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THE UNIVERSITY *of York*

WP 20/14

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July 2020

<http://www.york.ac.uk/economics/postgrad/herc/hedg/wps/>

Inequality of opportunity in bodyweight among middle-aged and older Chinese: a distributional approach

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Abstract

Using the 2011 and 2015 waves of the China Health and Retirement Longitudinal Study (CHARLS) linked with the 2014 CHARLS Life History Survey, we provide a comprehensive analysis on inequality of opportunity (IOp) in both body mass index (BMI) and waist circumference (WC) among middle-aged and older Chinese. We find that IOp ranges from 65.5% to 74.6% for BMI (from 82.1% to 95.5% for WC). Decomposition results show that spatial circumstances such as urban/rural residence and province of residence are dominant. Health status and nutrition conditions in childhood are the second largest contributor. Distributional decompositions further reveal that inequality in bodyweight is not simply a matter of demographic (age and gender) inequalities; our set of spatial and health and nutrition conditions in childhood become much more relevant towards the right tails of the bodyweight distribution, where the clinical risk is focused.

Keywords: inequality of opportunity; body mass index; waist circumference; CHARLS; Shapley-Shorrocks decomposition; unconditional quantile regressions

JEL classifications: D63; I12; I14

1. Introduction

The high prevalence and rising levels of excess weight and obesity around the world have become a global public health crisis (Ng *et al.*, 2014a; Wang *et al.*, 2019b), with worldwide obesity nearly tripling since 1975. More than 1.9 billion adults aged 18+ were overweight, and over 650 million were obese in 2016 (WHO, 2020). Obesity is not only a medical condition in itself but also increases the prevalence of chronic diseases, such as cardiovascular disease (CVD), stroke, type 2 diabetes and a subset of cancers (Haslam & James, 2005; Hill & Peters, 1998), as well as particular social and mental health risks (OECD, 2019). Importantly, obesity follows a socioeconomic gradient (Peeters & Backholer, 2015), and bodyweight inequality is an important driver for the future development of inequalities in health and longevity (Hoffmann *et al.*, 2015; Kulhánová *et al.*, 2016).

The processes that lead to adiposity involve numerous factors, including genetic predisposition, behavioral, environmental, social and cultural dynamics, family behaviors and circumstances (Bilger *et al.*, 2017; Matheson, 2016). In essence, disparities in such determinants are precursors for inequality in obesity, and identifying the underlying sources of these inequalities over the life course is important to reduce the high levels of obesity and associated health inequalities (Department of Health Public Health Research Consortium *et al.*, 2007). As suggested by previous studies (e.g., Alesina & Angeletos, 2005; Carrieri *et al.*, 2020; Carrieri & Jones, 2018; Davillas & Jones, 2020a; Rosa Dias, 2009; Trannoy *et al.*, 2010; Wendelspiess Chávez Juárez & Soloaga, 2014), not all of these sources of bodyweight inequalities are equally objectionable. Specifically, bodyweight inequalities due to factors that reflect individual choices (referred to as efforts), such as lifestyles, might be ethically acceptable and, to some extent, regarded as fair. In contrast, sources such as family socioeconomic characteristics which are beyond individuals' control (referred as circumstances) are typically regarded as illegitimate and objectionable. This perspective on social attitudes toward health inequalities and inequity chimes with the literature on inequality of

opportunity (IOp), which has emerged in social choice theory and normative economics (Roemer, 1998, 2002; Roemer & Trannoy, 2016).

The life course approach proposes that inequalities observed in later life are a result of disadvantages experienced across an individual's life, in other words, they accumulate over the life course (WHO, 2018). The WHO Commission on the Social Determinants of Health (CSDH) also underscores the role of childhood circumstances as a key source of unfair health inequality (Marmot *et al.*, 2008). For example, both early-life circumstances and efforts can lead to adverse socioeconomic conditions and poor health in adulthood and continue to later life. In particular, to some extent, bodyweight inequalities in middle-aged or older adults reflect accumulated effects of health determinants, such as childhood circumstances, backgrounds and lifestyles, across a lifespan. As highlighted by the WHO report of the Commission on Social Determinants of Health, an understanding of health inequalities and their determinants is important to establish informed policies to reduce them (WHO, 2008).

Based on Roemer's conceptual framework for IOp (Roemer, 1998, 2002; Roemer & Trannoy, 2016), our study is the first comprehensive analysis of IOp in bodyweight (including BMI and WC) among middle-aged and elderly Chinese to explore to what extent the objectionable circumstances and legitimate efforts explain bodyweight inequalities. China offers an interesting and unique setting for studying IOp in bodyweight among the middle-aged and older adults: First, over the past four decades of unprecedented economic growth, China has witnessed a major shift in diet – most notably, an increased intake of edible oils, fried foods, animal-sourced foods and snacks – accompanied by a sharp decline in occupational and domestic physical activity (Ng *et al.*, 2014b; Nie *et al.*, 2019a; Xi *et al.*, 2012). The prevalence of adult general obesity has tripled (increased from 3.6% in 1992 to 11.9% in 2012) (Wang *et al.*, 2019a) and the rate of abdominal obesity has also increased by more than 50% (Zhang *et al.*, 2019). Meanwhile, several studies confirm that, due to reduced total energy expenditure and muscle loss with ageing, high prevalence of overweight and obesity among middle-aged

and older adults has become a major concern (Liu *et al.*, 2018; Smith *et al.*, 2014; Zhang *et al.*, 2020). With the highest number of obese adults worldwide (The GBD 2015 Obesity Collaborators, 2017), China's rates of obesity-related non-communicable diseases (NCDs) have also increased dramatically and have become a major risk factors for morbidity, disability and mortality (Popkin, 2008). Consequently, China spends 24 billion yuan annually, 2.46% of its annual national health care expenditure, on overweight, obesity and their complications (Qin & Pan, 2016). This expenditure clearly indicates the magnitude of the challenge posed by this rapidly increasing obesity to China's health care system (Zhao *et al.*, 2008). Second, although the overall health status of the Chinese population has improved greatly, with life expectancy growing from 68 in 1981 to 77 in 2019 (World Population Review, 2019), the rapid economic growth has not been accompanied by equally substantial improvements in health and this has become a source of concern (Baeten *et al.*, 2013; Tang *et al.*, 2008). Rising health disparities are widespread in China and this is particularly evident among older people (WHO, 2015). In addition, over the period of 1991-2011, inequality in obesity increased significantly, especially among individuals with low socioeconomic status (SES) and those living in rural areas (Nie *et al.*, 2019b). The rise in aggregate obesity inequality is not being driven by changes in the demographic structure but rather by a population-wide increase across all subpopulations, suggesting that general increases in obesity might alter norms and perceptions of ideal bodyweight in the whole population, thereby cementing higher obesity rates (Nie *et al.*, 2019b).

Following Roemer's framework, which partitions sources of inequality into legitimate efforts and illegitimate circumstances, a large body of empirical applications have examined IOp in different outcomes, such as income (e.g., Aaberge *et al.*, 2011; Almås *et al.*, 2011; Checchi & Peragine, 2010; Corak, 2013; Marrero & Rodríguez, 2013), education (e.g., Asadullah & Yalonetzky, 2012; Gamboa & Waltenberg, 2012; Waltenberg & Vandenberghe, 2007) and health (e.g., Carrieri *et al.*, 2020; Carrieri & Jones, 2018; Davillas & Jones, 2020a; Rosa Dias, 2009). Regarding IOp in bodyweight,

Salas-Ortiz (2020) uses data from the 2012 and 2016 National Survey of Health and Nutrition to examine *ex ante* IOp in body mass index (BMI) and waist circumferences (WC) for Mexican adults. She shows that circumstances such as age and parental diabetes are the key contributors to IOp in bodyweight. Yet, despite the importance of knowing what contributes to a country's bodyweight inequality, there is no research on the IOp in bodyweight¹ in China.

We extend the existing literature in four ways:

First, our study is the first attempt to examine IOp in bodyweight (both BMI and WC) and to explore to what extent the circumstances and efforts explain bodyweight inequality in China, in a setting that has the largest number of people affected by obesity worldwide and where obesity inequality has increases sharply over time (Nie *et al.*, 2019b; The GBD 2015 Obesity Collaborators, 2017).

Second, unlike the commonly-used mean-based decomposition, our distributional analysis based on RIF quantile regressions reveals how the contributions of circumstances and efforts vary over the whole distribution of bodyweight, with a particular focus on the upper tails of the distribution, where individuals are at high risk of obesity and other health problems.

Third, the 2014 CHARLS Life History Survey allows us to introduce a rich set of childhood circumstances that may contribute to IOp, which addresses a concern that poor information on circumstances may lead to an underestimate of IOp and therefore mislead policymakers into a false sense of complacency that health inequality is largely fair (Kanbur & Wagstaff, 2016).

¹ Regarding bodyweight inequality, existing studies focus on the following three aspects. First, tracking changes of the mean or distributions of bodyweight across time (see, for instance, Contoyannis & Wildman, 2007; Madden, 2012; Nie *et al.*, 2019b). Second, identifying demographic and socioeconomic disparities (e.g., gender, age, education, income, region and childhood SES) in bodyweight (see, for instance, Aizawa & Helble, 2017; Ball *et al.*, 2002; Baum & Ruhm, 2009; Davillas & Jones, 2020b; Deuchert *et al.*, 2014; Dykes *et al.*, 2004; Giskes *et al.*, 2008; Monda *et al.*, 2008; Popkin *et al.*, 1995). Third, using concentration indices (CI) to quantify socioeconomic-related bodyweight inequality (e.g., Aizawa & Helble, 2017).

Fourth, our study uses objective measures of bodyweight, which few studies have at their disposal. The inclusion of both BMI and WC is particularly important for China because approximately two thirds obese adults would be missed if solely BMI was adopted to define obesity (Du *et al.*, 2013). Relative to BMI, WC is a stronger predictor of cardio-metabolic risk, particularly among Chinese adults (Du *et al.*, 2013). Having such rich objective data is important in order to credibly assess IOp in bodyweight.

