The evolution of educational inequalities in cardiovascular function over the life course and across birth cohorts in transitional China

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Abstract:

Background: The study examines the evolution of educational inequalities in cardiovascular function over age and across birth cohorts in China.

Methods: The longitudinal data from the China Health and Nutrition Survey (1991-2011) and the hierarchical growth-curve models are used to track the association between education and levels of systolic/diastolic blood pressure (BP) over age. Analyses were stratified by birth cohort, south/north region, and sex.

Results: Except for the 1931-1940 cohort, the direction of the association between education and BP levels has reversed from positive to negative across age among younger cohorts. The negative effects of education on the intercepts (BP levels at 44.5 years) and slopes of age (rates for BP) are stronger for younger versus older cohorts, and in the south versus the north.

Conclusions: Generally, the educational inequalities in cardiovascular function has emerged across age. And the socioeconomic patterning was strengthened across generations and more pronounced in the south than the north.

Keywords: Cardiovascular health, systolic/diastolic blood pressure, educational attainment, birth cohort, China

Extended abstract

Introduction

Cardiovascular diseases (CVDs) have emerged as the most common cause of mortality in both China and the world (Yang et al., 2013; Zhou et al., 2016; Hay et al., 2017). Blood pressure (BP) level is a critical indicator of cardiovascular function as cardiovascular mortality is positively related with systolic blood pressure (SBP) above 115 mmHg or diastolic blood pressure (DBP) above 75 mmHg (Lewington et al., 2002).

The socioeconomic status (SES) has been established as a major determinant of health (Marmot et al., 1991; Chetty et al., 2016). Education is the basic component of SES as it may determine occupation and income (Adler & Newman, 2003; Leng et al., 2015). Prior studies have confirmed that cardiovascular risks and outcomes disproportionately impact the less educated in developed countries (Chow et al., 2013; Mestral & Stringhini, 2017).

However, the association between education and CVDs remains unclear in transitional societies including China (Mestral & Stringhini, 2017; Allen et al., 2017). One explanation for inconsistent findings is that the majority of previous studies used a cross-sectional design (Yu et al., 2000; Allen et al., 2017) and may obscure the dynamics and complexity of the relationship. China has undergone sociohistorical changes after the implementation of economic reform in the late 1970s (Chen et al., 2010), which may differentiate the process of social stratification in cardiovascular function across generations. Understanding the evolution of social differentiation in cardiovascular health over the life course and across generations is critical to revealing the impact of social changes on the socioeconomic distribution of cardiovascular risk factors and an important step towards implementing social interventions to reduce avoidable gaps in population health.

The study has examined the evolution of educational inequalities in cardiovascular function over the life course and across birth cohorts in transitional China. The levels of blood pressure (BP), having a continuous association with cardiovascular mortality, is an important biomarker of cardiovascular function. Understanding the dynamics of social differentiation in BP trajectories is an important step towards implementing social interventions to reduce avoidable inequalities in population health.

Data

I used the longitudinal data from the China Health and Nutrition Survey that spans 20 years and hierarchical growth-curve models to assess the relationship between educational attainment and systolic/diastolic blood pressure (SBP/DBP) trajectories among individuals born in 1931-1980 (17,737 respondents, yielding 62,098 observations). Our analyses were stratified by birth cohort, south/north region and sex.

Every respondent had at least five minutes of rest before BP measurement and waited at least 1 minute between BP readings. The average of the three readings of SBP and DBP were the dependent variables. I classified respondents into three categories according to their highest attainment of education: (1) primary education or below, (2) lower secondary education, and (3) upper secondary education or above. The group with the primary education or below was the reference group.

Using birth years of respondents, I built 10-year birth cohorts except for the 1951-1955 cohort, the 1956-1961 cohort, and the 1962-1970 cohort due to the potential effect of early-life exposure to the Great Famine on their long-term cardiovascular function.

