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Exposure to urban life and mortality risk among older adults in China

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Abstract: We examined whether exposure to urban environments was linked with mortality in a longitudinal survey dataset of nearly 28,000 Chinese adults who were 65 years of age or older in the years 2002–2014. Urban life exposure was measured by residential status at birth, current residential status, and urban-related primary lifetime occupation, which generated eight different categories of urban life exposure: no exposure, mid-life-only exposure, late-life-only exposure, mid-late-life exposure, early-life-only exposure, early-mid-life exposure, early- & late-life exposure, and full life exposure. We also included a measure of migration, whether the respondent lived in the same county/city at birth and at first interview, to further classify these eight categories. Overall, we found that when demographics were controlled for, compared to those with no urban life exposure and no migration, mortality risk was lower for older adults with mid-late life exposure with or without migration and for older adults with full-life exposure with migration; mortality risk was higher for older adults with early-life-only exposure. Once socioeconomic status, family/social support, health behaviors, and baseline health were simultaneously controlled for, only the higher mortality risk for older adults with early-life-only exposure was still significant. Our findings provided valuable information about how urban life exposure at different life stages was associated with elderly mortality in China.

Keywords: *China; older adults; urban life exposure; mortality; rural; migration*

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1 Introduction

Urbanization is associated with profound changes in population health that result from changes in lifestyle, nutrition, ecological system, and socioeconomic conditions (Popkin, 1999) as well as social networks (Xu, Li and Jiao, 2016). Current urban residents in China tend to have higher prevalence rates of high fat diets, physical inactivity, obesity, and hypertension, as compared to their rural counterparts (Gong, Liang, Carlton, *et al*., 2012; Popkin and Du, 2003; Zhu, Chi and Sun, 2016). However, death rates at all ages were lower in urban areas than in rural areas in the latest four censuses (National Bureau of Statistics of China, 1984; 1992; 2002; 2012), which is common in many other developing countries (Leon, 2008).

A number of factors could help explain the urban health advantage in China, such as greater access to healthcare services, more socioeconomic resources, and better facilities and infrastructure such as safe water and easy transportation (Cai, Zhang, Ye, *et al*., 2010; Wang and Li, 2008; Zimmer, Kaneda and Spess, 2007; Zimmer, Kaneda, Tang, *et al*., 2010). One active research line of urban-rural health disparity in China adopts a life course perspective and looks into the impact of earlier life exposure to urban environments on health at later ages. Prior studies showed that older Chinese born in urban areas tend to have better cognitive function and self-rated health than those born in rural areas (Wen and Gu, 2011; Zeng, Gu and Land, 2007; Zhang, Gu and Hayward, 2010). More recent studies examined whether changes in urban-rural residential status affect later health conditions. Xu *et al*. (2017), for example, showed that those who were born in rural areas and urbanized later in the life course had better cognitive function compared to lifetime rural dwellers.

However, much of the existing literature only focuses on residential status at birth and/or at present, limiting the ability to capture more complete dynamics of urban life exposure among older adults. This issue is particularly important for the current cohorts of older adults in China who have been through a drastic historical transformation associated with complicated experiences of urban life. In particular, social welfare systems for older adults, important macro-level conditions that could affect health in late life (Zeng, Gu, Purser, *et al*., 2010), have gone through significant transformation in China (Cai and Du, 2015). After the establishment of communist China in 1949, the social service system for older adults was gradually established to complement the long tradition of family-based caregiving (Zhang, 2007). Although there have been occasional interruptions, this trend toward government-based social welfare has maintained and greatly speeded up in recent years. For example, in 2009 China launched a healthcare reform aiming for universal healthcare coverage by 2020 (Yip, Hsiao, Chen, *et al*., 2012). In the meantime, China unveiled the New-style Urbanization Plan (2014–2020) in an effort to steer the country's urbanization onto a more human-centered and environmentally friendly path (China Government Net, 2014). All of these macro-level contexts and changes have shaped and will continue to shape experiences of urban life for current cohorts of older adults (Xu, Dupre, Gu, *et al*., 2017). These complex trajectories justify more refined models to describe and interpret urban life exposure among older adults in China.

In this study, we propose to introduce lifetime occupation，an important but under-studied aspect of urban exposure in mid-life, to better investigate the association of urban life exposure with health outcomes among older adults in China. Urban-based occupations, in contrast to agricultural or related activities in rural areas, normally indicate higher socioeconomic statuses and advantaged life experiences, which may have critical implications for health status and health care consumption (Sorensen, 1996; Wen and Gu, 2011). We also propose to emphasize the role of migration, which is rarely investigated for the Chinese in this field (e.g., Xu, Dupre, Gu, *et al*., 2017). Older adults are increasingly mobile in the context of China's rapid urbanization (National Health and Family Planning Commission, 2016), so incorporation of rural-to-urban migration in urban life exposure analysis could have important implications. While some older adults move to cities with their children, permanently or temporarily, to provide care for grandchildren and households, others are still economically active in the labor market, seeking jobs in the urban areas (National Health and Family Planning Commission, 2016). All these issues suggest that adding occupation and migration information would better reflect life course urban exposure and provide some insights into its association with health or mortality at later ages.

Below we briefly review some selected theories that could be used to explain the association between exposure to urban context and health or mortality. We also provide a brief background on the institutional difference between urban and rural China, urbanization process in China, and research on health of rural-to-urban migrants. Section 2 presents data sources, measurements, and statistical modeling. Section 3 presents major results, followed by Section 4: Discussion and Conclusions.

1.1 Literature Review

Living in an urban area is a critical social determinant of health (Zimmer, Wen and Kaneda, 2010) that is frequently used as an indicator of socioeconomic status in addition to geographical location and surrounding environment (e.g., Zhu and Xie, 2007). This is particularly true for developing countries because urban areas in these societies often have better infrastructure, sanitation, healthcare, income, and social welfare systems compared to rural areas. The following three selected theoretical approaches could be used to explain the association between urban life exposure and health/mortality at older ages.

1.1.1 Socio-Ecological Theory

The socio-ecological model argues that contextual factors play a vital role in a wide range of individual outcomes (e.g., Kawachi and Berkman, 2000; Wen, Hawkley and Cacioppo, 2006; Zimmer, Wen and Kaneda, 2010). These contextual factors include physical environments, such as natural and built environments, and social environments consisting of socioeconomic status, social support, social networks, social cohesion, social capital, culture, and so forth (Engel, Chudyk, Ashe, *et al*., 2016).

Socio-ecological theory conceptualizes urban life exposure as an experience of living in an urban physical environment. For example, one study using data from Beijing, China showed that advantages in life expectancy and functional independence among older urban residents were largely attributable to differences in resources and health insurance coverage (Zimmer, Wen and Kaneda, 2010). Another China-based study reported that the nature of daily life activities and surrounding environments in rural settings contributed to rural residents being more likely than urban residents to do physical activities (Zhu, Chi and Sun, 2016).

Empirical evidence also suggests that distinct social environments in rural and urban areas may influence health. For example, urban residents are less helpful toward strangers and their social networks contain fewer kin compared to people in rural settings (Yang and Zeng, 2016). These characteristics of urban and rural social networks could lead to differences in interpersonal relationships, which may better buffer psychological distress among rural residents. Culture is another important component of social environment that plays a pivotal role in shaping individual attitudes and health behaviors (Grossmann, Karasawa, Kan, *et al*., 2014; Jopp, Wozniak, Damarin, *et al*., 2015; Löckenhoff, De Fruyt, Terracciano, *et al*., 2009), and in turn influences psychological and physiological well-being (Baum, 2017). Because rural areas are more likely to retain traditional culture than urban areas (Hu and Scott, 2016), rural residents may follow different attitudinal and behavioral norms. For example, due to traditional norms of filial piety and family care, Chinese rural older adults with physical limitation are less likely than their urban counterparts to report dependency in daily life (Purser, Feng, Zeng, *et al*., 2012).

