After adjusting for individual-level SES, relative income and community-level SES, Chinese adults living in a more unequal area are more likely to be obese.

The argument that inequality is destructive to population health (Wilkinson et al. 1992, 1996, and 2006) has generated heated debates. This association is attributed to the psychosocial impact of inequality such as stress, which leads to deteriorating health and increased mortality over time (Pickett et al. 2005). Similar findings of the positive inequality-BMI association at macro levels are reported in the U.S. (Robert and Reither 2004) and India (Subramanian, Kawachi, and Smith 2007). How income inequality in China is a whether regional disparities of obesity in China is attributable to independent inequality effects remains unknown. As similar studies in China are rare, we propose the income inequality hypothesis on obesity consistently with the mainstream literature based on the psychosocial-health mechanism. In addition, since evidence has shown that obesity prevalence is the highest in Beijing and Bohai coastal regions, followed by northern regions of China, and the lowest in southern regions (Zhuo et al. 2009), we further tested the effect modification of regions on the association between inequality and obesity by testing the interaction between inequality and region.

Hypothesis 7 *(cross-level interaction hypothesis)*: Income inequality influences risk of obesity less for Chinese adults with higher income or higher educational attainment, other factors being equal.

Income inequality effects on health were stronger among people with lower SES (Subramanian and Kawachi 2006). To better assess the income inequality-obesity relationships, cross-level interaction terms between individual income/education and the Gini coefficient are tested. Therefore, we propose Hypotheses 7 for the cross-level interaction between income inequality and individual SES based on the widely observed detrimental health effects of income inequality for the low income adults in society (Lynch et al. 2004; Wilkinson and Pickett 2006). Very few studies have ever examined the cross-level interaction between income inequality and education on obesity outcome. Based on the literature of stronger detrimental income inequality effects on health for lower SES groups, we propose a weaker effect of income inequality on obesity among the more educated adults in China.

Hypothesis 8 (the fast food environment hypothesis): Chinese adults with access to fast food restaurants are more likely to be obese, other factors being equal.

This hypothesis is generated based on the literature that access to fast food is linked with increased risk of being obesity. Portion size, calories and fat of fast food are well-known reasons that fast food is an unhealthy diet; hence frequent consumption of fast food may increase the risk of obesity. In addition, according to the studies of both adults (Zhang, van der Lans, and Dagevos 2011) and adolescents in China (Li, Dibley, and Yan 2011; Ma et al. 2004), the association between higher BMI and fast food access has been observed.

Hypothesis 9 (the sports environment hypothesis): Chinese adults with access to sports facilities in the local environment are less likely to be obese.

This hypothesis is generated upon the common observation that one's access to sports facilities increases physical activity, which in turn contributes to a lower risk of developing obesity. These sports facilities include gyms, parks, and playgrounds. This inverse association between sports environment has been observed among children (Wolch et al. 2011), adolescents (Li, Dibley, and Yan 2011), and adults (Jones and O'Beney 2004; Li et al. 2011). Although corresponding research in China has been very limited, we hypothesize the inverse association between the local sports environment based on the previous studies.

Hypothesis 10 (the environment- SES hypothesis): The associations between individual SES / community SES and risk of obesity are stronger in the local built environment with presence of fast food and absence of sports facilities than in other built environment contexts.

The presence of fast food and absence of sports facilities is, according to the literature reviewed, the most disadvantaged scenario for a healthy body weight. In addition to examining the main association between the built environment and obesity, we study the associations in the stratified setting in order to understand the associations between individual/community SES and obesity within different built environment contexts and whether the built environment amplifies advantages/disadvantages of SES effects in relation to body weight status, as described by the "deprivation amplification" process (Macintyre and Ellaway 2003; Macintyre 2007) observed in health literature.

Hypothesis 11 (the environment- the income inequality hypothesis): The association between income inequality and risk of obesity is stronger in the local built environment with presence of fast food and absence of sports facilities than in other built environment contexts.

This hypothesis is a further investigation of the income inequality hypothesis in different contexts. Wilkinson's work, representing a major health research tradition, examined the detrimental health outcome attributable to high income inequality, and found that rich people's health suffered from a high income inequality as well (Wiklinson 1992, 1996, 1997, 1999, 2006, 2007, 2009). As reported in the Western countries, the waistband is wider where income inequality is higher (Pickett et al. 2005; Robert and Reither 2004; Su, Esqueda, Li, and Pagan 2012). We hypothesize that the association between income inequality and obesity risk is stronger in the least healthy context with presence of fast food and absence of sports facilities.

Data and Methods

Data

The primary source of data was drawn from the 2006 wave of CHNS, including the individual- and community-level data with a response rate of 88%. CHNS is an ongoing longitudinal survey collaborated between the Carolina Population Center and the National Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention. The data set records demographic, social and economic and health information and is a valuable data source for studying nutrition and health issues in contemporary China. Its study population was drawn from a multistage, random cluster sample surveyed in nine provinces of regional and developmental disparities: Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong. Within each province, counties were stratified by income (low, middle and high); four counties were selected randomly including a provincial capital and lower-income cities. Villages and townships in the counties and urban and suburban neighborhoods in the cities were selected randomly. An urban community is a neighborhood committee (*Ju Wei Hui*), with a mean population slightly over 3,000, and a rural community is a village (*Zi Ran Cun*) with a mean population of slightly less than 3,800 (Chen and Meltzer 2008). In each community, 20 households were randomly selected and all household members were interviewed. There were no sampling weights in CHNS data (Popkin et al. 2009).

The 2006 CHNS was linked to the 2006 China's General Social Survey (CGSS) where the macro-level inequality data were calculated from. The CGSS, an on-going national survey of China's households starting from 2003 (rural China only), monitors the social structure and quality of life in urban and rural areas and are available in 2003 2005, 2006 and 2008. CGSS's sampling methods and participants varied from year to year. The data covered a representative sample of adult Chinese citizens of all of the 9 provinces in CHNS. Our analysis was based on 9,586 adults from CNHS.

Measures

Information on participants' socio-demographic characteristics and body weight was obtained by standardized self-administered questionnaires. The primary outcome variable is being obese based the WHO definition for Asian and Pacific adults (WHO, IASO, and IOTF 2000); it is a binary with "BMI $\geq$ 25 kg/m^2" coded as "1," and otherwise coded as “0”. The individual-level socio-demographic characteristics were assessed by age in years, gender, marital status (“1” as married, “0” otherwise), formal education (low, intermediate and high), occupation (professional, service and manual workers), equivalized household net income (derived from net household income), household wealth index (based on wealth and asset question), the relative income[1], smoking history, and alcohol consumption history. Our preliminary analysis shown that obesity was not clustered within households, so we did not treat the household level as a separate level in the analysis. The community-level exposure and covariates include community SES as assessed by mean income and education, urbanicity index score as an indicator for urbanization, and whether the community is rural or urban. As obesity in China seems to be more clustered in north regions (Zhao, 2009), we generated a region variable to control for regional effects on obesity: “north” regions included provinces of Heilongjiang, Liaoning, Henan and Shandong and “south” regions included provinces of Jiangsu, Hunan, Hubei, Guangxi, and Guizhou. The Gini coefficient is calculated at the provincial level, consistent with the recommendation in current literature that the scale of unequal income distribution should be assessed in a society rather than merely a community level. For example, Wilkinson and Pickett (2006) strongly argued for states as proper geographic units for testing the income inequality hypothesis rather than

[1] There are no set standards about what constitutes the relevant reference group of individuals. The community/neighborhood in CHNS makes a plausible reference group to study the relative income effects on obesity, because community constituted a good reference group based on the presumption that the relevant reference group consists of individuals living in the same area (Miller and Paxon 2000, Fiscella and Franks 1997, Daly et al. 1998, Gerdtham 2004). We derived four most commonly used types of relative income measures in literature, namely Yitzhaki’s Relative Deprivation of the absolute income (RDA)(Yitzhaki 1979);Deaton’s Relative Deprivation Index (RDI)(Deaton 2001);Log Difference Relative Deprivation and Income Rank(Li and Zhu 2006) and compared them in all analysis. Different measures of the relative income do not change the effects of the relative income on obesity outcome and do not influence the other variables in the model. Therefore, we present the results with RDI as the relative income measure.

communities. The local fast food environment is a dichotomous variable indicating the presence or absence of any fast food restaurants in community (yes=1, no=0). We created a dummy variable of local recreational and sports environment with "1" representing "any of the gym, park or playground is available within community," and "0" representing "none of these facilities are available within community." Hence we have four community context for understanding the obsogenic environment. In order to bring both fast food environment and local recreational environment together, we further define the four types of local obsogenic environment: presence of both fast food and sports environment (Presence-Presence); presence of fast food but absence of sports environment (Presence-Absence); absence of fast food but presence of sports environment (Absence-Presence), and absence of both fast food and sports environment (Absence-Absence). The measures are described in Table 1.

--- Table 1 about here ---

Multilevel Models

In the preliminary analysis, we use collinearity diagnostics to test the potential multicollinearity. We calculate bivariate correlations among variables, the absolute values of correlations ranged from 0.00 to 0.64, which is good evidence suggesting sufficient independent variance to estimate stable effects (Wolch et al. 2011). We also check the variance inflation factors (VIF) and examine detailed variance proportions of condition indexes. All diagnostics results indicate that multicollinearity is not a problem in this study.

Multilevel modeling provides a robust framework to analyze the clustered nature of the outcome; it is pertinent with predictor variables measured simultaneously at different levels (Goldstein 1995). In this paper, we use multilevel logistic regression to estimate associations between ecological and individual-level social determinants and obesity. We examined obesity and BMI separately as outcome variables in random intercept models; since the patterns of results were similar, we reported only the results from the obesity analysis.

Our basic form of multilevel logistic regression model with P level-1 explanatory variables $x_1, x_2 \cdots, x_p$ and Q level-2 explanatory variables $z_1, z_2 \cdots, z_q$ for obesity has the following form:

$$\text{logit}\left(Y_{ij}\right) = \text{logit}\left(\frac{p_{ij}}{1\text{-}p_{ij}}\right) = \gamma_{00} + \sum_{p=1}^{P} \gamma_{p0}\, x_{pij} + \sum_{q=1}^{Q} \gamma_{q0}\, z_{qj}$$

where Y_{ij} is the binary outcome of obesity for individual i living in community j, p_{ij} is the probability of being obese for individual i living in community j; i =1 to 9,586, j =1 to 218. γ_{00} is the grand mean. This equation uses two sets of independent variables, x_{pij} and z_{qj}, measured at the individual- and the area-level, respectively. The regression parameters γ_{p0} and γ_{q0} (p=1, 2, 3, …P; q=0, 1, 2, 3..Q) estimate the differentials in the log odds in the obesity outcome for the individual- and aggregate-level variables.

