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Re-examining the reversal hypothesis: A nationwide population-based study of the association between socioeconomic status, and NCDs and risk factors in China

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ABSTRACT

Background: According to the reversal hypothesis, as a country's economic and social development progresses, the burden of NCDs and risk factors shifts from rich to poor. The aim of this research is to examine the reversal hypothesis in the Chinese setting.

Methods: Using data from the China Health and Retirement Longitudinal Study (CHARLS) in 2015, we explored whether the reversal hypothesis applies at the subnational level. Participants aged 45 years and older in 2015 were included. We examined five risk factors (smoking, heavy drinking, physical inactivity, overweight, and obesity) and three objectively measured NCDs (diabetes, hypertension, dyslipidemia). Binary logistic regressions were performed to examine outcomes across people of differing SES in provincial level, in urban and rural areas, and across generations.

Results: Nationally, SES is positively associated with heavy drinking, obesity, diabetes and dyslipidemia, whereas it is negatively associated with physical inactivity. The association between SES and smoking and hypertension was not statistically significant. Except in the cases of diabetes and dyslipidemia, we found that risk factors of all kinds were more concentrated among richer people in rural than in urban areas. Across provinces with increasing GDP per capita, a downward trend in risk factors among those with high SES compared to those with low SES could be interpreted, while the opposite trend could be interpreted with respect to the metabolic syndrome conditions. Obesity and overweight exhibited slight downward trends (in line with those for risk factors) and upward trends (in line with those for metabolic syndrome conditions), respectively.

Conclusion: We conclude that China is at a relatively early stage of 'reversal', visible with respect to risk factors. If these patterns persist over time, the trend will likely feed through to metabolic disorders which will increasingly become diseases of the poor.

1. Introduction

Non-communicable diseases (NCDs) are a major contributor to health burdens globally. NCDs account for almost 75% of all deaths globally, and almost 71% of all deaths in low-and middle-income countries (LMICs) in 2019 (Institute for Health Metrics and Evaluation, 2022). In China, NCDs accounted for 90.08% of total deaths and 84.93% of total Disability-Adjusted Life Years (DALYs) lost in 2019 (Institute for Health Metrics and Evaluation, 2021). The rising prevalence of NCDs in China is attributed to a variety of factors, including demographic transition, accelerated urbanisation, and changes in lifestyle (Li et al., 2016; Miao & Wu, 2016). Lifestyle factors, such as smoking, alcohol consumption, and physical inactivity, are the leading factors associated with increased prevalence of NCDs in China and worldwide (Ding et al., 2020; Im et al., 2020; Li et al., 2020a; World Health Organization, 2021; Zhou et al., 2019). Socioeconomic status (SES), which influences the accessibility to health resources and choice-making, has a significant impact on the development of NCD outcomes (Galobardes et al., 2006). Studies of the SES-NCDs gradient from LMICs, for example, have found that overweight/obesity (Siddiquee et al., 2015; Subramanian et al., 2011), diabetes (Corsi & Subramanian, 2012; Moradi et al., 2016), hypertension (Corsi & Subramanian, 2019; Subramanian et al., 2013), and

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dyslipidemia (Espírito Santo et al., 2019) were more prevalent among higher SES groups compared to lower SES groups. However, the opposite is true in high-income countries (Pampel et al., 2012; Porhcisaliyan et al., 2021).

The "reversal hypothesis" suggests that the burden of NCDs and risk factors shifts from the rich to the poor as a country's economic and social development progresses, and with continued epidemiological transition (Aitsi-Selmi et al., 2012; Jung et al., 2019; Monteiro et al., 2001; Pampel et al., 2012). The rationale for this hypothesis in the existing literature is articulated that as countries "develop" (industrialise, urbanise and their economic prosperity increases), higher SES groups are more likely to afford excess calories and processed foods and avoid physically demanding work (Goryakin & Suhrcke, 2014; Zhou, 2019, 2021), which leads to weight gain and the development of diseases like diabetes, obesity, and hypertension (Bhimma et al., 2018; Wang & Wang, 2020). However, as the implications become clear, the same groups discard these behaviours early while lower SES groups start to adopt them. There are many possible factors that could underlie the 'reversal' stage of such trends. For example, compare with lower SES groups, higher SES groups tend to be better educated and have a higher level of health literacy, can afford to substitute out cheap processed foods (Kiadaliri, 2013; Miller et al., 2017), and can adopt deliberate exercise habits and have better access to parks or exercise facilities such as gyms. On the contrary, people belonging to lower SES groups, such as those living in rural and poor urban communities, persist with physically active agricultural labour and consumption of fresh produce as part of subsistence-based livelihood in the early stages of development. Then their income rises and they become more urbanized at the later stage of the development process, they acquire a set of risk factors such as processed foods, less physically demanding jobs, and unhealthy lifestyle (Golestani et al., 2021; Moradi et al., 2013). Those factors are likely to lead to overweight and obesity, which will thereafter result in metabolic syndromes such as diabetes and hypertension, but options to escape this fate are more limited for lower SES groups (Maimela et al., 2016; Thienemann et al., 2020). Central to much of this rationale for the proposed 'reversal hypothesis', is the process of urbanization (Miao & Wu, 2016), suggesting that analysis focused on urban-rural comparisons may be particularly helpful (Goryakin & Suhrcke, 2014). We should emphasise that all these arguments are poorly empirically explored and the literature debating the reversal hypothesis is not well developed. This is an important motivation for our study.

The concept of the 'reversal hypothesis' has substantial policy implications since it suggests that preventive strategies related to NCDs and risk factors should target the poor in places with higher economic development, but the wealthy in areas with lower economic development. Understanding better the processes involved in the acquisition and avoidance of NCDs at the level of sub-populations (such as those of higher and lower SES, urban and rural dwellers, recent and more established migrants) is likely to provide opportunities to better fine-tune prevention strategies. However, the existing literature has some gaps. It has focused most extensively on a limited range of conditions and risk factors and is highly dependent on international comparison (Goryakin & Suhrcke, 2014; He et al., 2014; Kinge et al., 2015; Pampel et al., 2012). There has been little analysis of the experience of individual countries over time, or comparison of sub-national level experience. An article related to the experience of India provides a limited exception to that point (Jung et al., 2019).

To examine the "reversal hypothesis" phenomenon that may occur over multiple decades, long-term panel data would be ideal to enable observation of the SES-NCDs gradient over time as the nation evolves. In the absence of such data sets, proxy analyses can seek to explore change over time in the SES-NCDs gradient in different areas using cross-sectional data (Jung et al., 2019). China offers a unique cross-sectional opportunity, for the following reasons. First, NCDs are the leading causes of death and DALYs in China and is a growing concern as the population ages (Zeng et al., 2017). By 2030, the total annual number of premature NCD-related deaths is expected to reach 3.52 million (Li et al., 2017). Although there are studies examining the association between SES and NCDs and risk factors in China, they are analyses at points in time, with a primary focus on the important issue of inequality (Xiao et al., 2013; Zhou, 2021). Second, the Chinese economy has been growing rapidly in the past four decades. The annual gross domestic product (GDP) growth rate was more than 10% between 1983 and 1988, 1992 and 1995, 2003 and 2007 (National Bureau of Statistics of China, 2022). This makes China well-suited to expand our understanding of the relationship between SES and NCD risk factors under rapid economic growth and transition. Similarly, the rapid growth implies that the different generations of the Chinese population have experienced stages of the life cycle under markedly different conditions. This also offers an opportunity to try to understand how NCDs and risk factors have been emerging in population sub-groups differently over time. Third, rapid rural-urban migration has also been a marked feature of the last decades in China. We can also gain insight by exploring rural-urban differences. Fourth, the economic development level is heterogeneous across different provinces in China. The GDP ranged from US$3893.06 for Gansu to US$17668.85 for Beijing in 2015. The large differences in economic development in China offer an opportunity to evaluate how the SES gradient in NCDs and risk factors change as development occurs.

We hypothesized that people with higher SES would be more likely to have NCDs and risk factors in poorer than in richer provinces, in rural than in urban area, and in older than in younger populations. The objectives of this study were to: 1) investigate the relationship between SES and NCDs and risk factors at the national level; 2) examine the relationship between SES and NCDs and risk factors at the provincial levels to assess the association as the provincial economy grows; 3) compare the association between SES and NCDs in rural and urban populations; 4) compare the association between SES and NCDs and risk factors in different age groups to proxy for the association with time.

