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Multilevel Socioeconomic Differentials in Allostatic Load among Chinese Adults

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Abstract

Capitalizing on the biomarker data from the 2009 wave of the China Health and Nutrition Survey (CHNS), this study examines the extent to which multilevel socioeconomic status (SES) gets "under the skin" to affect individuals' health, measured by allostatic load (AL). Multilevel analyses suggest that in the context of China's socioeconomic and health transitions, high income, prestigious but sedentary occupations, and high level of urbanization were independently associated with higher AL scores, or increased health risks of physiological dysfunction in cardiovascular, metabolic, inflammation, and urinary systems. Higher educational attainment was related to a decrease in AL, but the significant difference was only observed among the college-educated compared to lower levels of education.

Keywords

China; allostatic load; socioeconomic status; multilevel; health transition

Introduction

Socioeconomic inequalities in health have been well documented in both developed and developing countries (Bakkeli, 2016; Elo, 2009; Xu and Xie, 2017). What remains controversial is the underlying mechanism that relates socioeconomic status (SES) to specific health outcomes. The growing interest and efforts in collecting biomarker data in demographic surveys allow researchers to measure health status more accurately by using physiological indicators such as allostatic load (AL), compared to widely used respondents' self-reports in the literature. This, in turn, provides a great opportunity to better identify the biological pathway through which SES may affect health (Seeman et al. 2001).

AL is designed as a measure of long-run health consequences resulting from a multi-system physiological response to chronic stresses in order to maintain internal homeostasis. The notion of AL was introduced by McEwen and Stellar (1993), based on the concept of

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allostasis, which describes the ability of physiological systems to adjust to environmental challenges. McEwen and Stellar (1993) proposed that a long-term deviation from the normal range of physiological parameters as a result of allostasis can impose unnecessary strains on physiological systems and predispose individuals to disease. AL measures such exposure and vulnerability to disease. In empirical studies, AL is often calculated as a summary score of high risks with respect to various biomarkers. Recent studies have demonstrated that it is an independent, powerful predictor of mortality, cardiovascular and metabolism-related chronic diseases, and overall decline in physical and cognitive functioning (Kubzansky et al., 1999; Mattei et al., 2010; Seeman et al., 2004a; Seeman et al., 2001; Singer and Ryff, 1999).

However, despite the widely held expectation about the protective effect of SES against AL, empirical evidence remains surprisingly scarce across diverse populations as detailed below. This study postulates that as a composite measure of cardiometabolic risks and other physiological dysfunctions, the SES determinants of AL are context-dependent (Link and Phelan, 1995). In particular, certain SES indicators, such as income and occupation, may operate in ways opposite to comparable indicators in Western societies, to affect AL in low- and middle-income countries where poverty triggers chronic daily stress, but affluence and prestigious occupations may also induce negative health consequences in light of the ongoing health transition. Informed by the mounting literature on community effects on health in the past decade (e.g. Diez Roux, 2001), this study further emphasizes a multilevel perspective in understanding the complex patterns of SES determinants of biological wear and tear (Bird et al., 2010; Merkin et al., 2009).

This study tests these conjectures in China because its experiences of dramatic economic growth, rapid social changes, and health transition can provide valuable insights to many other developing countries worldwide (Popkin, 2014). Capitalizing on the recently available biomarker data from the 2009 China Health and Nutrition Survey (CHNS), this study seeks to examine the extent to which multilevel SES gets "under the skin" to affect individuals' health in terms of biological parameters among adult Chinese. More specifically, this study operationalizes the effect on AL of multilevel SES indicators, including education and occupation at the individual level, household income at the family level, and urbanization at the community level. To assess robustness, time-lagged models are estimated by regressing AL measured in 2009 on SES indicators measured in 2006 to assess the robustness of cross-sectional analyses. This study is among the first to systematically investigate the associations between multilevel SES factors and AL in China, the most populous country and the second largest economy in the world. Its empirical findings can enhance our understanding of the context within which different SES indicators operate, which is essential for designing intervention strategies that otherwise may be hopelessly ineffective (Link and Phelan, 1995).

Previous Research

In the U.S., several similar studies drew on data from the Third National Health and Nutrition Examination Survey (NHANES III), but reached inconclusive findings. Seeman et al. (2008) found that both education and household income were negatively associated with AL in adults aged 20 and older. However, focusing on young women aged 17–30, Allsworth et al. (2005) reported that neither education nor income was a significant predictor of AL.

Using samples of adults aged 20 and older from both NHANES III and NHANES 1999–2004, Crimmins et al. (2009) discovered higher levels of AL, without adjusting for other social and demographic characteristics, among people living in poverty or near poverty than among those with higher family incomes. Nonetheless, it is unclear whether the income gap would remain significant after controlling for other confounding variables. In a cohort study of community-dwelling men from the Greater Boston area, Kubzansky et al. (1999) found that the association between education and AL was no longer significant after controlling for a measure of psychosocial vulnerability.

Two cross-sectional U.S. studies (Bird et al., 2010; Merkin et al., 2009) have resorted to the NHANES III data to explore the independent effect of community SES on AL. Both studies approximated communities using the 1990 U.S. Census tracts and aggregated a community SES index across several domains (percent less than high school education, percent unemployment, median household income, etc.) from individual SES among those living in the community. This compositional approach leaves out other important measures of community characteristics that cannot be derived from individual level measures, such as urban development, environmental sanitation, and health-related resources, thereby subject to the risk of underestimating the community effect on AL. As a result, Bird et al. (2010) reported that community SES was inversely related to AL in adults aged 20 years or older; whereas Merkin et al. (Merkin et al., 2009) found that the inverse association between community SES and AL was significant only for non-Hispanic blacks, but not for non-Hispanic whites or Mexican Americans.

Researchers have also attempted to investigate the association between life course SES and AL in regional samples such as the Biomarker Substudy of the Study of Midlife in the U.S. (Gruenewald et al., 2011) and the subsample of the Wisconsin Longitudinal Study (Singer and Ryff, 1999). However, these studies did not fully control for important social and demographic confounders, which cast doubt on the robustness of their findings.

Several studies have expanded to a non-Western population by capitalizing on data from the Taiwan Social Environment and Biomarkers of Aging Study. Yet they yielded largely unfavorable results regarding the hypothesized protective effects of SES against AL. For example, Hu et al. (2007) reported significant bivariate associations of AL with education and family income, respectively; whereas in multiple regression models, neither of these associations remained significant in men or women aged 54 and older (Dowd and Goldman, 2006; Gersten, 2008). Nevertheless, Seeman et al. (2004b) found that husband's years of education was inversely related to AL for the nearly elderly women aged 54–70, but in terms of life course SES, a longitudinal measure of financial hardship did not predict AL in later life.

In light of the mixed results from high-income societies, this study seeks to contextualize health risk factors (Link and Phelan, 1995), that is, to identify the social conditions under which particular SES indicators are more or less consequential in predicting AL and in what directions among Chinese adults. It is expected that the association between SES and AL varies by the dimensions of SES (e.g., knowledge, material resources, and social capital), the hierarchy of resources (e.g., individual, family, and community levels), and broad societal contexts (e.g., Western vs. non-Western, developed vs. developing countries). China's ongoing economic, demographic, and health transitions are tightly interrelated, resulting in complex associations between SES and AL that are more dynamic than conventional wisdom would predict.

The Chinese Context

Most Western countries have already entered the late stage of a health transition, which involves a shift to a diet high in fat, cholesterol, sugar, and energy, but low in fiber, as well as an increasingly sedentary lifestyle and hence reduced energy expenditure. As a result, these countries have been seriously confronted by obesity epidemics and a range of nutrition-related noncommunicable diseases, notably related to cardiovascular and metabolic systems (Popkin, 2015; Popkin and Gordon-Larsen, 2004). In other words, the predominant disease profile among Western populations coincides with the health risk factors summarized by AL. By contrast, fueled by its rapid economic growth, social development, and urbanization in the last three decades, China has only recently embarked on the chronic disease phase of the health transition, that is, in the midst of the alteration from a situation of significant undernutrition and infectious diseases to that characterized by obesity and associated degenerative disease (Du et al., 2002; Popkin, 2014). Overall, China's health transition has been proceeding faster than it did in the U.S. and many high income countries (Popkin, 2002). Among Chinese adults of 18 years and old, for example, the prevalence of overweight and obesity more than doubled from 16.4% in 1992 to 42% in 2012, the hypertension rate increased by 75% from 14.4% in 1991 to 25.2% in 2012, and the prevalence of diabetes nearly tripled from 2.6% in 2002 to 9.7% in 2012 (CNHFPC, 2015; Wang, 2005; Wang et al., 2007).