We first present descriptive statistics on the individual-level socio-demographic characteristics, SES and contextual characteristics of the sample, and with an overview of obesity disparities by SES and regions in China. We then test hypotheses simultaneously at area- and individual- level, and examine bivariate and multivariate associations between obesity and social determinants as assessed by various indicators of SES, the relative income, and income inequality. By comparing coefficients from bivariate models with the corresponding ones in multivariate models, we can detect differentials of the effects of SES indicators, relative income and the income inequality. Altogether eight random intercept multilevel models were fitted. With the best model, we proceeded to test Hypothesis 8 and 9 by investigating the main effects of the local built environment on obesity, and then test Hypothesis 10 to 12 by examining the differences in the associations between obesity and social determinants across the local built environment contexts.

Stratified Models

When stratified, those individual and community level variables may have varying effects on across contexts. The likelihood ratio test (LRT) is a useful and flexible way to test the equality of GLM and logit coefficients across multiple social groups (Liao 2002; Liao 2004). Hence we use the LRT to test differences between the four contexts with all coefficients considered altogether.

To conduct the stratified analysis, we have four stratified models on the four contexts, i.e. from Absence-Absence to Presence-Presence. All the models have the same parameters as the overall model, and the subsample in each stratum adds up to the total sample in the overall model. According to Liao (2002), the null hypothesis for testing parameter equality among *G* (where *g* running from 1 to *G*) multiple groups is that the parameters are equal across the *G* groups, namely:

$$H_0\colon\ \beta_1 = \beta_2 = \cdots = \beta_G$$

The alternative hypothesis H_a is that at least one such equality does not hold. The LRT statistic for testing parameter equality among *G* (where *g* running from 1 to *G*) multiple groups is

$$LRT = -2\mathcal{L}(\hat{\beta}) - \sum_{g=1}^{G}\left[-2\mathcal{L}\left(\widehat{\beta_g}\right)\right] \qquad \sim\chi^2$$

where $-2\mathcal{L}(\hat{\beta})$ is the -2log-likelihood function for the overall model, and $-2\mathcal{L}(\widehat{\beta_g})$ is the -2log-likelihood function for an sub-model in a stratum. Hence the test of equality between parameters is based on the difference between the -2log-likelihood function for the overall model and the sum of the -2log-likelihood function for each stratum. The LRT calculated is χ^2 distributed, because the sum or difference) of two (or more) χ^2 distributions follows a χ^2 distribution, too. The degree of freedom for LRT is the difference of the degrees of freedom related to the overall model and the sum of individual models in the G strata. In the current study, G=4.

Results

Descriptive Results

Table 2 shows a detailed description of sample characteristics. Overall, 26.35% are classified as obese in this study. Further, Table 3 compares demographic, socioeconomic and contextual-related characteristics of the obese vs. non-obese subgroups, and corresponding *t*-statistics. Significant differences are observed in age, marital status and smoking status (p<.001), educational attainment (p<0.5), manual occupation (p<0.01), and most prominently, in income and wealth quintiles (p<0.01, respectively). At the area-level, group differences of mean community income, community mean education, urbanicity index, rural/urban communities, region and Gini coefficient are significant (p<0.01 respectively). However, relative income has no significant difference between the two groups.

--- Table 2 about here ---

--- Table 3 about here ---

The Absence-Absence (i.e. no fast food and no recreational facilities) local context has the largest sample size (N=5,222), the lowest mean BMI (23.31 kg/m^2), and the lowest obesity prevalence (24%). The Presence-Absence (i.e. has fast food but no recreational facilities) local context has the smallest sample size, the highest mean BMI (23.99 kg/m^2), and highest obesity prevalence (34%). The other two local contexts have sample sizes and obesity rates falling between two extremes. The Absence-Absence category is set as the reference group in the bivariate and multivariate analysis.

Figure 1 shows the provincial income inequality gradients assessed by Gini coefficients by provinces. Two coastal provinces, Jiangsu and Shandong, represent the highest and lowest level of income inequality. The Northeast (Heilongjiang and Liaoning) represents the major foundations of China's heavy industry in the northeast area and they are relatively egalitarian. Inland provinces (Henan, Hubei and Hunan) have similar Gini coefficients. Two mountainous southwestern provinces (Guangxi and Huizhou) represent relatively high levels of inequality.

--- Figure 1 about here ---

Figure 2 summarizes the obesity prevalence by individual SES. The obesity prevalence is lowest among the highest educational attainments group (23.39%), and lowest among the manual occupation category (21.57%). Individual income and household wealth are both positively related to obesity. The Gini coefficient and obesity prevalence by CHNS province are presented in Table 4 and Figure 3. A more unequal province is related to lower obesity prevalence.

--- Figure 2 about here ---

The Gini coefficient, mean BMI and percentage of obesity prevalence by CHNS province are presented in Table 4. Figure 4 shows the predicted obesity prevalence by Gini coefficient and Region.

--- Table 4 about here ---

--- Figure 3 about here ---

--- Figure 4 about here ---

Further bivariate analyses that examine the associations between predictors and obesity outcome are presented in Table 5. As expected, at the individual-level, income and wealth are positively associated with obesity. The association between education attainment and obesity is inverse while manual workers are less likely to be obese. None of the relative income measures is significantly associated with obesity. In addition, age, marital status and smoking status are significantly associated with obesity.

At the area-level, mean income and mean education are associated with an increased risk of obesity. Each unit increase in urbanicity score is positively associated with an increased likelihood of obesity. Urban communities are associated with an increased risk of obesity than rural communities. Each unit increase in the Gini coefficient is associated with a lower risk of obesity in North regions.

--- Table 5 about here ---

Mutivaraite Results

Table 6 presents multivariate regression results of random intercept multilevel models with the obesity outcome[2]. Models 1 to 6 estimate the demographic and SES main effects on obesity. Model 1, a baseline model with demographic variables, shows significant curvilinear and concave age effects. Being married also increase the odds of obesity. However, the sex effect is not significant. 10.2% of the variation in obesity risk can be explained by area-level variables. Model 2 adds the individual SES variables to Model 1, thereby testing the SES effect on the obesity outcome after adjusting for demographic factors. As expected, high educational attainment and a manual occupation are negatively related to obesity; individual income and wealth are positively related to obesity. Those

[2] The results from the analysis on BMI are similar and available by request.

with high educational attainment are associated with a 26.1% reduced risk of obesity (OR=0.739, p<.05); a manual occupation reduces the risk of obesity at 0.73 times as low as the reference group (OR=0.732, p<.001). However, obesity risks for those in the fourth and fifth wealth quintiles are 1.358 times and 1.315 times as high as the bottom quintile, respectively (p<0.001); likewise, obesity risks for the fourth and fifth income quintiles are 1.322 and 1.278 times as high as the bottom quintile, respectively (p<0.001).

Model 3 adds Deaton's RDI to Model 2 to examine the relative income effect. Adjusting for demographic factors and individual SES, the effect of the relative income is not significant. Model 4 includes the community SES measures in addition to the individual-level variables in Model 3. However, none of the community SES indicators (mean income, mean education, urbanicity) are significant.[3] Model 5 adds provincial Gini coefficient on top of demographic characteristics, individual SES, the relative income, and community SES and improves the model fit with a smaller BIC. The risk of obesity is significantly reduced by 5% with a 0.01 increase of Gini coefficient (OR=0.951, p<.001). Because the descriptive results of provincial Gini coefficient and obesity suggested some regional specificities, Model 6 adds a region (north) variable and the interaction between Gini coefficient and region to Model 5. While other predictors' effects largely remain, region and the interaction between region and Gini coefficient have significant associations with body weight outcomes.

Model 7 and Model 8 examine cross-level interactions and behavior modifications. We adopt the approach by Subramanian and Kawachi (2006) and create income

[3] In the preliminary analysis, we conducted collinearity diagnostics of community SES indicators and other participating variables, using bivariate correlations, variance inflation factors (VIF) and detailed variance proportions of condition indexes. All diagnostics results suggest sufficient independent variance to estimate stable effects, hence there is no multicollinearity issue.

inequality interaction variables by multiplying income inequality with individual SES variables, and examine all sets of interactions one at a time and additively. In Model 7, main effects for the Gini coefficient indicate that income inequality affects obesity negatively in the reference income and education categories. The coefficients for the interaction variables indicate how income inequality affects obesity for each of the specific income and education categories relative to the reference group. However, none of the cross-level interaction effect is significant at the 0.05 level. The final model, Model 8, adds behavior variables (smoking and alcohol consumption) which are more proximate to the outcome than social determinants. However, the inclusion of cross-level interactions and behaviors variables does not improve model goodness-of-fit based on BIC statistics. The best model for multilevel social determinants of obesity is Model 6, based on the comparison of BIC statistics and predictors' contributions to explain the outcome.

---Table 6 about here---

Hypothesis 1 (the education hypothesis) is supported: high educational attainment is associated with a 27.5% reduction in the risk of obesity. The effect of intermediate education is not significant. Hypothesis 2 (the occupation hypothesis) is also associated: a manual occupation reduces the risk of obesity by 28% than the reference category after controlling for covariates at the individual and contextual-level. There is an increased risk of obesity for individuals with higher income and more wealth, supporting Hypothesis 3 (the absolute income hypothesis). The risks of obesity for those in the fourth and fifth wealth quintile are 1.448 and 1.457 times as high as the reference group ($p<0.001$), respectively. The middle income quintile has 1.249 times higher risk of obesity ($p<0.5$), and the risks of obesity in the fourth and fifth income quintile are 1.307 and 1.363 times as high as the reference group ($p<0.001$), respectively. However, at the individual level, Deaton's RDI is not statistically related to the outcome in bivariate or multivariate analysis. The association between obesity and other three measures of the relative income are also not significant. Therefore, Hypothesis 4 (the relative income hypothesis) is not supported.