2. Methods

2.1. Data source and population

This study used data from the China Health and Retirement Longitudinal Study (CHARLS) in 2015. CHARLS is an ongoing nationally representative longitudinal survey that collects individual-data including demographics, biomarkers, health status, healthcare use, and household expenditures among Chinese adults aged 45 and up. CHARLS baseline survey was in 2011, including 17,708 respondents in 450 villages/urban communities, 150 counties/districts, and 28 provinces, across the country. A detailed description of the CHARLS methodology has been reported elsewhere (Zhao et al., 2014). We used the 2015 wave because it is the most recent wave that has biomarkers to objectively measure NCDs. There were 21,059 participants in 2015. We used data from other waves of CHARLS to fill in the missing values of key socio-demographic variables in 2015 (e.g., age, gender, SES). The consumer price index in the year was incorporated when filling the SES. The final sample size is 19,776 people after removing those who are under 45, and still have missing values for key socio-demographic variables (S1). The per capita GDP of each province in 2015 was obtained from the National Bureau of Statistics of China (National Bureau of Statistics of China, 2021) and represented in 2015 US dollars (Washington: International Monetary Fund, 2001).

2.2. Measurements

Our primary study variables were five risk factors (smoking, heavy drinking, overweight, obesity, and physical inactivity) and three objectively measured NCDs through biomarkers or blood pressure (diabetes, hypertension, dyslipidemia). The body mass index (BMI) was calculated using the measured weight in kilograms and height in meters, and was then divided into studied categories according to the Chinese Criteria of Weight for Adults recommended by the National Health and Family Planning Commission of the People's Republic of China: overweight (>23.9 kg/m2) (including overweight and obesity) and not overweight (≤23.9 kg/m2) (underweight and normal weight), obesity (>27.9 kg/m2) and not obesity (≤27.9 kg/m2) (underweight, normal weight, and overweight) (Hu et al., 2020; National Health and Family Planning, 2015). A code of 1 is given if the respondents were overweight and obese.

Two questions were used to define smoking status. The first was, "Have you ever chewed tobacco, smoked a pipe, smoked self-rolled cigarettes, or smoked cigarettes/cigars?" If the participant answered "yes" to the first question, the second one asked," Do you still have the habit or have you totally quit?" Participants who answered "yes" to both questions were classified as "smoking", while alternatives were classified as "not smoking" (former smokers and never smokers).

Participants were asked about their drinking status, drinking frequency, and drinking amount by the following questions: "Did you drink any alcoholic beverages, such as beer, wine, or liquor in the past year?", "How often did you drink wine or rice wine per month in the last year?", "The last time you drank it last year, how many liang of wine did you drink?". The frequency of drinking was represented, "1 Once A Month, 2–3 Times A Month, Once A Week, 2–3 Times A Week, 4–6 Times A Week, Once A Day, Twice A Day, and More Than Twice A Day". Then the drinking frequency per day was calculated: frequency of drinking divided the 30 days. CHARLS measured drinking amount in "Liang". We first converted "Liang" into milliliters and then converted milliliters into grams. In CHARLS. The total amount of drinks consumed by each participant per day was thus calculated using the formula: total drinking g/per day = (liquor g/per time)*(liquor frequency/per day)+(wine g/per time)*(wine frequency/per day)+(beer g/per time)*(beer frequency/per day). Heavy drinking was defined as total drinking g/per day >25g/per day for males and >15 g/per day for females (Chinese Nutrition Society, 2016) (S2).

Participants were asked about exercise intensity (vigorous, moderate, light), time of duration (<30min, 30min-2h, 2h-<4h, and ≥4h), and days (ranged from 1 to 7 days/week) they did physical activity (PA) at least 10 min continuously in a usual week. The daily duration of PA was estimated using the average value of time duration (15min, 75min, 180min, and 300min). The number of minutes spent doing Vigorous/Moderate/Light activity per week for each participant was calculated by multiplying the daily duration and frequency per week of each type of activity. The total metabolic equivalents (METs) per week for each participant were thus calculated following the International Physical Activity Questionnaire (IPAQ) criterion (IPAQ Research Committee, 2021) and literatures (Li et al., 2020b; Wang et al., 2019a). Physical inactivity (PI) was defined as < 150 min/week of moderate, and <75 min/week of vigorous activity, and a combination <600 METs (Ding et al., 2020; Wang et al., 2019a) (S3).

Hypertension was defined as a systolic blood pressure (SBP) ≥140 mmHg and/or DBP ≥90 mmHg, and/or receiving medication for hypertension (Chobanian et al., 2003). Diabetes was defined if the individual had fasting blood plasma glucose level of ≥7.0 mmol/L (126 mg/dL), and/or HbA1c concentration of ≥6.5%, and/or receiving insulin treatment and/or medication for high blood sugar level (Yuan et al., 2015). Dyslipidemia was defined as the total cholesterol (TC) ≥ 240 mg/dL, and/or low-density lipoprotein cholesterol (LDL-C) ≥ 160 mg/dL and/or, and/or high-density lipoprotein cholesterol (HDL-C) < 40 mg/dL and/or, and/or triglyceride (TG) ≥ 200 mg/dL and/or, and/or receiving *anti*-dyslipidemia medication (Pan et al., 2021).

Total household per capita consumption was used as the proxy for SES at the individual level. We used "per capita household expenditures" as the proxy of household permanent income. We elected to use "per capita household expenditures" rather than individual or household income as it is commonly deemed a better measure of permanent income in the context of China and particularly in the rural context (Deaton, 1997) (Deaton, 1997, pp. 335–357). Furthermore, the targeted participants of CHARLS are aged 45 and older, given that older adults may retire and had no stable paid work, we thus chose total household per capita consumption instead to measure financial status. We used log SES (continuous) in our main analysis and categorical SES in our sensitivity analysis. GDP per capita in 2015 was used as the province level socioeconomic indicator.

The following variables included as covariates were: gender (female, male), age (45–54, 55–64, 65–74, 75 and above years), education (illiterate, primary school [grades 1–6], secondary school [grades 7–12], college and above), marital status (married, partnered, separated, divorced, widowed, never married), residency (rural, urban), labor force status (never work, unemployed, retired, agricultural work, and non-agricultural work), and province (Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Shaanxi, Gansu, Xinjiang, Qinghai, Heilongjiang, Jilin, Liaoning, Hubei, Hunan, Henan, Shanghai, Shandong, Jiangsu, Anhui, Jiangxi, Zhejiang, Fujian, Guangdong, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan).

2.3. Statistical analyses

We reported the prevalence of risk factors and NCDs presented the weighted percentages (used the Household Weight without Response Adjustment) with 95% confidence intervals (CI). Binary logistic regressions were performed to examine the associations between SES and the presence of NCDs and risk factors at the national level. In the regressions, risk factors and NCDs were treated as dependent variables and SES and individual sociodemographic factors were treated as independent variables. We reported the adjusted odds ratios (AORs) which were adjusted for age, gender, education, marital status, residence, job status, and province, with 95% CI. We used the model with robust standard errors clustered at the community level. We used unweighted data in the logistic regressions because we aimed to investigate the association between SES and outcomes rather than produce nationally representative estimates.

To examine the "reversal hypothesis", long-term panel data would be ideal. In the absence of such data, we conducted the proxy analyses by provinces, residency (rural and urban), and generations to examine the SES gradient in NCDs and risk factors, using cross-sectional data. We used binary logistic regression analyses for provinces with different wealth levels to explore NCDs and risk factors across people of differing socioeconomic status. We plotted AORs against corresponding provinces to illustrate the pattern of association between SES and NCDs as the provincial wealth level increased. Provinces with a sample size <130 were excluded from provincial level analysis given the small sample size (Peng et al., 2002) (S4&S5). Furthermore, a critical factor in the reversal hypothesis is the urbanization with associated lifestyle changes. Therefore, we hypothesized people with higher SES would be more likely to have NCDs and risk factors in rural than in urban areas. We repeated the binary logistic regression analyses for population in rural and urban areas to test this hypothesis. In addition, over time, as China's economic and social development has progressed, NCDs and risk factor will have shifted to some extent from higher to lower socioeconomic status individuals. Our sample respondents were aged 45 years and above. Their current NCD status may be attributed to their behaviors at earlier stages of the life course, during the period when the economy of China was less developed. We hypothesized that people with higher SES would be more likely to have NCDs and risk factors in older than in younger populations. We explored the SES gradient in NCDs and risk factors among different age groups to test this hypothesis.

Two sensitivity analyses were performed: 1) we examined the association between continuous SES and studied outcomes using a linear probability model; 2) we investigated the association between categorical SES (i.e., SES quintiles, Q1 being the lowest and Q5 being the highest) and studied outcomes using a binary logistic regression model.

P-values less than 0.05 were considered statistically significant.