Today, China is a fast-developing middle-income country. Its GDP per capita rose from 1662.03 USD in 1960 to 7329.09 USD in 2017 (Trading Economics, 2018) and its Human Development Index increased from 0.499 in 1990 to 0.728 in 2015 at the ranked of 90 (UNDP, 2016). However, due to its enormous regional variations in baseline social conditions and the pace of economic reform (Xie and Hannum, 1996), China's economic and health transitions have been uneven both spatially and temporally. Epitomized by Deng Xiaoping's slogan, "let some of the people get rich first"(Hewitt, 2009), the urban population, especially those living in coastal provinces, have benefited disproportionately from the economic reform at the expense of their rural peers living inland. Consequently, despite overall improvements in living conditions and population health, the relatively affluent urban Chinese are undergoing a more accelerated health transition compared to their poor rural peers (Leow, 2014; Yang et al., 2013). For instance, the leading causes of mortality and morbidity have shifted to cancer, cardiovascular disease, cerebrovascular disease, and other types of chronic diseases in urban China, whereas infectious diseases, digestive diseases, and respiratory diseases still prevail in rural areas (Zhao, 2006). By 2010 the overall burden of disease for Chinese adults had become dominated by non-communicable diseases and chronic disability (Yang et al., 2013), but diarrhea, lower respiratory infections, and other common infectious diseases remain important causes of death by 2013 in remote, under-developed provinces such as Tibet, Qinghai, Guizhou, Sichuan, Yunnan, and Gansu (Zhou et al., 2016).

An even more striking example of the uneven pace of changing disease profiles is evident in the so-called "dual-burden households" documented in China and other transition economies (Doak et al., 2005; Doak et al., 2002). As the livelihood improves and diet and activity patterns begin to change, adult members of previously impoverished households are among the first to experience increased risks of obesity and other associated chronic diseases, despite persistent malnutrition among child members in the same households. In China, such a dual burden most often occurs in low-income urban households (Doak et al., 2002). The dual-burden households are likely to evolve into clustering of overweight and obese members as their wealth continues to accrue. By the same token, high-income rural residents will precede their low-income peers in terms of developing an obesity-related chronic disease profile as they benefit disproportionately from urbanization and economic growth in the countryside.

In short, the varying rates of economic growth and the uneven pace of the health transition experienced by different subpopulations dictate that the social production of illness is context-dependent and may operate through different or even opposite pathways in China than in developed countries (Sobal and Stunkard, 1989). The association between SES and health is not necessarily linear or positive in contemporary China. For example, as a determinant of purchasing power, high income may accelerate the shift towards an overnutritious diet and a sedentary lifestyle that together contribute to elevated risks of cardiovascular and metabolic diseases, despite high income's role in raising material living standards and securing quality health care. In principle, high income can buy a healthy lifestyle that involves such things as a nutrition-rich diet and gym membership. However, the consumption pattern partly depends on a country's economic development. In China, a fast-developing middle-income country, Western style fast food restaurants is often considered as a faddish diet that signifies modernity and novelty (Xu et al., 2013), and leisure physical activities has remained uncommon in the last two decades (Ng et al., 2014). As a result, the association between income and obesity risk was found to be positive in mainland China but negative in Taiwan, a region with similar genetic and cultural characteristics but at a higher level of economic development (Shimokawa et al., 2009). On the other hand, poverty remains a chronic stressor in many Chinese people's daily life, in addition to its threats of malnutrition and inability to obtain timely medical treatment in case of illness.

Similarly, occupational status can be health-promoting or detrimental, depending on the specific context. Prestigious white-collar jobs are associated not only with high income and low occupational hazards, but also great work pressures. Perhaps more importantly, such jobs substantially reduce the amount and intensity of occupational physical activity compared to the backbreaking agricultural work that prevailed at the early stage of the health transition (Ng et al., 2009). A recent study reported an approximately 30–40% decline in occupational physical activity among adult Chinese men and women from 1991 to 2011, which was the major driving force behind the reduction in overall physical activity during the same period (Ng et al., 2014). To the extent that being sedentary is a salient risk factor for an array of cardiovascular and metabolic diseases (Thorp et al., 2011), occupations characterized by physically inactivity tend to increase AL levels. As for the psychosocial pathway, more prestigious white-collar jobs may be associated with a stronger sense of control and a higher individual status in the social hierarchy, which in turn reduces the risk of biological dysregulation (Seeman et al., 2014), compared with physically strenuous agricultural work or non-agricultural manual work. In China, men and women with more prestigious jobs such as managers and professionals were found to report fewer work hours and better subjective well-being than those with less prestigious jobs such as unskilled workers and farmers (Bian et al., 2015; Xie et al., 2015). Therefore, higher occupational prestige may be associated with better psychosocial health and hence lower AL in Chinese adults.

By contrast, educational attainment contributes positively to health by accumulating health-promoting knowledge, improving problem-solving skills, and enhancing capacity to initiate behavior changes and maneuver resources to reduce health risks and combat diseases. As new disease risk factors become evident, people of higher education are more likely to be favorably situated to know about the risks and to mobilize the resources that help them to engage in preventative and protective efforts (Link and Phelan, 1995). Higher level of education is also associated with a greater sense of control, which, in turn, facilitates adaptive strategies for coping with material adversity and potential stressors (Williams, 1990).

At the community level, one of the most prominent SES changes in contemporary China lies in its rapid urbanization. The percentage of urban population in mainland China has more than doubled in about two decades, from 26% in 1990 to 52.6% in 2012 (NBSC 2013), an increase that used to take twice as long in Western countries. Despite substantial improvement in living standard and health infrastructure, the urbanization process has contributed to a fundamental shift towards Western lifestyles. In particular, occupational activity has become increasingly sedentary as technological advancement has reduced the physical demands of heavy occupational activities and white-collar and service industries have outgrown agriculture. For example, Monda et al. (2007) found that the average level of urbanization over a 6-year period in the community predicted 51–68% greater odds for Chinese men and women to participate in light versus heavy occupational activities. Ng et al. further (2009) reported a 32% decline in occupational, household, and leisure physical activities among Chinese adults between 1991 and 2006, of which 40–57% of the variation was explained by urbanization at the community level. In addition, several studies have suggested that urbanization in China is characterized by pollution, overcrowding, problems of public and traffic safety, social isolation, and inadequate public health infrastructures (Ng et al., 2014; Thompson et al., 2014b). Therefore, urbanization may also affect AL by increasing exposure to these psychosocial and environmental stressors.

To the extent that AL reflects chronic disease risks, especially in the cardiovascular and metabolic systems, this study expects that without adjusting for potential mediators such as levels of physical activity, dietary patterns, and other health-related lifestyle factors: (1) education is protective against chronic disease risks and thus is inversely related to AL; (2) prestigious and yet sedentary occupations are positively related to AL; (3) the association between income and AL is curvilinear in that the high-income group, who are at elevated risks of overnutrition and sedentary lifestyle, and the low income groups, who cannot afford a good diet, have higher AL compared with the middle income group; and (4) urbanization is positively related to AL.

Data and Measures

Subjects for this study are adult participants ages 18 or older in the CHNS, a panel survey that includes more than 4,000 households across 9 provinces in contemporary China. The CHNS data are not nationally representative, but the households were selected through a multistage, random cluster sampling process from a diverse set of nine provinces in northeast, central, and south China. Together, these nine provinces are home to more than 40% of China's population, or million people. The average response rate at the individual level is 88% across waves. Details on the design and sampling of CHNS are available elsewhere (Popkin et al., 2010).