1.1.2 Life Course Approach

The life course approach investigates how environmental exposures and conditions in earlier life stages affect health and wellbeing at later ages (Ben-Shlomo and Kuh, 2002; Cable, 2014; Eriksson, 2005; Hallqvist, Lynch, Bartley, *et al*., 2004; Lynch and Smith, 2005). It consists of three main conceptual models: the critical (or sensitive) period model, the cumulative risk model, and the social mobility model (Hallqvist Lynch, Bartley, *et al*., 2004). The critical period model emphasizes the importance of timing, with the effect of exposures or conditions being stronger during certain sensitive life course periods compared to other periods. The cumulative risk model highlights the direct and indirect effects of early-life exposures accumulated over time throughout the life course. The social mobility model focuses on trajectories of exposures or conditions in early-life, mid-life, and late-life; specifically, it argues that there would be a compensation effect if a person moved from a disadvantaged status in earlier life to an advantaged status in later life (upward mobility) and that there would be a penalty effect if a person moved from a higher status to a lower status in the life course. For example, Wen and Gu (2011) showed that upward mobility (measured by a transition from a lower socioeconomic status in early-life to a better socioeconomic status in mid-life) is associated with lower mortality and lower risk of cognitive impairment compared to persistently low social status among Chinese older adults. A U.S. study also reached a similar conclusion (Luo and Waite, 2005).

1.1.3 Healthy Migrant Theory

The healthy migrant theory highlights the selection effect in the health of migrants, arguing that migrants (except for forced migrants) tend to be healthier compared to non-migrants in the origin and/or native born in the destination (Abraido-Lanza, Dohrenwend, Ng-Mak, *et al*., 1999; Atella and Deb, 2013). Individuals who want to move to another place or country have to be healthy enough to move, be willing to undertake the hardships in the migration process, and be able to pass medical screenings before they can enter another country. All these issues will discourage or prevent individuals with health problems from initiating a geographic movement (Fu and VanLandingham, 2012).

However, there is evidence showing that the migrant health advantage may decline or diminish over time (Anson, 2004; Finch, Do, Frank, *et al*., 2009), possibly due to hardship encountered in the new environment; these hardships can include physical and psychosocial distress, loneliness, discrimination (Atella and Deb, 2013), adoption of less healthy lifestyles (Kristiansen, Razum, Tezcan-Güntekin, *et al*., 2016), and socioeconomic disadvantages (Wakabayashi, 2010). At the same time, some studies revealed that unhealthy migrants may go back to their origin, i.e., the salmon-bias effect (Abraido-Lanza, Dohrenwend, Ng-Mak, *et al*., 1999; Hu, Cook and Salazar, 2008; Palloni and Arias, 2004). Recently researchers started to study the linkage between the timing of migration and health at later ages (e.g., Wakabayashi, 2010). They documented that late-life migrants are disadvantaged compared to earlier-life migrants in some health indicators, possibly due to cumulative disadvantage in socioeconomics throughout the lifetime (Wakabayashi, 2010).

1.2 Urban Context in China

1.2.1 Urban-Rural Divide

China has implemented a dual-regime of governance in rural and urban areas since the early 1950s, which is still in effect even after the market reform initiated in the late 1970s (Liu and McGuire, 2015; Wu and Wang, 2014). This dual-regime restricts rural residents from moving to urban areas through a national household registration system (or *hukou*), dividing the nation's population and policies into two sectors with distinct contextual environments. Urban areas receive priority in financial investments, infrastructure construction, welfare and healthcare benefits, education, housing, food supply, and so forth (Liu and McGuire, 2015; Wu and Wang, 2014; Zimmer, Kaneda, and Spess, 2007). As a result, Chinese urban residents have higher income, more educational and job opportunities, improved housing and healthcare, improved infrastructure and sanitation, and more welfare and healthcare benefits compared to rural residents. Rural residents often face poor and unstable socioeconomic conditions; lack of welfare, education, and health care resources; vulnerability to natural disasters (floods/droughts); and loss of land due to urbanization (Gong, Liang, Carlton, *et al*., 2012). Accordingly, a large rural-urban health disparity exists that disadvantages rural residents (Fang, Chen, Rizzo, 2009).

This long-term rural-urban divide in China has recently undergone major transformation. Starting with the economic reform in the late 1970s, Chinese rural residents were allowed to migrate to urban areas, although their *hukou* status remained rural. With the huge flow of rural-to-urban migration from the hinterland to the east coast of China, the old household registration system was relaxed in some areas so that some migrants may obtain an urban status. Additionally, the rapid urbanization in China often changed previously rural lands to urban administration, so that rural residents could automatically acquire urban identities without geographic relocation (Zhu, 2015). However, the dual-regime system still creates barriers for rural-to-urban migrants to receive urban social welfare and healthcare entitlements (Gu, Zhu and Wen, 2015).

1.2.2 China's Urbanization Process

China has been experiencing a rapid process of urbanization in the last several decades, with the urban proportion of the population increasing from 13% in the early 1950s (United Nations, 2014) to 20% in 1982 (National Bureau of Statistics of China (NBSC), 1984) and to more than 55% in 2015 (NBSC, 2016). Of the more than 670 million Chinese currently living in urban areas, 225 million were rural-to-urban migrants (typically known as migrant workers or floating population in the Chinese literature) (NBSC, 2012). According to China's national plan (State of Council of People's Republic of China, 2014) and the projection made by the United Nations (United Nations, 2014), another 250 million rural residents are expected to move to urban areas or be locally urbanized in the next several decades. This massive rural to urban population movement in China is unprecedented (Johnson, 2013), and will impose great challenges on the public health system. The trajectory of China's urbanization process provides a good sample to study the relations between exposure to urban environments and health in late-life.

1.2.3 Health of Rural-to-Urban Migrants

In China, rural-to-urban migrants are often found to be advantaged in self-rated health, mental health, acute illnesses, and disabilities in comparison with native rural residents (origin) and native urban residents (destination) (Chen, 2011; 2013; Hu, Cook and Salazar, 2008; Lu and Qin, 2014; Tong and Piotrowski, 2012; Xu, Dupre, Gu, *et al*., 2017; Xu, Luo and Wu, 2015). However, these migrants often experienced stressful life events, such as loneliness because of separation from family (Lu, Hu and Treiman, 2012) and exclusion from access to social welfare, health insurance, and unemployment benefits in destination cities (Lee and Meng, 2010; Gu, Zhu and Wen, 2015), which in turn affected their health negatively (Gu, Zhu and Wen, 2015; Shankar, Hamer, McMunn, *et al*., 2013). Younger rural-to-urban migrants tend to be economically driven, but late-life migration in China could be due to health purposes, grandparenting, or family reunion (Dou and Liu, 2017). It is unclear whether the health advantage of rural-to-urban migrants still exists at old age due to very limited studies.

In sum, coupled with the rapid urbanization, China has undergone a major epidemiological transition, shifting from infectious to non-communicable diseases in a much shorter timeframe than many other countries (Li, Song, Lin, *et al*., 2016; Yang, Wang, Zeng, *et al*., 2013). Other population-level transitions include rapid population aging and an ongoing reform of China's national healthcare system (Ministry of Human Resources and Social Security of China, 2015). All these macro changes suggest a complicated scenario in the near future, in which urbanization intertwines with population aging and changing healthcare needs. Thus, it is imperative to examine the linkages between urban exposure and health among current older cohorts in China.

2 Methods

2.1 Study Population

We analyzed data from five waves of the Chinese Longitudinal Healthy Longevity Survey (CLHLS) in 2002, 2005, 2008/2009, 2011/2012, and 2014/2015. The age range of the respondents in each wave is from age 65 to age 100+. Following the common practice of prior studies (e.g., Gu, Brown and Qiu, 2016; Xu, Dupre, Gu, *et al*., 2017; Zhao, Sautter, Qiu, *et al*., 2017), we pooled these five waves together for more robust results. The first two waves of the CLHLS (1998 and 2000) were not included because they did not include older adults aged 65–79.