Statistical analyses were performed with Stata/MP 14.1.

3. Results

3.1. Descriptive statistics

In total 19,776 participants were included in our sample, among which 51.13% were female. The mean age was 60 years (IQR 52–67), 65.71% had an education level of primary school or less, 79.69% were married, 50.71% resided in rural areas. The overall weighted prevalence of smoking, heavy drinking, physical inactivity, overweight, obesity, diabetes, hypertension, and dyslipidemia were 27.75%, 11.45%, 17.02%, 47.01%, 13.14%, 19.98%, 41.66%, and 37.09%, respectively. Sample characteristics are reported in Table S5 in the supplementary files.

3.2. The association between SES and NCDs and risk factors at the national level

The associations between SES and NCDs and risk factors at the national level and for urban and rural residents respectively are reported in Table 1. Nationally, higher SES was positively associated with heavy drinking (AOR 1.13 [95% CI 1.06–1.20]), being overweight (AOR 1.09 [95% CI 1.04–1.13]), obesity (AOR 1.11 [95% CI 1.04–1.17]), diabetes (AOR 1.08 [95% CI 1.03–1.14]), and dyslipidemia (AOR 1.09 [95% CI 1.04–1.14]), whereas it was negatively associated with PI (AOR 0.84 [95% CI 0.78–0.90]). The association between SES and smoking and hypertension was not statistically significant at 5% level. When we disaggregate the effects by urban and rural residency, we found that the positive associations between SES and diabetes (AOR 1.09 [95% CI 1.01–1.18]) and dyslipidemia (AOR 1.17 [95% CI 1.09–1.27]) were more pronounced in the urban population, while the positive associations between SES and heavy drinking (AOR 1.16 [95% CI 1.08–1.25]), overweight (AOR 1.08 [95% CI 1.03–1.14]), and obesity (OR 1.11 [95% CI 1.02–1.19]) were more pronounced in rural populations. Compared to the rural population, the negative association between SES and PI (AOR 0.76 [95% CI 0.68–0.85]) was more pronounced in the urban population. Similar to national analysis, the association between SES and hypertension was not statistically significant.

3.3. The association between SES and NCDs and risk factors across provinces

Table 2 shows the relationship between SES and NCDs and risk factors across provinces. In line with the overall national results, in most provinces, SES was positively associated with smoking, heavy drinking, being overweight, obesity, diabetes, and dyslipidemia, whereas negatively associated with physical inactivity. Furthermore, the positive SES gradients of overweight, obesity, diabetes, hypertension, and dyslipidemia among the population were less pronounced in provinces with higher than lower GDP per capita. For example, rich people in high GDP Shandong were less likely to be overweight (AOR 1.16 [95% CI 1.02–1.32]) compared to those in low GDP Liaoning (AOR 1.55 [95% CI 1.26–1.91]) and Yunnan (AOR 1.17 [95% CI 1.04–1.33]). Rich people in higher GDP Inner Mongolia were less likely to have hypertension (AOR 1.23 [95% CI 1.10–1.39]), compared to those in lower GDP Qinghai (AOR 1.66 [95% CI 1.18–2.33]). We plotted the AORs against provincial GDP per capita (from lowest to highest), to depict the trend of association between SES and outcome variables at the provincial level (Fig. 1). The negative SES gradient of physical inactivity were more pronounced in provinces with higher GDP per capita. There were also downward trends of the positive SES gradients in smoking and heavy drinking, whereas upward trends of the positive SES gradients in overweight, diabetes, hypertension, and dyslipidemia. There was no discernible trend in relation to obesity.

3.4. The association of SES and NCDs and risk factors across different age groups

Table 3 presents the association between SES and NCDs and risk factors in the three different age groups (45–54, 55–64, and 65 and over) as a proxy for the association with change over time. In general, and in line with our national level findings, higher SES was associated with a higher prevalence of smoking, heavy drinking, being overweight, obesity, diabetes, and dyslipidemia across all age groups, and physical inactivity was negatively associated. Specifically, older people were equally likely to smoke whether they are rich or poor, but younger people (Chinese Nutrition Society, 2016; Chobanian et al., 2003; Deaton, 1997, pp. 335–357; Gu & Ming, 2020; IPAQ Research Committee, 2021; Li et al., 2020b; Pan et al., 2021; Peng et al., 2002; Wang et al., 2019a; Yuan et al., 2015) were more likely to smoke if rich (AOR 1.09, [95% CI 1.00–1.19]). Rich people aged 55 to 64 were more likely to drink heavily (AOR 1.29, [95% CI 1.17–1.41]), but this was not observed in the other two age groups. Poorer people are more physically inactive than richer people and this is more the case for older (65 and older) (AOR 0.78, [95% CI 0.70–0.87]) than younger people (AOR 0.83, [95% CI 0.73–0.93]). For BMI, there is a stronger pro-rich gradient among the old than the young and this means that younger people are equally likely to have overweight/obesity whether they are rich or poor, but older people are more likely to be overweight (AOR 1.16, [95% CI 1.07–1.25]) and obese (AOR 1.21, [95% CI 1.07–1.36]) if they are rich. For diabetes, younger groups (e.g., 45–54) are more likely to have diabetes if they are rich (AOR 1.14, [95% CI 1.02–1.28]), while the oldest groups are equally likely to have diabetes whether they are rich or poor. Rich people of all age groups investigated are more likely to develop dyslipidemia, and the association is most pronounced in the oldest

Table 1
The association between SES and NCDs and risk factors at the national level.

Variables	All		Urban		Rural	
	AOR	(95%CI)	AOR	(95%CI)	AOR	(95%CI)
Smoking	1.03	(0.99–1.08)	1.08	(1.00–1.17)	1.01	(0.95–1.06)
Heavy Drinking	1.13***	(1.06–1.20)	1.08	(0.97–1.19)	1.16***	(1.08–1.25)
Physical Inactivity	0.84***	(0.78–0.90)	0.76***	(0.68–0.85)	0.89***	(0.82–0.97)
Overweight	1.09***	(1.04–1.13)	1.07**	(1.01–1.14)	1.08***	(1.03–1.14)
Obesity	1.11***	(1.04–1.17)	1.09**	(1.00–1.18)	1.11**	(1.02–1.19)
Diabetes	1.08***	(1.03–1.14)	1.09**	(1.01–1.18)	1.07	(1.00–1.15)
Hypertension	1.00	(0.96–1.05)	0.96	(0.90–1.02)	1.03	(0.98–1.08)
Dyslipidemia	1.09***	(1.04–1.14)	1.17***	(1.09–1.27)	1.05	(0.99–1.11)

***$p < 0.01$, **$p < 0.05$.
AOR = Adjusted odds ratios.
Adjusted for gender, age, education, marital status, residency, occupation, and provinces.
Model with robust standard errors clustered at the community level.
Each cell (AOR and 95% CI) represents result from separate regression models.

Table 2
The association between SES and NCDs and risk factors across provinces.