The CHNS collected fasting blood samples for the first time in 2009, permitting the construction of AL from multiple biomarkers. AL was constructed using methods as close as possible to those used in prior studies. Specifically, AL scores were calculated from biological indicators of four major physiological systems. For each system, one or more biological measures were selected, upon their availability in the CHNS, to mimic those adopted in the previous research (Seeman et al., 2010; Seeman et al., 2008). Risk factors for the cardiovascular system include systolic and diastolic blood pressures. Markers of metabolic system include body mass index (BMI; overall body weight status), waist-to-hip ratio (central obesity), high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, total cholesterol, triglycerides, HbA1c (diabetes), and fasting glucose. Indicators of inflammation system include high-sensitivity C-reactive protein (CRP) and albumin. Urinary system is measured by creatinine clearance and uric acid. Laboratory analysis methods for the biomarkers have been described in detail elsewhere (Yan et al., 2012).

For each biological measure, a dichotomous variable was created to indicate whether the biomarker reading falls into the range of high risk (= 1) or not (= 0). The cut-points for high risk categories were chosen according to recommendations by international health organizations, world-renowned U.S. health organizations, and published studies of Chinese population (Xu et al., 2016; Yan et al., 2012), as well as the CHNS biomarker manual (CHNS, 2011a). Cut-off points that are specific to Asian or Chinese populations, as well as different age and gender groups were adopted where appropriate. It is also worth noting that the cut-off points for cardiovascular and metabolic disease risks recommended by American health organizations are wildly accepted in other countries including China. A detailed description of the biological measures considered, the reference ranges adopted, and descriptive statistics are presented in Table 1. Then the final AL score was obtained by summing up all the dichotomous indicators of high risk, which is a prevailing method in the literature. As a robust check, a weighted AL score was calculated to take into account the fact that the number of biomarkers is greater for metabolic system than for the others. The weight was constructed by taking the inverse of the total number of biological indicators available for a given physiological system so that each indicator carries less weight if more indicators are available within the same domain.

Multiple indicators were selected to measure respondents' individual, family, and community level SES. At the individual level, educational attainment was divided into five categories, as in previous research (Jones-Smith et al., 2012): no schooling, elementary school, middle school, high school or equivalent (e.g., technical school), and college or above. Occupational status was classified into four categories: unemployed, farming, unskilled worker, and skilled or professional worker. At the family level, annual household income per capita in the previous year was constructed by the CHNS research team in two steps (CHNS, 2011b). First, total household income was calculated as the self-reported sum of all sources of income and revenue (business, farming, fishing, gardening, livestock, wage, pension, government subsidies, and other income) minus expenditures. Then total household income was divided by household size which was sum of the number of household members who participated in the survey and the number of household members who were reported in the household roster but did not participate in the survey. In regression analysis, household income was divided into four quartiles to capture potential nonlinearity.

Community-level SES was measured by an urbanization index designed specifically for CHNS data. Capitalizing on the community data collected in the CHNS, this urbanization index captured twelve dimensions of urbanization: population density, economic activity, traditional markets, modern markets, transportation infrastructure, sanitation, communication, housing, education, diversity, health infrastructure, and social services. Each of these dimensions was measured by one or multiple variables and assigned 10 possible points, resulting in a maximum value of 120 points summed across all the dimensions, with higher values indicating greater urbanization. Construction of the urbanization index has been described in detail elsewhere (Jones-Smith and Popkin, 2010). To the extent that regional socioeconomic development is tightly linked to the urbanization process in contemporary China, the urbanization index serves a good proxy for community-level SES (Jones-Smith and Popkin, 2010; Monda et al., 2007). In regression analyses, the urbanization index was standardized into z-scores to facilitate computation and interpretation.

Demographic control variables include age (divided by ten and mean-centered to facilitate interpretation) and age-squared, gender (male versus female), marital status (married versus not), rural-urban residence, and a set of dummy variables for geographic regions. Several health behavior and lifestyle factors were treated as potential intermediate variables in the pathway between SES and AL. Smoking was measured by self-reported amount of cigarette consumption and divided into three categories: none, less than one pack of cigarettes per day, and one pack or more per day. Drinking was measured by self-reported frequency of alcohol consumption and divided into four categories: none, monthly drinking, weekly drinking, and daily drinking. Work-related physical activity level was measured by self-reported levels of physical activities in daily paid or unpaid work (e.g., housewife). Specifically, adult respondents were asked about the average time spent sitting, standing, walking, and lifting heavy loads during a typical day, which allowed the interviewers to assess the overall strenuousness of the work and categorize each respondent into a set of six levels of activity (Monda et al., 2007). The six levels were collapsed into four in this study: no working ability or very light (working in a sitting position), light (working in a standing position), moderate (e.g., student, driver, and electrician), and heavy (e.g., farmer, dancer, and athlete) or very heavy (e.g., logger, miner, and stonecutter). Leisure physical activity level was measured by a dichotomous variable indicating whether (=1) or not (=0) a respondent participated in any of six categories of sports, ranging from martial arts to dancing, from track and field to swimming, and from soccer to ping pong. Lastly, dietary fat intake was derived from three 24-hour recalls taken on consecutive days and measured as the percent of the total daily energy intake from fat (Thompson et al., 2014a).

Among the 8,690 adults (>=18 years) whose blood samples were drawn, 442 respondents were discarded for they had missing data on any of the AL components. Exploratory analysis revealed little significant difference in other characteristics between these subjects and the rest of the sample except that the former were slightly more represented in non-agricultural occupations and in the inland region. Another 389 respondents were excluded due to missing data on independent variables, resulting in a final analytical sample of 7,857 respondents.

As a robust check, the cross-sectional analysis was repeated by regressing the AL measures in 2009 on the same set of independent variables measured in 2006. The time-lagged models helped alleviate the challenge of reverse causality or self-selection bias. A total number of 5,647 respondents with no missing data in 2006 were successfully linked to their AL scores in 2009, resulting in a 72% follow-up rate, which is consistent with the literature (Zhang et al., 2014).

Methods

In both cross-sectional and time-lagged analyses, multilevel negative binomial models were fitted to adjust for potential over-dispersion in the count variable of unweighted AL score. Multilevel linear regression models were fitted to the continuous variable of weighted AL score. The multilevel models adjusted for the correlation among individuals (level-1) living in the same communities (level-2). In the time-lagged models, longitudinal sample attrition was adjusted by applying the inverse probability weighting (IPW) technique (Fitzmaurice et al., 2004). Specifically, a dichotomous variable indicating whether a respondent interviewed in 2006 was successfully followed up in 2009 was regressed on the aforementioned independent variables measured in 2006. Probabilities of dropping out of the study in 2009 were then predicted based on the regression estimates. Those who had a high probability of dropping out but remained in the survey were weighted upward, while those who had a low probability were weighted downward. Such IPW reduces bias and improves efficiency in the regression estimates.

For each outcome variable, two regression models were estimated. The first model included the SES indicators of interest and the demographic control variables. The second model added health-related lifestyle control variables. This stepwise modeling approach does not amount to a formal mediation analysis, but it sheds light on the way in which SES may affect AL. Throughout the regression analysis, statistical significance was based on robust standard errors that adjusted for within-community clustering.

Results

Descriptive Statistics

Table 1 reports definitions and rates of high risks for individual AL biomarkers measured in 2009. The most common risky biomarkers pertained to blood pressures, body weight status, and lipids, for the corresponding rates of at-risk respondents were 20% or higher. The prevalence rates of at-risk respondents were relatively low with respect to glucose control, inflammation, and urinary function, although approximately 24% of the respondents exhibited elevated CRP levels.

Table 2 reports summary statistics of the dependent variables in 2009 and independent variables in both 2006 and 2009. The average unweighted AL score was 3.0 with a standard deviation of 2.4, suggesting a skewed distribution of count data given its possible range of 0–14. Therefore, negative binomial models might be more appropriate than Poisson models for unweighted AL score. The average weighted AL score was 0.8 with a standard deviation of 0.7, while a post-regression diagnostic analysis indicated approximately normally distributed residuals (results not shown), supporting the choice of linear models.