The nine provinces surveyed were categorized into the south and north regions according to the Huai River-Qin Mountains Line. The south region includes Jiangsu, Guangxi, Guizhou, Hunan, and Hubei, and the north region includes Jilin, Liaoning, Shandong, and Henan. Details about the variables included in the statistical analyses were reported in Table 1.

Table 1 Descriptive statistics of all variables included in the analyses (N=62908).

Characteristics	Whole	South	North	P
N	62908	37721	25187	
Systolic blood pressure (mmHg), mean (S.D.)	119.06 (18.03)	117.04 (18.03)	122.09 (17.61)	<0.001
Diastolic blood pressure (mmHg), mean (S.D.)	77.43 (11.32)	75.73 (11.13)	79.97 (11.14)	<0.001
Age (years), mean (S.D.)	44.56 (14.62)	44.23 (14.99)	45.05 (14.05)	<0.001
Cohort, % (S.D.)				
1931-1940	12.32 (0.33)	12.97 (0.34)	11.35 (0.32)	<0.001
1941-1950	18.98 (0.39)	19.56 (0.40)	18.12 (0.39)	<0.001
1951-1955	14.11 (0.35)	14.16 (0.35)	14.04 (0.35)	0.682
1956-1961	13.45 (0.34)	12.60 (0.33)	14.73 (0.35)	<0.001

1962-1970	23.55 (0.42)	22.46 (0.42)	25.18 (0.43)	<0.001
1971-1980	17.58 (0.42)	18.25 (0.39)	16.58 (0.37)	<0.001
Male, % (S.D.)	47.72 (0.50)	48.09 (0.50)	47.15 (0.50)	0.021
Married, % (S.D.)	82.49 (0.38)	80.22 (0.40)	85.90 (0.35)	<0.001
Household income per capita (RMB), mean (S.D.)	7541.39 (10846.39)	7136.62 (10265.99)	8147.60 (11635.62)	<0.001
Education attainment, % (S.D.)				
Illiterate or primary school	45.80 (0.50)	48.20 (0.50)	42.22 (0.49)	<0.001
Junior high school	32.42 (0.47)	31.67 (0.47)	33.55 (0.47)	<0.001
High school or above	21.78 (0.41)	20.14 (0.40)	24.23 (0.43)	<0.001
Urban residents, % (S.D.)	32.84 (0.47)	33.21 (0.47)	32.27 (0.47)	0.014
Overweight (body mass index ≥25 kg/m^2, % (S.D.)	23.20 (0.42)	17.59 (0.38)	31.60 (0.46)	<0.001
Current smoker, % (S.D.)	29.65 (0.46)	29.67 (0.46)	29.62 (0.46)	0.894
Current drinker, % (S.D.)	34.23 (0.47)	33.74 (0.47)	35.00 (0.48)	0.001
Dead, % (S.D.)	3.83 (0.19)	4.44 (0.21)	2.93 (0.17)	0.001
Response, % (S.D.)	75.10 (0.43)	75.62 (0.43)	74.32 (0.44)	<0.001

Methods

The hierarchical growth-curve model was used to examine the educational differentials in the longitudinal trajectories of BP. The inclusion of linear, quadratic and interaction terms in the models was determined by the model fit.

In the level-1 model, SBP or DBP was regressed on age and age square for each respondent.

$$y_{ti} = \beta_{0i} + \beta_{1i}(Age_{ti} - \overline{Age}) + \beta_{2i}(Age_{ti} - \overline{Age})^2 + e_{ti}$$

In the level-2 model for the intercept, the intercept was further modelled as a function of individual-level attributes.

1) The level-2 model for the intercept:

$$\beta_{0i} = \gamma_{00} + \gamma_{01}Edu_i + \gamma_{02}Cohort_i + \gamma_{03}(Cohort_i)^2 + \gamma_{04}Region_i + \gamma_{05}Sex_i$$

$$+\gamma_{06}Cohort_i \cdot Edu_i + \gamma_{07}Cohort_i \cdot Region_i + \gamma_{08}Cohort_i \cdot Sex_i$$

$$+\gamma_{09}Edu_i \cdot Region_i + \gamma_{10}Edu_i \cdot Sex_i$$

$$+\gamma_{11}Cohort_i \cdot Edu_i \cdot Region_i + \gamma_{12}Cohort_i \cdot Edu_i \cdot Sex_i$$

$$+\mu_{0i} + \mu_{0prov}$$

In the level-2 model, the random slope of age was also impacted by education, cohort, region, and sex.