Province	Smoking		Heavy Drinking		Physical Inactivity		Overweight		Obesity		Diabetes		Hypertension		Dyslipidemia	
	AOR	(95%CI)	AOR	(95%CI)	AOR	(95%CI)	AOR	(95%CI)	AOR	(95%CI)	AOR	(95%CI)	AOR	(95%CI)	AOR	(95%CI)
Gansu	0.91	(0.68–1.22)	1.04	(0.62–1.72)	0.88	(0.64–1.21)	1.04	(0.88–1.24)	0.88	(0.56–1.37)	0.92	(0.63–1.34)	0.78	(0.59–1.02)	1.03	(0.77–1.37)
Guizhou	1.26	(0.56–2.82)	0.84	(0.45–1.54)	1.05	(0.41–2.71)	1.50	(0.73–3.07)	1.52	(0.58–3.96)	1.23	(0.37–4.12)	1.05	(0.77–1.43)	0.80	(0.57–1.14)
Heilongjiang	1.17	(0.90–1.51)	1.15	(0.74–1.80)	0.33	(0.09–1.23)	0.98	(0.73–1.32)	0.91	(0.68–1.22)	0.97	(0.68–1.39)	0.92	(0.77–1.10)	0.88	(0.61–1.27)
Guangxi	0.95	(0.71–1.28)	1.25	(0.98–1.59)	0.68	(0.44–1.05)	0.85	(0.72–1.00)	1.05	(0.81–1.37)	0.93	(0.71–1.21)	1.02	(0.83–1.26)	0.92	(0.66–1.28)
Yunnan	1.17	(0.99–1.40)	1.05	(0.86–1.29)	0.71**	(0.54–0.93)	1.17**	(1.04–1.33)	1.15	(0.89–1.49)	1.09	(0.90–1.32)	0.98	(0.86–1.12)	1.12	(0.92–1.36)
Shanxi	1.06	(0.81–1.40)	1.39	(0.76–2.56)	1.05	(0.75–1.47)	0.99	(0.82–1.19)	0.98	(0.73–1.30)	1.16	(0.80–1.70)	0.94	(0.72–1.24)	1.06	(0.93–1.20)
Qinghai	1.11	(0.66–1.86)	1.03	(0.12–8.74)	1.00	(0.03–38.99)	1.00	(0.75–1.32)	1.61	(0.87–2.99)	0.71	(0.39–1.29)	1.66***	(1.18–2.33)	1.53***	(1.21–1.93)
Hebei	0.89	(0.67–1.17)	1.35	(0.91–1.99)	0.87	(0.50–1.53)	0.91	(0.76–1.08)	1.07	(0.88–1.30)	1.16	(0.82–1.63)	0.98	(0.82–1.16)	1.14	(0.88–1.47)
Jilin	0.94	(0.80–1.10)	1.11	(0.78–1.58)	0.78	(0.59–1.03)	0.97	(0.75–1.26)	1.30	(1.00–1.70)	0.92	(0.68–1.23)	0.80	(0.54–1.19)	1.41**	(1.01–1.96)
Jiangxi	1.01	(0.77–1.31)	1.33**	(1.06–1.67)	0.79	(0.59–1.07)	1.10	(0.91–1.33)	1.39**	(1.04–1.84)	1.17	(0.89–1.53)	1.18**	(1.03–1.36)	1.21	(0.96–1.52)
Sichuan	0.84**	(0.71–1.00)	0.97	(0.81–1.16)	1.08	(0.81–1.43)	1.12**	(1.01–1.24)	1.06	(0.85–1.33)	0.92	(0.76–1.11)	1.08	(0.92–1.26)	1.16	(0.94–1.42)
Anhui	1.04	(0.86–1.26)	1.45***	(1.23–1.70)	0.84	(0.66–1.07)	0.97	(0.83–1.15)	1.03	(0.77–1.39)	1.08	(0.88–1.33)	0.95	(0.84–1.08)	1.03	(0.91–1.16)
Henan	1.28**	(1.06–1.55)	1.50***	(1.13–1.98)	0.83	(0.66–1.06)	1.00	(0.84–1.18)	0.91	(0.78–1.08)	1.02	(0.84–1.23)	0.94	(0.81–1.10)	1.11	(0.94–1.32)
Hunan	1.07	(0.87–1.30)	1.08	(0.76–1.53)	0.85	(0.58–1.23)	1.21	(0.97–1.51)	1.35**	(1.03–1.78)	0.93	(0.72–1.20)	1.09	(0.95–1.25)	1.12	(0.81–1.55)
Liaoning	1.12	(0.81–1.53)	1.11	(0.75–1.65)	1.16	(0.67–1.99)	1.55***	(1.26–1.91)	1.51**	(1.06–2.15)	1.17	(0.80–1.72)	0.94	(0.73–1.21)	1.27**	(1.02–1.59)
Shaanxi	1.16	(0.94–1.44)	2.11***	(1.32–3.37)	0.74	(0.49–1.13)	1.03	(0.84–1.26)	1.02	(0.80–1.31)	1.13	(0.85–1.50)	0.87	(0.67–1.12)	1.17	(0.93–1.46)
Inner Mongolia	0.95	(0.77–1.17)	1.10	(0.83–1.46)	0.91	(0.57–1.46)	1.04	(0.89–1.21)	1.23***	(1.05–1.43)	1.09	(0.82–1.45)	1.23***	(1.10–1.39)	1.16	(0.97–1.38)
Hubei	0.83	(0.63–1.08)	0.94	(0.69–1.28)	1.61	(0.89–2.91)	0.98	(0.69–1.39)	0.86	(0.48–1.54)	1.59***	(1.16–2.17)	1.10	(0.84–1.45)	0.98	(0.79–1.21)
Chongqing	1.73**	(1.00–2.98)	0.97	(0.64–1.47)	0.30*	(0.08–1.22)	1.08	(0.77–1.52)	1.47	(0.61–3.57)	1.68	(0.82–3.42)	1.20	(0.93–1.56)	1.04	(0.61–1.75)
Shandong	1.05	(0.94–1.17)	1.11	(0.94–1.30)	0.75***	(0.62–0.91)	1.16**	(1.02–1.32)	1.11	(0.95–1.31)	1.14*	(1.00–1.29)	0.91	(0.81–1.04)	1.07	(0.96–1.19)
Guangdong	1.03	(0.86–1.25)	1.08	(0.74–1.57)	0.60***	(0.43–0.84)	1.17	(0.97–1.40)	1.17	(0.86–1.59)	1.07	(0.81–1.42)	1.00	(0.78–1.26)	1.29*	(0.96–1.72)
Fujian	0.91	(0.67–1.24)	0.95	(0.57–1.59)	1.04	(0.60–1.78)	1.14	(0.89–1.45)	0.80	(0.55–1.16)	1.07	(0.81–1.42)	0.97	(0.73–1.29)	1.18	(0.94–1.48)
Tianjin	0.91	(0.55–1.49)			0.27**	(0.09–0.81)	1.31	(0.49–3.46)	1.21	(0.51–2.89)	1.32	(0.43–4.04)	1.54	(0.73–3.25)	1.36	(0.87–2.15)
Zhejiang	1.09	(0.95–1.26)	1.01	(0.81–1.25)	0.86	(0.67–1.10)	1.01	(0.80–1.28)	1.05	(0.65–1.68)	1.20	(0.87–1.65)	0.95	(0.80–1.12)	1.02	(0.85–1.21)
Jiangsu	1.03	(0.80–1.32)	1.10	(0.86–1.41)	0.82	(0.60–1.12)	1.06	(0.83–1.36)	1.25	(0.97–1.61)	1.15	(0.96–1.38)	1.19**	(1.01–1.41)	0.96	(0.72–1.27)

***$p < 0.01$, **$p < 0.05$.
AOR = Adjusted odds ratios.
Adjusted for gender, age, education, marital status, residency, occupation, and provinces.
Model with robust standard errors clustered at the community level.
Each cell (AOR and 95% CI) represents result from separate regression models.
Beijing (Nam et al., 2013), Shanghai (85), and Xinjiang (113) were not included in the provincial model due to small sample size.
The provinces were ordered based on the GDP per capita (US$) in 2015.