The remainder of the paper is organized as follows: Section 2 documents the empirical strategy. Section 3 describes the datasets used, and then Section 4 presents the results. Section 5 discusses the major findings and concludes.

2. Methods

2.1 Estimation strategy

Following Roemer's (1998) framework, the determinants of individual bodyweight can be separated into following components: circumstances (C_i), for which individuals are not held responsible, efforts (E_i), which are under the partial control of individuals, and demographics (D_i) (including gender and age). Inequalities due to circumstances (i.e. IOp) should be compensated (*compensation principle*) whereas inequalities arising from different efforts are normatively acceptable (*reward principle*). Following the existing literature on IOp in health (Bricard *et al.*, 2013; Deuchert *et al.*, 2014; Ferreira & Gignoux, 2011; Jusot *et al.*, 2013; Roemer & Trannoy, 2015), individual bodyweight y_i is assumed to be a function of circumstances, efforts and demographics.² We also assume that circumstances are unaffected by efforts, but efforts may be influenced by circumstances and demographics. Thus, a generalized production function for bodyweight y_i of individual i can be defined as:

$$y_i = h(C_i, E(C_i, D_i, v_i), D_i, u_i) \quad (1)$$

² Whether the bodyweight differences due to biological factors (e.g. gender and age) are legitimate is a philosophical issue. Following Jusot *et al.* (2013), we separate gender and age from other circumstances.

where v_i and u_i are unobserved error terms. Specifically, v_i represents random variation in effort that is independent of C_i , and D_i , and u_i denotes random variation in bodyweight that is independent of C_i , E_i and D_i .

In accordance with Bricard *et al.* (2013) and Jusot *et al.* (2013), we adopt a linear parametric approach, which does not suffer from the curse of dimensionality especially for a rich set of circumstances. The latter arises in the nonparametric approach due to insufficient sample sizes for specific social *types* (groups of individuals who share identical circumstances) and *tranches* (groups of individuals who share same efforts). Assuming additive separability and linearity of $h(\cdot)$ and $E(\cdot)$ (Davillas & Jones, 2020a), we have a linear structural form for individual bodyweight:

$$y_i = \alpha C_i + \beta E_i + \gamma D_i + \varepsilon_i \quad (2)$$

According to Roemer's definition of equality of opportunity, IOp requires that efforts to be purged of any contamination from circumstances and demographics, meaning that they are the pure or direct contribution of efforts. Thus, we estimate auxiliary regressions, which regress each effort on demographics and circumstances:

$$E_i = \delta C_i + \lambda D_i + e_i \quad (3)$$

where e_i is the effort purged from circumstances and demographics. We then substitute the vector of efforts E_i in equation (2) with the estimated residuals \hat{e}_i of equation (3). Therefore, the equation (2) can be reformulated as:

$$y_i = \alpha C_i + \beta \hat{e}_i + \gamma D_i + \varepsilon_i \quad (4)$$

In this form the first term on the right-hand side captures the total (direct and indirect) contribution of circumstances, while the second term captures the direct contribution of efforts (e.g. Carrieri *et al.*, 2020). We use ordinary least squares (OLS) to estimate the bodyweight production function. Regarding the binary variables of efforts used in our analysis, following Bricard *et al.* (2013), we employ a linear probability model for the auxiliary equations (3). The main interest of our paper is on the explained variance of bodyweight in equation (4). Finally, we quantify the magnitude of explained

bodyweight inequalities (i.e. explained variances) and the individual contributions of circumstances, efforts and demographics.

2.2 Mean-based regressions

Since we aim to quantify the magnitude of bodyweight inequality and decompose it into different sources, the variance share is a suitable index of IOp for two key reasons. First, its decomposition has desirable properties such as independence of the level of disaggregation, consistent decomposition and population symmetry (Shorrocks, 1982). Second, as Ferreira and Gignoux (2014) highlight, the variance share is simple to calculate: it is the R^2 of an OLS regression. Despite its simplicity, it provides a parametric approximation to the lower bound on the share of total inequality in bodyweight that is explained by circumstances, efforts and demographics. Therefore, the estimate of equation (4) can also be expressed as:

$$\hat{y}_i = \hat{\alpha}C_i + \hat{\beta}\hat{e}_i + \hat{\gamma}D_i \quad (5)$$

Specifically, the variance of explained bodyweight is given by:

$$\sigma^2(\hat{y}_i) = cov(\hat{y}_C, \hat{y}_i) + cov(\hat{y}_e, \hat{y}_i) + cov(\hat{y}_D, \hat{y}_i) \quad (6)$$

where \hat{y}_C , \hat{y}_e , and \hat{y}_D are the first, second and third terms of the right hand of equation (5), respectively. Based on the OLS estimates, the contribution of the group of observed circumstances to the explained bodyweight inequality (IOp) is given by:

$$IOp = cov(\hat{y}_C, \hat{y}_i) / \sigma^2(\hat{y}_i) \quad (7)$$

Similarly, the combined contributions of efforts (IEF) and of demographics (DEM) to total explained bodyweight inequality can be written as:

$$IEF = cov(\hat{y}_e, \hat{y}_i) / \sigma^2(\hat{y}_i) \quad (8)$$

$$DEM = cov(\hat{y}_D, \hat{y}_i) / \sigma^2(\hat{y}_i) \quad (9)$$

2.3 RIF quantile regressions

In the context of IOp using a mean-based approach, based on fitted values from OLS

regressions, implies utilitarian reward and inequality neutrality towards individuals that share the same values of the independent variables. However, this assumption may be regarded as too restrictive and we may wish to give greater weight to the upper tail of the distribution of bodyweight, where individuals are at great risk of health problems (Davillas & Jones, 2020a). To allow for this we use the RIF unconditional quantile regression approach (Firpo *et al.*, 2009) to estimate marginal effects of circumstances, efforts and demographics at different points of the bodyweight distribution. Then we quantify the contribution of each set of factors to the explained bodyweight inequality at different quantiles of bodyweight distribution.

We first regress the RIF vector on the factor variables:

$$RIF(y_i; q_Y(\tau)) = \alpha^\tau C_i + \beta^\tau \hat{e}_i + \gamma^\tau D_i + \varepsilon_i^\tau \quad (10)$$

The estimate of equation (10) is:

$$\hat{y}_i^\tau = \hat{\alpha}^\tau C_i + \hat{\beta}^\tau \hat{e}_i + \hat{\gamma}^\tau D_i \quad (11)$$

where \hat{y}_i^τ is the estimated RIF value for individual i at quantile τ , $\hat{\alpha}^\tau$, $\hat{\beta}^\tau$ and $\hat{\gamma}^\tau$ represent the estimated coefficients of circumstances, efforts and demographics, respectively, at different quantiles (τ). Then we can express the variance of explained bodyweight at quantile τ as:

$$\sigma^2(\hat{y}_i^\tau) = cov(\hat{y}_C^\tau, \hat{y}_i^\tau) + cov(\hat{y}_e^\tau, \hat{y}_i^\tau) + cov(\hat{y}_D^\tau, \hat{y}_i^\tau) \quad (12)$$

Where \hat{y}_C^τ , \hat{y}_e^τ and \hat{y}_D^τ is the first, second and third terms of the right hand of equation (11), respectively. Similarly to equations (7) to (9), we compute the contributions of circumstances, efforts and demographics at different quantiles of bodyweight.

Since the RIF equations are additive and linear, we also use a Shapley-Shorrocks decomposition to identify the relative contribution of each factor for circumstances, efforts and demographics at the different quantiles.

2.4 Shapley-Shorrocks decomposition

We decompose the total explained bodyweight inequality into its underlying sources.

Specifically, the regression-based Shapley decomposition method can identify the contributions of each factor to the total explained variance (Ferreira & Gignoux, 2014; Shorrocks, 2013). The main advantage of this decomposition technique is that it is path independent, i.e., the order of changing variables for the decomposition does not affect the results. Additionally, it is also exactly additive, meaning that the different components sum up to the total explained variance (Wendelspiess Chávez Juárez & Soloaga, 2014). To do so, we first estimate variance for all possible permutations of each independent variable, and then average the marginal effect of each independent variable in every case on total explained variance to obtain the contribution of each independent variable to explained bodyweight inequality (Ferreira & Gignoux, 2014; Ferreira *et al.*, 2011; Wendelspiess Chávez Juárez & Soloaga, 2014).

3. Data

3.1 Data and study population

The data are drawn from the China Health and Retirement Longitudinal Study (CHARLS), administered by the National School of Development together with the Institute for Social Science Surveys at Peking University, a nationally representative longitudinal survey of the middle-aged and elderly in China, including assessments of social, economic, and health circumstances of community-residents (Zhao *et al.*, 2014). The CHARLS sample is obtained via multistage stratified probability proportional to size (PPS) sampling design (Zhao *et al.*, 2014). The national baseline survey was conducted in 2011-2012 on 17,708 respondents residing in 10,257 households in 450 villages/urban communities. Two follow-up interviews were conducted in 2013 and 2015. In 2014, there was a retrospective Life History Survey, including demographics, household SES, health, work, wealth history of respondents and rich information of individual circumstances, which facilitates estimation of IOp. The CHARLS is part of a group of ageing surveys worldwide that are harmonized to the Health and Retirement

Study (HRS) in the US, the English Longitudinal Survey on Ageing (ELSA) in England, and the Survey on Health, Ageing and Retirement in Europe (SHARE) in Europe.