At the area level, results are mixed for Hypothesis 5 (the community SES hypothesis). Each additional year more of community average education results in 5% lower obesity risk ($p<0.01$), and each urbanicity index score increases obesity risk by 0.8% ($p<0.05$), but community mean income is not statistically significant. However, we find an inverse inequality-obesity link which is opposite to Hypothesis 6 (the income inequality hypothesis). The area-level income inequality has an independent effect on obesity over and above the effects of individual income, wealth and individual-level relative deprivation ($p<0.001$), regardless of the measure of absolute income and the relative income. Specifically, with each 1% increase in Gini coefficient (i.e. from an egalitarian income distribution to total income being concentrated by one individual) in North regions, the risk of being obese is decreased by 8%. Finally, no significant cross-level interaction effect is found in Models 7 and 8, and effects of income inequality on obesity does not favor higher SES group over the reference group, so there is no support for Hypothesis 7 (cross-level interaction hypothesis).

The associations between fast food and local sports accessibility and the proportion of obese individuals are examined using chi-square tests, described in Table 7. Hypotheses 8 and 9 are supported.

--- Table 7 about here ---

Bivariate results in Table 8 suggest that (1) individuals with access to either fast food or sports facilities have a significantly higher risk of obesity than those with no access; (2) individuals with access to fast food restaurants but limited access to sports facilities are at the highest risk of obesity; (3) limited access to fast food restaurants but access to sports facilities could significantly, though modestly, affect one's risk of obesity in bivariate associations; (4) although individuals with access to both fast food and sports facilities are at higher risk of obesity than those with access to neither, the difference is not statistically significant; (5) compared with sports facilities environment, food environment seems to be a stronger factor with regard to obesity risk.

---Table 8 about here---

Based on the best Model, in each set, in Table 9, Model A and B examine the effect of fast food restaurants and sports facilities accessibility respectively controlling for individual and area-level characteristics. Further, Model C examines associations of both fast food and sports facilities controlling for the other factors. We find that the significant association observed in the bivariate analysis became attenuated in the multivariate setting, while individual SES and income inequality effects remained significant. The results suggest that compared with social determinants of obesity, accessibility to fast food restaurants and sports facilities might be a weaker factor to predict obesity risk.

---Table 9 about here---

We further conduct stratified analysis to examine whether SES and income inequality effects on obesity vary across local built environment contexts, and whether these effects are greater in certain local built environment context. As shown in Table 10, we have estimated five models with the same explanatory variables. The overall model is the best model (Model 6) in Table 8.The overall model represents the null hypothesis that the associations between individual and community level variables and obesity outcome are equal across different local built environment contexts. The four stratified models, each representing a nested sample from the overall model, are the four strata. Applying the LRT, the SES and inequality effects on obesity in four separate models can be compared with each other for equality. The LRT statistic has a value of 97.62 on 81 degrees of freedom ($p<0.05$). Hence the null hypothesis for parameter equality across contexts as represented by formula (7.1) is rejected. Stratified by contexts, the associations between obesity and education, income, wealth and occupation become amplified or attenuated, even non-significant, compared with the overall model. However, the association between Gini and obesity remains significant across the strata. The above results also suggest that the effects of SES on BMI/obesity are amplified in the context that tends to encourage unhealthy life styles. Hypothesis 9 and Hypothesis 10 are supported.

---Table 10 about here---

The region indicator has a consistent impact on obesity regardless of the contexts. In addition, with each 0.01 or 1% increase in the Gini coefficient, in the north regions, the odds ratio (significant at the 0.001 level) of being obese is decreased by 8% in the overall model, and decreased by 6% to 8% across the contexts. The magnitude of income inequality effect on obesity is quite sizable, for example, the difference between a community in Shandong and another in Hunan would have a difference of 21% in obesity prevalence. Hypothesis 11 is not supported. By contrast, we observed that higher level inequality has a consistently negative impact on obesity regardless of the context.

Discussions and Conclusion

Individual-level SES and Obesity

Significant positive associations between individual income, household wealth and obesity suggest China is a developing society where obesity is more common among the rich.[4] These associations are robust after adding relative income and income inequality into the model, and consistent in all bivariate and multivariate models. Adults of the top two quintiles or top 40% of the income and wealth distribution are at significantly higher risk of obesity. The curve becomes flatter at lower ends of income and wealth. These non-linear associations between individual income/wealth and obesity are consistent with previous studies on concave effects of income on health (Wagstaff and van Doorslaer 2000). Besides, a higher educational attainment is associated with significant lower risk of obesity. A manual occupation is an independent protective factor against obesity, consistent with Ng, Norton, and Popkin's (2009) occupation-related physical activity argument about obesity.

Literature suggested inverse relations between multi-level SES measures and obesity in industrial societies but a distinct story in developing countries. McLaren's (2007) systematic review found the inverse SES-obesity association became increasing positive from developed countries to developing countries. SES indicators also differ in effects. In highly developed countries, the inverse SES-obesity association is most

[4] In sensitivity analyses, there are three different measures for the absolute income: (1) absolute income measured by equivalence scale adjusted household income in 1000 *yuan* and its quadratic term; (2) logarithmically transformed absolute income; (3) absolute income quintiles. Results show that the different measures are not influential cases. Therefore, we present the income quintiles.

common with education, whereas in developing countries, income explains a substantial part of the positive association (McLaren 2007, Roskam et al. 2010).

In China, we observe a similar positive income/wealth-obesity association as other developing countries, but an inverse educational gradient in obesity like many developed countries. During China's nutrition transition, highly educated populations may benefit from their high health literacy and stick to a more health-conscious diet and lifestyle. The nature of manual work is related to more intensive physical activity than that of professional and service workers.

Such mixed results seem to be surprising, but China is a society where income/wealth and educational attainment are not highly related. With China's economic and social institutions reform, most adults have savored income and wealth increase, but only less than 10% received advanced education. One may be well-educated with a low/moderate level of income, vice versa. Therefore, a substantial part of the SES-obesity association can be explained to the non-linear association between individual income and obesity, rather than education.

Community-level SES and Obesity

The community SES effects on obesity in China show a mixed pattern. A lower obesity rate is found in a community with higher average education attainments, consistent with Western studies. However, a higher level of urbanization is associated with a higher obesity rate. Three previous studies examined Community SES effects on obesity in multilevel approaches, suggesting a positive association between obesity and community deprivation (King et al. 2005; Robert and Reither 2004; Sundquist, Malmström, and Johansson 1999), and we observe the same story in terms of community education of our study. In developing countries like India, average levels of state economic development were strongly associated with degrees of overnutrition and obesity (Subramanian, Kawachi, and Smith 2007). Yet we find no support for the community income hypotheses. Finally, China's case is similar in that higher urbanization level is positively related to obesity rate. The coexistence of supportive and inconsistent evidence shows the complexity of community SES effect on obesity in China, a developing country.

The Relative Income and Obesity

Very few studies have assessed the association between individual-level relative deprivation and obesity. We assessed four measures (Yizhakis' RDA, Deaton's RDI, log difference relative deprivation, income percentile rank) of the relative income respectively. In bivariate associations, a lower relative income (larger Yitzhaki's RDA, smaller Deaton's RDI and log difference relative deprivation, or higher income percentile rank) would increase the risk of obesity. However, adjusting for other covariates, the relevant income measure is no longer significant. Our findings are consistent with a previous study on adults' self-reported health using 1993 CHNS data (Li and Zhu 2006). However, it is different from a Western study that found Yitzhaki's measure of relative deprivation was associated with higher BMIs (Eibner and Evans 2005).

One possible interpretation is that effects of relative income may have already been explained by absolute income at the individual-level and income inequality at the community-level. Statistically, all measures of relative income are convex functions of individual income that decline with the increase of one's income, holding income distribution constant; they all increase with the increase in income inequality, holding constant individual income and the mean reference group income (Reagan, Salsberry, and

Olsen 2007). The association between the relative income and obesity, if any, could simply be a statistical correlation, rather than a causal link.

Income Inequality and Obesity

After controlling for individual- and community-level SES, income inequality still has an independent effect of on obesity.[5] The sizable, inverse association between Gini coefficient and obesity is against Hypothesis 6 based on previous findings in the U.S. (Robert and Reither 2004), Europe (Pickett et al. 2005), OECD countries (Su, Esqueda, Li, and Pagan 2012) and India (Subramanian, Kawachi, and Smith 2007). Our finding agrees with a recent study (Ling 2009) that Gini coefficient had a significant and negative impact on the probability of being overweight for the whole sample of CHNS 1989-2004. However, Ling's study was inconclusive since she found significant, positive Gini effect on the waist circumference and significant, negative Gini effect on overweight and insignificant Gini effect on obesity. Our results are inconsistent with another study using the rural sample of CHNS 1989-2000 (Chen and Meltzer 2008). Of note, both Ling and Chen and Meltzer's studies used an average of 20 houses in a community for calculating the community-level income inequality, which is inappropriate for assessing inequality (Wilkinson and Pickett 2006).

[5] Is the change in BMI and obesity over the past years (between 1989 and 2006) highly related to inequality rather than the characteristics of the provinces? We further examined the obesity prevalence and mean BMI by province in 1989, and compared the results with those in 2006. In 1989, the income inequality in China was lower and the regional differences were smaller than those in 2006. In 1989, obesity prevalence in each province was much lower than that in 2006, and the provincial difference in the obesity prevalence were much smaller. The Pearson correlation between the change of obesity prevalence and Gini coefficient in 2006 was -0.43 ($p<0.001$). Similarly, the mean BMI in each province was lower than that in 2006, and the provincial difference in the mean BMI was smaller. The Pearson correlation between the change of mean BMI and Gini coefficient in 2006 was -0.21 ($p<0.001$). Hence, inequality, rather than fixed characteristics of the provinces, is highly related to the change in BMI and obesity over the years.