The CLHLS was originally conducted in a randomly selected half of the counties/cities in 22 provinces. The de facto total population of these 23 provinces accounted for 89% of the total population of China in the 2010 census (Zhang, Dupre, Qiu, *et al*., 2017). From 2002 to 2011/2012, 33,512 respondents contributed 57,285 observations to the CLHLS datasets. Among the 33,512 respondents, 783 respondents

(2.3%) survived to 2014, 8,179 (24.4%) had 2+ interviews but were lost to follow-up afterwards, 18,944 (about 56.5%) died between 2002 and 2014, and 5,606 (16.7%) had only one interview and were lost to follow-up afterwards. Because the survival status and the mortality exposure for those 5,606 respondents were unknown, they were excluded from the study. The total valid sample size is 27,906 (= 33,512 - 5,606) individuals who were recruited from 2002 to 2011/2012 and exposed to mortality risk from 2002 to 2014. For those who had 2+ interviews and then were lost to follow-up, information after their last interview was excluded from modeling since their survival status and the length of mortality exposure were unknown. The sampling procedures and assessments of data quality of the CLHLS can be found elsewhere and thus are not detailed here (Gu, Brown and Qiu, 2016; Gu, 2008).

2.2 Measurements

2.2.1 Urban life exposure

Urban life exposure was measured in reference to three stages throughout the life course of the respondent. Routine measures for urban life exposure include being born in an urban area (early-life exposure, yes vs. no) and living in an urban area at the time of the interview (late-life exposure, yes vs. no). We added a measure of urban-related primary lifetime occupation (PLO) (mid-life exposure, yes vs. no), a binary variable of primarily doing a non-agricultural job before age 60 (u-PLO) versus agricultural sector or unemployment before age 60 (r-PLO). We further added migration experience by asking whether the respondent had a geographic movement beyond their county/city administrative boundary of birth. The urban-rural definition comes from the National Bureau of Statistics of China (NBSC, 2002; 2008).

Based on different combinations of these measures of life course urban status, we obtained three classification schemes for urban exposure with 4, 8, and 14 categories reflecting degrees of exposure to urban life (see Table 1). These specific categories are all meaningful types of urban exposure in the context of China. Those who were born in a rural area, reported a rural PLO, and lived in a rural area at the first CLHLS interview were defined as no exposure, while those who were born in an urban area, reported an urban PLO, and lived in an urban area at the first CLHLS interview were defined as full exposure. Besides these two extreme ends of urban life exposure, combinations of the measurements above further created a series of categories, reflecting a spectrum of urban life exposure in the life course (See Table 1).

2.2.2 Outcome

The outcome variable is mortality risk, measured by the duration of exposure (in days) from the date of the first CLHLS interview in 2002–2011 until the date of death (for those who died in 2002–2014), the date of the 2014 interview (for survivors), or the date of the latest CLHLS interview (for those who had at least two interviews but were lost to follow-up afterwards). The dates of death for those who died between 2002 and 2014 were collected from official death certificates when available; otherwise, they were collected from the next-of-kin of the deceased respondents and local residential committees. The mortality data in the CLHLS were of high quality (Gu and Dupre, 2008).

2.2.3 Covariates

To ensure robust results, we controlled for a wide range of covariates that are associated with mortality (Wen and Gu, 2011; Woods, 2003; Zhao, Sautter, Qiu, *et al.*, 2017; Zimmer, Kaneda and Spess, 2007). The covariates included age (single year), sex (men vs. women), educational attainment (no formal education, received 1–6 years of schooling, and received 7+ years of schooling), economic independence (main financial resource was from own or spouse's retirement wage/pension or self-employment vs. from children or other sources), adequate medical services (yes vs.

Table 1. Classification of urban exposure under different combinations of variables

Four-type classification	Eight-type classification	Fourteen-type classification
Measures:	**Measures:**	**Measures:**
1. Rural/urban birth place	1. Rural/urban birth place	1. Rural/urban birth place
2. Rural/urban residential status at the first interview	2. Rural/urban residential status at the first interview	2. Rural/urban residential status at the first interview
	3. Rural/urban primary lifetime occupation (PLO)	3. Rural/urban primary lifetime occupation (PLO)
		4. Yes/no moved to another county/city (migration)
Types:	**Types:**	**Types:**
1. Rural-rural: rural birth place and rural status at the first interview	1. Rural-rural, r-PLO (no exposure)	1. No exposure, no migration 2. No exposure, migrated
	2. Rural-rural, u-PLO (mid-life-only exposure)	3. Mid-life-only exposure, no migration 4. Mid-life-only exposure, migrated
2. Rural-urban: rural birth place and urban status at the first interview	3. Rural-urban, r-PLO (late-life-only exposure)	5. Late-life-only exposure, no migration 6. Late-life-only exposure, migrated
	4. Rural-urban, u-PLO (mid-late-life exposure)	7. Mid-late-life exposure, no migration 8. Mid-late-life exposure, migrated
3. Urban-rural: urban birth place and rural status at the first interview	5. Urban-rural, r-PLO (early-life-only exposure)	→ 9. Early-life exposure, yes/no migration
	6. Urban-rural, u-PLO (early-mid-life exposure)	→ 10. Early-mid-life exposure, yes/no migration
4. Urban-urban: urban birth place and urban status at the first interview	7. Urban-urban, r-PLO (early- & late-life exposure)	11. Early- & late-life exposure, no migration 12. Early- & late-life exposure, migrated
	8. Urban-urban, u-PLO (full exposure)	13. Full exposure, no migration 14. Full exposure, migrated

no), current marital status (married vs. no), coresidence with children (yes vs. no), and frequency of participation in six leisure activities. Frequency of participation in leisure activities includes doing housework, gardening, raising domestic animals or poultry, reading books/newspapers, watching TV/listening to radio, and any other personal outdoor activities. Each physical activity was measured on a five-point Likert scale (from never to almost daily) and the values were summed; following previous research, we categorized respondents into three groups of participation: low level (never involved in these activities), high level (involved 1–7 times per week in at least one activity), and medium level (the remaining respondents) (Zhao, Sautter, Qiu, *et al.*, 2017).

We also controlled for baseline health. Disability in activities of daily living (ADL) was measured by six activities: (a) bathing, (b) dressing, (c) indoor transferring, (d) toileting, (e) eating, and (f) continence (Zeng, Gu and Land, 2007). Each item had three response categories: "able to do without help," "need some help," and "need full help." The respondents were considered as ADL disabled (coded as 1) if they reported needing any help in performing any of the six items; otherwise they were coded as 0. Disability in IADL was adopted from the Katz scale (Gu, 2008), which included eight self-reported activities: (a) visiting neighbors, (b) shopping, (c) cooking, (d) washing clothes, (e) walking one kilometer, (f) lifting a 5-kg bag, (g) crouching and standing up three times, and (h) taking public transportation; dichotomous coding was similar to that used for ADL disability. Cognitive function was measured using the Mini-mental State Examination (MMSE) that includes six domains of cognition—orientation, reaction, calculation, short-term memory, naming, and language—with a total score of 30. The MMSE items were adopted from the Folstein MMSE scale (Zhang, Gu and Hayward, 2008). Respondents were categorized as cognitively impaired if their MMSE score was below 24 (Zhang, Gu and Hayward, 2008). Given the low level of educational attainment among most older adults in China, we assessed alternative criteria (*e.g.*, score of 18) for those with no education to test the sensitivity of different cut-points for defining cognitive impairment (available upon request from the authors); we obtained similar results to those presented here. To account for possible difference in mortality risk over time, we controlled for year of the CLHLS survey.

2.3 Analytical Strategy

We modeled the association between exposure to urban life and mortality under different measurement schemes of urban life exposure: residential status at birth and at older ages (the preliminary measurements; Table 3), change or stability in residential status between these two life stages (four-type classification; Table 4), change or stability in residential status plus mid-life exposure (*i.e.*, PLO) (eight-type classification; the upper panel of Table 5), and finally, we included migration (fourteen-type classification; the lower panel of Table 5).