1) The level-2 model for the slope of age:

$$\beta_{1i} = \gamma_{10} + \gamma_{11}Cohort_i + \gamma_{12}Edu_i + \gamma_{13}Region_i + \gamma_{14}Sex_i$$

$$+\gamma_{15}Cohort_i \cdot Edu_i + \gamma_{16}Cohort_i \cdot Region_i + \gamma_{17}Cohort_i \cdot Sex_i$$

$$+\gamma_{18}Edu_i \cdot Region_i + \gamma_{19}Edu_i \cdot Sex_i$$

$$+\mu_{1i}+\mu_{1prov}$$

Time-varying control variables were added in the level-1 model, and time-constant control variables were included in the level-2 model. Analyses were performed using the NLME package in R (version 3.3.2).

Results

Table 2 reports the results from the hierarchical growth-curve models of SBP and DBP. The SBP/DBP increased across age. Men and northern residents had higher estimated levels of BP at the mean age of the sample (44.5 years).

Among the female belong to the 1931-1940 cohort in the south region (the reference group), the high level of education (at least upper-secondary education) had a positive effect on SBP/DBP levels at the mean age (the intercept) but the effect was not statistically significant (SBP: 1.45, 95% CI: -0.78, 3.68; DBP: 0.42, 95% CI: -1.11, 1.95). The negative effect of the interaction between the educational level and north was strong (SBP: -5.15, 95% CI: -7.72, -2.58; DBP: -2.39, 95% CI: -4.13, -0.65), suggesting that persons with at least upper-secondary education had lower BP levels at 44.5 years than those with the least education (primary education or below) among women belong to the oldest cohort in the north.

The negative coefficient of the interaction of the highest level of education with cohort in both the SBP (-1.17, 95% CI: -1.88, -0.46) and DBP (-0.51, 95% CI: -1.00, -0.02) models suggested that the magnitude of the positive relationship between the high education and BP levels at 44.5 years decreased, and the association turned to be negative in younger cohorts since the 1956-1961 cohort among women in the south region. The coefficient of the interaction between the highest level of education, cohort, and north was positive (SBP: 1.51, 95% CI: 0.67, 2.35; DBP: 0.66, 95% CI: 0.09, 1.23) and its absolute value was higher than the interaction of the high education with cohort, which indicated that the education's negative effect on BP levels at the mean age in the north region decreased across cohorts.

Table 2 Hierarchical growth-curve models of systolic/diastolic blood pressure for Chinese born in 1931-1980, China Health and Nutrition Survey (1991-2011).

	Systolic blood pressure Coefficient (S.E.)	Diastolic blood pressure Coefficient (S.E.)
Intercept model		
Intercept	106.81 (1.02)***	71.84 (0.69)***
Cohort	2.90 (0.48)***	0.76 (0.32)*
Cohort square	-0.10 (0.08)***	0.09 (0.06)
North	9.20 (1.31)***	5.44 (0.88)***
Male	0.64 (0.82)	1.36 (0.56)*
Lower secondary education	1.11 (0.90)	0.70 (0.62)
⩾Upper secondary education	1.45 (1.14)	0.42 (0.78)
Second income quartile	1.10 (0.76)	0.49 (0.52)
Third income quartile	0.89 (0.85)	1.30 (0.59)*
Fourth income quartile	3.14 (1.13)**	1.92 (0.78)*
Urban	2.20 (0.81)**	0.91 (0.55)
Married	-1.06 (0.21)***	-0.70 (0.15)***
Overweight	5.54 (0.16)***	3.86 (0.11)***
Smoking	0.49 (0.18)**	-0.03 (0.12)
Alcohol drinking	0.51 (0.15)***	0.37 (0.10)***
Dead	2.33 (0.45)***	1.20 (0.30)***
Response	-0.40 (0.17)*	-0.44 (0.12)***
Lower secondary×Sex	2.25 (1.06)*	1.24 (0.73)
⩾Upper secondary×Sex	1.47 (1.31)	1.49 (0.89)
Second income quartile×Sex	0.58 (0.95)	0.51 (0.66)
Third income quartile×Sex	2.35 (1.05)*	0.55 (0.73)
Fourth income quartile×Sex	1.07 (1.38)	0.82 (0.95)
Urban×Sex	0.02 (1.02)	-0.37 (0.68)
Lower secondary×North	-3.02 (1.08)**	-1.78 (0.74)*
⩾Upper secondary×North	-5.15 (1.31)***	-2.39 (0.89)**
Second income quartile×North	-1.34 (0.99)	-0.44 (0.69)
Third income quartile×North	-1.37 (1.10)	-1.54 (0.76)*
Fourth income quartile×North	-0.93 (1.45)	-0.43 (1.00)
Urban×North	-2.22 (1.06)*	-0.49 (0.71)