In terms of demographic characteristics, the average age of the analytical sample was about 51 years old in both 2006 and 2009. There were slightly more women than men, which is consistent with the gender composition in other studies using the 2006 and 2009 CHNS data (Batis et al., 2014; Yan et al., 2012). The marriage rate was close to 90% in 2006, reflecting the tradition of universal marriage in China, and it dropped a little by 2009 largely due to an increase in widowhood rather than divorce.

Turning to SES indicators, the majority (about three quarters) of the respondents did not graduate from senior high school or above, and farmers remained the dominant group among those who were employed. The average inflation-adjusted annual household income per capita increased remarkably by about 45% from 8,062 RMB in 2006 to 11,685 RMB in 2009, reflecting China's rapid economic growth. The overall pace of urbanization was slow at the community level urbanization as the proportion of rural respondents only increased from 26.0% to 29.7% and the average urbanization index score increased from about 66 in 2006 to 67 in 2009. However, the relatively large standard deviation of the urbanization index score (about 19 in both 2006 and 2009) implied a considerable amount of between-community variation.

As for health behaviors and lifestyle factors, more than a quarter of respondents smoked cigarettes and nearly a third drank alcohol in both 2006 and 2009. Participation in leisure physical activities remained below 10% in both years. However, there was a statistically significant reduction in the intensity of work-related physical activity. Most notably, the proportion of respondents who reported heavy or very heavy physical activity at work dropped from 41.3% in 2006 to 34.0% in 2009. There was also a significant increase in the average percent of total daily energy intake from fat which exceeded the 30% cut-off point for high-fat diet (Thompson et al., 2014a) in 2009.

Cross-sectional Regression Estimates

Table 3 reports coefficient estimates from the cross-sectional multilevel negative binomial models of unweighted AL scores. Model 1 shows a negative AL gradient by education, but only the respondents in the highest educational category (college or above) had significantly lower AL scores than the reference group who received no education. Supplemental analyses revealed that college graduates or above also had significantly lower AL scores than those who received elementary or middle school education (results not shown). Compared with farmers, the unemployed and skilled or professional workers had significantly higher AL scores. Surprisingly, household income was not significantly associated with AL. At the community level, higher urbanization index scores were associated with higher AL scores. Living in urban areas was related to higher AL than in rural areas, although this association was only marginally significant.

Model 2 added control variables of health behaviors and lifestyle factors. As a result, high school graduates had marginally significantly lower AL scores than those without formal education. The significance level was attenuated for skilled workers or professionals at the individual level, as well as urbanization index at the community level. The coefficient estimates for other SES indicators remained qualitatively unchanged. As for health behaviors, light smokers (less than a pack of cigarettes per day) had significantly lower AL scores than non-smokers, but such an association was not significant for heavy smokers. Weekly alcohol drinkers had significantly higher AL scores than abstainers, but such an association was not significant for daily drinkers. Participation in heavy or very heavy work-related physical activity was negatively associated with AL scores compared with participation in very light work-related physical activity. High-fat diet was associated with higher AL scores.

Time-lagged Regression Estimates

Table 4 reports coefficient estimates from the time-lagged multilevel negative binomial models of unweighted AL scores measured in 2009 regressed on independent variables measured in 2006. By and large, the patterns of SES differentials in AL found in the cross-sectional models still hold. In Model 1, for example, AL scores remained significantly lower among the most educated (college or above) respondents, the unemployed, skilled or professional workers, and those living in more urbanized communities. Nevertheless, statistical significant levels changed for some coefficients. Specifically, unskilled workers in 2006 had significantly higher AL scores in 2009 compared with farmers, and respondents from the richest families in 2006 had significantly higher AL scores in 2009 compared with those from the poorest families. These associations were not significant in the cross-sectional model (Model 1 in Table 3).

After controlling for health behavior and lifestyle factors in Model 2, the significant levels were fully attenuated for skilled or professor workers at the individual level and urbanization index at the community level, whereas the results for other SES indicators remained qualitatively unchanged. The estimates for the health behavior and lifestyle factors were similar to those found in the cross-sectional models. One notable exception was that daily alcohol drinkers in 2006 had significantly higher AL scores in 2009 compared with abstainers, although this association was not significant in the cross-sectional model (Model 2 in Table 3).

Sensitivity Checks

Appendix Table A1 reports coefficient estimates from the cross-sectional multilevel linear models of weighted AL scores. Most results are similar to those reported in Table 3, with one important difference pertaining to household income in both Models 1 and 2. Compared with those from the poorest families, respondents from the richest families had significantly higher weighted (Table A1) but not unweighted (Table 3) AL scores. Another evident difference pertains to drinking in Model 2. Weekly alcohol drinker had significantly higher unweighted (Table 3) but not weighted (Table A1) AL scores than abstainers.

Appendix Table A2 report coefficient estimates from the time-lagged multilevel linear models of weighted AL scores. Again, the results are largely similar to those reported in Table 4, with two exceptions in Model 2. First, unskilled workers had significantly higher unweighted (Table 4) but not weighted (Table A2) AL scores than farmers. Second, respondents whose work involved moderate physical activity had significantly lower weighted (Table A2) but not unweighted (Table 4) AL scores than those whose work only involved very light physical activity.

Discussion

Contrary to the conventional wisdom about the protective health effects of SES, this study found detrimental effects of high income, prestigious occupations, and community-level urbanization on AL. The only health-promoting SES indicator was education, and only those who achieved the highest educational attainment were at reduced risk of AL. These findings are robust against different constructions of AL score (weighted or unweighted) and modeling strategies (negative binomial or linear model) and further strengthened by time-lagged regression analyses that more or less address the challenge of reverse causality between SES and health.

Overall, the findings are consistent with our theoretical expectation about the mechanisms linking SES to chronic health risks in transition China that differ from links in developed Western societies. In fact, several recent studies have suggested that as Chinese children and adults are transitioning from scarcity and extensive undernutrition to obesity epidemics, from physically intensive domestic, occupational, and travel activities to sedentary work and lifestyles, they are increasingly confronted by rising cardiometabolic disease risks (Adair et al., 2014; Ng et al., 2014; Zhai et al., 2014). The occupational gradient in AL reported in this study is consistent with the hypothesis that declined physical activity at work contributes to higher cardiometabolic risks with respect to elevated blood pressure, diabetes, inflammation and dyslipidemia (Adair et al., 2014). The health-damaging effect of income may be correlated with, among others, the shift towards an unhealthy Western type of diet characterized by high fat, high calorie, and added sugar, which in turn increase nutrition-related non-communicable disease risks (Zhai et al., 2014).

A commonly cited environmental factor driving the trends of declining physical activity and unhealthy diet change in China is its rapid urbanization (Ng et al., 2014; Zhai et al., 2014). However, the cross-sectional regression models revealed a significant association between urbanization and AL after controlling for levels of physical activities and dietary fat intake – two potential mediators. This finding suggests that urbanization may affect AL through other pathways such as increased exposure to environmental pathogens that trigger inflammation (Thompson et al., 2014a). This finding also highlights the importance of a multilevel perspective in designing interventions to reduce AL levels among Chinese adults.

The only silver lining discovered in this study pertains to education, one of the most robust and protective SES factors for health. Not only do well-educated people tend to have better health-related knowledge and stronger capacity to acquire and mobilize various resources to improve their health status, but they are also more skilled in coping with stress from chronic economic hardship, adverse work environments, and other types of stressful life events (Elo, 2009). Unfortunately, this study only found significantly lower AL among those with college educations or above. Despite China's expansion of higher education since the turn of the 21st century, the bulk of the current adult population is insulated from the benefit of attending college.