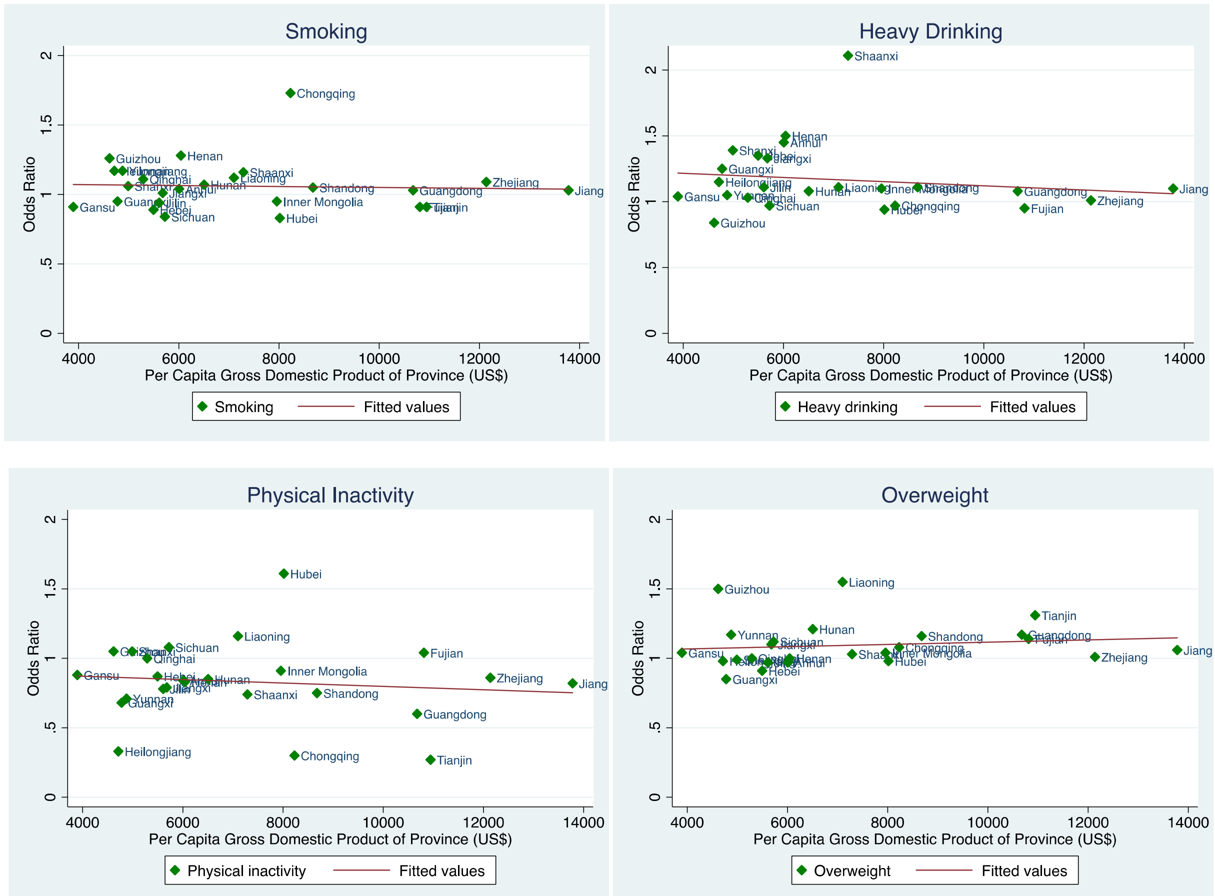

Fig. 1. The pattern of association between SES and NCDs and risk factors across provinces.

groups (AOR 1.10, [95% CI 1.02–1.18]). People of all studied ages are equally likely to have hypertension.

3.5. Sensitivity analysis

The results from sensitivity analyses are in line with our main findings. First, when using a linear probability model to evaluate the relationship between continuous SES and NCDs and risk factors, the national and provincial results were consistent with the main findings yielded from the binary logistic model (S7&S8). Secondly, we repeated the binary logistic regression model to investigate the association between categorical SES and NCDs and risk factors (S9). We found similar associations with our original findings, showing higher SES quintiles were associated with the higher prevalence of smoking, heavy drinking, overweight, obesity, diabetes, hypertension, and dyslipidemia, while it was associated with the lower prevalence of PI. For example, the highest SES quintiles and heavy drinking (AOR 1.49 [95% CI 1.27–1.76]), overweight (AOR 1.23 [95% CI 1.09–1.38]), obesity (AOR 1.33 [95% CI 1.13–1.57]), diabetes (AOR 1.26 [95% CI 1.08–1.47]), and dyslipidemia (AOR 1.23 [95% CI 1.08–1.39]) were positively related, but it was negatively related to PI (AOR 0.57 [95% CI 0.47–0.70]). All these analyses imply that our results are not contingent on these choices of method.

4. Discussion

This study examined the reversal hypothesis for NCDs and risk factors in a Chinese setting using nationally representative longitudinal survey of middle-aged and older Chinese people. Firstly, consistent with the findings from previous studies in China and other countries, our national findings suggest a significant positive association between higher SES and higher prevalence of heavy drinking (Gu & Ming, 2020), overweight/obesity (Siddiquee et al., 2015), diabetes (Corsi & Subramanian, 2012; Dagadu, 2019; Hosseinpoor et al., 2012; Lai et al., 2019; Moradi et al., 2016), and dyslipidemia (Espírito Santo et al., 2019), although the opposite association was found for physical inactivity ($p < 0.01$) (Jurj et al., 2007; Li et al., 2012). Our study did not find a significant association between SES and hypertension, which is consistent with prior research (Wu & Wang, 2019). In contrast to our findings, a few studies from LMICs concluded that lower SES groups were more likely to be overweight/obese (Emamian et al., 2017; Li et al., 2012), and have diabetes (Wang et al., 2019b), hypertension (Veisani et al., 2019) and dyslipidemia (Nam et al., 2013; Nikparvar et al., 2021), and be less likely to be physically inactive (Allen et al., 2017; Moradi et al., 2013), than higher SES groups. One explanation might be that these studies were from different LMICs which might be at different stages of transition, and the factors that influence the occurrence of NCDs differ across countries and regions at different stages of socioeconomic development (Wang & Wang, 2020).

In what we believe is original analysis, we found that the prevalence of overweight, obesity, diabetes, hypertension, and dyslipidemia was less pronounced among the richer population in provinces with higher GDP per capita when compared to provinces with lower GDP per capita. These findings are broadly consistent with a weakening of the largely positive relationship between SES, NCDs and risk factors at the stage of development of the richer Chinese provinces. We observed that the prevalence of smoking, heavy drinking, and PI showed a downward trend among the population with higher SES as the GDP of the province

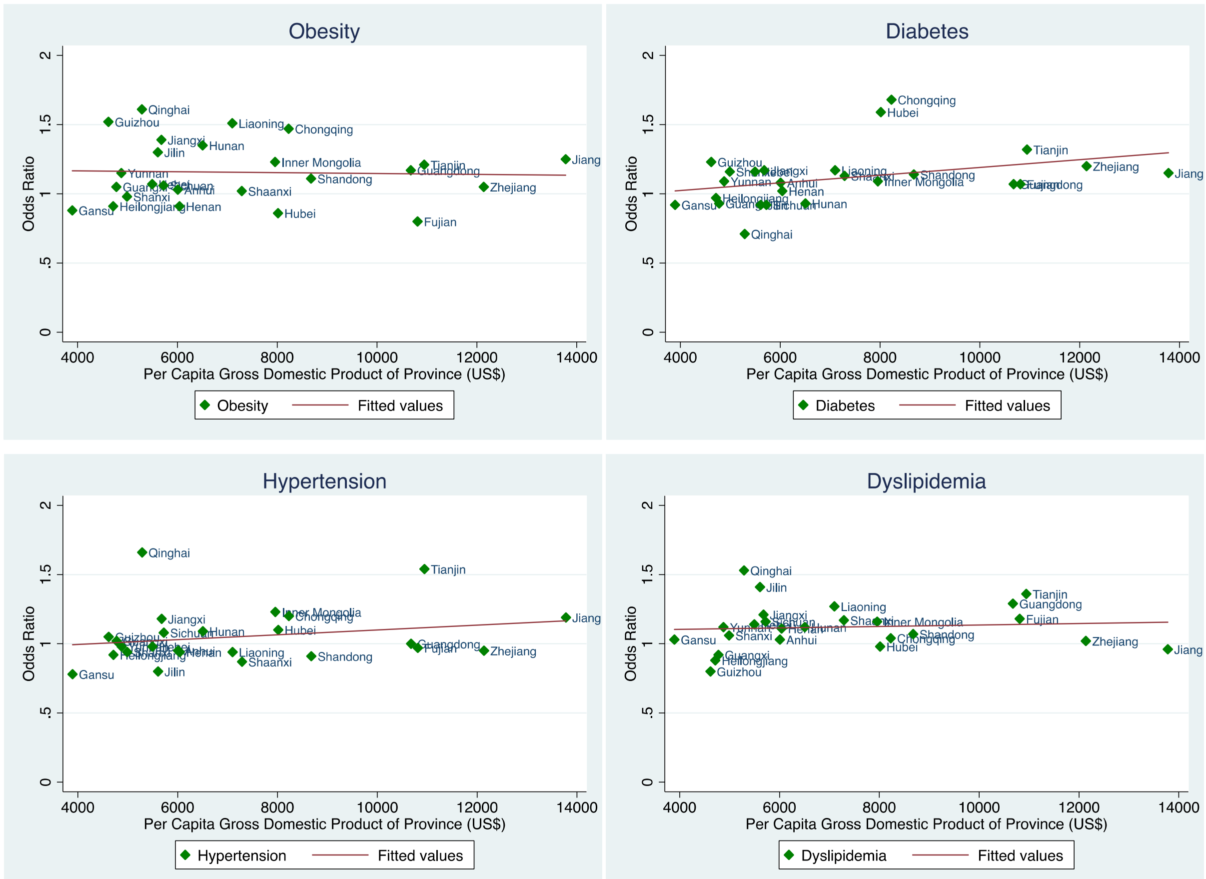

Fig. 1. (*continued*).

Table 3
The association of SES and NCDs and risk factors across different age groups.