We used Weibull hazard regression models to examine the association between urban exposure and mortality, with two sequential models. Model I (the partial model) controlled for age (single year) and sex whenever appropriate; Model II (the full model) additionally controlled for socioeconomic status, family/social support, health behaviors, and health condition. We also designed other models that added only one set of all covariates in Model II into Model I, but the results were similar to Models I and II. To save space, we thus opted to present the simplest model and the full model. Multicollinearity among variables was tested and found to be not a problem, with all variance inflation factors less than 3 (Chatterjee and Hadi, 2012). We performed analyses separately by sex and age group to investigate possible differences between men and women and between the young-old and the oldest-old (ages 65–79, ages 80+). However, we did not do so for models that included PLO because of the small sample size of some categories. In all models by age group, the single year of age was still controlled for.

In the analytical sample, all variables had a missing value of less than 2%. We used multiple imputation for these missing values, assuming that the respondents who had missing values would have the same value for a given variable as those who had no missing values if the former had the same conditions on factors with non-missing values.

For survival status and the length of exposure to death, we applied multiple imputation to impute missing survival/mortality status, and it produced results close to those we present here, in which we did not impute survival/mortality status. The reasons that we did not use imputed results were because the survival status—and the length of exposure to death—are dependent variables in the survival analysis and because its proportion of missing is high (nearly 30%). Those who had at least two interviews and were lost to follow-up afterwards in the subsequent waves were included in the analysis; however, only information before lost to follow-up was included. Those who were only had one interview were excluded from the analysis.

In all analytical models, we did not apply the sampling weight because the CLHLS weights were constructed from population distributions of age, sex, and urban/rural residence—variables that were controlled for in the models (Winship and Radbill, 1994). Furthermore, no longitudinal weight was attached in the released CLHLS datasets. All analyses were performed using Stata version 13.1.

3 Results

3.1 Description of Urban Life Exposure among the Sample

Table 2 presents the distribution of study variables among the analytical sample of older adults recruited in the CLHLS 2002–2014. In this sample, 12.7% were born in an urban area and 39.1% were living in an urban area at the time of the first CLHLS interview. When the respondents were classified with both time points, 58.9% were born and remained in a rural area (rural-rural), 28.4% moved from a rural area to an urban area (rural-urban), 10.6% were born and remained in an urban area (urban-urban), and 2.1% moved from an urban area to a rural area (urban-rural). These urban-to-rural older adults with early-life-only urban exposure were possibly people who moved to the countryside to avoid war and never returned to urban areas. It is also possible that some of them were urban youth migrating to rural areas for the call of government in the 1950s and 1960s.

When PLO was further incorporated into the four types of classification, we found that about half of respondents had no urban life exposure, 6.1% had full urban exposure, and about 20% had late-life-only exposure (rural-urban, r-PLO). Other types of urban life exposure had low representation: 4.3% had mid-life-only exposure (rural-rural, u-PLO), possibly industrial workers in township/village enterprises; around 8.6% had mid-late-life exposure (rural-urban, u-PLO), possibly those who moved to an urban area in their early occupational career; about 1.5% had early-life-only exposure (urban-rural, r-PLO); 0.6% had early-mid-life exposure (urban-rural, u-PLO); and about 4.5% had early-late-life exposure (urban-urban, r-PLO), possibly those who assumed an agricultural job in a suburb.

About 21.7% of the analytical sample reported migration during the life course, ever moving to another county/city. For both lifetime-exposure and lifetime-no-exposure respondents, most had no migration experience. Overall, in a relative scale, the mid-late-life exposure older adults had the highest proportion of migration (60%), as compared to only 12% among the no exposure older adults.

3.2 Association between Exposure to Urban Life and Mortality Risk

Table 3 presents relative hazards of mortality and 95% confidence intervals (CIs) for urban versus rural environment at birth and at the first CLHLS interview, stratified by age group and gender. Except for women aged 65–79 (Model II in the upper panel of Table 3), those born in an urban area had no advantages in mortality over those born in a rural area. Urban residence at the first CLHLS interview was associated with lower risk of mortality for men and both sexes combined in each age group when only demographics were controlled for (Model I), yet the relative mortality risk was not significant when other covariates were added (Model II).

Table 4 further presents the relative hazards of mortality for the four-type classification of urban life exposure with rural-rural as reference. Among older adults aged 65–79, rural-to-urban migrants had 13% lower mortality risk when only demographics were controlled for, but the relative mortality risk was not significant when other covariates were further controlled for. Residential change from urban to rural areas (urban-to-rural migrants) was associated with increased mortality risk compared to rural-rural. The increased risk was more robust in the oldest-old than in the younger old adults, and more robust in women than in men. Although the urban-urban respondents had a lower mortality risk compared to rural-rural for the two age groups and two sexes, the association was generally not significant at $p < 0.05$ except that women at ages 65–79 had a 37% ($p < 0.05$) higher mortality risk when socioeconomic status, family/social support, health behaviors, and baseline health were taken into consideration.

Table 5 further incorporates PLO and migration into urban exposure, representing the eight-type and fourteen-type classifications, respectively. The upper panel shows that compared to no exposure, those with mid-late-life exposure had 9% lower mortality

Table 2. Distribution of study variables among the analytical sample, CLHLS 2002-2014

Sample size, urban life exposure, and survival	%[a], #	Covariates	%[a]
Total participants #	27, 906	Age	
		Ages 65–79	25.3
Place of birth		Ages 80+	74.7
Rural	87.3	Sex	
Urban	12.7	Women	58.2
Residential status at the first interview		Men	41.8
Rural	60.9	Educational attainment	
Urban	39.1	0 (years)	65.1
Residential status at birth and at the first interview[b]		1–6 (years)	26.4
Rural-rural (born in rural, currently in rural)	58.9	7+ (years)	8.5
Rural-urban (born in rural, currently in urban)	28.4	Economic independence	
Urban-rural (born in urban, currently in rural)	2.0	No	74.6
Urban-urban (born in urban, currently in urban)	10.7	Yes	25.4
Primary lifetime occupation (PLO)		Get adequate medical services at present	
Rural-related (agriculture) (r-PLO)	80.5	No	10.4
Urban-related (non-agriculture) (u-PLO)	19.5	Yes	89.6
Residential status at birth & first interview, & PLO[c]		Currently married	
Rural-rural, r-PLO (no exposure)	54.6	No	69.9
Rural-rural, u-PLO (mid-life-only exposure)	4.3	Yes	30.1
Rural-urban, r-PLO (late-life-only exposure)	19.8	Coresidence with children	
Rural-urban, u-PLO (mid-late-life exposure)	8.6	No	34.9
Urban-rural, r-PLO (early-life-only exposure)	1.5	Yes	65.1
Urban-rural, u-PLO (nearly-mid-life exposure)	0.6	Frequency of leisure activities[e]	
Urban-urban, r-PLO (early- & late-life exposure)	4.5	Low	36.4
Urban-urban, u-PLO (full exposure)	6.1	Medium	45.0
Migrated to another city/county after birth		High	18.6
No	78.3	Disabled in activities of daily living (ADL)	
Yes	21.7	No	72.3
Residential status at birth, first interview, PLO, & migration[d]		Yes	27.7
No exposure, no migration	47.6	Disabled in instrumental ADL	
No exposure, migrated	7.0	No	28.8
Mild-life-only exposure, no migration	3.5	Yes	71.2
Mid-life-only exposure, migrated	0.8	Cognitively impaired	
Late-life-only exposure, no migration	13.8	No	56.1
Late-life-only exposure, migrated	6.0	Yes	43.9
Mid-late-life exposure, no migration	3.5	Survey years	
Mid-late-life exposure, migrated	5.1	2002	49.2
Early-life-only exposure, yes/no migration	1.5	2005	21.0
Early-mid-life exposure, yes/no migration	0.6	2008/2009	26.0
Early- and late-life exposure, no migration	3.6	2011/2012	3.8
Early- and late-life exposure, migrated	0.9		
Full exposure, no migration	4.5		
Full exposure, migrated	1.6		
Survival status			
Died in 2002–2014	67.9		
Survived to the 2014 survey	2.8		
Lost to follow-up with 2+ interviews	29.3		

Notes: All percentages in the table referred to proportion among the 27,906 respondents who either had 2+ interviews, died with confirmation, or survived to the 2014 wave.
[a] all percentage distributions were unweighted.
[b] this was a cross-tabulation for place of birth and current residence.
[c] this variable was a combination of three variables.
[d] this variable was a combination of four variables; some categories were combined.
[e] frequency of engagement in leisure activities was measured from six activities. Each item is measured on a five-point Likert scale (from never to almost daily) and the values are summed and categorized into tertiles to denote low, medium, and high levels of engagement in leisure-time activity.
Except survival status, all variables were measured at the baseline interview of each respondent.

risk when controlling for demographics only (Model I), but had 7% higher mortality risk when other covariates were controlled (Model II). Those with full exposure shared a similar pattern as those with mid-late-life exposure. By contrast, early-life-only exposure was associated with 14% higher mortality risk compared to no exposure, and this higher risk was persistent when other covariates were added. Higher mortality risk was also found for mid-life-only exposure when all covariates were controlled for.