Several findings related to demographic and lifestyle factors are also worth noting. Being married was protective against AL in some but not all the regression models. This may be attributed to the nearly universal marriage in Chinese adults (Yeung and Hu, 2016), resulting in limited variation in marital status to detect its health impact. Participation in leisure physical activities was surprisingly not associated with AL. A possible explanation is that not only was overall participation rate very low (less than 10% in Table 2), but the level of leisure physical activities was not high enough to produce any health benefit among the participants. One recent study estimated that in 2006, the amount of Chinese adults' leisure activities accounted for only 1% of their total physical activities (Ng et al., 2009). Alcohol use appeared to provide some health benefits. In the cross-sectional analysis, weekly drinkers had significantly lower AL scores than abstainers. This finding is consistent with another study using the CHNS 2009 data which reported a lower risk of diabetes as measured by HbA1c among moderate alcohol (Batis etal., 2014). In the time-lagged analysis, daily drinkers also had significantly lower AL scores than abstainers. One possibility is that the Chinese heavy drinkers consist of self-selected healthier individuals. Another possibility is that alcohol is detrimental to certain physiological systems but beneficial to others. For example, one study using the CHNS 2009 data reported that, despite having higher waist-to-height ratio, both moderate and heavy drinkers had significantly lower levels of inflammation than abstainers (Thompson et al., 2015). Lastly, light smokers – those who smoked less than a pack of cigarettes per day – had significantly lower AL scores than non-smokers across all the model specifications. Despite its well-known detrimental health effects, smoking has been related to better self-rated health (Yen et al., 2010) and healthier body weight status (Wang, 2015) in Chinese adults. It is also possible that the light smokers in this study used cigarettes as a strategy to cope with stress, which in turn might reduce AL.

This study is subject to several limitations that merit further research. First and foremost, the research design is unable to fully resolve the endogeneity problem and make a causal inference for a variety of reasons. For example, biomarker data were collected only in the 2009 wave of the CHNS to date, restricting us from adopting a difference-in-difference approach that could net out time-constant unobserved heterogeneity as well as trend-induced bias. Second, similar to other survey research, the regression analyses are susceptible to a missing data problem, although it is not severe (only about 7% are missing cases in the cross-sectional models) according to the conventional standard. Statistical adjustment techniques such as IPW or multiple imputations rely on an assumption of missing at random that can never be verified in reality. Third, cut-off points for high risks that were specific to age, gender, and Chinese ethnic groups were available for some but not all biomarkers. Lastly, the CHNS sample only covers nine provinces, precluding us from generalizing the findings to the entire country.

Despite these limitations, the findings from this study have important policy implications. First, public health campaign is needed to better educate the Chinese population about the health risks of reductions in physical activities at work and leisure times, increasingly popular but unhealthy dietary pattern, as well as the awareness of chronic diseases in general (Ng et al., 2014; Thompson et al., 2015). Second, despite China's rapid urbanization, the government, communities, and employers should work together to build an environment where physical activities, nutrition-rich diet, and other healthy lifestyles are encouraged both in daily life and at workplace. To the extent that China's experience is informative for other developing countries currently undergoing health transition (Popkin, 2014), this research contributes to increasing efforts to understand emerging chronic disease profiles and new patterns of health disparities by SES in the Global South.

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Appendix Table A1.: Cross-sectional multilevel linear models of weighted AL.

	weighted AL in 2009					
	Model 1			Model 2		
Independent variables in 2009	**β**	**RSE**		**β**	**RSE**	
Age (centered)	0.156	0.006	***	0.152	0.006	***
Age-squared	−0.003	0.003		−0.005	0.003	
Male (ref: female)	0.030	0.017	†	0.070	0.021	**

	weighted AL in 2009					
	Model 1			Model 2		
Independent variables in 2009	**β**	**RSE**		**β**	**RSE**	
Married (ref: no)	−0.034	0.021		−0.034	0.021	
Education (ref: no)						
Elementary school	0.035	0.027		0.030	0.027	
Middle school	0.016	0.028		0.007	0.028	
High school or equivalent	−0.021	0.032		−0.033	0.031	
College or above	−0.096	0.047	*	−0.113	0.047	*
Occupation (ref: farmer)						
Unemployed	0.137	0.020	***	0.093	0.023	***
Unskilled	0.017	0.022		−0.019	0.024	
Skilled/Professional	0. 072	0.026	**	0.032	0.028	
Household income per capita (ref: poorest)						
2nd quartile	−0.019	0.020		−0.021	0.020	
3rd quartile	0.020	0.022		0.016	0.022	
4th quartile (richest)	0.054	0.025	*	0.049	0.025	*
Urbanization index (z-score)	0.044	0.012	***	0.030	0.012	*
Urban (ref: rural)	0.057	0.027	*	0.055	0.028	*
Smoking (ref: none)						
< 1 pack per day				−0.082	0.024	**
>= 1 pack per day				−0.030	0.024	
Drinking (ref: none)						
Monthly				−0.015	0.021	
Weekly				0.004	0.026	
Daily				−0.016	0.030	
Work-related PA (ref: very light)						
Light				−0.024	0.022	
Moderate				−0.021	0.026	
Heavy or very heavy				−0.097	0.027	***
Leisure PA (ref: no)				−0.035	0.029	
% of daily energy intake from fat				0.002	0.001	*
Region (ref: inland)						
Northeast	0.058	0.025	*	0.057	0.025	*
Coastal	0.018	0.025		0.022	0.025	
Mountainous South	−0.036	0.026		−0.026	0.025	
Constant	0.642	0.04	***	0.679	0.052	***
σ (random effects)	0.085	0.01	***	0.084	0.01	***
σ (residual)	0.619	0.008	***	0.617	0.008	***

Notes: AL = allostatic load; RSE = robust standard error; PA = physical activity.

† $p<.1$

* $p<.05$

** $p<.01$

*** p<.001

Appendix Table A2.: Time-lagged multilevel linear models of weighted AL.

	weighted AL in 2009					
	Model 1			Model 2		
Independent variables in 2006	β	RSE		β	RSE	
Age (centered)	0.166	0.008	***	0.158	0.008	***
Age-squared	−0.014	0.004	**	−0.016	0.004	***
Male (ref: female)	0.025	0.019		0.032	0.025	
Married (ref: no)	−0.060	0.031	†	−0.062	0.031	*
Education (ref: no)						
Elementary school	−0.015	0.031		−0.020	0.031	
Middle school	−0.031	0.036		−0.043	0.036	
High school or equivalent	−0.042	0.039		−0.058	0.039	
College or above	−0.150	0.061	*	−0.178	0.063	**
Occupation (ref: farmer)						
Unemployed	0.152	0.026	***	0.115	0.027	***
Unskilled	0.070	0.030	*	0.044	0.029	
Skilled/Professional	0.060	0.033	†	0.020	0.033	
Household income per capita (ref: poorest)						
2nd quartile	−0.032	0.025		−0.031	0.025	
3rd quartile	0.020	0.027		0.013	0.027	
4th quartile (richest)	0.077	0.030	*	0.069	0.031	*
Urbanization index (z-score)	0.044	0.015	**	0.020	0.017	
Urban (ref: rural)	0.048	0.035		0.045	0.036	
Smoking (ref: none)						
< 1 pack per day				−0.063	0.031	*
>= 1 pack per day				−0.016	0.031	
Drinking (ref: none)						
Monthly				0.025	0.033	
Weekly				0.019	0.027	
Daily				0.094	0.033	**
Work-related PA (ref: very light)						
Light				−0.022	0.032	
Moderate				−0.084	0.035	*
Heavy or very heavy				−0.108	0.035	**
Leisure PA (ref: no)				0.013	0.035	
% of daily energy intake from fat				0.002	0.001	*
Region (ref: inland)						
Northeast	0.051	0.028	†	0.043	0.029	
Coastal	0.010	0.029		0.002	0.029	
Mountainous South	−0.043	0.032		−0.043	0.033	
Constant	0.753	0.044	***	0.814	0.057	***

	weighted AL in 2009					
	Model 1			Model 2		
Independent variables in 2006	**β**	**RSE**		**β**	**RSE**	
σ (random effects)	0.110	0.01	***	0.111	0.011	***
σ (residual)	0.622	0.009	***	0.620	0.009	***

Notes: AL = allostatic load; RSE = robust standard error; PA = physical activity.

† $p<.1$

* $p<.05$

** $p<.01$

*** $p<.001$

References

Chinese National Health and Family Planning Commission, 2015 Report of Chinese Residents' Nutrition Status and Chronic Diseases. People's Medical Publishing House, Beijing.