Our analytical sample is middle-aged and elderly adults aged 45+ in 2011 and 2015. We first match the 2011 and 2015 CHARLS to the 2014 Life History Survey to enable linkage of respondents' anthropometric measures with their childhood circumstances. Given that some individuals interviewed in 2011 or 2015 are not included in 2014, we use *t-tests* to check whether there are statistically significant differences in demographic, socioeconomic and lifestyle variables between the matched sample and the original samples in 2011 or 2015. As shown in Table A.1 of the Appendix, we do not find any evidence of significant differences, other than for urban/rural residence and employment status in 2011. Second, we retain the individuals without missing values for any of the explanatory variables for demographics, efforts and circumstances from the matched sample. Table A.2 in the Appendix reveals no evidence of statistical differences between the matched sample and the matched sample without the missing values for explanatory variables (with the exception of age in 2011 and 2015 and marital status in 2011). Since we attempt to retain the largest sample possible for analysis of each bodyweight measure, the number of observations for BMI and WC differs slightly because of missing data for the individual bodyweight indicators. Our final analysis samples are 7,231 for BMI and 7,181 for WC in 2011 and 9,729 for BMI and 9,620 for WC in 2015. As Table A.3 in the Appendix shows, there are no statistically significant differences between our analytical samples and the matching sample with no missing values for explanatory variables, indicating that there is not an issue with sample selection on observables in our study.

3.2 Bodyweight variables

The CHARLS includes professionally measured weight, height and waist circumference, which eliminates the reporting bias inherent in self-reported anthropometric information (Shields *et al.*, 2011). This bias tends to result in underestimation of BMI (Burkhauser & Cawley, 2008). We adopt BMI defined as weight (in kg) divided by the square of

height (in metres) and WC (in cm) as bodyweight indicators.

3.3 Circumstances

Following the existing literature (Davillas & Jones, 2020a; Trannoy *et al.*, 2010; Yan *et al.*, 2020), we classify the circumstances into five domains (see Table 1):

(1) Region/province: including urban or rural residence (1 = rural, 0 = urban) and province of residence;

(2) War. China experienced the War with Japan and the Civil War in the 1930s and 1940s. We use two dummies measuring whether an individual was born during the War with Japan or the Civil War periods, respectively;

(3) Parental health status and health behaviors in childhood: including parental health status (1 = long time in bed, 0 = none), mother's smoking (1 = yes, 0 = no), and father's smoking (1 = yes, 0 = no) and drinking (1 = yes, 0 = no);

(4) Health nutrition and conditions in childhood. It is widely acknowledged that poor social conditions early in life such as hunger and other adversities can exert long-term impacts on individuals' health capital (e.g., Alvarado *et al.*, 2008; Barker, 1994; Cui *et al.*, 2020). As such, we include self-reported health (SRH) before age 15 (1 = much less healthy, 2 = somewhat less healthy, 3 = about average, 4 = somewhat healthier, 5 = much healthier) and whether they experienced hunger before age 17 (1 = yes; 0 = no);

(5) Household SES in childhood, including parental political status (1 = Communist Party member, 0 = no), mother's education (1 = illiterate, 0 = literate), father's education (1 = illiterate, 0 = literate) and self-reported household SES compared with the average family in the same community/village at that time (1 = a lot worse off than them, 2 = somewhat worse off than them, 3 = same as them, 4 = somewhat better off than them, 5 = a lot better off than them).

3.4 Efforts

We introduce a set of efforts including lifestyles and SES, which have been showed to affect bodyweight (Sturm, 2002; Wang *et al.*, 2012; Zhang *et al.*, 2020). Specifically,

the lifestyles include alcohol drinking (1 = yes, 0 = no) and smoking (1 = yes, 0 = no). The respondent SES variables encompass their education (1 = high, 0 = low), current marital status (1 = married/partnered, 0 = separated/divorced/widowed/never married) and current employment status (1 = yes, 0 = no).

4. Results

4.1 Descriptive statistics

Table 1 shows the descriptive statistics for our analysis sample. The mean values of BMI and WC are 23.62 and 85.76 in 2011, respectively, and increase to 23.98 and 86.86 in 2015. The prevalence of general obesity increases from 11.8% to 13.1%, and central obesity from 61.7% to 66.2%. These results are in line with Xi *et al.*'s (2012) report of a moderate increase in general obesity but a sharper rise in abdominal obesity. Nevertheless, the increase in both general obesity and central obesity within the 5-year timeframe of our analysis is striking.

Regarding circumstances, approximately 61.8% of respondents resided in rural areas in 2011 and this proportion decreased to 57.0% in 2015. During the period 2011-2015, the trajectories of parental health status and smoking, as well as father's alcohol drinking are relatively stable. It is noteworthy that, parental illiteracy declines over the study period, from 89.5% to 86.4% for mothers, and from 63.3% to 58.2% for fathers, respectively, which reflects improvements in education over time.

As for the efforts, the prevalence of drinking alcohol increases from 38.2% in 2011 to 47% in 2015. During the same period, there is an upward trend in smoking, increasing from 38.4% to 43%. There is also a slight rise in the proportion with higher education, increasing from 10.6% in 2011 to 11.6% in 2015. The prevalence of being married or partnered is stable over the study period, with 87.8% in 2011 and 87.2% in 2015.

Table 1 Descriptive statistics

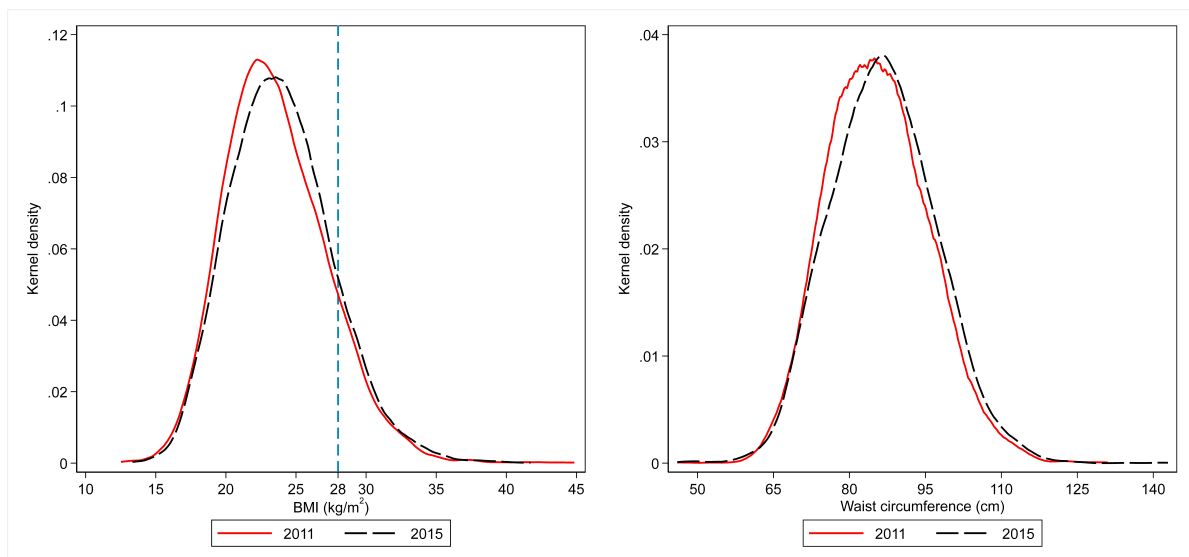
| Variables | 2011 | | | 2015 | | | Mean diff. |
|---|----------------------|-------|------|----------------------|--------|------|------------|
| | Mean/ proportions | SD | Obs. | Mean/ proportions | SD | Obs. | |
| Bodyweight | | | | | | | |
| Body mass index (BMI, kg/m ²) | 23.623 | 3.564 | 7231 | 23.980 | 3.677 | 9729 | 0.357*** |
| Waist circumference (WC, cm) | 85.760 | 9.810 | 7181 | 86.864 | 10.538 | 9620 | 1.104*** |
| General obesity ^a | 0.118 | 0.317 | 7231 | 0.131 | 0.342 | 9729 | 0.012* |
| Central obesity ^a | 0.617 | 0.477 | 7181 | 0.662 | 0.480 | 9620 | 0.045*** |
| Demographics | | | | | | | |
| Gender (1=male, 0=female) | 0.458 | 0.488 | 7231 | 0.472 | 0.507 | 9729 | 0.014 |
| Age | 58.540 | 8.944 | 7231 | 60.198 | 9.667 | 9729 | 1.658*** |
| Circumstances | | | | | | | |
| Urban/rural residence (1=rural, 0=urban) | 0.618 | 0.476 | 7231 | 0.570 | 0.503 | 9729 | -0.049*** |
| War | | | | | | | |
| Born in the Japanese War era | 0.164 | 0.363 | 7231 | 0.141 | 0.353 | 9729 | -0.023*** |
| Born in the Civil War era | 0.128 | 0.327 | 7231 | 0.114 | 0.322 | 9729 | -0.014** |
| Parental health status and health behaviors | | | | | | | |
| Parental health status | 0.176 | 0.374 | 7231 | 0.176 | 0.387 | 9729 | -0.0002 |
| Mother's smoking | 0.102 | 0.296 | 7231 | 0.104 | 0.311 | 9729 | 0.003 |
| Father's smoking | 0.506 | 0.490 | 7231 | 0.526 | 0.507 | 9729 | 0.020** |
| Father's alcohol drinking | 0.071 | 0.252 | 7231 | 0.073 | 0.265 | 9729 | 0.002 |
| Health and nutrition conditions in childhood | | | | | | | |
| Self-reported health before age 15 | | | 7231 | | | 9729 | |
| Much less healthy | 0.050 | 0.213 | 7231 | 0.045 | 0.211 | 9729 | -0.004 |
| Somewhat less healthy | 0.087 | 0.276 | 7231 | 0.088 | 0.287 | 9729 | 0.001 |
| About average | 0.506 | 0.490 | 7231 | 0.505 | 0.508 | 9729 | -0.001 |
| Somewhat healthier | 0.186 | 0.381 | 7231 | 0.189 | 0.398 | 9729 | 0.003 |
| Much healthier | 0.172 | 0.370 | 7231 | 0.173 | 0.384 | 9729 | 0.001 |
| Experienced hunger before age 17 | 0.712 | 0.444 | 7231 | 0.686 | 0.471 | 9729 | -0.026*** |
| Household SES in childhood | | | | | | | |
| Parental political status | 0.140 | 0.340 | 7231 | 0.159 | 0.371 | 9729 | 0.019** |
| Mother's education | 0.895 | 0.300 | 7231 | 0.864 | 0.349 | 9729 | -0.032*** |
| Father's education | 0.633 | 0.472 | 7231 | 0.582 | 0.501 | 9729 | -0.051*** |
| Household economic status | | | 7231 | | | 9729 | |
| A lot worse off than them | 0.230 | 0.413 | 7231 | 0.217 | 0.419 | 9729 | -0.013 |
| Somewhat worse off than them | 0.153 | 0.353 | 7231 | 0.154 | 0.367 | 9729 | 0.001 |
| Same as them | 0.524 | 0.489 | 7231 | 0.527 | 0.507 | 9729 | 0.002 |
| Somewhat better off than them | 0.079 | 0.264 | 7231 | 0.090 | 0.290 | 9729 | 0.011* |
| A lot better off than them | 0.013 | 0.113 | 7231 | 0.012 | 0.111 | 9729 | -0.001 |
| Efforts | | | | | | | |
| Lifestyles | | | | | | | |
| Alcohol drinking | 0.382 | 0.476 | 7231 | 0.470 | 0.507 | 9729 | 0.087*** |
| Smoking | 0.384 | 0.477 | 7231 | 0.430 | 0.503 | 9729 | 0.047*** |
| Socioeconomic status (SES) | | | | | | | |
| High education | 0.106 | 0.301 | 7231 | 0.116 | 0.325 | 9729 | 0.010 |
| Married/partnered | 0.878 | 0.320 | 7231 | 0.872 | 0.340 | 9729 | -0.007 |
| Employed | 0.705 | 0.447 | 7231 | 0.673 | 0.477 | 9729 | -0.032*** |