The middle panel of Table 5 additionally splits the sample by migration. Results in Model I suggest that in most cases, the results were similar to those in the upper panel. Full exposure with migration was associated with 23% lower mortality risk compared to no exposure without migration; however, the significance disappeared when other covariates were added in Model II. At the same time, full exposure without migration was only significant when all covariates were considered, with 12% higher mortality risk.

We further tested the role of migration in the relation between each type of exposure to urban life and mortality at older ages in Table 5 (see the low panel). We did not observe a significant role of migration in most exposure types, except that migration to another urban area was associated with 19% lower mortality risk when only age and sex were controlled for ($p < 0.05$) and 14% lower mortality risk when all other covariates were controlled for ($p < 0.1$).

4 Discussion

Based on five waves of the CLHLS, the current study examined the association between exposure to urban life and mortality at older ages. This study expanded the traditional approach of measuring exposure to urban life in terms of place of birth and residence at older ages (Allender, Foster, Hutchinson, *et al*., 2008; Vlahov and Galea, 2002; Wen and Gu, 2011; Xu, Dupre, Gu, *et al*., 2017; Zeng, Gu and Land,

Table 3. Relative hazard (mortality) and 95% CIs for urban life exposure based on residential status at birth and at the first interview, CLHLS 2002–2014

	Both sexes	Women	Men
Residential status at birth (urban vs. rural)			
Model I			
Ages 65+	1.02 (0.98–1.07)	1.01 (0.95–1.07)	1.05 (0.98–1.12)
Ages 65–79	1.04 (0.92–1.18)	0.94 (0.78–1.14)	1.12 (0.95–1.33)
Ages 80+	1.03 (0.98–1.08)	1.03 (0.96–1.09)	1.04 (0.96–1.12)
Model II			
Ages 65+	0.97 (0.93–1.02)	0.96 (0.90–1.03)	0.98 (0.91–1.05)
Ages 65–79	0.91 (0.80–1.05)	0.74 (0.60–0.91)**	1.04 (0.87–1.25)
Ages 80+	0.99 (0.94–1.04)	1.00 (0.94–1.07)	0.97 (0.90–1.05)
Residential status at the first interview (urban vs. rural)			
Model I			
Ages 65+	0.96 (0.93–0.99)**	0.98 (0.94–1.02)	0.93 (0.89–0.98)**
Ages 65-79	0.89 (0.82–0.97)**	0.90 (0.79–1.03)	0.88 (0.78–0.98)*
Ages 80+	0.96 (0.93–0.99)*	0.98 (0.94–1.02)	0.93 (0.89–0.99)*
Model II			
Ages 65+	0.98 (0.95–1.02)	0.98 (0.94–1.02)	0.99 (0.94–1.04)
Ages 65-79	0.97 (0.89–1.07)	0.99 (0.86–1.15)	0.96 (0.84–1.09)
Ages 80+	0.97 (0.94–1.01)	0.96 (0.93–1.01)	0.98 (0.92–1.04)

Note: (1) Relative mortality risk and the 95% CIs were estimated from 27,906 respondents interviewed in 2002–2011/2012 and their survival status in the subsequent waves 2005–2014, with the length of risk exposure recorded in 2002–2014. Model I controlled for demographics, whereas Model II controlled for all covariates listed in the right column of Table 2. (2) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4. Relative hazard (mortality) and 95% CIs for urban life exposure based on residential status at birth and at the first interview combined, CLHLS 2002–2014

	Both sexes	Women	Men
Model I			
Ages 65+			
From rural to urban (ref: rural-rural)	0.97 (0.94–1.00)†	0.99 (0.94–1.03)	0.94 (0.89–0.99)*
From urban to rural (ref: rural-rural)	1.10 (0.99–1.22)†	1.13 (0.99–1.29)†	1.05 (0.89–1.25)
Remaining in urban (ref: rural-rural)	0.94 (0.90–0.99)*	0.96 (0.90–1.03)	0.91 (0.85–0.99)*
Ages 65–79			
From rural to urban (ref: rural-rural)	0.87 (0.79–0.96)**	0.86 (0.74–1.00)*	0.88 (0.77–1.00)*
From urban to rural (ref: rural-rural)	0.93 (0.70–1.24)	1.01 (0.68–1.49)	0.86 (0.57–1.30)
Remaining in urban (ref: rural-rural)	0.92 (0.80–1.06)	1.02 (0.82–1.26)	0.86 (0.71–1.03)
Ages 80+			
From rural to urban (ref: rural-rural)	0.98 (0.94–1.01)	0.99 (0.95–1.04)	0.95 (0.90–1.00)†
From urban to rural (ref: rural-rural)	1.13 (1.01–1.26)*	1.14 (0.99–1.31)†	1.11 (0.91–1.34)
Remaining in urban (ref: rural-rural)	0.93 (0.88–0.98)*	0.94 (0.88–1.01)†	0.92 (0.85–1.00)†
Model II			
Ages 65+			
From rural to urban (ref: rural-rural)	0.98 (0.95–1.02)	0.98 (0.94-1.03)	0.99 (0.93-1.04)
From urban to rural (ref: rural-rural)	1.13 (1.02–1.26)*	1.18 (1.04–1.35)*	1.07 (0.89–1.28)
Remaining in urban (ref: rural-rural)	1.00 (0.94–1.05)	1.00 (0.93–1.07)	1.01 (0.92–1.10)
Ages 65–79			
From rural to urban (ref: rural-rural)	0.94 (0.85–1.05)	0.94 (0.80–1.10)	0.94 (0.82–1.08)
From urban to rural (ref: rural-rural)	0.96 (0.72–1.29)	1.13 (0.77–1.68)	0.81 (0.53–1.25)
Remaining in urban (ref: rural-rural)	1.09 (0.93–1.28)	1.37 (1.07–1.76)*	0.96 (0.78–1.17)
Ages 80+			
From rural to urban (ref: rural-rural)	0.98 (0.95–1.02)	0.98 (0.94–1.03)	0.98 (0.92–1.05)
From urban to rural (ref: rural-rural)	1.16 (1.04–1.31)*	1.19 (1.03–1.36)*	1.14 (0.93–1.39)
Remaining in urban (ref: rural-rural)	0.97 (0.91–1.03)	0.95 (0.88–1.03)	1.00 (0.91–1.09)

Note: (1) Relative mortality risk and the 95% CIs were estimated from 27,906 respondents interviewed in 2002–2011/2012 and their survival status in the subsequent waves 2005–2014 with the length of risk exposure recorded in 2002–2014. Model I controlled for demographics only, while Model II controlled for all covariates listed in the right column of Table 2. (2) † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

2007; Zhang, Gu and Hayward, 2008) by incorporating primary lifetime occupation (PLO) and migration experience into the classification of urban exposure in the life course. To our knowledge, this study is among the first to examine this expanded concept of exposure to urban ecological context on mortality at later ages in Chinese older adults. Our measurement scheme refines the routine measures to better capture the heterogeneous experience of urban life among Chinese older adults, producing meaningful typologies that represent varying degrees of urban life exposure and diverse life courses. It echoes the call for more sophisticated classifications of residential status in studying urban-rural experiences and disparities (Judd, Jackson, Komiti, *et al*., 2002), and provides a useful analytical tool to understand diverse life courses of the current Chinese elderly and their health care needs. This measurement advance is important for a nation such as China that has gone through profound transformations in institutions and economy over the past century, thus generating cohorts of older adults with distinct experiences of urban and rural life.