Adair LS, Gordon-Larsen P, Du SF, Zhang B, Popkin BM, 2014 The Emergence of Cardiometabolic Disease Risk in Chinese Children and Adults: Consequences of Changes in Diet, Physical Activity and Obesity. Obesity Reviews 15, 49–59. [PubMed: 24341758]

Allsworth JE, Weitzen S, Boardman LA, 2005 Early Age at Menarche and Allostatic Load: Data from the Third National Health and Nutrition Examination Survey. Annals of Epidemiology 15, 438–444. [PubMed: 15967391]

Bakkeli NZ, 2016 Income Inequality and Health in China: A Panel Data Analysis. Social Science & Medicine 157, 39–47. [PubMed: 27060540]

Batis C, Mendez MA, Sotres-Alvarez D, Gordon-Larsen P, Popkin BM, 2014 Dietary Pattern Trajectories during 15 Years of Follow-Up and HbA1c, Insulin Resistance and Diabetes Prevalence among Chinese Adults. Journal of Epidemiology & Community Health 68, 773–779. [PubMed: 24729424]

Bian Y, Zhang L, Yang J, Guo X, Lei M, 2015 Subjective Wellbeing of Chinese People: A Multifaceted View. Social Indicators Research 121, 75–92.

Bird CE, Seeman TE, Escarce JJ, Basurto-Dávila R, Finch BK, Dubowitz T, Heron M, Hale L, Merkin SS, Weden M, Lurie N, 2010 Neighbourhood socioeconomic status and biological 'wear and tear' in a nationally representative sample of US adults. Journal of Epidemiology & Community Health 64, 860–865. [PubMed: 19759056]

China Health and Nutrition Survey, 2011a Biomarker methods used in CHNS 2009 Carolina Population Center, University of North Carolina - Chapel Hill.

China Health and Nutrition Survey, 2011b Household income variable construction Carolina Population Center, University of North Carolina - Chapel Hill.

Crimmins EM, Kim JK, Seeman TE, 2009 Poverty and Biological Risk: The Earlier "Aging" of the Poor. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 64A, 286–292.

Diez Roux AV, 2001 Investigating Neighborhood and Area Effects on Health. American Journal of Public Health 91, 1783–1789. [PubMed: 11684601]

Doak CM, Adair LS, Bentley M, Monteiro CA, Popkin BM, 2005 The dual burden household and the nutrition transition paradox. International Journal of Obesity 29, 129–136. [PubMed: 15505634]

Doak CM, Adair LS, Bentley M, Zhai F, Popkin BM, 2002 The underweight/overweight household: An exploration of household sociodemographic and dietary factors in China. Public Health Nutrition 5, 215–221. [PubMed: 12027287]

Dowd JB, Goldman N, 2006 Do biomarkers of stress mediate the relation between socioeconomic status and health? J Epidemiol Community Health 60, 633–639. [PubMed: 16790837]

Du S, Lu B, Zhai F, Popkin BM, 2002 A new stage of the nutrition transition in China. Public Health Nutrition 5, 169–174. [PubMed: 12027281]

Elo IT, 2009 Social Class Differentials in Health and Mortality: Patterns and Explanations in Comparative Perspective. Annual Review of Sociology 35, 553–572.

Fitzmaurice GM, Laird NM, Ware JH, 2004 Applied Longitudinal Analysis John Wiley & Sons, Inc, New Jersey.

Gersten O, 2008 Neuroendocrine biomarkers, social relations, and the cumulative costs of stress in Taiwan. Social Science & Medicine 66, 507–519. [PubMed: 18022742]

Gruenewald TL, Karlamangla AS, Hu P, Stein-Merkin S, Crandall C, Koretz B, Seeman TE, 2011 History of socioeconomic disadvantage and allostatic load in later life. Social Science & Medicine

Hewitt D, 2009 China: Getting Rich First: A Modern Social History Pegasus publications, New York.

Hu P, Wagle N, Goldman N, Weinstein M, Seeman TE, 2007 The Associations between Socioeconomic Status, Allostatic Load and Measures of Health in Older Taiwanese Persons: Twaiwan Social Environment and Biomarkers of Aging Study. Journal of Biosocial Science 39, 545–556. [PubMed: 17052381]

Jones-Smith JC, Gordon-Larsen P, Siddiqi A, Popkin BM, 2012 Emerging disparities in overweight by educational attainment in Chinese adults (1989–2006). International Journal of Obesity 36, 866–875. [PubMed: 21730966]

Jones-Smith JC, Popkin BM, 2010 Understanding community context and adult health changes in China: Development of an urbanicity scale. Social Science & Medicine 71, 1436–1446. [PubMed: 20810197]

Kubzansky L, Kawachi I, Sparrow D, 1999 Socioeconomic status, hostility, and risk factor clustering in the normative aging study: Any help from the concept of allostatic load? Annals of Behavioral Medicine 21, 330–338. [PubMed: 10721441]

Leow R, 2014 China's health transitions. The Lancet 384, 738–739.

Link BG, Phelan J, 1995 Social Conditions As Fundamental Causes of Disease. Journal of Health and Social Behavior 35, 80–94.

Mattei J, Demissie S, Falcon LM, Ordovas JM, Tucker KL, 2010 Allostatic load is associated with chronic conditions in the Boston Puerto Rican Health Study. Social science & medicine (1982) 70, 1988. [PubMed: 20381934]

McEwen BS, Stellar E, 1993 Stress and the Individual: Mechanisms Leading to Disease. Archives of Internal Medicine 153, 2093–2101. [PubMed: 8379800]

Merkin SS, Basurto-Dávila R, Karlamangla A, Bird CE, Lurie N, Escarce J, Seeman TE, 2009 Neighborhoods and Cumulative Biological Risk Profiles by Race/Ethnicity in a National Sample of U.S. Adults: NHANES III. Annals of Epidemiology 19, 194–201. [PubMed: 19217002]

Monda KL, Gordon-Larsen P, Stevens J, Popkin BM, 2007 China's Transition: The Effect of Rapid Urbanization on Adult Occupational Physical Activity. Social Science & Medicine 64, 858–870. [PubMed: 17125897]

National Bureau of Statistics of China, 2013 The 2012 Statistical Report of China's Economic and Social Development National Bureau of Statistics of China, Beijing.

Ng SW, Howard AG, Wang HJ, Su C, Zhang B, 2014 The Physical Activity Transition among Adults in China: 1991–2011. Obesity Reviews 15, 27–36.

Ng SW, Norton EC, Popkin BM, 2009 Why have Physical Activity Levels Declined among Chinese Adults? Findings from the 1991–2006 China Health and Nutrition Surveys. Social Science & Medicine 68, 1305–1314. [PubMed: 19232811]

Popkin BM, 2002 The shift in stages of the nutrition transition in the developing world differs from past experiences! Public Health Nutrition 5, 205–214. [PubMed: 12027286]

Popkin BM, 2014 Synthesis and Implications: China's Nutrition Transition in the Context of Changes across other Low- and Middle-Income Countries. Obesity Reviews 15, 60–67. [PubMed: 24341759]

Popkin BM, 2015 Nutrition Transition and the Global Diabetes Epidemic. Current Diabetes Reports 15, 1–8.