Our study is the first to find strong negative effects of inequality on obesity. The strong and negative effect of income inequality on obesity in China contradicts the positive correlation between income inequality and obesity prevalence observed in OECD countries (Su, Esqueda, Li, and Pagan 2012). So far, existing knowledge is inconclusive on the health effect of income inequality (Gerdtham and Johannesson 2004). Although many studies by Wilkinson and colleagues (1992, 1996, 1997, 1998, 2002, 2006, and 2009) reported the detrimental inequality effect on health in the OECD countries, results of income inequality and health are still mixed (Subramanian and Kawachi 2004). Ideally, convincing answers to the income inequality hypothesis depend on a combination of quality data, sophisticated analytical methods, and rigorous application of theory (Subramanian and Kawachi 2004). The positive association between income inequality and obesity may be unique in Western countries. Our unique finding in China warrants further investigation of income inequality and obesity.

Further Explanations

China has undergone profound economic and social changes, with health outcomes closely related with urbanization and nutritional transition (Popkin et al. 1993; Popkin 2001). Meanwhile, an alarming inequality in China has been reported. The World Bank reported that the Gini index in China went up by 2.0 percent a year between 1990 and 2001. In 2005, the Gini index in China reached an alarming point at 41.5, much higher than all developed countries and most developing countries (World Bank 2005).

Examining our observed obesity patterns against the literature, we may realize that China is a transitional developing country; hence some dimensions of socioeconomic disparities in obesity resemble that of the West (such as education), other SES dimensions follow the pattern observed in the developing nations (such as the income), while the inequality-obesity link shows uniquely. The heterogeneous patterns are accompanied by dynamic social processes characterized by economic development, deepening inequality, urbanization and nutrition transition. Mechanisms through which income may positively influence obesity have been proposed. More people are involved in the nutrition transition characterized by a shift toward an unhealthy diet of higher fat and calories and increased inactivity (Du, Lu, Zhai, and Popkin 2002). Daily diets rely more on animal food sources and people' lifestyles are increasingly sedentary. Hence, higher-income people are more susceptible to excessive consumption of higher calories and fat condensed food (Du, Mroz, Zhai, and Popkin 2004), or snacking and shifting away from traditional healthy cooking patterns (Wang et al. 2008). Likewise, China's massive urbanization process has transformed occupations and dramatically reduced occupation-related physical activity (Ng, Norton, and Popkin 2009). Compared with professionals and service workers, manual workers have more intensive levels of physical activity which prevents them from being obese. However, similar to protective effects of education on general health, people of higher educational attainment have more resources for a healthy lifestyle which prevents them from being obese, consistent with a previous study that education could influence obesity through its association with health literacy which translates into healthy behaviors (Sobal 1991).

Our independent but opposite income and education effects on obesity is similar to a Brazilian study: comparing adults in a developed region against a poor region, income was positively associated with obesity in both regions, and education was slightly inversely associated with men's obesity in a developed region and strongly inversely associated with women's obesity in both regions (Monteiro et al. 2001). Our observations suggest that in a transitional society such as China, the income–obesity gradient remains that of a typical developing country's pattern whereas the education–obesity gradient may have shifted to that of a typical developed country's pattern.

We also observe regional disparities of obesity independent from SES or inequality, as indicated by Jiangsu and Guangxi provinces, possibility due to the level of the energy intake and physical activity related to cultural factors and even ethnicity. Previous studies have suggested some geographical and cultural factors with effects independent of that of SES and inequality. For example, Shi et al. (2008) found that Jiangsu people were at a higher risk of obesity due to excessive intake of energy from their cooking methods, namely a generous use of oil for stir-frying, and higher or excessive intake of sugar in daily cooking and sweet fruits. Compared with other eight provinces with majority Han people, Guangxi is multi-ethnic. A study reported ethnic differences in overweight and obesity between the Han and minority ethnic groups, and a lower prevalence existed in minority ethnic group (Zhang et al. 2009). These social conditions beyond SES or inequality should be considered when comparing regional obesity disparities.

Of note, the Gini coefficient is strongly and inversely associated with obesity in North regions. Even when individual income and relative income were included in the regression, income inequality was still significantly related to obesity, and consistent throughout all models. The mechanism can be explained by psychosocial pathways that a high income inequality undermines social capital and increases stress that causes general health issues but prevents people from weight gain.

Fast Food Restaurants Accessibility and Obesity

The positive association between fast food accessibility and obesity as observed in our study is consistent with the majority of literature on this topic showing a positive association between access to fast food and obesity risk (Morland et al 2006; Kipke et al. 2007). However, such results should be interpreted with caution: on one hand, significant effects are observed in bivariate analysis; on the other hand, in multivariate setting, the associations become attenuated.

Access to fast food may influence the risk of obesity through several mechanisms. First, individuals who have access to fast food tend to have a higher caloric intake and poorer dietary quality, which are established risk factors for obesity (Prentice and Jebb 2003, Bowman et al. 2004. Furthermore, individuals who have access to fast food may also have unhealthy lifestyles that may increase obesity (Jeffery and French 1998; Utter et al. 2003). Frequent consumption of fast food could simply be a marker for a generally unhealthy lifestyle, such as less restrained eating behavior, fatty and sweet food preferences, and a sedentary lifestyle (Stender, Dyerberg et al. 2007) which increases obesity.

The positive association between accessibility to fast food and the obesity outcome observed in the bivariate analysis become attenuated and non-significant after other factors are taken into account, indicating two possibilities: first, compared with the factors affecting the obesity outcome such as individual SES and community inequality, access to fast food might be a weaker factor influencing obesity. In addition, access to fast food might not be a good surrogate to real fast food consumption in China. In fact, this is not a unique case in China. An Australia study examining associations between density of and proximity to fast food outlets and body weight found that, although consumption of fast food was associated with higher risk of obesity, there was no evidence indicating exposure to fast food outlets in the local neighborhood increased the risk of obesity (Crawford et al. 2008). Future studies will be more informative with the frequency of fast food consumption.

Sports Facilities Accessibility and Obesity

One's access to sports facilities is associated with an increased risk of obesity in the bivariate analysis; it needs to be interpreted with caution. First, this finding might be due to chance, rather than due to real differences, given the magnitude of the association. Indeed, there is not much difference in the percentage of obese population whether sports facilities are accessible in communities (27.54% in communities with sports facilities vs. 25.64% in communities with no recreational facilities). Secondly, access to sport facilities may not reflect an individual's daily physical activity level, which is the real influential factor for one's weight status. Rather, the access to sports facilities may partly reflect the income levels of residents.

A community might have some sports facilities (such as gyms and parks), yet they are not equally accessible by all residents, due to the costs, the schedule, or subjective individual tastes and preference (Dahmann et al. 2010). In addition, the modest positive association in the bivariate analysis becomes non-significant after controlling for other factors such as income in the multivariable analysis. This suggests that access to sports facilities is not an important factor to predict obesity risk compared with the social factors. In China, areas with a high income population are more likely to have a facility such as a gym. In this study, in communities with sports facilities available, 48.45% of the randomly sampled residents are in the top two income quintiles, whereas in communities with no sports facilities available, 34.96% of the randomly sampled residents are in the top two income quintiles. Therefore, the positive association observed for access to sports facilities with obesity may partly represent the associations observed for high income population. In fact, pricy sports facilities in China were related to prestige, rather than daily activities (French and Crabbe 2010).

The Built Environment and Obesity

This study began with a question: Can the local obsogenic built environment influence one's risk of obesity in China? Therefore, in addition to examining the fast food accessibility and sports facilities accessibility separately, we bring the two together and study the potential effects of different categories of community built environment on body weight status. As summarized previously, the bivariate analysis shows significant positive association between body weight outcome in the Presence-Absence and Absence-Presence categories, and non-significant positive association for the Presence-Presence category (with the Absence-Absence category set as the reference); meanwhile, in the multivariate analysis, both significant.

The most prominent amplified SES effects are observed in education, income and community mean income. The results are consistent with the way that education and income may affect one's health literacy and health behavior. A majority of studies on SES effects on health reported that higher educational attainment is generally related to better health and longer lives through pathways of cumulative advantage and healthy life styles (Mirowsky and Ross 2003; Winkleby et al. 1992), while evidence from the developed world shows a very consistent inverse income-obesity link (McLaren 2007;

Sobal 1991). The individuals with higher income in the developing countries may be exposed to a more calorie-density diet, and this disadvantage effect of income on obesity can be amplified in contexts with access to the fast food. Previous studies among Chinese adults have found that high income was associated with increased risk of obesity through unhealthy diets (Li et al. 2005; Ma et al. 2007) and sedentary lifestyles (Yang et al. 2005a), while higher education level was associated with a healthier diet and a lower prevalence of overweight/obesity (Woo et al. 1999).

Conceptually, this is consistent with the "deprivation amplification" observed in health studies that exposure to the poor neighborhood food and physical activity environment may amplify the association between low SES and poor health (Macintyre 2007). In China, high levels of education are associated with a much lower odds ratio of developing obesity in the Presence-Absence context that has fast food but no sports facilities. Yet the protective effect of education on obesity is not observed when the local built environment has no fast food or no sports facilities. Such differences may be interpreted that people with higher levels of education have more health literacy and keep healthier lifestyles than those with lower levels of education. When there is no environmental obesity-related risk factor such as the presence of fast food, the relative advantage associated with higher levels of education in relation to obesity outcome is not evident; however, when the fast food is available locally, the relative advantage associated with higher levels of education is significant. The amplified income effect and community mean income effect on obesity in the Presence-Absence context can be understood in a similar way. A higher mean community income is associated with a lower obesity risk, significant at the 0.01 level in the Presence-Absence context, which is consistent with the Western observation that the less deprived communities are associated with better health and a lower prevalence of obesity (Morland, Diez Roux, and Wing 2006; Robert 1998).

In addition to the amplified SES effects on obesity in the Presence-Absence context, we observe that the significant effect of having a manual occupation in the overall model is found only in the Absence-Absence context. This is not beyond our expectation, as in the least developed context, the manual workers are obviously less likely to be obese due to the high level of physical activity in their work. Comparing the results across the contexts with the overall model, we may also find that the significant effect of high education in the overall model is still significant and lowers the obesity risk in the Presence-Presence setting. This is further proof that high education and high health literacy are protective factors of obesity when the built environment has both fast food and sports facilities. In summary, the significant LR test and results from the associations between BMI/obesity and SES examined in stratified contexts lead to our conclusion that the SES effects on obesity depend on the context of the built environment.

Income Inequality Effects Invariant of Contexts

The stratified analysis results show that being less economically deprived (i.e. with a higher relative income) does not have a higher obesity risk that is significant, regardless of the context. However, obesity outcome in China is sensitive to larger scale income stratification and distribution, which can be assessed by provincial Gini coefficients and its interaction with regional disparity.