Variables	Age groups	AOR	(95%CI)
Smoking	45–54	1.09**	(1.00–1.19)
	55–64	1.06	(0.98–1.15)
	65+	0.98	(0.92–1.05)
Heavy Drinker	45–54	1.08	(0.96–1.20)
	55–64	1.29***	(1.17–1.41)
	65+	1.07	(0.98–1.17)
Physical Inactivity	45–54	0.93	(0.81–1.08)
	55–64	0.83***	(0.73–0.93)
	65+	0.78***	(0.70–0.87)
Overweight	45–54	1.06	(0.98–1.14)
	55–64	1.04	(0.97–1.12)
	65+	1.16***	(1.07–1.25)
Obesity	45–54	1.11**	(1.02–1.22)
	55–64	1.02	(0.93–1.12)
	65+	1.21***	(1.07–1.36)
Diabetes	45–54	1.14**	(1.02–1.28)
	55–64	1.11**	(1.02–1.21)
	65+	1.03	(0.95–1.12)
Hypertension	45–54	0.99	(0.92–1.07)
	55–64	1.04	(0.97–1.11)
	65+	0.98	(0.92–1.05)
Dyslipidemia	45–54	1.09**	(1.00–1.19)
	55–64	1.09**	(1.01–1.18)
	65+	1.10**	(1.02–1.18)

***$p < 0.01$, **$p < 0.05$.
AOR = Adjusted odds ratios.
Adjusted for gender, age, education, marital status, residency, occupation, and provinces.
Model with robust standard errors clustered at the community level.
Each cell (AOR and 95% CI) represents result from separate regression models.

increased suggesting the most marked evidence of reversal among risk factors in comparison to established disease and this is consistent with the logic that patterns of established disease would reflect earlier changes in patterns of risk factors. The persistence of an upward trend in relation to overweight, diabetes, hypertension, and dyslipidemia suggests that such changes in the trends in risk factors have not yet emerged in established diseases.

Further analyses of rural or urban residence and comparison of the age groups available in the CHARLS data sets suggest mixed patterns that are difficult to interpret in relation to the reversal hypothesis and we discuss how confounding factors may be constraining our ability to detect clear patterns in the following section.

We found some evidence to support the argument that the reversal of the socio-economic gradient of NCDs from rich to poor is beginning to occur in China. Our analysis of the patterns of risk factors across the spectrum of poorer to richer provinces and across socio-economic groups suggests that risky behaviours are beginning to transfer from richer to poorer populations as provincial GDP increases, but the implications of those shifts for the emergence of established disease are not fully realised. We acknowledge that this evidence is quite weak and inconclusive, and that further monitoring of trends as updated data sets are published will be needed to clarify whether the suggested trend emerges more strongly or should ultimately be judged an artefact.

In relation to urban-rural comparison, there are confounding factors that may have obscured our ability to detect patterns. First, lifestyles of Chinese rural residents have become increasingly similar to those of urban residents with rapid social and economic development. For example, physical activity has been gradually replaced by machine operation in rural areas (Tian et al., 2014). Unhealthy diets and decreased physical activity may increase the epidemic of overweight/-obesity and physical inactivity among rural residents. Another explanation is that more educated rural young adults migrate to cities, and that there is lower health awareness and behaviors among rural residents (Ding et al., 2017; Liu et al., 2020; Wang et al., 2015).

The evidence of SES gradients in NCDs and risk factors in the analysis comparing age groups was mixed. One possible explanation of our findings is that social mobility has obscured evidence of a reversal of the socio-economic gradient. We also need to consider more complex processes in the emergence of NCDs. We know that early-life disadvantages such as low family and parental SES, or bad health in infancy and childhood (Ding et al., 2021; McEniry, 2013; Ogunsina et al., 2018; Zhang et al., 2021), have significant impacts on health in adulthood and old age. Participants in our study were aged from 45 to 115, with birth years spanning from 1900 to 1970, and 68% of them were 45–64 years old (born between 1951 and 1970). The majority of our participants experienced extreme events in the history of China (e.g., the Great Leap Forward, 1956–1966; the Great Famine, 1959–1962; and the Proletarian Cultural Revolution, 1966 to 1977) during their infancy, childhood, or adulthood, characterized by famine and food shortages, high prevalence of infectious diseases and stresses associated with losses of parents and other family members on which they may have been dependent. Evidence that being exposed to famine as an infant and during gestation increases the risk of NCDs like hypertension in adulthood, and that being exposed to a nutrient-rich environment after infancy may increase the risk even more (Wang et al., 2016) exemplifies how a simple analysis of intergenerational disease experience is confounded by such historical considerations. The socio-economic incidence of such historical disadvantage is not to our knowledge recorded. In line with this perspective, Chang (2018) found that undernutrition at a young age during the Great Famine period in China increased the risks of overweight or obesity in women, and the risk of abdominal obesity both in men and women in their later life (Chang et al., 2018). Wang et al. (2017) also found that Chinese people, who were exposed to the Great Famine during their early life, are more likely to develop diabetes as adults (Wang et al., 2017).

4.1. Strengths and limitations

To our knowledge, this is the first study that assesses the reversal hypothesis of NCDs and risk factor burdens among middle-aged and older populations using a population-based longitudinal dataset in a Chinese setting. However, there are several constraints that should be considered. Firstly, self-reported information on smoking status, alcohol consumption, physical activity and individual SES might be subject to recall or social conformity bias. Secondly, some provinces (e.g., Tibet and Ningxia) were not included in the CHARLS, we also excluded several provinces due to small sample size, limiting our capacity to estimate the prevalence of outcomes across all provinces in China. Thirdly, the cross-sectional design of this study limits our ability to detect a causal relationship between SES and NCDs and risk factors. Finally, CHARLS focuses on the population aged 45 and older, while the younger generations who were born and grew up during the period when the economy of China was more developed are missing. This limited our ability to investigate the dynamic trend of the relationship between SES and NCDs and risk factors over time. Long-term panel data may enable observation of the SES-NCDs gradient over time and further investigate the "reversal hypothesis" phenomenon.

5. Conclusion

We conclude that if reversal is occurring in China, it is not yet at an advanced stage. NCDs and risk factors persist as concentrated among richer population groups. We consider that some evidence of early stages of reversal may be detectable, to the extent that richer provinces have lower concentrations of NCDs and risk factors in richer population groups and that this phenomenon appears more marked with respect to risk factors than established diseases as might be expected. It will be important to continue to monitor these potential trends. The process of the emergence of NCDs has likely been complicated by extreme historical events that the surviving older Chinese population experienced when younger. This may be obscuring the detection of patterns that are premised on behavioural risk factors alone.

Ethical approval

This research analyses a secondary dataset. CHARLS that is available for public use. The original CHARLS was reviewed and approved by the Biomedical Ethics Review Committee of Peking University, and all participants signed written informed consent at the time of participation. The ethical approval number was IRB00001052-11015.

Contributors

XMZ and BM conceived and designed the study. XMZ compiled the data and did the analyses, with input from BM and TXP. XMZ wrote the first draft of the paper. BM and TXP provided critical input in revising the manuscript. XMZ, BM, and TXP proofread all sections. All authors contributed to writing, reviewing, and editing multiple versions of the manuscript.

Data sharing

The datasets generated and analyzed during the current study are available in the CHARLS website, available in http://charls.pku.edu.cn/en.

Declaration of competing interest

We declare no competing interests.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2022.101335.

References

Aitsi-Selmi, A., Chandola, T., Friel, S., Nouraei, R., Shipley, M. J., & Marmot, M. G. (2012). Interaction between education and household wealth on the risk of obesity in women in Egypt. *PLoS One, 7*(6), Article e39507.

Allen, L., Williams, J., Townsend, N., Mikkelsen, B., Roberts, N., Foster, C., et al. (2017). Socioeconomic status and non-communicable disease behavioural risk factors in low-income and lower-middle-income countries: A systematic review. *Lancet Global Health, 5*(3), e277–e289.

Bhimma, R., Naicker, E., Gounden, V., Nandlal, L., Connolly, C., & Hariparshad, S. (2018). Prevalence of primary hypertension and risk factors in grade XII learners in KwaZulu-natal, South Africa. *International Journal of Hypertension, 2018*, Article 3848591.

Chang, X., Song, P., Wang, M., & An, L. (2018). The risks of overweight, obesity and abdominal obesity in middle age after exposure to famine in early life: Evidence from the China's 1959-1961 famine. *The Journal of Nutrition, Health & Aging, 22*(10), 1198–1204.

Chinese Nutrition Society. (2016). *Chinese dietary guidelines*. Available: http://dg.cnsoc.org/article/04/8a2389fd5520b4f30155be01beb82724.html. (Accessed 14 October 2021).

Chobanian, A. V., Bakris, G. L., Black, H. R., Cushman, W. C., Green, L. A., Izzo, J. L., Jr., et al. (2003). Seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure. *Hypertension, 42*(6), 1206–1252.