Notes: Sampling weights are applied. The significance level is based on independent *t*-tests. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

^aWe define general obesity (BMI of 24 kg/m² or over) and central obesity (WC \geq 85 cm for men and WC \geq 80 cm for women) according to the criteria of the Working Group on Obesity in China (Zhou & the Cooperative Meta-analysis Group of Working Group on Obesity in China, 2002).

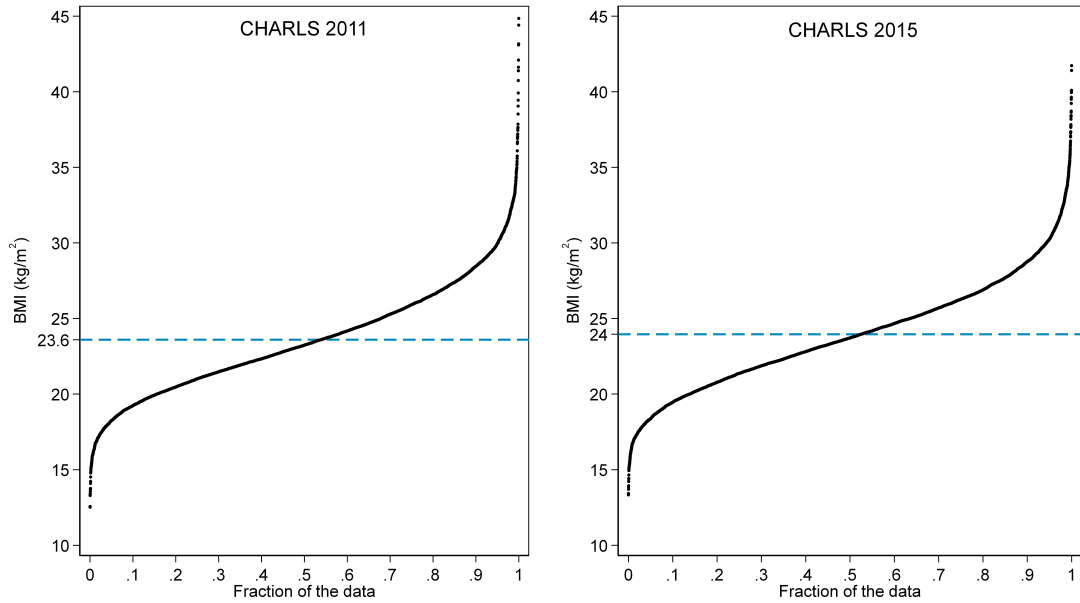
We also graph the kernel density curves for BMI and WC by survey years (see Figure 1). During the period 2011-2015, we find a clear rightward shift in BMI and WC distributions, reflecting the significant increases in both general obesity and central obesity. Figures 2 and 3 depict different quantiles of BMI and WC distributions for both survey years. The BMI value increases monotonically, from 21.0 at the 25th quantile, to 23.2 at the median and 28.5 at the 90th quantile in 2011 (from 21.4 at the 25th quantile to 23.7 at the median and 28.8 at the 90th quantile in 2015). Similarly, WC rises from 78.2 at the 25th quantile to 85 at the median and 99 at the 90th quantile in 2011 (from 79.4 at the 25th quantile to 86.5 at the median and 100.2 at the 90th quantile in 2015). Clearly, a shift of bodyweight from normal weight to obesity is discernable from the lower part to the upper tail of the distribution of bodyweight, for both BMI or WC.

Figure 1 Kernel density estimates for BMI and WC by survey year



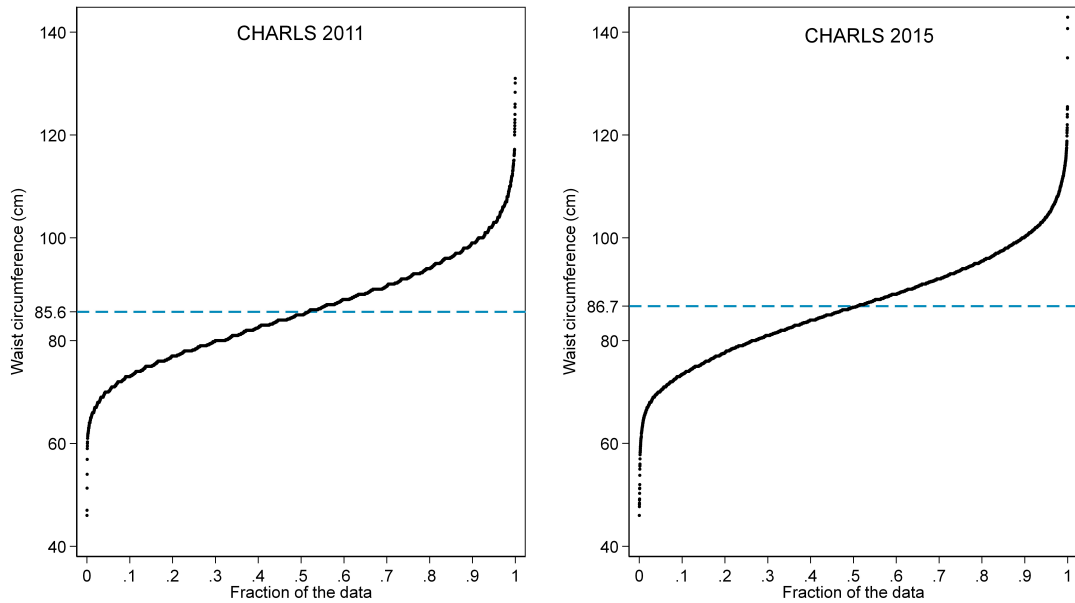
Notes: The blue dashed line is the cutoff for general obesity for Chinese adults. Two-sample *Kolmogorov-Smirnov* tests reject the null hypothesis of equality in distributions between two waves (p -value = 0.000 for both BMI and WC).

Figure 2 Quantiles of BMI by survey year



Notes: The blue dashed line is the mean of BMI.

Figure 3 Quantiles of WC by survey year



Notes: The blue dashed line is the mean of waist circumference.

4.2 Mean-based measures of IOp

To quantify the contributions to overall bodyweight inequality, we first perform the Shapley-Shorrocks decomposition based on the OLS regressions for BMI and WC (see

Appendix Table A.4). Table 2 and Figure 4 show the decomposition results. Circumstances are the dominant contributor to total explained inequality in BMI in both survey years, with 69.0% in 2011 and 69.4% in 2015, respectively. This also holds for WC, with 88.6% in 2011 and 92.4% in 2015. The second contributor to total explained inequality in BMI is demographics, ranging between 22.0% in 2011 and 23.9% in 2015. Nonetheless, the contribution of demographics to explained inequality in WC is negligible. The contribution of efforts to explained inequality in BMI (6.7%-9.0%) is comparable to that of explained inequality in WC (7.2%-10.8%).

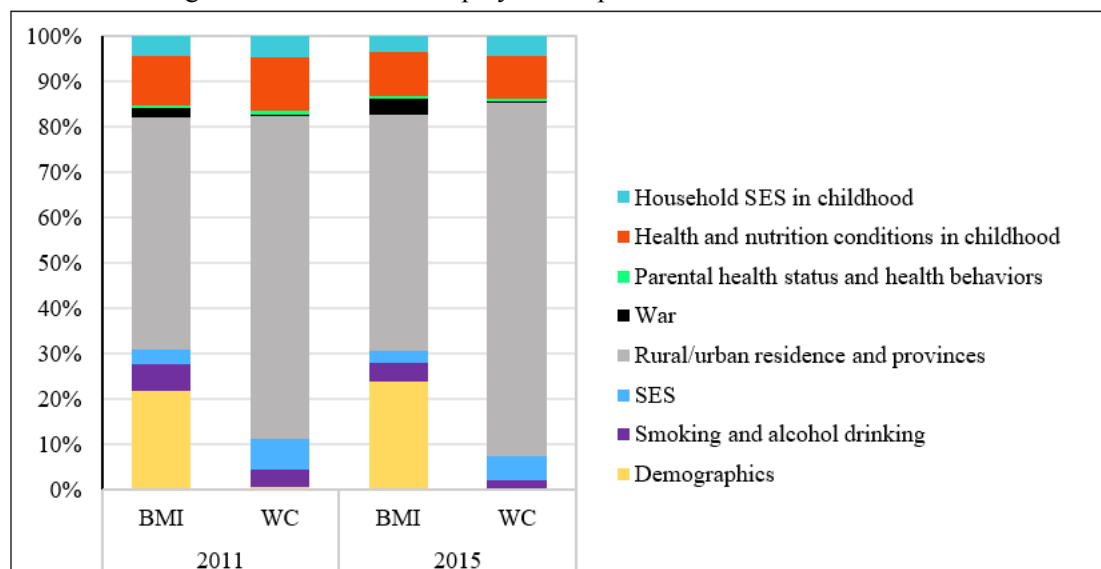
With respect to contributions of specific circumstances: rural/urban residence and province of residence are the largest contributors to IOp in bodyweight, accounting for 51.2%-52.2% for BMI, and 71.1%-78.0% for WC. In addition, the contribution of health nutrition conditions in childhood to IOp in bodyweight is non-trivial. However, the contributions of household SES, war and parental health status and health behaviors to IOp in bodyweight are relatively small. Interestingly, the contribution of circumstances to explained inequality in bodyweight rise over time, especially for WC, which might be driven by the increasing contribution of spatial factors.