Are effects of inequality due unmeasured variables unique for the provinces, rather than the effect of inequality? We address this question by two set of analyses. First, we replace the Gini coefficient by the provincial dummy variables (with Shandong set as the reference because Shandong has the lowest level of inequality) in the overall model and the stratified analysis for both BMI and obesity outcomes. There are no significant differences to any part of the main analysis in terms of the coefficients especially the SES effects. The comparison between the stratified setting and the overall setting is still significant. Second, in order to determine whether there are unmeasured, innate provincial factors, we conduct obesity change from 1989 to 2006 by examining the obesity prevalence by province in 1989, and compare the results with those in 2006. If there were innate provincial characteristics that are associated with obesity, these factors should be there in 1989 when inequality was still mostly low. Instead, if inequality is at work, the increase in obesity should correlate significantly and negatively with inequality. We find that in 1989, the income inequality in China was lower and the regional differences were smaller than those in 2006. In 1989, the obesity prevalence in each province was much lower than that in 2006, and the provincial difference in obesity prevalence were much smaller. The Pearson correlation between the change of obesity prevalence and Gini coefficient in 2006 was -0.43 ($p<0.001$). There results imply that the change in obesity between 1989 and 2006 are associated with inequality rather than the innate characteristics of the provinces.

A fundamental point of the income inequality hypothesis in Western societies is population health tends to be better in societies where income is more equally distributed. A health outcome is sensitive to the scale of social stratification and status competition underpinned by societal differences in material inequality (Wilkinson and Pickett 2009). The potential pathways included disinvestments in human capital which causes poorer health (Kaplan et al. 1996), the erosion of social capital and social cohesion (Kawachi and Kennedy 1997; Subramanian and Kawachi 2004; Wilkinson 1996), or psychosocial effects of social comparisons (Kondo et al. 2008; Lynch et al. 2000; Marmot and Wilkinson 2001). However, China has a much higher Gini coefficient than many developed countries. At such high levels, the mechanisms found in Western countries through which income inequality negatively affects health may be common problems to all provinces. Therefore, the psychosocial impact of living in a hierarchical society on obesity observed in the developed countries may not be illustrative to China's case.

There are two potential interpretations of the inverse association between inequality and obesity. Firstly, the psychosocial impact of living in a hierarchical society on obesity is complex rather than a straightforward, linear way. China is a society that has experienced a lot of recently economic development, and by no means has the development reached its plateau. When a region is experiencing development, income inequality tends to increase with it. Therefore, regions with less income inequality tend to be less developed, and places with greater income inequality tends to be more developed, and is still developing. Thus, such places tend to give people hope that there will be opportunities for pursue their economic objectives. Contrary to the stressor effect found in the west, in China (or societies on a similar path of development), there can be some aspiration effect of inequality, which gives people hope instead of stress, and may keep people on the go to pursue their objectives. Therefore, the effect of inequality on obesity can be negative in these places, other things being equal, especially when poor diet is already available (like in the north).

Another interpretation that the inequality is inversely associated with obesity may be that inequality affects the susceptibility to nutrition transition. China has entered a new stage of the nutrition transition characterized by high-fat, high-energy-density and low-fiber diet, and physical inactivity (Du et al, 2002). However, the nutrition transition, including dietary structure change and increased inactivity at work or leisure, is a long-term shift and is sensitive to the diversity within a province. Therefore, different provinces (with varying inequality levels) in China may show a diverse picture of nutrition transition. In provinces with lower inequality, there is higher level of social homogeneity, so that more people are susceptible to the nutrition transition. By contrast, provinces with higher inequality have high levels of social diversity. Hence, people may be less susceptible to the nutrition transition, resulting in the lower obesity prevalence.

Income inequality's effect on health is still inconclusive across the populations and over time (Lynch et al. 2004b; Subramanian and Kawachi 2004; Wagstaff and van Doorslaer 2000a). The inverse Gini effect on obesity observed from selected provinces of China in this study provides an intriguing example of the complex association between income inequality and health outcomes. Wilkinson's thesis on obesity might be supported by the more developed societies such as the European countries and the U.S. where Gini coefficients are lower. Even in China, as we compare across the negative inequality effects across contexts, we notice that the absence-absence context (the least developed setting) has the strongest negative effect. This could be a notable contribution to the literature on obesity in China and the world as a whole, as well as studies on the associations between income inequality and health. With this finding, with a global perspective, the inequality effects on obesity could be an inverted "U" shape: in more egalitarian countries (such as those in Wilkinson's studies), increment in inequality is associated with higher risk of obesity, while in more in-egalitarian countries (such as China), the increment in inequality is associated with a lower risk of obesity.

Strengths and Limitations

The present study has several strengths. It is the first to study the impact of local built environment as assessed by fast food restaurants and sports facilities on the body weight outcomes among Chinese adults while taking demographic characteristics, SES and inequality into account. It is also the first study to examine the SES effects and inequality effect on obesity across different built environment contexts within such a large developing country as China. Bivariate analysis shows the simple associations between access and obesity. The multilevel design is critical to understand relationships between obesity and the built environment while simultaneously taking into account individual characteristics and community income inequality. The stratified analysis enriches the evaluation of the absolute income hypothesis, the relative income hypothesis, and income inequality hypothesis in different contexts.

Our study fills the gap in the literature by modeling both individual- and community-SES effects as well as inequality effects on the risk of obesity. However, this study is limited in several ways. The cross-sectional design prevented it from evaluating causal inferences, the directionality of associations or the time lag effects. Despite of our sample size, caution should be taken about drawing extensive inferences, because CHNS is not a nationally representative sample of the entire Chinese population. In fact, provinces surveyed in CHNS have a more compact income distribution than national income distribution (Chen and Meltzer 2008). A related issue of the data quality is the confidentiality restrictions of geographic identifiers: although CHNS is widely regarded as one of the best available datasets on China, the smallest geographic unit identifiable is province, not county or neighborhoods that are held confidential. Therefore, it is not possible to match county-level inequality data from the CGSS with county-level CHNS data.

Conclusion

In conclusion, this study considered both research traditions in the literature, and investigated the relationship between socioeconomic disparities, income inequality and obesity among Chinese adults using a multilevel analysis to systematically examine links between absolute income, relevant income, income inequality and obesity at individual- and community/area-level. The study has found strong evidence supporting the effects of the absolute income and income inequality on obesity, although the direction of association is opposite to most studies on self-reported health status. Our analyses here presented a simultaneous test of the absolute income, education, and inequality effects on obesity in contemporary China not found in the literature.

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Table 1 Definition of study variables, CHNS 2006

Variables	Definition
Dependent Variables	
BMI	Body mass index derived from weight (in kilograms) by height (in meters) squared
Obesity	1 if BMI is equal or larger than 25 kg/m^2, 0 if otherwise
Independent Variables	
Individual-level	
Female	1 if gender is female, 0 if gender is male
Age	The sample's age is restricted to 18 years and older
Age Squared	a squared term of one's age
Marital Status	1 if married , 0 otherwise
Smoking	1 if ever smoked , 0 if otherwise
Alcohol Consumption	1 if one consume alcoholic drinks, 0 if never drinking
Educational Attainment	
Low	1 if one has no formal schooling or up to 6 years of education, 0 otherwise
Intermediate	1 if one's highest level of education is 7 to 12 years , 0 otherwise
High	1 if one's highest level of education is over 12 years , 0 otherwise
Work Status	1 if currently working; 0 if otherwise
Occupation	
Professional	1 if one's occupation belongs to a category of officers, administrators, and cadres
Manual	1 if one's occupation belongs to a category of farmers, fishers, hunters, soldiers, and laborers
Service	1 if one's occupation belongs to a category of cooking, driving, and housekeeping
Wealth Index	Household wealth index based on wealth and asset questions.
Individual Income	Equalized household income derived from net household income (in 1000 *yuan*)
Relative Income	Deaton's Relative Deprivation Index
Community/ Provincial-level	
Mean Income	Community mean income (in 1000 *yuan*)
Mean Education	Community mean education in years
Urbanicity Index	An index made from 12 dimensions to reflect the community urbanicity level
Urban Indicator	1 if the community is urban, 0 otherwise
Gini Coefficient	Provincial Gini coefficient based on the CGSS 2006
North	1 if the community is located in North China, 0 otherwise

Table 2 Descriptive statistics for all variables in the analysis (N=9,586)

Variables	Mean	SD	Min	Max
Dependent Variable				
BMI	23.35	3.63	15	40
Obesity (Yes=1)	0.26	0.44	0	1
Independent Variables, individual-level				
Female	0.52	0.50	0	1
Age	49.34	15.29	18	97
Marital status (Married=1)	0.83	0.37	0	1
Work Status (Working=1)	0.59	0.49	0	1
Education	7.42	4.43	0	19
Low (0-6)	0.43	0.49	0	1
Intermediate (7-12)	0.51	0.50	0	1
High (12+)	0.07	0.25	0	1
Occupation				
Professional	0.17	0.37	0	1
Manual	0.63	0.48	0	1
Service	0.20	0.40	0	1
Smoking	0.32	0.47	0	1
Alcohol Consumption	0.31	0.46	0	1
Wealth Index	2.32	1.02	0	5.00
1st Qunitle	0.91	0.36	0	1.37
2nd Qunitle	1.67	0.16	1.38	1.93
3rd Qunitle	2.20	0.16	1.93	2.54
4th Quintile	2.86	0.20	2.54	3.26
5th Qunitile	3.76	0.36	3.26	5.00
Income (in 1000 *yuan*)	11.92	15.28	-6.44	315.61
1st Qunitle	1.68	1.07	-6.44	3.2
2nd Qunitle	4.74	0.89	3.21	6.34
3rd Qunitle	8.29	1.21	6.34	10.57
4th Quintile	13.55	1.96	10.57	17.33
5th Qunitile	31.35	24.72	17.36	315.61
Deaton's RDI	0.23	0.18	0	1
Independent Variables, Community/Provincial -level				
Mean Income (in 1000 *yuan*)	11.92	7.52	2.58	55.01
Mean Education (in years)	7.43	2.17	2.24	13.64
Urbanicity Index	64.43	20.40	27.22	101.6
Urban Community (Urban=1)	0.31	0.46	0	1
Gini Coefficient * 100	47.30	7.02	38.63	59.61
North	0.44	0.50	0	1