North×Cohort	-1.50 (0.32)***	-0.57 (0.22)**
Male×Cohort	1.02 (0.31)**	0.57 (0.22)**
Lower secondary×Cohort	-0.62 (0.29)*	-0.33 (0.20)
⩾Upper secondary×Cohort	-1.17 (0.36)**	-0.51 (0.25)*
Second income quartile×Cohort	-0.32 (0.29)	-0.12 (0.20)
Third income quartile×Cohort	-0.08 (0.31)	-0.31 (0.21)
Fourth income quartile×Cohort	-0.76 (0.36)*	-0.46 (0.25)
Urban×Cohort	-0.61 (0.27)*	-0.08 (0.18)
Lower secondary×Cohort×North	0.93 (0.36)**	0.59 (0.25)*
⩾Upper secondary×Cohort×North	1.52 (0.43)***	0.66 (0.29)*
Second income quartile×Cohort×North	0.39 (0.38)	0.18 (0.26)
Third income quartile×Cohort×North	0.28 (0.39)	0.54 (0.27)*
Fourth income quartile×Cohort×North	0.18 (0.47)	0.29 (0.32)
Urban×Cohort×North	0.23 (0.34)	-0.26 (0.24)
Lower secondary×Cohort×Sex	-0.65 (0.35)	-0.35 (0.24)
⩾Upper secondary×Cohort×Sex	-0.05 (0.43)	-0.23 (0.29)
Second income quartile×Cohort×Sex	-0.13 (0.37)	-0.07 (0.26)
Third income quartile×Cohort×Sex	-0.90 (0.38)*	-0.18 (0.26)
Fourth income quartile×Cohort×Sex	-0.38 (0.45)	-0.19 (0.31)
Urban×Cohort×Sex	0.15 (0.33)	0.23 (0.23)
Slope model		
Intercept	0.98 (0.06)***	0.44 (0.04)***
Cohort	-0.05 (0.02)*	-0.01 (0.01)
North	-0.01 (0.06)	-0.05 (0.04)
Male	0.05 (0.06)	0.05 (0.04)
Lower secondary	-0.001 (0.04)	0.01 (0.03)
⩾Upper secondary	0.02 (0.05)	0.01 (0.03)
Second income quartile	-0.05 (0.04)	-0.03 (0.03)
Third income quartile	-0.01 (0.04)	-0.05 (0.03)
Fourth income quartile	-0.12 (0.05)*	-0.11 (0.03)**
Urban	-0.12 (0.04)**	-0.04 (0.02)
North×Cohort	-0.05 (0.02)**	0.01 (0.01)
Male×Cohort	-0.02 (0.02)	-0.005 (0.01)
Lower secondary×Cohort	-0.02 (0.01)**	-0.01 (0.005)**
⩾Upper secondary×Cohort	-0.05 (0.01)***	-0.03 (0.01)***