Table 2 Mean-based Shapley decomposition results—BMI and WC (variance share)

| | 2011 | | 2015 | |
|--|-----------------------|-----------------------|-----------------------|-----------------------|
| | BMI | WC | BMI | WC |
| Explained variance | 16.25% ^{***} | 12.67% ^{***} | 13.50% ^{***} | 10.57% ^{***} |
| Demographics (gender and age) | 21.96% ^{***} | 0.62% | 23.93% ^{***} | 0.37% |
| Efforts | | | | |
| Lifestyles (smoking and alcohol drinking) | 5.71% ^{***} | 3.73% ^{***} | 4.04% ^{***} | 1.85% ^{***} |
| SES | 3.29% ^{***} | 7.03% ^{***} | 2.63% ^{***} | 5.33% ^{***} |
| Total | 9.00% | 10.76% | 6.67% | 7.18% |
| Circumstances | | | | |
| Rural/urban residence and provinces | 51.18% ^{***} | 71.09% ^{***} | 52.20% ^{***} | 77.96% ^{***} |
| War | 2.22% | 0.14% | 3.57% | 0.09% |
| Parental health status and health behaviors | 0.44% | 1.05% | 0.55% | 0.56% |
| Health and nutrition conditions in childhood | 10.77% ^{***} | 11.80% ^{***} | 9.68% ^{***} | 9.49% ^{***} |
| Household SES in childhood | 4.43% ^{**} | 4.53% ^{**} | 3.39% [*] | 4.34% ^{***} |
| Total | 69.04% | 88.61% | 69.39% | 92.44% |

Notes: Sampling weights are applied. Bootstrapped standard errors in parenthesis (500 replications). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Figure 4 Mean-based Shapley decomposition results—BMI and WC



4.3 RIF-based measures of IOp

Table 3 and Figure 5 display the Shapley-Shorrocks decomposition based on RIF regressions. Several findings are worth mentioning: first, similar to the mean-based decomposition results, circumstances remain the largest contributor to explained inequality in bodyweight at all quantiles ranging between 66.5% at the 25th quantile and 72.8% at the 90th quantile for BMI in 2011 and from 65.5% at the 25th quantile to 71.7% at the 90th quantile in 2015. This also holds for WC. In line with mean-based decomposition results, the second contributor to explained inequality in BMI is demographics. In contrast, for both BMI and WC, the contribution of efforts is marginal over all quantiles (except for WC at the median in 2011 and the 25th quantile in 2015).

Second, regarding observed circumstances, rural/urban residence and province of residence are the dominant factors. Health and nutrition conditions in childhood come out as the second largest contributor in IOp in bodyweight. Nevertheless, the contribution of household SES in childhood to the explained inequality in weight

outcomes is only marginal. This also applies to the contributions of war, parental health status and health behaviors.

Third, it is worthwhile to emphasize that, the contribution of circumstances increases towards the upper tail of the distribution of bodyweight, where individuals are most at risk of general obesity or central obesity. For instance, it increases from 87.0% at the 25th quantile to 93.1% at the median and 95.5% at the 90th quantile for WC in 2015. Particularly, among the circumstance factors, the relative contribution of health and nutrition conditions in childhood to IOP in bodyweight increases from 10.4% at the 25th quantile to 12.4% at the 90th quantile for BMI in 2011 (from 10.2% to 14.8% for WC). We still observe a similar pattern in 2015.

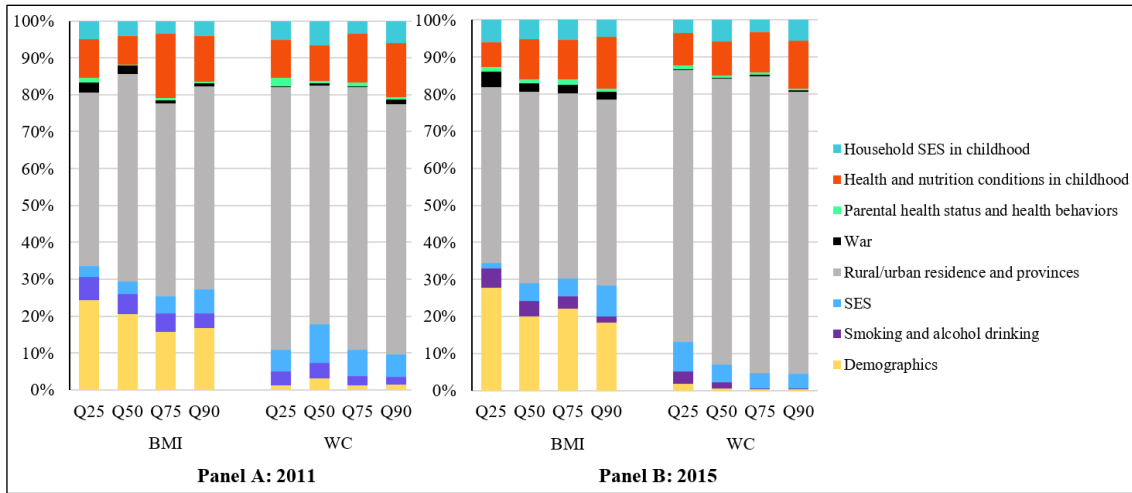
Finally, it is also interesting that the contribution of demographics to BMI declines towards the upper tail of the BMI distribution, from 24.2% at the 25th quantile to 16.7% at the 90th in 2011 (from 27.8% at the 25th quantile to 18.4% at the 90th in 2015). As for efforts, we also observe that the relative contribution of lifestyles declines towards the upper tails of both BMI and WC distributions in both waves (e.g., from 6.3% at the 25th quantile to 4.4% at the 90th for BMI, and from 3.8% at the 25th quantile to 2.0% at the 90th for WC in 2011). For SES, its contribution increases from 2.9% to 6.4% for BMI in 2011 (from 1.5% to 8.2% for BMI in 2015). In 2015, the contribution of SES for WC decreases from 7.8% to 4.0%. Such results may suggest that SES disparities in WC are less visible especially towards the upper tail of WC. One possible explanation is that with the sharp rise in the rate of central obesity, it has become more and more common for Chinese adults to be centrally obese, regardless of low or high SES groups (Lao *et al.*, 2015), i.e., the prevalence of central obesity has increased across all SES groups.

Table 3 RIF-based Shapley decomposition results—BMI and WC (variance share)

| | BMI | | | | WC | | | |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Panel A: 2011 | | | | | | | | |
| Quantiles | Q25 | Q50 | Q75 | Q90 | Q25 | Q50 | Q75 | Q90 |
| | 21.06 | 23.30 | 25.94 | 28.43 | 78.40 | 85.33 | 92.21 | 99.19 |
| Explained variance | 11.20% | 12.05% | 9.92% | 5.29% | 7.31% | 10.20% | 8.58% | 5.01% |
| Demographics (gender and age) | 24.24% ^{***} | 20.44% ^{***} | 15.70% ^{***} | 16.71% ^{***} | 1.23% | 3.14% ^{***} | 1.16% | 1.40% |
| Efforts | | | | | | | | |
| Lifestyles (smoking and alcohol drinking) | 6.32% ^{***} | 5.61% ^{***} | 5.00% ^{***} | 4.14% ^{***} | 3.81% ^{***} | 4.14% ^{***} | 2.49% ^{***} | 2.04% [*] |
| SES | 2.92% ^{***} | 3.21% ^{***} | 4.70% ^{***} | 6.39% ^{***} | 5.77% ^{***} | 10.63% ^{***} | 7.16% ^{***} | 6.16% ^{***} |
| Total | 9.24% | 8.82% | 9.70% | 10.53% | 9.58% | 14.77% | 9.65% | 8.20% |
| Circumstances | | | | | | | | |
| Rural/urban residence and provinces | 47.15% ^{***} | 56.43% ^{***} | 52.31% ^{***} | 55.06% ^{***} | 71.23% ^{***} | 64.64% ^{***} | 71.24% ^{***} | 67.76% ^{***} |
| War | 2.59% | 2.20% | 0.78% | 0.77% | 0.33% | 0.57% | 0.31% | 1.23% |
| Parental health status and health behaviors | 1.42% ^{**} | 0.36% | 0.54% | 0.49% | 2.26% | 0.57% | 0.96% | 0.68% |
| Health and nutrition conditions in childhood | 10.44% ^{***} | 7.58% ^{***} | 17.54% ^{***} | 12.42% ^{***} | 10.18% ^{***} | 9.68% ^{***} | 13.14% ^{***} | 14.79% ^{***} |
| Household SES in childhood | 4.91% ^{**} | 4.18% | 3.42% | 4.02% | 5.19% [*] | 6.64% ^{**} | 3.55% | 5.93% |
| Total | 66.51% | 70.75% | 74.59% | 72.76% | 89.19% | 82.10% | 89.20% | 90.39% |
| Panel B: 2015 | | | | | | | | |
| Quantiles | Q25 | Q50 | Q75 | Q90 | Q25 | Q50 | Q75 | Q90 |
| | 21.45 | 23.75 | 26.28 | 28.71 | 79.62 | 86.66 | 93.75 | 100.30 |
| Explained variance | 8.89% | 10.12% | 7.40% | 4.53% | 6.45% | 8.12% | 6.42% | 4.78% |
| Demographics (gender and age) | 27.79% ^{***} | 20.02% ^{***} | 22.03% ^{***} | 18.40% ^{***} | 1.81% ^{**} | 0.48% | 0.31% | 0.24% |
| Efforts | | | | | | | | |
| Lifestyles (smoking and alcohol drinking) | 5.14% ^{***} | 4.05% ^{***} | 3.43% ^{***} | 1.68% [*] | 3.41% ^{***} | 1.63% ^{**} | 0.17% | 0.33% |
| SES | 1.53% ^{**} | 4.91% ^{***} | 4.88% ^{***} | 8.20% ^{***} | 7.81% ^{***} | 4.88% ^{***} | 4.21% ^{***} | 3.96% ^{***} |
| Total | 6.67% | 8.96% | 8.31% | 9.88% | 11.22% | 6.51% | 4.38% | 4.29% |
| Circumstances | | | | | | | | |
| Rural/urban residence and provinces | 47.53% ^{***} | 51.58% ^{***} | 49.81% ^{***} | 50.36% ^{***} | 73.44% ^{***} | 77.30% ^{***} | 80.14% ^{***} | 76.21% ^{***} |
| War | 4.09% | 2.48% | 2.42% | 1.90% | 0.23% | 0.13% | 0.31% | 0.23% |
| Parental health status and health behaviors | 1.16% | 0.99% | 1.36% [*] | 0.98% | 0.96% | 0.68% | 0.78% | 0.54% |
| Health and nutrition conditions in childhood | 6.84% ^{***} | 10.81% ^{***} | 10.73% ^{***} | 13.96% ^{***} | 8.94% ^{***} | 9.06% ^{***} | 10.73% ^{***} | 12.92% ^{***} |
| Household SES in childhood | 5.91% ^{***} | 5.16% ^{***} | 5.35% | 4.51% | 3.40% | 5.84% ^{***} | 3.34% | 5.58% |
| Total | 65.53% | 71.02% | 69.67% | 71.71% | 86.97% | 93.01% | 95.30% | 95.48% |