Corsi, D. J., & Subramanian, S. V. (2012). Association between socioeconomic status and self-reported diabetes in India: A cross-sectional multilevel analysis. *BMJ Open, 2*(4).

Corsi, D. J., & Subramanian, S. V. (2019). Socioeconomic gradients and distribution of diabetes, hypertension, and obesity in India. *JAMA Network Open, 2*(4), Article e190411.

Dagadu, H. E. (2019). Socioeconomic and gender health disparities in diabetes: The lower middle income case of Ghana. *Sociological Inquiry, 89*(3), 453–481.

Deaton, A. (1997). *The analysis of household surveys: A microeconometric approach to development policy*. World Bank Publications. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://documents1.worldbank.org/curated/en/593871468777303124/pdf/17140-PUB-revised-PUBLIC-9781464813313-Updated.pdf . (Accessed 21 October 2022).

Ding, X., Billari, F. C., & Gietel-Basten, S. (2017). Health of midlife and older adults in China: The role of regional economic development, inequality, and institutional setting. *International Journal of Public Health, 62*(8), 857–867.

Ding, S., Chen, J., Dong, B., & Hu, J. (2021). Association between parental socioeconomic status and offspring overweight/obesity from the China family panel studies: A longitudinal survey. *BMJ Open, 11*(4), Article e045433.

Ding, L., Liang, Y., Tan, E. C. K., Hu, Y., Zhang, C., Liu, Y., et al. (2020). Smoking, heavy drinking, physical inactivity, and obesity among middle-aged and older adults in China: Cross-sectional findings from the baseline survey of CHARLS 2011-2012. *BMC Public Health, 20*(1), 1062.

Emamian, M. H., Fateh, M., Hosseinpoor, A. R., Alami, A., & Fotouhi, A. (2017). Obesity and its socioeconomic determinants in Iran. *Economics and Human Biology, 26*, 144–150.

Espírito Santo, L. R., Faria, T. O., Silva, C. S. O., Xavier, L. A., Reis, V. C., Mota, G. A., et al. (2019). Socioeconomic status and education level are associated with dyslipidemia in adults not taking lipid-lowering medication: A population-based study. *International health, 14*(4), 346–353.

Galobardes, B., Shaw, M., Lawlor, D. A., Lynch, J. W., Smith, G. D. J. J. E., & Health, C. (2006). *Indicators of socioeconomic position (part 1)* (Vol. 60, pp. 7–12), 1.

Golestani, M., Sadeghi-Bazargani, H., Saadati, M., Farahbakhsh, M., & Dalal, K. (2021). Lifestyle risk factor assessment through WHO STEP approach in tabriz, Iran. ClinicoEconomics and outcomes research. *CEOR, 13*, 487–492.

Goryakin, Y., & Suhrcke, M. (2014). Economic development, urbanization, technological change and overweight: What do we learn from 244 demographic and health surveys? *Economics and Human Biology, 14*, 109–127.

Gu, J., & Ming, X. (2020). Perceived social discrimination, socioeconomic status, and alcohol consumption among Chinese adults: A nationally representative study. *International Journal of Environmental Research and Public Health, 17*(17).

He, W., James, S. A., Merli, M. G., & Zheng, H. (2014). An increasing socioeconomic gap in childhood overweight and obesity in China. *American Journal of Public Health, 104*(1), e14–e22.

Hosseinpoor, A. R., Bergen, N., Mendis, S., Harper, S., Verdes, E., Kunst, A., et al. (2012). Socioeconomic inequality in the prevalence of noncommunicable diseases in low- and middle-income countries: Results from the World health survey. *BMC Public Health, 12*, 474.

Hu, F., Xu, L., Zhou, J., Zhang, J., Gao, Z., & Hong, Z. (2020). Association between overweight, obesity and the prevalence of multimorbidity among the elderly: Evidence from a cross-sectional analysis in Shandong, China. *International Journal of Environmental Research and Public Health, 17*(22).

Im, P. K., Millwood, I. Y., Chen, Y., Guo, Y., Du, H., Kartsonaki, C., et al. (2020). Problem drinking, wellbeing and mortality risk in Chinese men: Findings from the China kadoorie biobank. *Addiction, 115*(5), 850–862.

Institute for Health Metrics and Evaluation. Global burden of disease compare. Available: https://vizhub.healthdata.org/gbd-results/. (Accessed 21 August 2022).

Institute for Health Metrics and Evaluation. Global burden of disease compare. Available: https://vizhub.healthdata.org/gbd-compare/. (Accessed 20 July 2021).

IPAQ Research Committee. Guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ)-short and long forms. Available: https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnx0aGVpcGFxfGd4OjE0NDgxMDk3NDU1YWRlZTM. (Accessed 12 April 2021).

Jung, L., De Neve, J. W., Chen, S., Manne-Goehler, J., Jaacks, L. M., Corsi, D. J., et al. (2019). The interaction between district-level development and individual-level socioeconomic gradients of cardiovascular disease risk factors in India: A cross-sectional study of 2.4 million adults. *Social Science & Medicine, 239*, Article 112514.

Jurj, A. L., Wen, W., Gao, Y. T., Matthews, C. E., Yang, G., Li, H. L., et al. (2007). Patterns and correlates of physical activity: A cross-sectional study in urban Chinese women. *BMC Public Health, 7*, 213.

Kiadaliri, A. A. (2013). Demographic and socioeconomic differences in fruit and vegetables consumption, 2007-2009: A province-level study in Iran. *International Journal of Preventive Medicine, 4*(7), 831–840.

Kinge, J. M., Strand, B. H., Vollset, S. E., & Skirbekk, V. (2015). Educational inequalities in obesity and gross domestic product: Evidence from 70 countries. *Journal of Epidemiology & Community Health, 69*(12), 1141–1146.

Lai, S., Shen, C., Yang, X., Zhang, X., Xu, Y., Li, Q., et al. (2019). Socioeconomic inequalities in the prevalence of chronic diseases and preventive care among adults aged 45 and older in Shaanxi Province, China. *BMC Public Health, 19*(1), 1460.

Li, X., Cai, L., Cui, W. L., Wang, X. M., Li, H. F., He, J. H., et al. (2020a). Association of socioeconomic and lifestyle factors with chronic non-communicable diseases and multimorbidity among the elderly in rural southwest China. *Journal of Public Health, 42*(2), 239–246.

Li, X., Song, J., Lin, T., Dixon, J., Zhang, G., & Ye, H. J. E. H. (2016). *Urbanization and health in China, thinking at the national, local and individual levels* (Vol. 15, pp. 113–123), 1.

Liu, L., Qian, X., Chen, Z., & He, T. (2020). Health literacy and its effect on chronic disease prevention: Evidence from China's data. *BMC Public Health, 20*(1), 690.

Li, Y., Zeng, X., Liu, J., Liu, Y., Liu, S., Yin, P., et al. (2017). Can China achieve a one-third reduction in premature mortality from non-communicable diseases by 2030? *BMC Medicine, 15*(1), 132.

Li, Y., Zhang, M., Jiang, Y., & Wu, F. (2012). Co-Variations and clustering of chronic disease behavioral risk factors in China: China chronic disease and risk factor surveillance, 2007. *PLoS One, 7*(3), Article e33881.

Li, X., Zhang, W., Zhang, W., Tao, K., Ni, W., Wang, K., et al. (2020b). Level of physical activity among middle-aged and older Chinese people: Evidence from the China health and retirement longitudinal study. *BMC Public Health, 20*(1), 1682.

Maimela, E., Alberts, M., Modjadji, S. E., Choma, S. S., Dikotope, S. A., Ntuli, T. S., et al. (2016). The prevalence and determinants of chronic non-communicable disease risk factors amongst adults in the dikgale health demographic and surveillance system (HDSS) site, limpopo province of South Africa. *PLoS One, 11*(2), Article e0147926.

McEniry, M. (2013). Early-life conditions and older adult health in low- and middle-income countries: A review. *Journal of developmental origins of health and disease, 4*(1), 10–29.

Miao, J., & Wu, X. (2016). Urbanization, socioeconomic status and health disparity in China. *Health & Place, 42*, 87–95.

Miller, V., Mente, A., Dehghan, M., Rangarajan, S., Zhang, X., Swaminathan, S., et al. (2017). Fruit, vegetable, and legume intake, and cardiovascular disease and deaths in 18 countries (PURE): A prospective cohort study. *Lancet (London, England), 390*(10107), 2037–2049.

Monteiro, C. A., Conde, W. L., & Popkin, B. M. (2001). Independent effects of income and education on the risk of obesity in the Brazilian adult population. *Journal of Nutrition, 131*(3), 881s-6s.