Second income quartile×Cohort	0.01 (0.01)	0.0002 (0.005)
Third income quartile×Cohort	0.004 (0.01)	0.01 (0.005)
Fourth income quartile×Cohort	0.03 (0.01)**	0.03 (0.01)***
Urban×Cohort	0.02 (0.01)**	0.01 (0.005)*
Lower secondary×North	0.08 (0.04)*	0.07 (0.03)**
⩾Upper secondary×North	0.14 (0.05)**	0.08 (0.03)*
Second income quartile×North	0.02 (0.04)	0.02 (0.03)
Third income quartile×North	0.01 (0.05)	0.07 (0.03)*
Fourth income quartile×North	0.02 (0.06)	0.01 (0.04)
Urban×North	-0.001 (0.04)	-0.04 (0.03)
Lower secondary×Sex	-0.11 (0.04)**	-0.07 (0.02)**
⩾Upper secondary×Sex	-0.02 (0.05)	-0.05 (0.02)
Second income quartile×Sex	-0.01 (0.04)	0.01 (0.03)
Third income quartile×Sex	-0.12 (0.05)**	-0.03 (0.03)
Fourth income quartile×Sex	-0.06 (0.06)	-0.04 (0.04)
Urban×Sex	-0.01 (0.04)	0.01 (0.02)
Age square	0.004 (0.002)*	-0.008 (0.001)***
Age square×Cohort	-0.0001 (0.0002)	0.001 (0.0001)***
Age square×North	-0.01 (0.002)***	0.001(0.001)
Age square×Male	-0.01 (0.002)***	-0.003 (0.001)**

*** P<0.001, ** P<0.01, * P<0.05

In Figure 1 and 2, I reported the educational differentials in BP trajectories for the 1931-1940, 1956-1961, and 1971-1980 cohorts to represent the old, middle, and young cohort, respectively. The coefficient of age-education interaction was positive but nonsignificant (SBP: 0.02, 95% CI: -0.08, 0.12; DBP: 0.01, 95% CI: -0.05, 0.07), suggesting that the growth rates among the highly educated were not significantly different from the low educated in the reference group. As shown in Figure 1 and 2, the gap in BP levels between the low and high educated remained constant across age in the 1931-1940 cohort among women in the south.

But the positive and strong coefficient of the interaction among the high level of education, age, and north (SBP: 0.14, 95% CI: 0.04, 0.24; DBP: 0.08, 95% CI: 0.02, 0.14) suggested that the high educated had experienced a steeper rise in BP with age than those with the least educated for the 1931-1940 cohort of the north. As a result, the BP levels of the highly educated were lower in middle adulthood but higher in late adulthood compared to the least educated in both men and women of this group.

The three-way interaction among the highest level of education, cohort, and age was negative and statistically significant (SBP: 1.52, 95% CI: 0.68, 2.36; DBP: 0.66, 95% CI: 0.09, 1.23), which suggested that the high educated had a lower rate of increase for SBP/DBP relative to the least educated among younger cohorts. Taking women in the south as an example, people with the highest level of education had a lower rate of increase for both SBP (-0.1) and DBP (-0.05) relative to the least educated since the 1951-1955 cohort.

For the middle cohort in the female of the south, as shown in Figure 1 and 2, the highly educated had lower estimated levels of BP than the least educated and the educational gap had widened across age. For the same cohort in both men and women of the north, the highly educated had lower estimated levels of BP than the least educated, but the educational gap had remained constant across age. While for the same cohort in men of the south region, the association between the highest level of education and BP levels was positive in young adulthood but became negative in late adulthood.

The educational differentials in the growth rates for BP had become more pronounced in the two youngest cohorts (the 1962-1970 and 1971-1980 cohorts). For instance, among women in the south region, the low educated experienced a larger increase of 0.15 mmHg in SBP and 0.08 mmHg in DBP per age than the high educated in the 1941-1950 cohort, while the educational gaps in growth rates rose to 0.26 mmHg in SBP and 0.13 mmHg in DBP in the 1971-1980 cohort. Among the 1971-1980 cohort, as shown in Figure 1 and 2, the association between the highest level of education and BP levels had shifted from positive to negative across age.