Table 3 Descriptive statistics of characteristics for obese vs. non-obese people in China (N=9,586)

Variable	**Mean and SD**				***t*-Statistic**
	Obese	**SD**	**Non-Obese**	**SD**	
Individual-level					
Socio-demographic background					
Female	0.53	0.50	0.52	0.50	-1.28
Age	51.25	13.49	48.65	15.83	-7.34***
Marital status (Married=1)	0.88	0.32	0.82	0.39	-8.04***
Behavior Control					
Smoking	0.29	0.45	0.33	0.47	3.46***
Alcohol Consumption	0.74	1.16	0.75	1.16	0.02
SES					
Education	7.37	4.38	7.45	4.45	0.79
Low Education (0-6)	0.44	0.50	0.42	0.49	-0.98
Intermediate Education (7-12)	0.51	0.50	0.51	0.50	0.10
High Education (12+)	0.06	0.24	0.07	0.25	1.76*
Work Status (Currently working=1)	0.53	0.50	0.62	0.49	7.59**
Occupation					
professional	0.10	0.30	0.10	0.30	-0.22
Manual	0.31	0.46	0.40	0.49	8.24**
Service	0.12	0.33	0.12	0.32	-0.60
Wealth Index	2.45	1.03	2.27	1.02	-7.75***
1st Qunitle	0.15	0.35	0.20	0.40	6.03**
2nd Qunitle	0.18	0.38	0.20	0.40	1.82*
3rd Qunitle	0.19	0.39	0.20	0.40	1.70
4th Quintile	0.22	0.41	0.18	0.38	-4.39**
5th Qunitile	0.25	0.44	0.20	0.40	-5.58**
Income (in 1000 yuan)	12.76	15.08	11.62	15.81	-3.22**
1st Qunitle	0.18	0.38	0.21	0.41	3.43**
2nd Qunitle	0.18	0.38	0.21	0.41	3.58**
3rd Qunitle	0.20	0.42	0.20	0.39	0.36
4th Quintile	0.23	0.42	0.19	0.39	-4.13**
5th Qunitile	0.22	0.42	0.19	0.39	-3.24**
Relative Income (RDI)	0.23	0.18	0.23	0.17	-0.96
Community/Provincial-level					
Community Mean Income (in 1000 *yuan*)	12.78	8.09	11.61	7.28	-6.76**
Community Mean Education (in years)	7.69	2.13	7.33	2.18	-7.21**
Urbanicity Index	67.20	20.03	63.44	20.44	-7.99**
Urban Community (Urban=1)	0.36	0.48	0.30	0.46	-5.66**
Gini Coefficient*100	45.74	7.34	47.86	6.81	13.16**
North	0.56	0.50	0.39	0.49	-15.36***

Notes: Heteroscedastic *t*-test.

*Significance at 5% level; ** significance at 1% level; *** significance at 0.1% level

Table 4 Gini coefficient, mean BMI and percentage of obesity by CHNS provinces, 2006 (N=9,586)

Province	Gini Coefficient	Mean BMI	SD	Obesity (%)	N
Liaoning	0.390	24.29	4.15	37.10	1,035
Heilongjiang	0.400	23.92	3.98	31.42	977
Jiangsu	0.596	23.42	3.54	28.35	1,076
Shandong	0.386	24.56	3.44	42.10	1,088
Henan	0.426	23.86	3.56	25.65	1,080
Hubei	0.453	23.33	3.35	24.95	942
Hunan	0.504	22.74	3.34	20.23	1,112
Guangxi	0.503	21.89	3.04	11.85	1,198
Guizhou	0.556	22.36	3.32	17.90	1,078

Note: In the following tables that report results from bivariate or multivariate analysis, the Gini coefficient is replaced by the Gini index (i.e. Gini coefficient × 100) so that interpretation of the result can be based on each unit of change of the Gini index (i.e. each 0.01 change in the Gin coefficient).

Table 5 Bivariate analysis of BMI vs. obesity outcome (N=9,586)

	BMI		Obesity (Yes=1)	
	Coefficient	**SE**	**Odds Ratio**	**SE**
Level-1 Variables:				
Demographic Control				
Female	0.093	0.074	1.061	0.049
Age	0.015***	0.002	1.011***	0.002
Married	1.089***	0.099	1.735***	0.120
Education				
Low (0-6)				
Intermediate (7-12)	0.086	0.077	0.972	0.047
High (12+)	-0.188	0.155	0.831*	0.083
Work Status (ref.=not working)	-0.546***	0.075	0.702***	0.033
Occupation				
Professional	-0.134	0.128	0.860	0.069
Manual	-0.616***	0.079	0.651***	0.033
Service				
Wealth Index				
1st Qunitle				
2nd Qunitle	0.197	0.117	1.262**	0.098
3rd Qunitle	0.251*	0.116	1.271**	0.098
4th Quintile	0.745***	0.118	1.686***	0.128
5th Qunitile	0.783***	0.114	1.742***	0.128
Income (in 1000 yuan)	0.020***	0.004	1.010***	0.002
1st Qunitle				
2nd Qunitle	0.087**	0.117	0.992	0.076
3rd Qunitle	0.334***	0.117	1.16*	0.087
4th Quintile	0.643***	0.117	1.417***	0.104
5th Qunitile	0.649***	0.117	1.364***	0.101
Relative Income (RDI)	0.211	0.210	0.882	0.116
Behavioral Control				
Smoker	-0.301***	0.080	0.840***	0.043
Alcohol Consumption	0.019	0.032	1.000	0.020
Level-2 Variables:				
Community/Provincial Characteristics				
Mean Income (in 1000 *yuan*)	0.030***	0.005	1.020***	0.003
Mean education (in years)	0.141***	0.017	1.079***	0.011
Urbanicity Index	0.014***	0.002	1.009***	0.001
Urban (ref.=Rural)	0.525***	0.080	1.319***	0.065
Gini Coefficient *100	-0.085***	0.005	0.956***	0.003
North	1.442***	0.131	2.092 ***	0.17

Notes: *Significance at 5% level; ** significance at 1% level; *** significance at 0.1% level

Table 6 Odds ratio estimates from random intercept multilevel logistic models of obesity (N=9,586)

Fixed effects	Model 1		Model 2		Model 3		Model 4	
	OR	SE	OR	SE	OR	SE	OR	SE
Level-1 Variables:								
Demographic Control								
Female	1.069***	0.052	1.002	0.051	1.001	0.051	1.000	0.051
Age	1.119***	0.013	1.125***	0.013	1.125***	0.013	1.124***	0.013
Age^2	0.999**	<0.001	0.999***	<0.001	0.999***	<0.001	0.999***	<0.001
Married	1.249	0.102	1.249**	0.102	1.256**	0.103	1.258**	0.103
SES								
Education (ref.=0-6)								
Intermediate (7-12)			0.925	0.058	0.920	0.057	0.911	0.058
High (12+)			0.739*	0.097	0.736*	0.096	0.723*	0.097
Work Status (ref.=not working)			0.893	0.079	0.895	0.079	0.897	0.079
Occupation (ref.= service)								
Professional			0.867	0.100	0.869	0.100	0.868	0.100
Manual			0.732***	0.065	0.738	0.066	0.747***	0.067
Wealth (ref.=1st Q)								
2nd Qunitle			1.158	0.105	1.148	0.104	1.139	0.104
3rd Qunitle			1.139	0.105	1.122	0.104	1.105	0.104
4th Quintile			1.358**	0.133	1.321**	0.130	1.290*	0.132
5th Qunitile			1.415***	0.144	1.361**	0.141	1.321*	0.146
Income (ref.=1st Q)								
2nd Qunitle			0.993	0.082	1.064	0.095	1.061	0.102
3rd Qunitle			1.165	0.096	1.311**	0.135	1.307*	0.158
4th Quintile			1.322***	0.111	1.558***	0.187	1.548**	0.233
5th Qunitile			1.278**	0.117	1.605**	0.241	1.597*	0.322
Relative Income (RDI)					0.607	0.158	0.611	0.212
Behavioral Control								
Smoker								
Alcohol Consumption								
Level-2 Variables:								
Community/ Provincial Characteristics								
Mean Income (in 1000 *yuan*)							0.996	0.009
Mean education (in years)							1.015	0.033
Urbanicity Index							1.002	0.004
Urban (ref.=Rural)							1.005	0.129
Gini Coefficient *100								
Region Indicator								
North								
Cross-level Interactions								
Gini*Low Income (Q2)								
Gini*Middle Income (Q3)								
Gini*High Income (Q4)								
Gini*Top Income (Q5)								
Gini*Middle Education								
Gini*High Education								
ICC	0.102	(0.012)	0.086	(0.011)	0.084	(0.011)	0.084	(0.011)
Level 2 variance	0.374	(0.002)	0.309	(0.002)	0.304	(0.002)	0.303	(0.002)
Goodness-of-fit (BIC)	10,576.2		10,612.5		10,618.1		10,653.8	

Table 6 Odds ratio estimates from random intercept multilevel logistic models of obesity (N=9,586) *(Cont.)*