Moradi, G., Majdzadeh, R., Mohammad, K., Malekafzali, H., Jafari, S., & Holakouie-Naieni, K. (2016). Is the status of diabetes socioeconomic inequality changing in kurdistan province, west of Iran? A comparison of two surveys. *Medical Journal of the Islamic Republic of Iran, 30*, 375.

Moradi, G., Mohammad, K., Majdzadeh, R., Ardakani, H. M., & Naieni, K. H. (2013). Socioeconomic inequality of non-communicable risk factors among people living in kurdistan province, Islamic Republic of Iran. *International Journal of Preventive Medicine, 4*(6), 671–683.

Nam, G. E., Cho, K. H., Park, Y. G., Han, K. D., Choi, Y. S., Kim, S. M., et al. (2013). Socioeconomic status and dyslipidemia in Korean adults: The 2008-2010 korea national health and nutrition examination survey. *Preventive Medicine, 57*(4), 304–309.

National Bureau of Statistics of China. Annual economic data-GDP growth (percentage). Available: https://data.stats.gov.cn/easyquery.htm?cn=C01. (Accessed 18 April 2022).

National Bureau of Statistics of China. Annual economic data by province-Per capita GDP. Available: https://data.stats.gov.cn/easyquery.htm?cn=E0103. (Accessed 21 May 2021).

National health and family planning commission of the People's Republic of China. Criteria of weight for adults. Available: http://www.chinanutri.cn/fgbz/fgbzhybz/201501/P020170721497677913633.pdf. (Accessed 11 October 2021).

Nikparvar, M., Khaladeh, M., Yousefi, H., Vahidi Farashah, M., Moayedi, B., & Kheirandish, M. (2021). Dyslipidemia and its associated factors in southern Iranian women, Bandare-Kong Cohort study, a cross-sectional survey. *Scientific Reports, 11*(1), 9125.

Ogunsina, K., Dibaba, D. T., & Akinyemiju, T. (2018). Association between life-course socio-economic status and prevalence of cardio-metabolic risk ractors in five middle-income countries. *J Glob Health, 8*(2), Article 020405.

Pampel, F. C., Denney, J. T., & Krueger, P. M. (2012). Obesity, SES, and economic development: A test of the reversal hypothesis. *Social Science & Medicine, 74*(7), 1073–1081.

Pan, T., Mercer, S. W., Zhao, Y., McPake, B., Desloge, A., Atun, R., et al. (2021). The association between mental-physical multimorbidity and disability, work productivity, and social participation in China: A panel data analysis. *BMC Public Health, 21*(1), 376.

Peng, C.-Y. J., Lee, K. L., & Ingersoll, G. M. (2002). An introduction to logistic regression analysis and reporting. *The Journal of Educational Research, 96*(1), 3–14.

Porhcisaliyan, V. D., Wang, Y., Tan, N. C., & Jafar, T. H. (2021). Socioeconomic status and ethnic variation associated with type 2 diabetes mellitus in patients with uncontrolled hypertension in Singapore. *BMJ open diabetes research & care, 9*(1).

Siddiquee, T., Bhowmik, B., Da Vale Moreira, N. C., Mujumder, A., Mahtab, H., Khan, A. K., et al. (2015). Prevalence of obesity in a rural Asian Indian (Bangladeshi) population and its determinants. *BMC Public Health, 15*, 860.

Subramanian, S. V., Corsi, D. J., Subramanyam, M. A., & Smith, G. D. (2013). Jumping the gun: The problematic discourse on socioeconomic status and cardiovascular health in India. *International Journal of Epidemiology, 42*(5), 1410–1426.

Subramanian, S., Perkins, J. M., Özaltin, E., & Smith Gjtajocn, D. (2011). *Weight of nations: A socioeconomic analysis of women in low-to middle-income countries* (Vol. 93, pp. 413–421), 2.

Thienemann, F., Ntusi, N. A. B., Battegay, E., Mueller, B. U., & Cheetham, M. (2020). Multimorbidity and cardiovascular disease: A perspective on low- and middle-income countries. *Cardiovascular Diagnosis and Therapy, 10*(2), 376–385.

Tian, X., Zhao, G., Li, Y., Wang, L., & Shi, Y. (2014). Overweight and obesity difference of Chinese population between different urbanization levels. *The Journal of Rural Health*

: Official Journal of the American Rural Health Association and the National Rural Health Care Association, 30(1), 101–112.
Veisani, Y., Jenabi, E., Nematollahi, S., Delpisheh, A., & Khazaei, S. (2019). The role of socio-economic inequality in the prevalence of hypertension in adults. *Journal of Cardiovascular and Thoracic Research, 11*(2), 116–120.
Wang, R., Bishwajit, G., Zhou, Y., Wu, X., Feng, D., Tang, S., et al. (2019a). Intensity, frequency, duration, and volume of physical activity and its association with risk of depression in middle- and older-aged Chinese: Evidence from the China Health and Retirement Longitudinal Study, 2015. *PLoS One, 14*(8), Article e0221430.
Wang, N., Cheng, J., Han, B., Li, Q., Chen, Y., Xia, F., et al. (2017). Exposure to severe famine in the prenatal or postnatal period and the development of diabetes in adulthood: An observational study. *Diabetologia, 60*(2), 262–269.
Wang, S., Kou, C., Liu, Y., Li, B., Tao, Y., D'Arcy, C., et al. (2015). Rural-urban differences in the prevalence of chronic disease in northeast China. *Asia-Pacific Journal of Public Health, 27*(4), 394–406.
Wang, Z., Li, C., Yang, Z., Zou, Z., & Ma, J. (2016). Infant exposure to Chinese famine increased the risk of hypertension in adulthood: Results from the China health and retirement longitudinal study. *BMC Public Health, 16*, 435.
Wang, Y., & Wang, J. (2020). Modelling and prediction of global non-communicable diseases. *BMC Public Health, 20*(1), 822.
Wang, X., Zhang, T., Wu, J., Yin, S., Nan, X., Du, M., et al. (2019b). The association between socioeconomic status, smoking, and chronic disease in inner Mongolia in northern China. *International Journal of Environmental Research and Public Health, 16*(2).
Washington: International Monetary Fund. National currency per U.S. dollar, end of period. Principal global indicators (PGI) database. Available: https://www.principalglobalindicators.org/regular.aspx?key=60942001. (Accessed 17 June 2021).
World Health Organization. Noncommunicable diseases. Available: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases. (Accessed 12 July 2021).
Wu, X., & Wang, Z. (2019). Role of socioeconomic status in hypertension among Chinese middle-aged and elderly individuals. *International Journal of Hypertension, 2019*, Article 6956023.
Xiao, Y., Zhao, N., Wang, H., Zhang, J., He, Q., Su, D., et al. (2013). Association between socioeconomic status and obesity in a Chinese adult population. *BMC Public Health, 13*, 355.
Yuan, X., Liu, T., Wu, L., Zou, Z. Y., & Li, C. (2015). Validity of self-reported diabetes among middle-aged and older Chinese adults: The China health and retirement longitudinal study. *BMJ Open, 5*(4), Article e006633.
Zeng, X. Y., Li, Y. C., Liu, J. M., Liu, Y. N., Liu, S. W., Qi, J. L., et al. (2017). [Estimation of the impact of risk factors control on non-communicable diseases mortality, life expectancy and the labor force lost in China in 2030]. *Zhonghua yu fang yi xue za zhi [Chinese journal of preventive medicine], 51*(12), 1079–1085.
Zhang, X., Jiang, X., Sha, M., Zhou, Q., Li, W., Guo, Y., et al. (2021). Life-course pathways from childhood socioeconomic status to type 2 diabetes in mid-late Chinese adulthood. *Scientific Reports, 11*(1), Article 13051.
Zhao, Y., Hu, Y., Smith, J. P., Strauss, J., & Yang, G. (2014). Cohort profile: The China health and retirement longitudinal study (CHARLS). *International Journal of Epidemiology, 43*(1), 61–68.
Zhou, M. J. I. S. (2019). *The shifting burden of obesity: Changes in the distribution of obesity in China, 2010–2015* (Vol. 34, pp. 347–367), 3.
Zhou, M. (2021). The shifting income-obesity relationship: Conditioning effects from economic development and globalization. *SSM - population health, 15*, Article 100849.
Zhou, M., Wang, H., Zeng, X., Yin, P., Zhu, J., Chen, W., et al. (2019). Mortality, morbidity, and risk factors in China and its provinces, 1990–2017: A systematic analysis for the global burden of disease study 2017. *Lancet (London, England), 394*(10204), 1145–1158.