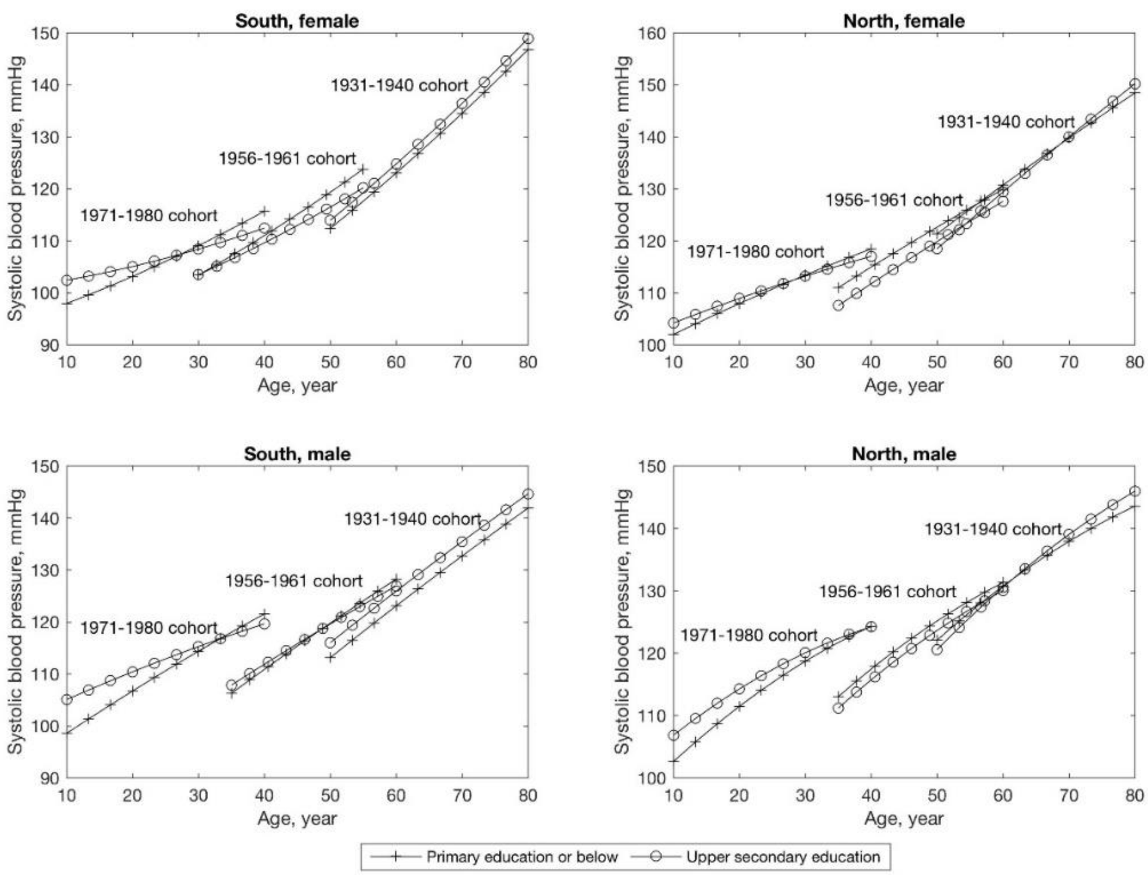

Figure 1 Estimated age-related trajectories of systolic blood pressure by education, birth cohort, south/north region, and sex.