Popkin BM, Du S, Zhai F, Zhang B, 2010 Cohort Profile: The China Health and Nutrition Survey - Monitoring and Understanding Socio-economic and Health Change in China, 1989–2011. International Journal of Epidemiology 39, 1435–1440. [PubMed: 19887509]

Popkin BM, Gordon-Larsen P, 2004 The Nutrition Transition: Worldwide Obesity Dynamics and Their Determinants. International Journal of Obesity 28, S2–S9. [PubMed: 15543214]

Seeman M, Stein Merkin S, Karlamangla A, Koretz B, Seeman TE, 2014 Social Status and Biological Dysregulation: The “Status Syndrome” and Allostatic Load. Social Science & Medicine 118, 143–151. [PubMed: 25112569]

Seeman TE, Crimmins E, Huang M-H, Singer B, Bucur A, Gruenewald T, Berkman LF, Reuben DB, 2004a Cumulative biological risk and socio-economic differences in mortality: MacArthur Studies of Successful Aging. Social Science & Medicine 58, 1985–1997. [PubMed: 15020014]

Seeman TE, Epel E, Gruenewald T, Karlamangla A, McEwen BS, 2010 Socio-economic Differentials in Peripheral Biology: Cumulative Allostatic Load. Annals of the New York Academy of Sciences 1186, 223–239. [PubMed: 20201875]

Seeman TE, Glei D, Goldman N, Weinstein M, Singer B, Lin Y-H, 2004b Social relationships and allostatic load in Taiwanese elderly and near elderly. Social Science & Medicine 59, 2245–2257. [PubMed: 15450701]

Seeman TE, Merkin SS, Crimmins E, Koretz B, Charette S, Karlamangla A, 2008 Education, Income and Ethnic Differences in Cumulative Biological Risk Profiles in a National Sample of US Adults: NHANES III (1988–1994). Social Science & Medicine 66, 72–87. [PubMed: 17920177]

Seeman TE, Singer B, Rowe J, McEwen B, 2001 Exploring a New Concept of Cumulative Biological Risk—Allostatic Load and Its Health Consequences: MacArthur Studies of Successful Aging. Proceedings of the National Academy of Sciences USA 98, 4770–4775.

Shimokawa S, Chang H-H, Pinstrup-Andersen P, 2009 Understanding the Differences in Obesity among Working Adults between Taiwan and China. Asia Pacific Journal of Clinical Nutrition 18, 88–95. [PubMed: 19329401]

Singer B, Ryff CD, 1999 Hierarchies of Life Histories and Associated Health Risks. Annals of the New York Academy of Sciences 896, 96–115. [PubMed: 10681891]

Sobal J, Stunkard AJ, 1989 Socioeconomic Status and Obesity: A Review of the Literature. Psychological Bulletin 105, 260–275. [PubMed: 2648443]

Thompson AL, Adair L, Gordon-Larsen P, Zhang B, Popkin B, 2015 Environmental, Dietary, and Behavioral Factors Distinguish Chinese Adults with High Waist-to-Height Ratio with and without Inflammation. The Journal of Nutrition

Thompson AL, Houck KM, Adair LS, Gordon-Larsen P, Du S, Zhang B, Popkin BM, 2014a Pathogenic and Obesogenic Factors Associated with Inflammation in Chinese Children, Adolescents and Adults. American Journal of Human Biology 26, 18–28. [PubMed: 24123588]

Thompson AL, Houck KM, Adair LS, Gordon-Larsen P, Popkin BM, 2014b Multilevel Examination of the Association of Urbanization with Inflammation in Chinese Adults. Health & Place 28, 177–186. [PubMed: 24908386]

Thorp AA, Owen N, Neuhaus M, Dunstan DW, 2011 Sedentary Behaviors and Subsequent Health Outcomes in Adults: A Systematic Review of Longitudinal Studies, 1996–2011. American Journal of Preventive Medicine 41, 207–215. [PubMed: 21767729]

Trading Economics, 2018 China GDP per capita 1960–2018

United Nations Development Programme, 2016 Human Development Reports

Wang L, 2005 Summary Report of the 2002 China National Nutrition and Health Survey People’s Medical Publishing House, Beijing.

Wang Q, 2015 Smoking and Body Weight: Evidence from China Health and Nutrition Survey. BMC Public Health 15, 1238. [PubMed: 26666320]

Wang Y, Mi J, Shan X. y., Wang QJ, Ge K. y., 2007 Is China facing an obesity epidemic and the consequences? The trends in obesity and chronic disease in China. International Journal of Obesity 31, 177–188. [PubMed: 16652128]

Williams DR, 1990 Socioeconomic Differentials in Health: A Review and Redirection. Social Psychology Quarterly 53, 81–99.

Xie Y, Hannum E, 1996 Regional Variation in Earning Inequality in Reform-Era Urban China. The American Journal of Sociology 101, 950–992.

Xie Z, Poon AN, Wu Z, Jian W, Chan KY, 2015 Is Occupation a Good Predictor of Self-Rated Health in China? PLos One 10, e0125274. [PubMed: 25951087]

Xu H, Li L, Zhang Z, Liu J, 2016 Is Natural Experiment A Cure? Re-Examining the Long-Term Health Effects of China's 1959–1961 Famine. Social Science & Medicine 148, 110–122. [PubMed: 26692092]

Xu H, Short SE, Liu T, 2013 Dynamic relations between fast-food restaurant and body weight status: a longitudinal and multilevel analysis of Chinese adults. Journal of Epidemiology & Community Health 67, 271–279. [PubMed: 22923769]

Xu H, Xie Y, 2017 Socioeconomic Inequalities in Health in China: A Reassessment with Data from the 2010–2012 China Family Panel Studies. Social Indicators Research 132, 219–239. [PubMed: 28694561]

Yan S, Li J, Li S, Zhang B, Du S, Gordon-Larsen P, Adair L, Popkin B, 2012 The expanding burden of cardiometabolic risk in China: the China Health and Nutrition Survey. Obesity Reviews 13, 810–821. [PubMed: 22738663]

Yang G, Wang Y, Zeng Y, Gao GF, Liang X, Zhou M, Wan X, Yu S, Jiang Y, Naghavi M, Vos T, Wang H, Lopez AD, Murray CJL, 2013 Rapid Health Transition in China, 1990–2010: Findings from the Global Burden of Disease Study 2010. The Lancet 381, 1987–2015.

Yen ST, Shaw WD, Yuan Y, 2010 Cigarette smoking and self-reported health in China. China Economic Review 21, 532–543.

Yeung W-JJ, Hu S, 2016 Paradox in marriage values and behavior in contemporary China. Chinese Journal of Sociology 2, 447–476.

Zhai FY, Du SF, Wang ZH, Zhang JG, Du WW, Popkin BM, 2014 Dynamics of the Chinese Diet and the Role of Urbanicity, 1991–2011. Obesity Reviews 15, 16–26. [PubMed: 24341755]

Zhang B, Zhai FY, Du SF, Popkin BM, 2014 The China Health and Nutrition Survey, 1989–2011. Obesity Reviews 15, 2–7.

Zhao Z, 2006 Income Inequality, Unequal Health Care Access, and Mortality in China. Population and Development Review 32, 461–483.

Zhou M, Wang H, Zhu J, Chen W, Wang L, Liu S, Li Y, Wang L, Liu Y, Yin P, Liu J, Yu S, Tan F, Barber RM, Coates MM, Dicker D, Fraser M, González-Medina D, Hamavid H, Hao Y, Hu G, Jiang G, Kan H, Lopez AD, Phillips MR, She J, Vos T, Wan X, Xu G, Yan LL, Yu C, Zhao Y, Zheng Y, Zou X, Naghavi M, Wang Y, Murray CJL, Yang G, Liang X, 2016 Cause-specific mortality for 240 causes in China during 1990–2013: a systematic subnational analysis for the Global Burden of Disease Study 2013. The Lancet 387, 251–272.

Highlights

- Occupational prestige was positively associated with allostatic load.
- Household income was positively associated with allostatic load.
- Community-level urbanization was positively associated with allostatic load.
- Education was protective against allostatic load but only for college graduates.

Table 1.