Fixed effects	**Model 5**		**Model 6**		**Model 7**		**Model 8**	
	OR	SE	OR	SE	OR	SE	OR	SE
Level-1 Variables:								
Demographic Control								
Female	1.005	0.051	1.000	0.051	0.999	0.051	0.824**	0.056
Age	1.124***	0.013	1.126***	0.013	1.126***	0.013	1.131***	0.013
Age^2	0.999***	<0.001	0.999***	<0.001	0.999***	<0.001	0.999***	<0.001
Married	1.252**	0.103	1.232*	0.099	1.236*	0.101	1.232*	0.101
SES								
Education (ref.=0-6)								
Medium Education (7-12)	0.914	0.058	0.917	0.058	1.842	0.653	1.753	0.623
High Education (12+)	0.722*	0.096	0.713*	0.095	0.501	0.360	0.490	0.353
Work Status (ref.=not working)	0.920	0.081	0.919	0.081	0.931	0.082	0.931	0.082
Occupation (ref.= service)								
Professional	0.847	0.097	0.832	0.095	0.822	0.094	0.827	0.095
Manual	0.752***	0.067	0.736***	0.066	0.729***	0.065	0.729***	0.065
Wealth (ref.=1st Q)								
2nd Qunitle	1.144	0.102	1.152	0.102	1.152	0.102	1.142	0.101
3rd Qunitle	1.135	0.105	1.138	0.104	1.137	0.104	1.134	0.104
4th Quintile	1.320**	0.132	1.323**	0.130	1.339**	0.132	1.337**	0.132
5th Qunitile	1.428***	0.155	1.446**	0.154	1.452**	0.154	1.451**	0.155
Income (ref.=1st Q)								
2nd Qunitle	1.056	0.100	1.042	0.098	1.145	0.663	1.189	0.632
3rd Qunitle	1.285*	0.152	1.247	0.144	0.912	0.519	0.908	0.518
4th Quintile	1.526**	0.222	1.456**	0.207	0.748	0.425	0.773	0.439
5th Qunitile	1.585*	0.309	1.469*	0.207	0.492	0.293	0.507	0.302
Relative Income (RDI)	0.648	0.217	0.716	0.232	0.702	0.227	0.665	0.220
Behavioral Control								
Smoker							0.711***	0.049
Alcohol Consumption							1.005	0.066
Level-2 Variables:								
Community / Provincial Characteristics								
Mean Income (in 1000 *yuan*)	1.002	0.008	0.995	0.008	0.994	0.008	0.994	0.008
Mean education (in years)	0.933*	0.028	0.945*	0.003	0.944*	0.025	0.942*	0.025
Urbanicity Index	1.007*	0.003	1.007*	0.107	1.007**	0.003	1.007**	0.003
Urban (ref.=Rural)	1.044	0.114	1.082	0.097	1.081	0.097	1.078	0.106
Gini Coefficient*100	0.951***	0.006	1.014	0.010	1.008	0.014	1.007	0.014
Region Indicator								
North			87.237***	85.730	74.026***	72.263	76.542***	75.067
Gini Coefficient*North			0.918***	0.021	0.921***	0.021	0.920***	0.012
Cross-level Interactions								
Gini*Low Income (Q2)					0.998	0.012	0.999	0.012
Gini*Middle Income (Q3)					1.007	0.012	1.005	0.012
Gini*High Income (Q4)					1.015	0.012	1.014	0.012
Gini*Top Income (Q5)					1.024	0.013	1.024	0.013
Gini*Middle Education					0.985	0.007	0.986	0.007
Gini*High Education					1.008	0.015	1.008	0.015
ICC	0.054	(0.009)	0.037	(0.007)	0.036	(0.007)	0.035	(0.007)
Level 2 variance	0.187	(0.001)	0.125	(0.001)	0.122	(0.001)	0.122	(0.001)
Goodness-of-fit (BIC)	10,600.2		10,570.7		10,614.3		10,607.5	

Notes: Number of observation = 9586; Number of community = 218.
Numbers are odds ratios. ICC and Level 2 variances have standard errors in parentheses.
* signifies that differences observed are statistically significant at 5% level; ** significance at 1% level; *** significance at 0.1% level

Table 7 a Categories of community context for understanding the obsogenic environment

		Local Recreational and Sports Environment	
		Yes	No
Local Fast Food Environment	Yes	Presence-Presence	Presence-Absence
	No	Absence-Presence	Absence-Absence

Table 7 b Descriptive statistics of obesity for four categories of community context

Local Environment	Mean BMI (kg/m^2)	SD	N of obese	N	% of obese
Absence-Absence	23.21	3.63	1271	5,222	24%
Absence-Presence	23.44	3.60	766	2,777	28%
Presence-Absence	23.99	3.78	271	791	34%
Presence- Presence	23.23	3.47	218	796	27%
Total			2526	9586	26%

Table 7 c Crosstab tables between fast food accessibility, sports facilities and obesity outcome (N=9,586)

		Obesity		
		No	Yes	Total
Fast Food	No	5,962 (74.53%)	2,037(25.47%)	7,999
	Yes	1,098 (69.19%)	489 (30.81%)	1,587
Chi-Square = 19.51***	Total	7,060 (73.65%)	2,526 (26.35%)	9,586
Sports facilities	No	4,471 (74.36%)	1,542(25.64%)	6,013
	Yes	2,589 (72.46%)	984 (27.54%)	3,573
Chi-Square = 4.15*	Total	7,060 (73.65%)	2,526 (26.35%)	9,586

Table 8 Bivariate analysis of community contexts and BMI and obesity outcome

	BMI		Obesity (Yes=1)	
	Coefficient	SE	Odds Ratio	SE
Fast Food Restaurant	0.053***	0.012	1.303***	0.078
Sports and Rec. Facility	0.019*	0.009	1.102*	0.053
Absence-Absence (ref.)			1.000	
Absence-Presence	0.231 **	0.085	1.184**	0.063
Presence-Absence	0.780***	0.138	1.620***	0.132
Presence-Presence	0.016	0.138	1.172	0.101

Notes: *Significance at 5% level; ** significance at 1% level; *** significance at 0.1% level
Numbers are coefficients. Random-effects parameters have standard errors in parentheses.

Table 9 Multivariate analysis of community contexts and obesity outcome (N=9,586)

Fixed effects	**Model 1**		**Model 2**		**Model 3**	
	OR	SE	OR	SE	OR	SE
Level-1 Variables:						
Demographic Control						
Female	1.000	0.051	1.000	0.051	0.999	0.051
Age	1.126***	0.013	1.126***	0.013	1.126***	0.013
Age^2	0.999***	<0.001	0.999***	<0.001	0.999***	<0.001
Married	1.232	0.101	1.232	0.101	1.234*	0.101
SES						
Education (ref.=0-6)						
Medium Education (7-12)	0.917	0.058	0.917	0.058	0.918	0.058
High Education 2 (12+)	0.714*	0.095	0.713*	0.095	0.712*	0.095
Work Status						
(ref.=not working)	0.919	0.081	0.919	0.081	0.921	0.081
Occupation						
(ref.= service)						
Professional	0.831	0.095	0.832	0.095	0.826	0.094
Manual	0.736***	0.066	0.736***	0.066	0.733***	0.065
Wealth (ref.=1st Q)						
2nd Qunitile	1.152	0.102	1.152	0.102	1.153	0.102
3rd Qunitile	1.138	0.102	1.137	0.104	1.134	0.103
4th Quintile	1.322**	0.130	1.324**	0.131	1.311**	0.130
5th Qunitile	1.441**	0.154	1.448**	0.155	1.434**	0.153
Income (ref.=1st Q)						
2nd Qunitile	1.042	0.098	1.042	0.098	1.037	0.097
3rd Qunitile	1.247	0.144	1.247*	0.144	1.240	0.144
4th Quintile	1.456**	0.207	1.444**	0.199	1.446**	0.205
5th Qunitile	1.458*	0.279	1.456*	0.207	1.455*	0.276
Relative Income (RDI)	0.715	0.232	0.716	0.232	0.726	0.235
Level-2 Variables:						
Community Characteristics						
Mean Income						
(in 1000 *yuan*)	0.994	0.008	0.995	0.008	0.995	0.008
Mean Education (in years)	0.946*	0.025	0.946	0.026	0.950	0.026
Urbanicity Index	1.006	0.003	1.007	0.003	1.005	0.003
Urban (ref.=Rural)	1.079	0.107	1.081	0.107	1.093	0.109
Gini Coefficient *100	1.013	0.010	1.014	0.010	1.011*	0.010
Region Indicator						
North	83.045***	82.009	87.131***	85.624	75.550***	74.404
North*Gini	0.919***	0.021	0.918***	0.021	0.920***	0.021
Context						
Fast Food Restaurant	1.049	0.104				
Sports and Rec. Facility			1.009	0.085		
Absence-Absence (ref.)						
Absence-Presence					1.077	0.099
Presence-Absence					1.203	0.161
Presence-Presence					0.978	0.143
ICC	0.036	(0.007)	0.037	(0.007)	0.036	(0.007)
Level 2 variance	0.130	(0.001)	0.125	(0.001)	0.122	(0.001)
Goodness-of-fit (BIC)	10,5479.7		10,579.9		10,595.7	

Notes: Number of observation = 9586; Number of community = 218.
Numbers are odds ratios. ICC and Level 2 variances have standard errors in parentheses.
*Significance at 5% level; ** significance at 1% level; *** significance at 0.1% level

Table 10 Stratified analysis of community contexts and obesity outcome (N=9,586)