Notes: Sampling weights are applied. Bootstrapped standard errors in parenthesis (500 replications). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Figure 5 RIF-based Shapley decomposition results—BMI and WC



Overall, we consistently find that rural/urban residence and province of residence are the leading contributors to IOp in bodyweight. Figures 6 and 7 show the mean values of BMI and WC by provinces in both waves. Generally, substantial geographical heterogeneities exist in bodyweight: in 2011, the mean BMI value ranges from 22.0 in Guangxi to 25.8 in Beijing (between 22.6 in Yunnan and 25.6 in Beijing in 2015). However, the average value of WC ranges from 81.3 in Guangxi to 93.2 in Xinjiang in 2011 (from 81.0 in Guizhou to 95.9 in Xinjiang in 2015). Such results are also in accordance with previous studies (Zhang *et al.*, 2020; Zhang *et al.*, 2019) that reveal a North-South gradient in bodyweight.

Figure 8 displays urban-rural disparities in bodyweight. In both waves, the mean BMI and WC values in the urban area are higher than these in the rural area (BMI: 24.4 versus 23.1 in 2011, 24.5 versus 23.6 in 2015; WC: 87.9 versus 84.4 in 2011, 88.5 versus 85.6 in 2015). Interestingly, during the period of 2011-2015, the urban-rural difference in both BMI and WC become smaller. Such results are consistent with previous studies, showing that although urban residents are more likely to be overweight or obese (Fang & Liang, 2017; Hou, 2008; Shen *et al.*, 2019; Wang *et al.*, 2007; Zhang, 2019) whereas the prevalence of general obesity and abdominal obesity is increasing faster in rural than in urban areas in China (Bixby *et al.*, 2019; Gong *et al.*, 2012; Nie *et al.*, 2019b; Popkin, 2019; Van de Poel *et al.*, 2009; Xi *et al.*, 2012).

Figure 6 Geographical variations of the mean BMI and WC in 2011

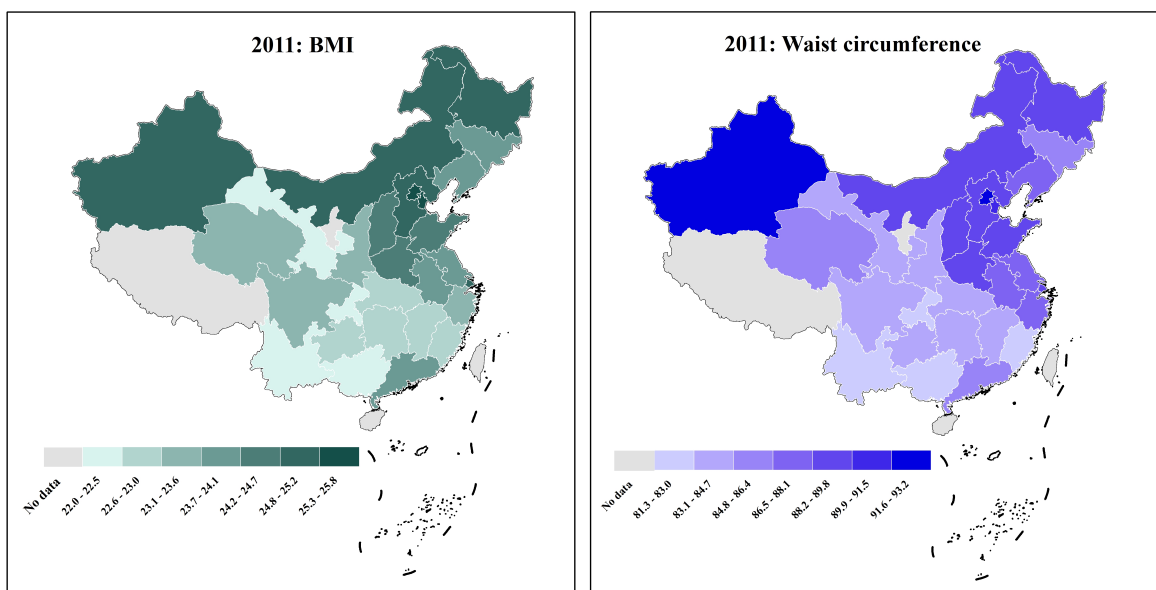


Figure 7 Geographical variations of the mean BMI and WC in 2015

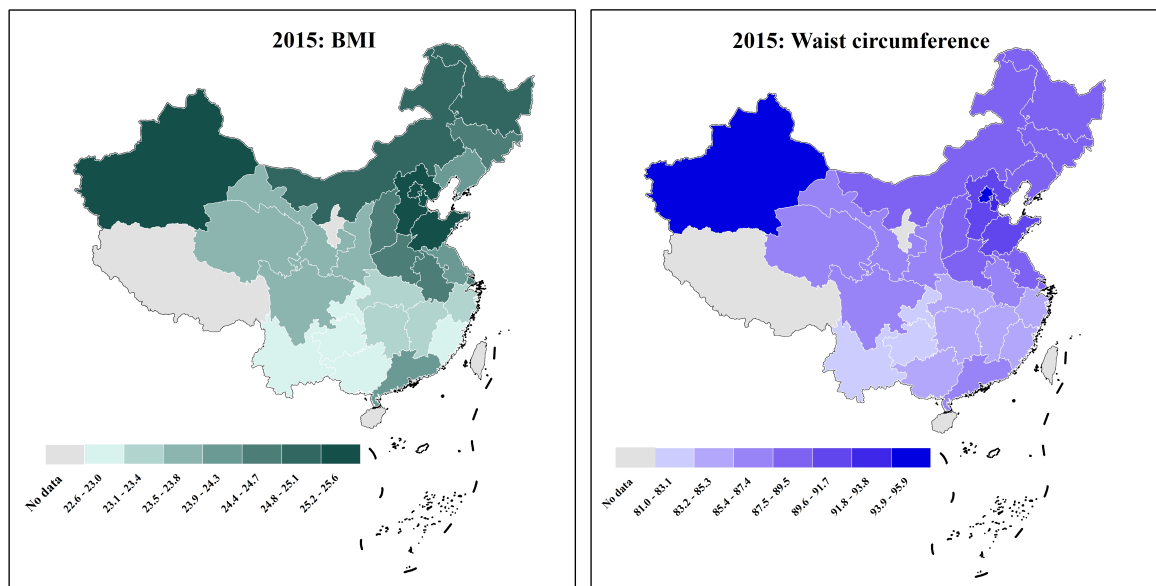
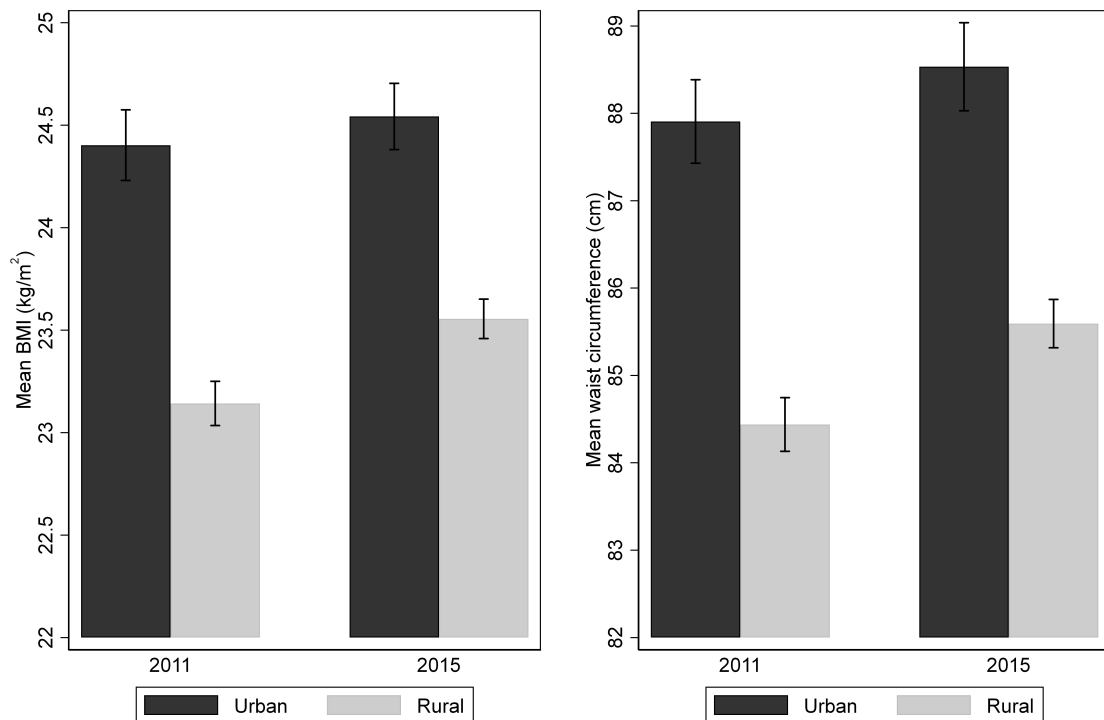