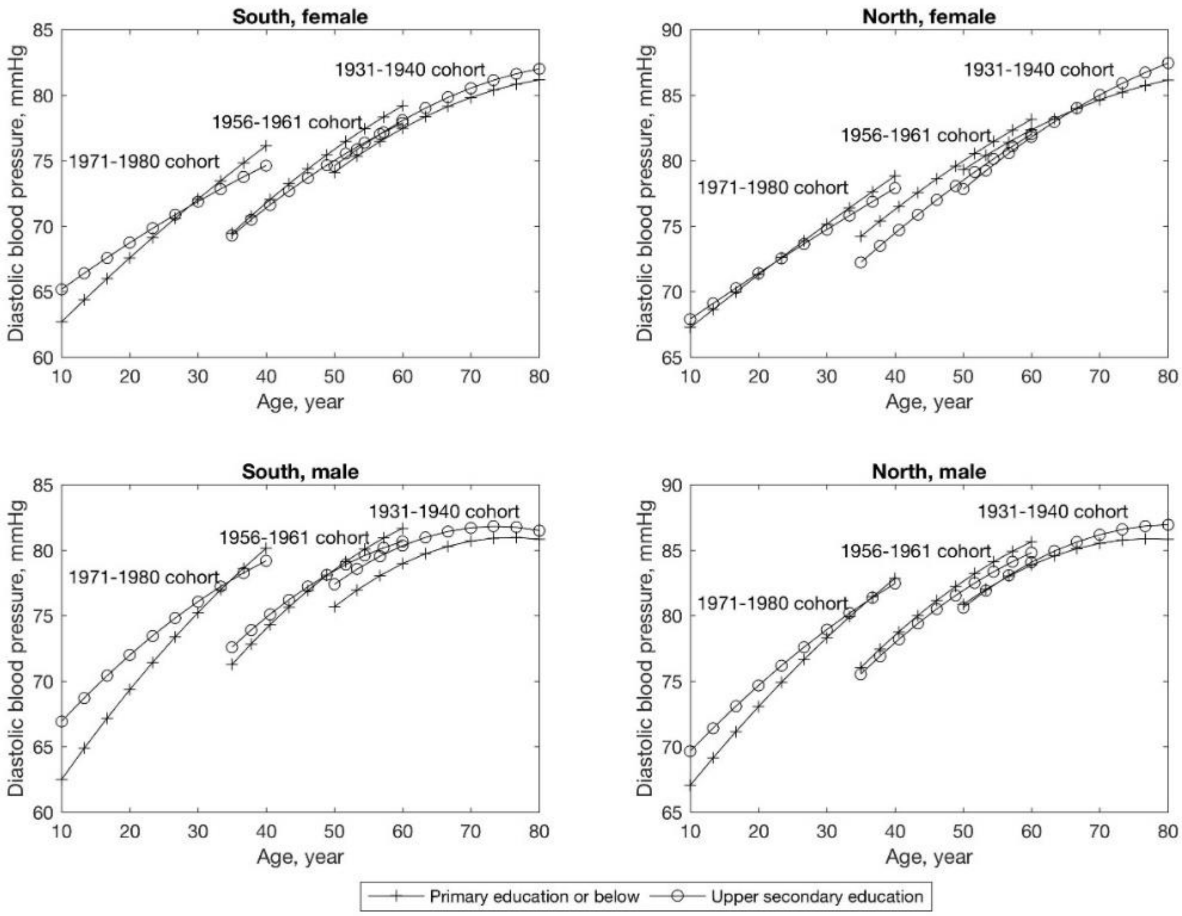

Figure 2 Estimated age-related trajectories of diastolic blood pressure by education, birth cohort, south/north region, and sex.

Discussion and conclusion

Our study provides evidence that the direction of the association between education and BP levels had changed over the life course. And the socioeconomic patterning of BP trajectories was strengthened across successive generations. Moreover, the emerging gap in cardiovascular function over age and across birth cohorts was more apparent in the south relative to the north.

Specifically, the high level of education had reduced the increase rate for BP in younger cohorts but not in the 1931-1940 cohort (the oldest cohort). Among the oldest cohort in the south region, the more educated had higher estimated levels of BP than the least educated over the twenty-year trajectories. While in the oldest cohort of the north region, the more educated had lower estimated levels of BP during middle adulthood relative to the less educated. But the reverse was true in late adulthood as the former experienced a steeper increase in BP levels.