	Overall Model		Absence-Absence		Absence-Presence		Presence-Absence		Presence-Presence	
Fixed effects	OR	SE	OR	SE	OR	SE	OR	SE	OR	SE
Level-1 Variables:										
Demographic Control										
Female	1.000	0.051	1.170*	0.083	0.921	0.087	0.733	0.123	0.684*	0.122
Age	1.126***	0.013	1.114***	0.018	1.133***	0.025	1.161***	0.045	1.169***	0.049
Age^2	0.999***	<0.001	0.999***	< .001	0.999***	<0.001	0.999***	<0.001	0.999***	<0.001
Married	1.232*	0.099	1.353*	0.16	1.278	0.193	0.819	0.202	0.900	0.246
SES										
Education (ref.=0-6)										
Medium Education (7-12)	0.917	0.058	1.031	0.087	0.838	0.101	0.523***	0.117	0.926	0.227
High Education (12+)	0.713*	0.095	0.868	0.193	0.791	0.171	0.159***	0.070	0.796	0.317
Work Status (ref.=not working)	0.919	0.081	0.972	0.126	0.958	0.15	0.889	0.248	0.855	0.229
Occupation (ref.= service)										
Professional	0.832	0.095	0.939	0.167	0.727	0.145	0.931	0.315	0.774	0.245
Manual	0.736***	0.066	0.712**	0.09	0.741*	0.119	0.580	0.192	0.782	0.262
Wealth (ref.=1st Q)										
2nd Qunitle	1.152	0.102	1.095	0.116	1.342	0.246	1.612	0.740	1.264	0.599
3rd Qunitle	1.138	0.104	1.196	0.135	1.116	0.201	1.073	0.475	1.217	0.604
4th Quintile	1.323**	0.13	1.376*	0.179	1.241	0.236	1.378	0.578	1.931	0.891
5th Qunitile	1.446**	0.154	1.251	0.194	1.465	0.302	2.236*	0.935	2.027	0.896
Income (ref.=1st Q)										
2nd Qunitle	1.042	0.098	1.022	0.124	1.104	0.207	1.267	0.477	0.856	0.375
3rd Qunitle	1.247	0.144	1.111	0.173	1.543	0.353	1.708	0.783	1.679	0.790
4th Quintile	1.456**	0.207	1.249	0.24	1.972*	0.555	2.854*	1.609	1.359	0.758
5th Qunitile	1.469*	0.207	1.219	0.321	2.655*	0.967	2.211	1.634	1.121	0.815
Relative Income (RDI)	0.716	0.232	0.835	0.384	0.347	0.214	0.441	0.514	1.020	1.148
Level-2 Variables:										
Community Characteristics										
Mean Income (in 1000 yuan)	0.995	0.008	0.996	0.013	0.985	0.012	0.921**	0.028	1.024	0.042
Mean Education (in years)	0.945*	0.003	0.926	0.035	0.982	0.044	1.118	0.073	0.867	0.134
Urbanicity Index	1.007*	0.107	1.007	0.004	1000	0.006	0.995	0.012	1.018	0.018
Urban (ref.=Rural)	1.082	0.097	1.234	0.184	1142	0.185	0.790	0.183	1.029	0.583
Gini Coefficient *100	1.014	0.010	0.98	0.015	1.05	0.011	1.031	0.022	1.012	0.038
Region Indicator										
North	87.237***	85.73	19.54*	25.785	1,283.746 ***	2239.086	87528.27**	365,695.800	1,681.330 **	7,396.671
Gini Coefficient*North	0.918***	0.021	0.947*	0.028	0.871***	0.034	0.7611**	0.080	0.842**	0.086
Random-effects Parameters										
ICC	0.037	0.007	0.029	0.009	0.022	0.010	0.001	-0.017	0.012	<0.001
Level-2 Variance	0.125	0.001	0.1	0.003	0.073	0.004	< 0.001	<0.001	0.405	<0.001
Model Chi-square	412.04		217.55		177.98		83.93		53.2	
Model df	27		27		27		27		27	
-2 LL	10,323.20		5,436.23		3,210.74		911.6		862.254	
LRT	97.62									
N	9,586		5,222		2,777		791		796	

Notes: Number of observation = 9586; Number of community = 218.
Numbers are odds ratios. Random-effects parameters have standard errors in parentheses.
In the Presence-Absence context, Guangxi Province is omitted due to collinearity.
*Significance at 5% level; ** significance at 1% level; *** significance at 0.1% level

Figure 1 Gini coefficients by province, CHNS 2006

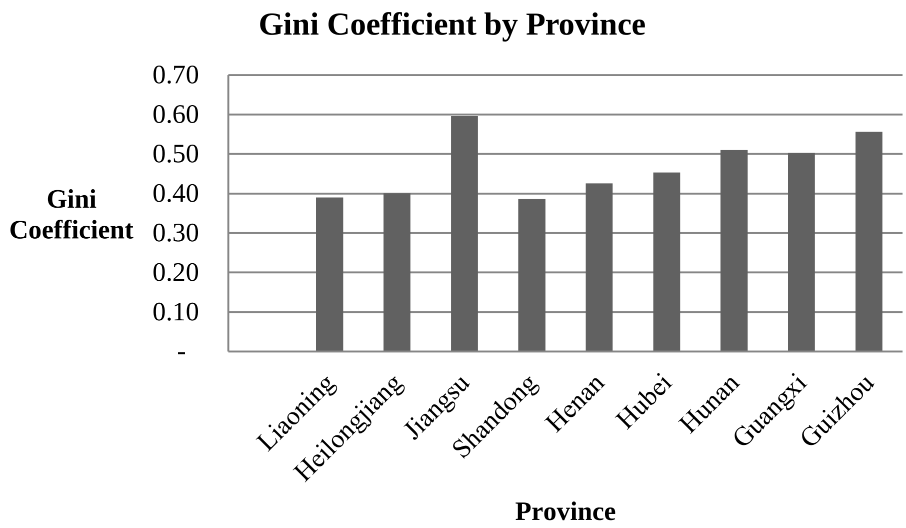

Figure 2: Prevalence of obesity by individual SES, CHNS 2006

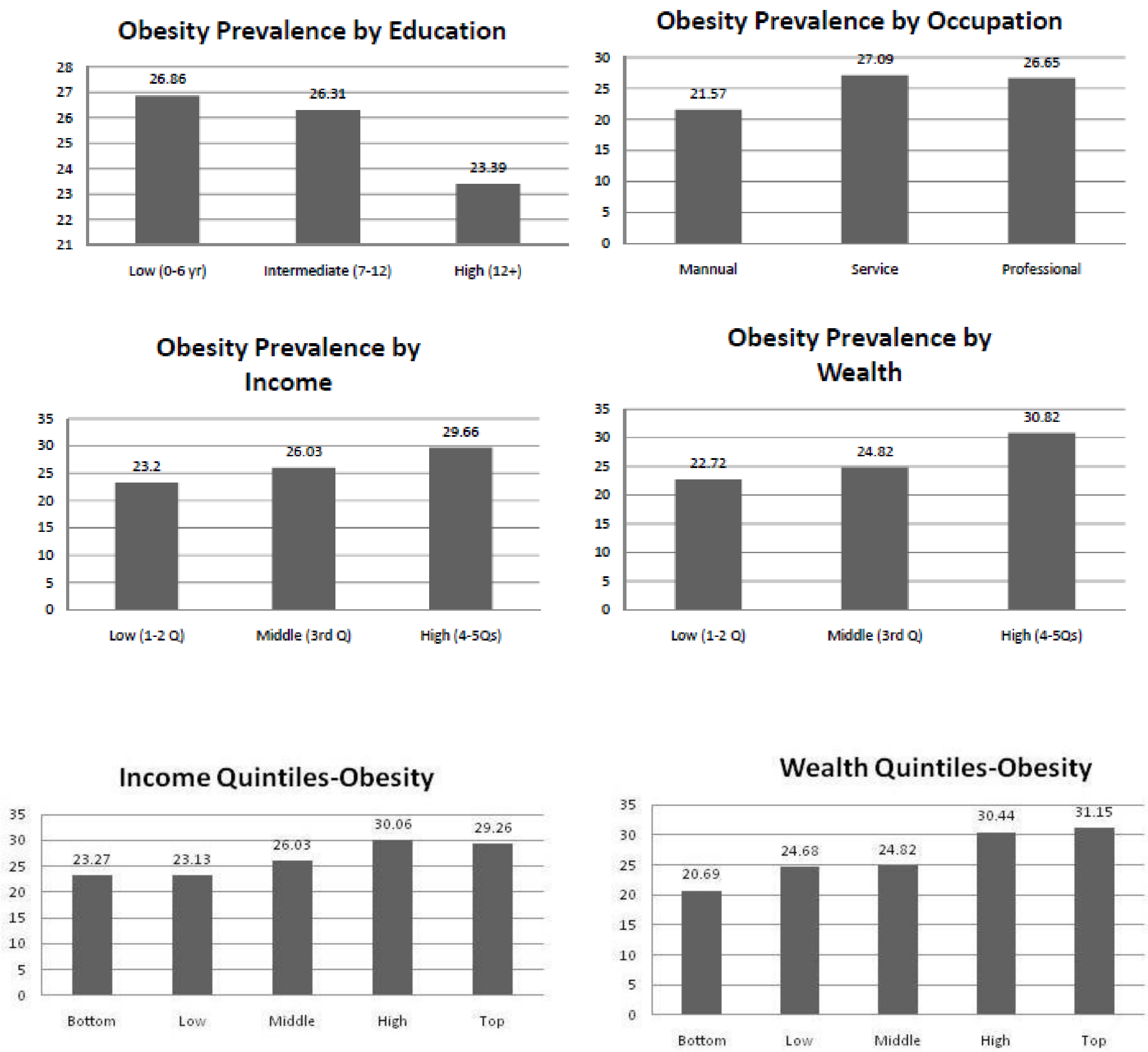

Figure 3: Provincial Gini coefficients and obesity prevalence

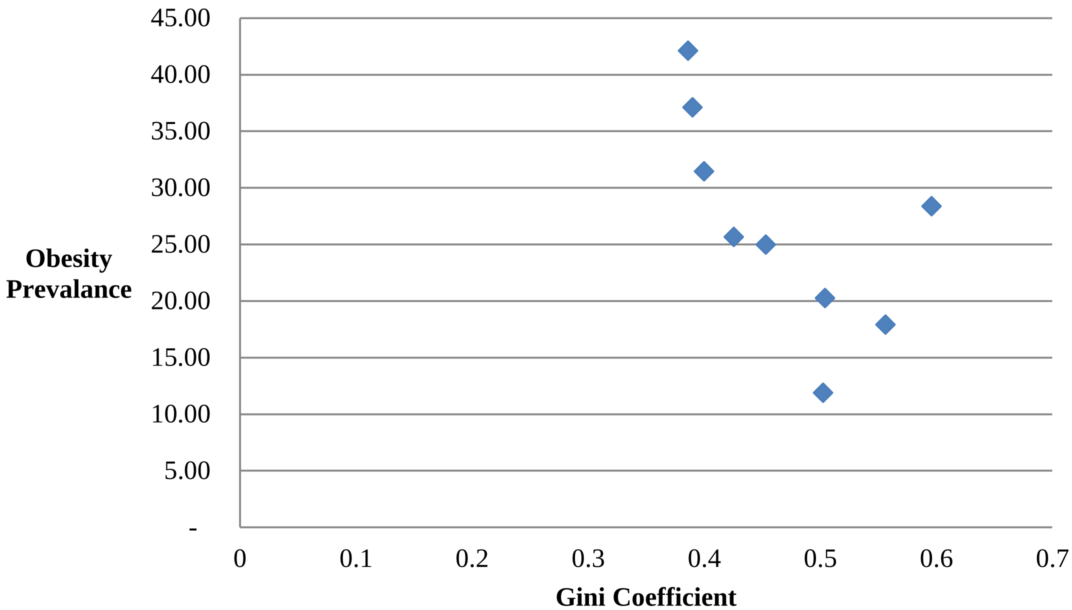

Figure 4: Predicted obesity rates by region and Gini coefficient