Figure 8 Mean BMI and WC by urban and rural residence in 2011 and 2015



5. Discussion

As a developing country, China is currently undergoing rapid economic, social and cultural transformations, including an accelerated pace of nutritional transition that may lead to a greatly increased burden of chronic diseases such as obesity (Xi *et al.*, 2012; Zhai *et al.*, 2009). Although many studies have investigated the associations of adulthood obesity with demographic, socioeconomic, dietary and physical activity factors in China, virtually no research examines IOp in bodyweight to disentangle legitimate and inequitable sources of bodyweight inequality, especially the contribution of inequitable circumstances. Understanding the sources of bodyweight inequality in Roemer's framework of equality of opportunity is crucial to effectively reduce bodyweight inequality. This is because if bodyweight inequality is mainly due to efforts that are under individual control, such inequality may be regarded as reasonable and acceptable. However, if inequality mainly comes from circumstances for which individuals are not held responsible, such inequality is ethically objectionable. In this

regard, it is essential that differentiated health policies should be designed to mitigate unequal circumstances and compensate people for an unequal playing field.

Using nationally representative survey data from CHARLS, our study is the first attempt to provide a comprehensive analysis of IOP in bodyweight among middle-aged and elderly Chinese. We identify the relative contributions of circumstances, demographics and efforts when explaining inequality in bodyweight. Further, employing the RIF-based Shapley-Shorrocks decomposition, we quantify heterogeneous contributions of circumstances, demographics and efforts to IOP over the whole distribution of bodyweight, with a particular focus on the upper tails of the distribution of bodyweight, where individuals are at high risk of obesity.

The study yields several findings. First, we find that the obesity problem is growing in middle-aged and elderly adults in China. During such a short timeframe (from 2011 to 2015), both BMI and WC values have increased and the prevalence of general obesity and central obesity also rapidly grows. These results are in line with previous studies on the dynamics of Chinese adulthood bodyweight (Nie *et al.*, 2019a; Sun *et al.*, 2018; Zhang *et al.*, 2019). Moreover, the rate of central obesity is substantially higher than that of general obesity and the increase in central obesity is faster than that of general obesity, which is also mirrored by previous studies (e.g., Zhang *et al.*, 2019).

Second, our decomposition results reveal that the relative contribution of circumstances (i.e. IOP) to total explained inequality in bodyweight is dominant and. Among observed circumstances, the largest contribution is attributable to urban/rural residence and province of residence. Our finding of considerable geographical heterogeneities in the mean BMI and WC values echoes previous research, indicating that a striking North-South gradient exists in the prevalence of obesity (Zhang *et al.*, 2020; Zhang *et al.*, 2019). Additionally, health and nutrition conditions in childhood comes out as the second largest contributor to IOP in bodyweight. This may imply that health status and nutrition conditions in childhood play a vital role in adult bodyweight, and disparities of these early-life circumstances may greatly contribute to adult bodyweight inequality. To

some extent, our results accord with “*life course epidemiology*” studies (Kuh & Ben-Shlomo, 2016), showing that early social and biological factors affect adults health, ageing and disease risk. A growing number of studies confirm the early life origins of adulthood chronic diseases and function (e.g., Adhvaryu *et al.*, 2019; Briana & Malamitsi-Puchner, 2018; Hoffman *et al.*, 2019). Particularly, metabolic programming by early nutrition conditions could partially explain the developments of later obesity and adult diseases (Liu *et al.*, 2019; Rolland-Cachera *et al.*, 2016).

Third and more importantly, results from the RIF-based Shapley decomposition reveal heterogeneities in the contributions of observed circumstances, efforts and demographics to IOp in individual bodyweight. It is noteworthy that the relative contribution of observed circumstances to total explained inequality in bodyweight increases towards the upper tails of both BMI and WC distributions. In particular, regarding circumstances, the contribution of health and nutrition conditions in childhood to IOp in bodyweight increases towards the upper tail of BMI and WC, where individuals are most at risk of obesity. However, the contribution of biological factors (gender and age) declines at the high quantiles, especially for BMI. As for the efforts, the contribution of lifestyles declines towards the upper tails of both BMI and WC distributions in 2011 and 2015. This may imply that the conventional mean-based Shapley-Shorrocks decomposition would mask the heterogeneous contributions of measured circumstances such as regions/provinces, health and nutrition conditions in childhood to IOp in bodyweight outcomes. More importantly, our unconditional quantile-based decomposition supports the conclusion that obesity is not simply a matter of demographic (age and gender) inequalities, as our set of spatial and health and nutrition conditions in childhood circumstances become much more relevant towards the right tails of bodyweight distribution, where clinical concerns are focused.

Our findings have potential policy implications. In addition to preventing obesity among young people, our study may suggest that effective public health strategies mitigating adiposity in the middle-aged and the elderly should be developed. Thus,

there is an urgent need for public health interventions to respond to obesity at all ages (Schooling *et al.*, 2006). Also, given that observed circumstances play a dominant role in explained inequality in bodyweight, public health policies should pay special attention to unreasonable circumstances disparities, especially urban and rural residence and province of residence to effectively mitigate obesity inequality. Marked provincial diversity in obesity prevalence indicates health equality remains a challenge in China. Improving health equity has long been a government priority, and *Healthy China 2030* (Zhou *et al.*, 2019) includes justice and equity as one of its four core principles. Thus tailored, province-specific policy development and interventions are urgently needed to lessen major risk factors (e.g. obesity) of chronic diseases in each province. Finally, various health programs and interventions aiming at improving childhood health and nutrition conditions are also desirable to achieve health equity in the long term.

Acknowledgements

Andrew Jones acknowledges funding from the Leverhulme Trust Major Research Fellowship (grant number MRF-2016-004). Peng Nie acknowledges funding from National Natural Science Foundation of China (grant number 71804142) and the Start-up Fund for Young Talent Support Plan (grant number 113055107001). The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors, and all errors are our own.

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Appendix:

Table A.1 Statistical tests to compare the full sample and matched sample

| Variables | 2011 | | | 2015 | | |
|------------------------------|---------|-------------|------------|---------|-------------|------------|
| | Matched | Full sample | Mean diff. | Matched | Full sample | Mean diff. |
| Gender | 0.466 | 0.472 | 0.006 | 0.470 | 0.471 | 0.001 |
| Age | 58.98 | 59.15 | 0.171 | 60.63 | 60.51 | -0.117 |
| Rural/urban residence | 0.656 | 0.636 | -0.021*** | 0.633 | 0.621 | -0.012 |
| Born in the Japanese War era | 0.170 | 0.169 | -0.001 | 0.149 | 0.147 | -0.002 |
| Born in the Civil War era | 0.131 | 0.127 | -0.003 | 0.118 | 0.117 | -0.002 |
| Alcohol drinking | 0.389 | 0.391 | 0.001 | 0.461 | 0.462 | 0.001 |
| Smoking | 0.393 | 0.396 | 0.004 | 0.435 | 0.435 | -0.001 |
| Education | 0.100 | 0.107 | 0.007 | 0.093 | 0.097 | 0.004 |
| Marital status | 0.881 | 0.876 | -0.005 | 0.865 | 0.866 | 0.001 |
| Employment status | 0.712 | 0.691 | -0.021*** | 0.688 | 0.685 | -0.003 |

Notes: The matched sample is observations from the full sample that can be linked with the 2014 CHARLS Life History Survey. The significance is based on independent *t*-tests. *** $p < 0.01$.