Among younger cohorts particularly in the south region, however, we found that the direction of the association between education and BP levels across age had reversed from positive to negative. One possible explanation is that the effect of education on cardiovascular function may be mediated by the increased awareness of unhealthy eating linked with CVDs and reinforced by the availability and affordability of healthy foods versus less healthy options. Foods rich in fat (e.g., animal foods, edible oil, processed foods), once had been perceived as luxury items and only accessible to the high-income group until the late 1990s (Du et al., 2014; Popkin & Du, 2003), have become more available and affordable due to the industrialization, globalization and urbanization (Drewnowski & Specter, 2004; Haines, 2004; Popkin et al., 2012). However, nutrition-dense foods, like fresh vegetables and fruit, had become less affordable as the urbanisation has increased the prices of natural foods (Stage et al., 2010). Owing to increased awareness about the detrimental effect of unhealthy eating on cardiovascular function, the highly educated, with better financial capacity, were more likely to shift toward healthy dietary patterns compared to the least educated. This may result in socioeconomic inequalities in healthy eating. Evidence shows that the consumption of energy-rich diets including edible oil and fast foods has substantially increased in the poor but increased at a slower rate or even decreased among the rich since the late 1990s (Du et al., 2004; Ng & Popkin, 2008; Xue et al., 2016). However, whether the modernisation had contributed to the socioeconomic inequalities of cardiovascular health by increasing the availability of energy-rich diets and decreasing the relative price of industrial foods versus natural foods needs further investigation.

The diverging trend in BP trajectories between the low and high educated had become more pronounced in the succession of generations. One possible explanation is that the educational composition has upgraded across cohorts attributable to educational expansion efforts (Treiman, 2013; Piotrowski & Tong, 2016). According to the “crowding-out hypothesis” (Gesthuizen & Wolber, 2010), people with the least education are at a higher risk of getting pushed out of the labor market as the better educated may carry out the jobs that once occupied by the least educated due to the intensified competition in the context of education expansion (Delaruelle et al., 2015). The widening of income inequalities between the highly educated and the least educated may be related with the rising inequalities in cardiovascular health across generations.

Another explanation is that the relationship between education and cardiovascular function may be mediated by the acceptability of new fashions (e.g., eating away from home, snacking). Compared with older cohorts, younger cohorts may be more responsive to the modern market that characterised by highly differentiated products (Ryder, 1965; Hawkes, 2006), which may result in greater heterogeneity in preferences and consumption behaviours within younger generations relative to older generations. This may, in turn, strengthen the role of education in ensuring making healthy choices for younger cohorts. Taken together, changes in social contexts will modify the magnitude of the educational gap in cardiovascular health. But the impact of social changes on the gap may be related to each cohort's response to those changes.

Moreover, we found a south-north difference in the socioeconomic patterning of BP trajectories across cohorts. The diverging trend in BP trajectories between the low and high educated over the life course and across cohorts was more noticeable in the south relative to the north. As the northern provinces included in the CHNS have been the areas where people move out from since the 1990s (Wang & Fan, 2009; Yang & Zhang, 2016), the socioeconomic patterning of cardiovascular health in the north region may be partly alleviated by the selection effect of migration (Qi & Niu, 2013). But further research is needed to examine whether there are any contextual factors that could account for the south-north difference in the evolution of educational inequalities in cardiovascular function.

This study has some limitations. Firstly, although the CHNS collects samples from provincial areas that vary substantially in socioeconomic development and geography, it is not a nationally representative survey. Therefore, our findings could not be generalised to the whole country but the nine provinces included in our study. Secondly, we compared the life course pattern of the association between education and BP levels based on different segments of life course as each cohort's life course observed by the CHNS is limited. Thirdly, we did not explicitly incorporate the period effect in our analyses as the age variable is perfectly correlated with the period variable in the longitudinal data.

This study indicated that the life course pattern of socioeconomic inequalities in cardiovascular function varied by generation and south/north region. Generally, the diverging trend of BP trajectories between the high and low educated was more pronounced for younger cohorts versus older cohorts, in the south compared to the north.

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