We found that current urban residence, rather than birth in an urban area, matters for mortality at old ages in China. Those who were born in an urban area have a similar mortality risk compared to those rurally born, regardless of the presence of different covariates. Mortality selection may have played a role here. Because rurally born Chinese likely encountered more adversities in their life course and had higher mortality (as shown in censuses) in earlier life stages, many rural residents in China

Table 5. Relative hazard (mortality) and 95% CIs for urban life exposure based on residential status at birth and at the first interview, plus primary lifetime occupation and migration, CLHLS 2002–2014

	Model I	Model II
Classified by residential status at birth, at the first interview, and occupation		
Ages 65+ (reference: Rural-rural, r-PLO, or no exposure)		
Rural-rural, u-PLO (mid-life-only exposure)	0.97 (0.89–1.05)	1.09 (1.00–1.18)*
Rural-urban, r-PLO (late-life-only exposure)	0.99 (0.95–1.03)	0.98 (0.95–1.02)
Rural-urban, u-PLO (mid-late life exposure)	0.91 (0.86–0.96)**	1.07 (1.00–1.15)*
Urban-rural, r-PLO (early-life-only exposure)	1.14 (1.01–1.28)*	1.15 (1.02–1.31)*
Urban-rural, u-PLO (early-mid-life exposure)	0.98 (0.78–1.23)	1.16 (0.93–1.45)
Urban-urban, r-PLO (early- & late-life exposure)	0.98 (0.92–1.06)	0.99 (0.92–1.07)
Urban-urban, u-PLO (full exposure)	0.90 (0.84–0.96)**	1.09 (1.01–1.18)*
Classified by residential status at birth, at the first interview, occupation, and migration		
Ages 65+ (reference: rural-rural, r-PLO, no migration, or no exposure, no migration)		
No exposure, migrated	1.01 (0.95–1.07)	1.00 (0.94–1.06)
Mid-life-only exposure, no migration	0.98 (0.89–1.07)	1.09 (0.99–1.19)†
Mid-life-only exposure, migrated	0.94 (0.78–1.13)	1.08 (0.91–1.29)
Late-life-only exposure, no migration	0.98 (0.94–1.03)	0.99 (0.95–1.04)
Late-life-only exposure, migrated	1.00 (0.94–1.06)	0.97 (0.9–1.03)
Mid-late-life exposure, no migration	0.89 (0.82–0.97)*	1.06 (0.97–1.16)
Mid-late-life exposure, migrated	0.92 (0.86–0.99)*	1.07 (0.9–1.17)†
Early-life-only exposure, yes/no migration	1.14 (1.01–1.28)*	1.15 (1.03–1.30)*
Early-mid-life exposure, yes/no migration	0.98 (0.78–1.23)	1.16 (0.92–1.45)
Early- & late-life exposure, no migration	1.00 (0.92–1.08)	1.01 (0.93–1.09)
Early- & late-life exposure, migrated	0.94 (0.82–1.09)	0.94 (0.81–1.08)
Full exposure, no migration	0.95 (0.88–1.02)	1.12 (1.04–1.22)**
Full exposure, migrated	0.77 (0.67–0.89)***	0.97 (0.83–1.13)
Classified by residential status at birth, at the first interview, occupation, and migration		
Ages 65+ (migration vs. no migration for each type of exposure)		
No exposure, migrated (vs. no migration)	1.01 (0.95–1.07)	1.00 (0.94–1.06)
Mid-life-only exposure, migrated (vs. no migration)	0.97 (0.79–1.18)	1.00 (0.82–1.20)
Late-life-only exposure, migrated (vs. no migration)	1.02 (0.96–1.10)	0.96 (0.91–1.04)
Mid-late-life exposure, migrated (vs. no migration)	1.03 (0.93–1.15)	1.01 (0.91–1.13)
Early- & late-life exposure, migrated (vs. no migration)	0.95 (0.81–1.12)	0.93 (0.79–1.09)
Full exposure, migrated (vs. no migration)	0.82 (0.70–0.96)*	0.86 (0.73–1.01)†

Notes: (1) Relative mortality risk and the 95% CIs were estimated from 27,906 respondents interviewed in 2002–2011/2012 and their survival status in the subsequent waves 2005–2014 with the length of risk exposure recorded in 2002–2014. Model I controlled for demographics only, whereas Model II controlled for all covariates in the right column of Table 2. Results by age-sex were unreliable due to small sample size and thus were not shown. (2) r-PLO: the primary lifetime occupation is related to agricultural sector. u-PLO, the primary lifetime occupation is related to non-agricultural sectors. Migration status was defined as the residential place at the first interview being in a different county/city from the place of birth. In the bottom panel two types of exposures (early-life-only exposure and early-mid-life exposure) were not presented due to small sample size. (3) † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

may have died before reaching old age; consequently, the rural older adults who lived up to older ages are likely composed of more robust individuals who have lower mortality rates at later ages. In contrast, current urban residence is associated with lower risk of mortality; particularly, older adults who were born in a rural area but migrated to an urban ecological context through mid-life occupation and continuously stayed in an urban area onward in the life course tend to enjoy lower mortality risks compared to older adults with no urban exposure in their lifetime. Considering the fact that the large-scale rural-to-urban migration only occurred in China after the 1980s, most of current older adult cohorts who migrated to urban areas during adulthood for work were not part of that specific demographic and economic shift. Instead, this group of urban workers was more likely composed of those who participated in the movement to establish socialist China before the 1950s, and who were admitted to tertiary education in urban areas or joined the army in the 1950s and 1960s. These individuals were more likely to come from rural economic or political elites with a relatively higher socioeconomic status than their other rural peers (Chan and Zhang, 1999). In this sense, the lower risk of mortality associated with this type of urban exposure may have resulted in part from the healthy migrant effect and in part from favorable institutional factors.

Moreover, unlike many of today's young rural-to-urban migrants in China who are still bound by *hukou* status and often experience stressful life events related to migration (Chen, 2013; Li, Wang, Ye, *et al*., 2007), the current cohorts of older adults who migrated from rural to urban areas before late-life were likely not seeking jobs in the urban regions, but were urbanized under institutional procedures such as cadre assignment, graduate placement, and post-army arrangement; they were entitled to the same social welfare benefits as urban-born residents and experienced relatively less discrimination. China's urban-rural dual-regime system led to the advantages of urban areas, thus effectively compensating these individuals who had rural experience in early years of human development (Wen and Gu, 2011). In this regard, our findings could be aligned with the social mobility theory, which posits that upward social mobility could offset adversity in earlier childhood and benefit health at later ages (Wen and Gu, 2011; Luo and Waite, 2005).

Those who were exposed to urban settings in mid-late-life without migration to another county/city also had lower mortality risks compared to those with no exposure to urban life. We speculate that many of these respondents were possibly workers at township/village enterprises who had a better income and more social benefits compared to those older adults with no urban exposure. This group of people may also include many who lived in the rural areas adjacent to cities and were later locally urbanized through administrative delineations which directly changed the rural status to urban. Literature has shown that residents living in suburban or rural places near metropolitan areas have better health than residents living in either the city proper or rural areas (Eberhardt and Pamuk, 2004). In the case of China, this group may have long enjoyed more opportunities for urban jobs and advanced socioeconomic conditions that are related to lower mortality risk.

Older adults who were exposed to urban ecological contexts throughout the life course and migrated to another city made up another group that had a lower mortality risk in reference to the lifetime rural dwellers (i.e., no exposure). Given that urban areas are advantaged over rural areas in China, and the fact that those who moved to another city were more likely to seek higher income, better job, and other opportunities for career development (Zimmer, Wen and Kaneda, 2010), it is not surprising that this group had a lower mortality risk compared to those with no exposure to urban settings throughout the life course. Furthermore, the migration advantage in mortality risk was still valid when compared to those with full urban exposure but without migration. These findings somewhat support socio-ecological theory and the healthy migrant hypothesis.