Table A.2 Statistical tests of demographics, efforts and circumstances variables

| Variables | 2011 | | | 2015 | | |
|------------------------------------|--|----------------|------------|--|----------------|------------|
| | Matched sample with no missing demographics, efforts and circumstances | Matched sample | Mean diff. | Matched sample with no missing demographics, efforts and circumstances | Matched sample | Mean diff. |
| Gender | 0.467 | 0.466 | -0.001 | 0.472 | 0.470 | -0.002 |
| Age | 58.36 | 58.98 | 0.625*** | 60.18 | 60.63 | 0.448*** |
| Alcohol dinking | 0.393 | 0.389 | -0.004 | 0.466 | 0.461 | -0.004 |
| Smoking | 0.391 | 0.393 | 0.002 | 0.435 | 0.435 | 0.0001 |
| High education | 0.105 | 0.100 | -0.006 | 0.101 | 0.093 | -0.007 |
| Married/partnered | 0.894 | 0.881 | -0.013*** | 0.875 | 0.865 | -0.010 |
| Employed | 0.725 | 0.712 | -0.013 | 0.697 | 0.688 | -0.010 |
| Urban/rural residence | 0.654 | 0.656 | 0.003 | 0.634 | 0.633 | -0.001 |
| Born in the Japanese War era | 0.161 | 0.170 | 0.009 | 0.141 | 0.149 | 0.008 |
| Born in the Civil War era | 0.130 | 0.131 | 0.001 | 0.117 | 0.118 | 0.001 |
| Parental health status | 0.186 | 0.195 | 0.010 | 0.189 | 0.198 | 0.009 |
| Mother's smoking | 0.105 | 0.106 | 0.001 | 0.110 | 0.110 | -0.0004 |
| Father's smoking | 0.503 | 0.500 | -0.003 | 0.522 | 0.520 | -0.002 |
| Father's alcohol drinking | 0.070 | 0.072 | 0.002 | 0.072 | 0.073 | 0.001 |
| Self-reported health before age 15 | | | | | | |
| Much less healthy | 0.047 | 0.052 | 0.005 | 0.047 | 0.052 | 0.005 |
| Somewhat less healthy | 0.078 | 0.079 | 0.001 | 0.079 | 0.081 | 0.001 |
| About average | 0.518 | 0.520 | 0.002 | 0.510 | 0.512 | 0.002 |
| Somewhat healthier | 0.186 | 0.183 | -0.003 | 0.190 | 0.186 | -0.003 |
| Much healthier | 0.170 | 0.165 | -0.006 | 0.174 | 0.169 | -0.004 |
| Experienced hunger before age 17 | 0.719 | 0.720 | 0.001 | 0.695 | 0.697 | 0.001 |
| Parental political status | 0.137 | 0.129 | -0.008 | 0.146 | 0.139 | -0.008 |
| Mother's education | 0.900 | 0.906 | 0.006 | 0.875 | 0.881 | 0.006 |
| Father's education | 0.632 | 0.644 | 0.012 | 0.597 | 0.609 | 0.012 |
| Household SES in childhood | | | | | | |
| A lot worse off than them | 0.227 | 0.246 | 0.019*** | 0.227 | 0.245 | 0.017*** |
| Somewhat worse off than them | 0.158 | 0.159 | 0.001 | 0.161 | 0.161 | 0.00001 |
| Same as them | 0.526 | 0.509 | -0.017 | 0.521 | 0.506 | -0.015 |
| Somewhat better off than them | 0.079 | 0.076 | -0.003 | 0.083 | 0.080 | -0.003 |
| A lot better off than them | 0.010 | 0.009 | -0.001 | 0.009 | 0.009 | 0.0004 |

Notes: The matched sample is observations from the full sample that can be linked with the 2014 CHARLS Life History Survey. The significance is based on independent *t*-tests. *** $p < 0.01$.

Table A.3 Statistical tests (*p-values*) between the matched sample with no missing demographics, efforts and circumstances and analytical sample

| Variables | 2011 | | 2015 | |
|------------------------------------|-------|-------|-------|-------|
| | BMI | WC | BMI | WC |
| Gender | 0.487 | 0.545 | 0.988 | 0.948 |
| Age | 0.306 | 0.224 | 0.653 | 0.583 |
| Alcohol dinking | 0.829 | 0.782 | 0.969 | 0.924 |
| Smoking | 0.802 | 0.822 | 0.934 | 0.985 |
| High education | 0.140 | 0.093 | 0.911 | 0.861 |
| Married/partnered | 0.465 | 0.424 | 0.803 | 0.829 |
| Employed | 0.263 | 0.321 | 0.523 | 0.940 |
| Urban/rural residence | 0.175 | 0.099 | 0.771 | 0.992 |
| Born in the Japanese War era | 0.486 | 0.469 | 0.933 | 0.955 |
| Born in the Civil War era | 0.474 | 0.449 | 0.878 | 0.969 |
| Parental health status | 0.892 | 0.904 | 0.913 | 0.719 |
| Mother's smoking | 0.815 | 0.919 | 0.994 | 0.969 |
| Father's smoking | 0.920 | 0.990 | 0.981 | 0.845 |
| Father's alcohol drinking | 0.908 | 0.763 | 0.883 | 0.961 |
| Self-reported health before age 15 | | | | |
| Much less healthy | 0.749 | 0.537 | 0.972 | 0.866 |
| Somewhat less healthy | 0.821 | 0.670 | 0.932 | 0.736 |
| About average | 0.932 | 0.957 | 0.838 | 0.998 |
| Somewhat healthier | 0.992 | 0.950 | 0.959 | 0.870 |
| Much healthier | 0.902 | 0.965 | 0.892 | 0.867 |
| Experienced hunger before age 17 | 0.501 | 0.562 | 0.982 | 0.804 |
| Parental political status | 0.571 | 0.674 | 0.983 | 0.886 |
| Mother's education | 0.367 | 0.349 | 0.993 | 0.983 |
| Father's education | 0.919 | 0.854 | 0.972 | 0.821 |
| Household SES in childhood | | | | |
| A lot worse off than them | 0.411 | 0.382 | 0.988 | 0.834 |
| Somewhat worse off than them | 0.954 | 0.969 | 0.922 | 0.946 |
| Same as them | 0.842 | 0.914 | 0.948 | 0.849 |
| Somewhat better off than them | 0.534 | 0.430 | 0.969 | 0.906 |
| A lot better off than them | 0.285 | 0.351 | 0.933 | 0.870 |

Notes: *p* values are reported.

Table A.4 OLS regressions for BMI and WC among Chinese adults aged 45+

| | 2011 | | 2015 | |
|------------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| | BMI | WC | BMI | WC |
| Male | -0.862 ^{***} (0.090) | -0.521 ^{**} (0.256) | -0.773 ^{***} (0.085) | -0.234 (0.261) |
| Age | -0.060 ^{***} (0.007) | 0.019 (0.022) | -0.060 ^{***} (0.007) | -0.012 (0.021) |
| Residuals | | | | |
| Alcohol drinking | 0.038 (0.107) | 0.217 (0.316) | 0.064 (0.099) | 0.663 ^{**} (0.292) |
| Smoking | -0.952 ^{***} (0.127) | -1.912 ^{***} (0.371) | -0.774 ^{***} (0.133) | -1.080 ^{***} (0.404) |
| High education | -0.006 (0.155) | -0.599 (0.439) | 0.170 (0.148) | 0.687 (0.430) |
| Married/partnered | 0.344 [*] (0.148) | 1.146 ^{**} (0.468) | 0.273 ^{**} (0.118) | 0.980 ^{***} (0.365) |
| Employed | -0.657 ^{***} (0.119) | -2.279 ^{***} (0.330) | -0.510 ^{***} (0.110) | -1.730 ^{***} (0.324) |
| Rural | -1.170 ^{***} (0.104) | -3.303 ^{***} (0.292) | -0.975 ^{***} (0.092) | -2.621 ^{***} (0.266) |
| Born in the Japanese War era | 0.154 (0.164) | 0.059 (0.470) | 0.050 (0.154) | -0.083 (0.474) |
| Born in the Civil War era | 0.238 [*] (0.137) | 0.426 (0.396) | 0.098 (0.133) | 0.093 (0.419) |
| Parental health status | 0.078 (0.117) | -0.294 (0.320) | 0.011 (0.105) | 0.022 (0.317) |
| Mother's smoking | -0.331 ^{**} (0.149) | -0.102 (0.447) | -0.274 ^{**} (0.133) | -0.716 [*] (0.408) |
| Father's smoking | 0.094 (0.094) | 0.278 (0.266) | 0.134 (0.093) | 0.342 (0.284) |
| Father's alcohol drinking | 0.218 (0.176) | 0.813 (0.526) | -0.034 (0.185) | -0.225 (0.579) |
| Self-reported health before age 15 | | | | |
| Somewhat less healthy | -0.173 (0.307) | -0.080 (0.730) | -0.211 (0.290) | 1.167 (0.820) |
| About average | 0.282 (0.270) | 1.034 [*] (0.576) | 0.245 (0.229) | 1.498 ^{***} (0.515) |
| Somewhat healthier | 0.927 ^{***} (0.281) | 2.707 ^{***} (0.650) | 0.717 ^{***} (0.239) | 2.691 ^{***} (0.559) |
| Much healthier | 1.227 ^{***} (0.284) | 3.168 ^{***} (0.634) | 1.012 ^{***} (0.247) | 3.418 ^{***} (0.596) |
| Experienced hunger before 17 | 0.021 (0.106) | -0.041 (0.299) | 0.079 (0.098) | 0.327 (0.291) |
| Parental political status | 0.083 (0.132) | 0.059 (0.382) | 0.013 (0.128) | 0.203 (0.376) |
| Mother's education | 0.107 (0.156) | 0.075 (0.442) | 0.307 ^{**} (0.147) | 0.784 [*] (0.423) |
| Father's education | -0.155 (0.096) | -0.250 (0.269) | -0.168 [*] (0.094) | -0.665 ^{**} (0.297) |
| Household SES in childhood | | | | |

| | | | | |
|-------------------------------|----------------------|----------------------|----------------------|----------------------|
| Somewhat worse off than them | 0.111 (0.149) | 0.531 (0.440) | 0.199 (0.132) | 0.893** (0.371) |
| Same as them | -0.073 (0.118) | -0.066 (0.338) | 0.065 (0.109) | 0.526* (0.311) |
| Somewhat better off than them | 0.447** (0.196) | 1.609*** (0.602) | 0.299 (0.192) | 1.240** (0.613) |
| A lot better off than them | 0.606 (0.581) | 2.675* (1.486) | 0.668 (0.565) | 2.038 (1.480) |
| Constant | 28.555*** (1.172) | 86.338*** (2.324) | 27.641*** (0.788) | 86.739*** (2.175) |
| <i>N</i> | 7231 | 7181 | 9729 | 9620 |
| <i>R</i> ² | 0.157 | 0.127 | 0.132 | 0.107 |

Notes: Sample weights are applied. Province dummies are controlled. Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.