High-risk prevalence of individual biomarkers for allostatic load in the 2009 China Health and Nutrition Survey (CHNS)

Biomarker	% High risk	High risk range
Cardiovascular System		
Systolic blood pressure	19.8	>= 140 mmHg[a]
Diastolic blood pressure	20.3	>= 90 mmHg[a]
Metabolic System		
Body weight related		
Body mass index	29.6	>= 25[b]
Waist-to-hip ratio	49.1	> .9 for men; > .85 for women[b]
Lipids		
High-density lipoprotein (HDL) cholesterol	25.7	< 40 mg/dl for men; < 50 mg/dl for women[a]
Low-density lipoprotein (LDL)	30.5	> 130 mg/dl[a]
cholesterol		
Total cholesterol	34.1	>= 200 mg/dl[a]
Triglycerides	28.7	>= 160 mg/dl[a]
Glucose control		
HbA1c	4.1	>= 7%[c]
Fasting glucose	6.3	>= 126 mg/dl[d]
Inflammation System		
High-sensitivity C-reactive protein (CRP)	23.9	>= 0.3 mg/dl[a]
Albumin	0.4	< 3.8 g/dl[e]
Urinary System		
Creatinine clearance	12.8	0.5–1.0 mg/dl for ages 18–19; 0.66-1.25 for men ages 20+; 0.52–1.04 mg/dl for women ages 20+[f]
Uric acid	4.5	3.5–8.5 mg/dl for men ages 18+; 2.5-6.2 mg/dl for women ages 18–34; 2.5–7.0 mg/dl for women ages 35–44; 2.5–7.5 mg/dl for women ages 45+[f]
N	7,857	

[a]American Heart Association

[b]World Health Organization

[c]American Diabetes Association

[d]International Diabetes Federation

[e]Visser et al. 2005

[f]Minnesota reference provided by the CHNS

Table 2.

Descriptive statistics of the variables used in regression analysis

	2006		2009	
	Mean or %	SD	Mean or %	SD
Allostatic load score (unweighted)	—	—	3.0	2.4
Allostatic load score (weighted)	—	—	0.8	0.7
Age (years)	50.8	13.5	50.8	15.0
Male	45.6	—	46.7	—
Married	88.5	—	84.9	—
Education				
No school	15.2	—	12.7	—
Elementary school	30.6	—	28.9	—
Middle school	31.0	—	34.6	—
High school or equivalent	18.6	—	18.2	—
College or above	4.6	—	5.6	—
Occupation				
Unemployed	39.5	—	41.3	—
Farmer	32.8	—	28.6	—
Unskilled	15.7	—	16.9	—
Skilled/Professional	12.0	—	13.1	—
Household income per capita (RMB)	8,062	10,956	11,685	14,302
Urbanization index	65.9	19.1	66.9	19.5
Urban residence	26.0		29.7	—
Smoking				
None	73.3	—	72.5	—
< 1 pack per day	12.0	—	12.9	—
>= 1 pack per day	14.6	—	14.6	—
Drinking				
None	68.9	—	67.5	—
Monthly	7.5	—	11.5	—
Weekly	12.4	—	11.5	—
Daily	11.1	—	9.5	—
Work-related PA				
Very light	24.1		29.6	—
Light	20.2		22.8	—
Moderate	14.5		13.7	—
Heavy or very heavy	41.3		34.0	—
Leisure PA	9.0		9.5	—
% of daily energy intake from fat	28.2	11.8	30.7	11.6
Region				
Northeast	20.7		20.4	—
Coastal	24.1		24.1	—

	2006		2009	
	Mean or %	SD	Mean or %	SD
Inland	34.2		33.9	—
Mountainous South	21.1		21.6	—
N	5,647		7,857	

Note: PA = physical activity.

Table 3.

Cross-sectional multilevel negative binomial models of unweighted AL.

	Unweighted AL in 2009					
	Model 1			Model 2		
Independent variables in 2009	**β**	**RSE**		**β**	**RSE**	
Age (centered)	0.191	0.008	***	0.189	0.008	***
Age-squared	−0.038	0.004	***	−0.040	0.004	***
Male (ref: female)	−0.012	0.021		0.010	0.024	
Married (ref: no)	−0.035	0.023		−0.035	0.024	
Education (ref: no)						
Elementary school	−0.001	0.027		−0.004	0.027	
Middle school	−0.017	0.031		−0.026	0.031	
High school or equivalent	−0.054	0.034		−0.065	0.034	†
College or above	−0.127	0.055	*	−0.143	0.055	**
Occupation (ref: farmer)						
Unemployed	0.160	0.026	***	0.109	0.030	***
Unskilled	0.036	0.033		−0.008	0.036	
Skilled/Professional	0.120	0.033	***	0.068	0.037	†
Household income per capita (ref: poorest)						
2nd quartile	−0.035	0.024		−0.038	0.024	
3rd quartile	0.015	0.025		0.009	0.025	
4th quartile (richest)	0.029	0.028		0.021	0.027	
Urbanization index (z-score)	0.049	0.014	***	0.033	0.015	*
Urban (ref: rural)	0.054	0.031	†	0.054	0.031	†
Smoking (ref: none)						
< 1 pack per day				−0.102	0.030	**
>= 1 pack per day				−0.018	0.028	
Drinking (ref: none)						
Monthly				−0.005	0.028	
Weekly				0.064	0.031	*
Daily				0.010	0.032	
Work-related PA (ref: very light)						
Light				−0.024	0.023	
Moderate				−0.006	0.030	
Heavy or very heavy				−0.109	0.032	**
Leisure PA (ref: no)				−0.030	0.032	
% of daily energy intake from fat				0.002	0.001	*
Region (ref: inland)						
Northeast	0.073	0.030	*	0.074	0.03	*
Coastal	0.029	0.03		0.033	0.03	
Mountainous South	−0.109	0.033	**	−0.099	0.032	**
Constant	1.046	0.044	***	1.086	0.057	***

	Unweighted AL in 2009					
	Model 1			Model 2		
Independent variables in 2009	**β**	**RSE**		**β**	**RSE**	
α (logged)	−1.703	0.062	***	−1.708	0.062	***
σ (random effects)	0.013	0.003	***	0.013	0.003	***

Notes: AL = allostatic load; RSE = robust standard error; PA = physical activity.

† $p<.1$

* $p<.05$

** $p<.01$

*** $p<.001$

Table 4.

Time-lagged multilevel negative binomial models of AL.

	Unweighted AL in 2009					
	Model 1			Model 2		
Independent variables in 2006	**β**	**RSE**		**β**	**RSE**	
Age (centered)	0.200	0.010	***	0.192	0.010	***
Age-squared	−0.048	0.005	***	−0.049	0.005	***
Male (ref: female)	−0.024	0.024		−0.034	0.028	
Married (ref: no)	−0.055	0.035		−0.057	0.035	†
Education (ref: no)						
Elementary school	−0.034	0.030		−0.037	0.030	
Middle school	−0.045	0.035		−0.056	0.036	
High school or equivalent	−0.039	0.040		−0.052	0.040	
College or above	−0.151	0.069	*	−0.172	0.069	*
Occupation (ref: farmer)						
Unemployed	0.177	0.029	***	0.135	0.030	***
Unskilled	0.129	0.039	**	0.091	0.038	*
Skilled/Professional	0.098	0.040	*	0.044	0.041	
Household income per capita (ref: poorest)						
2nd quartile	−0.029	0.029		−0.028	0.029	
3rd quartile	0.028	0.031		0.022	0.031	
4th quartile (richest)	0.093	0.033	**	0.085	0.033	
Urbanization index (z-score)	0.040	0.016	*	0.018	0.018	
Urban (ref: rural)	0.025	0.036		0.023	0.036	
Smoking (ref: none)						
< 1 pack per day				−0.073	0.038	†
>= 1 pack perday				−0.019	0.034	***
Drinking (ref: none)						
Monthly				0.056	0.042	
Weekly				0.058	0.034	†
Daily				0.127	0.034	***
Work-related PA (ref: very light)						
Light				0.004	0.032	
Moderate				−0.056	0.042	
Heavy or very heavy				−0.105	0.038	**
Leisure PA (ref: no)				0.005	0.038	
% of daily energy intake from fat				0.002	0.001	†
Region (ref: inland)						
Northeast	0.058	0.032	†	0.053	0.033	
Coastal	0.018	0.033		0.010	0.034	
Mountainous South	−0.114	0.038	**	−0.112	0.039	**
Constant	1.115	0.046	***	1.164	0.060	***

	Unweighted AL in 2009					
	Model 1			Model 2		
Independent variables in 2006	β	RSE		β	RSE	
α (logged)	−1.825	0.076	***	−1.845	0.077	***
σ (random effects)	0.017	0.003	***	0.018	0.003	***

Notes: AL = allostatic load; RSE = robust standard error; PA = physical activity.

† $p<.1$

* $p<.05$

** $p<.01$

*** $p<.001$