However, once socioeconomic status, family/social support, health behaviors, and baseline health were controlled for, the beneficial association between urban exposure and mortality risk became disadvantageous. This finding highlights the importance of socioeconomic factors, health behaviors, and baseline health in affecting mortality at older ages. This pattern is also generally in line with one recent study which found that the urban advantage in older age mortality was either largely reduced or disappeared once demographic factors and differences in socioeconomic characteristics were controlled for (Zimmer, Kaneda, Tang, *et al*., 2010). This provides additional evidence to the argument that it is the rural-urban dual system that has been driving the health and mortality differentials between urban and rural areas in China (Zimmer, Wen and Kaneda, 2010).

One interesting finding is that those who were exposed to urban contexts in early-life only tended to have higher mortality risk compared to those with lifelong no exposure. Examining possible historical backgrounds, we speculate that many older adults with early-life-only exposure moved to the countryside with family before the 1950s to avoid social turmoil and wars, and some of them moved to rural areas at young ages in response to political call of the government, which peaked during the late 1950s and the Cultural Revolution, usually known as “sent-down to the countryside” or the rustication movement (Seybolt, 1975). Although a majority of these youth finally returned to their home cities, some settled in the villages and never returned. With such a disrupted life course, this group tended to be even more disadvantaged than the local peasants. This finding provides some evidence to support the penalty hypothesis of downward mobility (moving from an urban to rural area could be considered downward mobility in China) (Luo and Waite, 2005).

One unexpected result is that, compared to older adults with no exposure to urban settings, those who experienced a full exposure to urban context with no migration had a similar mortality risk when only demographics were controlled for, and had a higher mortality risk when socioeconomic status, family/social support, health practice, and baseline health were additionally controlled for. This finding seems counterintuitive because urban life is usually advantaged, but not uninterpretable, due to the specific Chinese context. Nearly a century ago, the socioeconomic condition, infrastructure, and sanitation in urban China were only marginally better than in rural areas. As China underwent political and social turmoil from the 1950s to the 1970s, urban residents might have born relatively more health risks than the rural peers (Seybolt, 1975), which may affect their health at older ages. Moreover, the recent crowding and polluted environments in urban China may also run against the health of city residents (Zheng and Kahn, 2017). In addition, mortality selection as noted earlier may have played a role in this process.

Overall, our findings provide some evidence in support of the urban advantages in health as proposed by socio-ecological theory, the compensation of social upward mobility for early life disadvantages and penalty of social downward mobility as highlighted by the social mobility hypothesis and the healthy migrants theory. At the same time, we acknowledge several limitations of this study. First, although our classification of urban life exposure expanded upon those used in most previous studies, classification still needs further improvements. We were not able to model the changes in residence status before the very first interview and whether the rural-to-urban migrants are permanent (obtained an urban *hukou* status) or temporary (living in urban areas with rural *hukou*). For example, we did not have data on the number of years of stay in the reported residential place before the survey, which prevented us from measuring the timing of change in residential status. We were also not able to distinguish suburban residents from residents living in city property. Studies in the U.S. showed that health status of suburban residents was different from rural and urban residents (Eberhardt and Pamuk, 2004). As the current Chinese older cohorts have witnessed drastic social transformation, industrialization, and political movements in their lifetime, more sophisticated classifications are needed in future research to better reflect their complicated experiences of urban life. Furthermore, because of the lack of data, we were also not able to adequately test the healthy migrant theory, although we examined the association between migration and mortality within each type of exposure. Because healthy migrant selection likely interacts with the better condition in urban areas to affect the health of current older adults in China, it is difficult to disentangle their independent roles without scientific designs and solid evidence. We call for more studies to provide insights into this theme.

Second, as China has witnessed rapid urbanization, residential status of many rural residents has changed even if they live in the same village/township of their birth or nearby due to *in situ* urbanization (Zhu, 2015). Moreover, the Chinese government’s official definition of urban areas and the administrative boundaries of some counties/cities have been changing over time (NBSC, 2002; 2008) and different names were sometimes used for the same counties/cities over time. Consequently, migration as indicated by survey data may not happen with actual geographic mobility. Although we have incorporated PLO and migration that could partially capture the difference between those who actually migrated and those who did not, these issues may still cause bias. It would be ideal to collect data from each individual to distinguish *in situ* urbanization and urbanization due to geographical migration within and beyond the home county.

Third, specific contextual factors that are associated with health/mortality were not included in the present study due to unavailability of data. The linkage between urbanization and health is complex in that it involves multiple processes along environmental, socioeconomic, epidemiological, spatial, behavioral, and psychological dimensions (Gong, Liang, Carlton, *et al*., 2012). Environmental quality and healthcare services are also associated with health outcomes (Zeng, Gu, Purser, *et al*., 2010; Zhang, Dupre, Qiu, *et al*., 2017). In that regard, incorporation of specific physical and social contextual factors is necessary to better reveal the mechanisms between urban exposure and mortality (Wen and Gu, 2011).

Despite these shortcomings, our findings shed new light on urban-rural health disparity in China, with implications for future research in this important field. As proposed in this study, multiple urban-rural residential transitions over the life course, rather than status at birth, current residential status, or rural-urban migration, should be highlighted in future studies to better identify key aspects in the process of urbanization that are beneficial or detrimental to health (Gong, Liang, Carlton, *et al*, 2012). The study results are also informative for those countries, similar to China, that are undergoing significant urbanization, population aging, and epidemiological transition; however, interpretation of the impacts of urban exposure on mortality should always consider specific contexts and histories.

Authors' Contribution

D Gu designed the study, supervised the analysis, drafted and revised the manuscript. Q Feng and JM Sautter revised the manuscript and interpreted the results. L Qiu prepared the data and performed the analysis.

Conflict of Interest

No conflict of interest has been reported by the authors.

Ethics Approval

No ethics approval was required for this study. The datasets were obtained from a publicly accessible database of the Chinese Longitudinal Healthy Longevity Survey at the National Archive of Computerized Data on Aging, University of Michigan (http://www.icpsr.umich.edu/icpsrweb/NACDA/studies/36179) with a signed data use agreement.

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Disclaimer

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References

Allender S, Foster C, Hutchinson L, *et al*. (2008) Quantification of urbanization in relation to chronic diseases in development countries: A systematic review. *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, 85(6): 938–951.
https://doi.org/10.1007/s11524-008-9325-4

Anson J (2004). The migrant mortality advantage: A 70 month follow-up of the Brussels population. *European Journal of Population*, 20(3): 191–218.
https://doi.org/10.1007/s10680-004-0883-1

Abraido-Lanza AF, Dohrenwend BP, Ng-Mak DS, *et al*. (1999) The Latino mortality paradox: A test of the "salmon bias" and healthy migrant hypotheses. *American Journal Public Health*, 89(10): 1543–1548.
https://doi.org/10.2105/AJPH.89.10.1543

Atella V and Deb P (2013). Gender difference in long term health outcomes of internal migrants in Italy. *CEIS Working Paper No. 269,* 11(5). Centre for Economic and International Studies.
https://doi.org/10.2139/ssrn.2241507

Baum WM (2017). Understanding behaviorism: Behavior, culture, and evolution. 3rd ed. New York, NY, USA: John Wiley & Sons, Inc.
https://doi.org/10.1002/9781119143673

Ben-Shlomo Y and Kuh D (2002). A life course approach to chronic disease epidemiology: Conceptual models, empirical challenges and interdisciplinary perspectives. *International Journal of Epidemiology,* 31(2): 285–293.
https://doi.org/10.1093/intjepid/31.2.285

Cable N (2014). Life course approach in social epidemiology: An overview, application and future implications. *Journal of Epidemiology*, 24(5): 347–352.
https://doi.org/10.2188/jea.JE20140045

Cai F and Du Y (2015). The social protection system in ageing China. *Asian Economic Policy Review*, 10(2): 250–270.
https://doi.org/10.1111/aepr.12103

Cai YY, Zhang XY, Ye E, *et al.* (2010). Analysis of differences in mortality of Chinese urban and rural residents and influencing factors. *Modern Preventive Medicine*, 37(21): 4070–4072. [in Chinese]

Chan KW and Zhang L (1999). The *hukou* system and rural-urban migration in China: Processes and changes. *The China Quarterly*, 160: 818–855.
https://doi.org/10.1017/S0305741000001351

Chatterjee S and Hadi AS (2012). Regression analysis by example. 5th ed. New York, NY, USA: John Wiley & Sons, Inc.

Chen J (2011). Internal migration and health: Re-examining the healthy migrant phenomenon in China. *Social Science & Medicine,* 72(8): 1294−1301.
https://doi.org/10.1016/j.socscimed.2011.02.016

——— (2013). Perceived discrimination and subjective well-being among rural-to-urban migrants in China. *Journal of Sociology & Social Welfare,* 40(1): 131−156.

China Government Net (2014). [National New Urbanization Plan (2014–2020)]. Accessed on May 2, 2017. [in Chinese]
http://www.gov.cn/zhengce/2014-03/16/content_2640075.htm

Dou X and Liu Y (2017). Elderly migration in China: Types, patterns and determinants. *Journal of Applied Gerontology*. 36(6): 751–771.
https://doi.org/10.1177/0733464815587966

Eberhardt MS and Pamuk ER (2004). The importance of place of residence: Examining health in rural and nonrural areas. *American Journal of Publish Health*, 94(10): 1682–1686.
https://doi.org/10.2105/AJPH.94.10.1682

Engel L, Chudyk AM, Ashe MC *et al*. (2016). Older adults' quality of life—Exploring the role of the built environment and social cohesion in community-dwelling seniors on low income. *Social Science & Medicine*, 164; 1–11.
https://doi.org/10.1016/j.socscimed.2016.07.008

Eriksson JG (2005). The fetal origins hypothesis—10 years on. The BMJ, 330(7500): 1096–1097.
https://doi.org/10.1136/bmj.330.7500.1096

Fang H, Chen J and Rizzo JA (2009). Explaining urban-rural health disparities in China. *Medical Care*, 47(12): 1209–1216.
https://doi.org/10.1097/MLR.0b013e3181adcc32

Finch BK, Do DP, Frank R, *et al.* (2009). Could "acculturation" effects be explained by latent health disadvantages among Mexican immigrants? *The International Migration Review*, 43(3): 471–495.
https://doi.org/10.1111/j.1747-7379.2009.00774.x

Fu H and VanLandingham MJ (2012). Disentangling the effects of migration, selection and acculturation on weight and body fat distribution: Results from a natural experiment

involving Vietnamese Americans, returnees, and never-leavers. *Journal of Immigrant and Minority Health*, 14(5): 786–796.
https://doi.org/10.1007/s10903-012-9595-5

Gong P, Liang S, Carlton EJ, *et al.* (2012) Urbanization and health in China. *The Lancet*, 379(9818): 843–852.
https://doi.org/10.1016/S0140-6736(11)61878-3

Grossmann I, Karasawa M, Kan C, *et al*. (2014) A cultural perspective on emotional experiences across the life span. *Emotion*, 14(4): 679–692.
https://doi.org/10.1037/a0036041

Gu D (2008). General data quality assessment of the Chinese Longitudinal Healthy Longevity Survey. In: Zeng Y, Poston Jr DL, Vlosky DA, *et al*. (eds.). *Healthy longevity in China: Demographic, socioeconomic, and psychological dimensions*. Dordrecht, The Netherlands: Springer Publisher. p. 39-59.

Gu D, Brown BL and Qiu L (2016). Self-perceived uselessness is associated with lower likelihood of successful aging among older adults in China. *BMC Geriatrics*. 16(172): 1–12.
https://doi.org/10.1186/s12877-016-0348-5

Gu D and Dupre ME (2008). Assessment of reliability of mortality and morbidity in the 1998–2002 CLHLS waves. In: Zeng Y, Poston Jr DL, Vlosky DA, *et al*. (eds.). *Healthy longevity in China: Demographic, socioeconomic, and psychological dimensions*. Dordrecht, The Netherlands: Springer Publisher. p. 99-115.

Gu D, Zhu H and Wen M (2015). Neighborhood-health links: Differences between rural-to-urban migrants and natives in Shanghai. *Demographic Research*, 33(17): 499–524.
https://doi.org/10.4054/DemRes.2015.33.17

Hallqvist J, Lynch J, Bartley M, *et al*. (2004) Can we disentangle life course processes of accumulation, critical period and social mobility? An analysis of disadvantaged socio-economic positions and myocardial infarction in the Stockholm Heart Epidemiology Program. *Social Science & Medicine*, 58(8): 1555–1562.
https://doi.org/10.1016/S0277-9536(03)00344-7

Hu X, Cook S and Salazar MA (2008). Internal migration and health in China. *The Lancet*, 372(9651): 1717–1719.
https://doi.org/10.1016/S0140-6736(08)61360-4

Hu Y and Scott J (2016). Family and gender values in China: Generational, geographic and gender differences. *Journal of Family Issues*, 37(9): 1267–1293.
https://doi.org/10.1177/0192513X14528710

Johnson I (2013). China's great uprooting: Moving 250 million into cities. Leaving The Land: Part I (Internet). *The New York Times*. Accessed on 16 October, 2016.

Jopp DS, Wozniak D, Damarin AK, *et al*. (2015). How could lay perspectives on successful aging complement scientific theory? Findings from a U.S. and a German life-span sample. *Gerontologist*, 55(1) : 91–106.
https://doi.org/10.1093/geront/gnu059

Judd FK, Jackson HJ, Komiti A, *et al*. (2002) High prevalence disorders in urban and rural communities. *Australian and New Zealand Journal of Psychiatry*, 36(1): 104–113.
https://doi.org/10.1046/j.1440-1614.2002.00986.x

Kawachi I and Berkman L (2000). Social cohesion, social capital, and health. In: Berkman LF and Kawachi I (editors). 1st ed. *Social epidemiology*. London, UK: Oxford University Press. p. 174–190.

Kristiansen M, Razum O, Tezcan-Güntekin H, *et al*. (2016) Aging and health among migrants in a European perspective. *Public Health Reviews*, 37(20): 1–14.
https://doi.org/10.1186/s40985-016-0036-1

Lee L and Meng X (2010). Jobs, working hours, and remuneration packages for migrants and urban residents. In: Meng X, Manning C, Shi L, *et al*. (eds.) *The great migration: Rural–urban migration in China and Indonesia*. Cheltenham, UK: Edward Elgar Publishing. p. 47-73.

Leon DA (2008). Cities, urbanization and health. *International Journal of Epidemiology*, 37(1): 4–8.
https://doi.org/10.1093/ije/dym271

Li L, Wang H-M, Ye X-J , *et al.* (2007). The mental health status of Chinese rural-urban migrant workers. *Social Psychiatry and Psychiatric Epidemiology*, 42(9): 716–722.
http://dx.doi.org/10.1007/s00127-007-0221-0

Li X, Song J, Lin T, *et al*. (2016) Urbanization and health in China, thinking at the national, local and individual levels. *Environmental Health*, 15(32): 1–11.
https://doi.org/10.1186/s12940-016-0104-5

Liu P and McGuire W (2015). One regulatory state, two regulatory regimes: Understanding dual regimes in China's regulatory state building through food safety. *Journal of Contemporary China*, 24(91): 119–136.
http://dx.doi.org/10.1080/10670564.2014.918411

Löckenhoff CE, De Fruyt F, Terracciano A, *et al.* (2009) Perceptions of aging across 26 cultures and their culture-level associates. *Psychology and Aging*, 24(4): 941–954.

http://dx.doi.org/10.1037/a0016901

Lu Y, Hu P and Treiman DJ (2012). Migration and depressive symptoms in migrant-sending areas: Findings from the survey of internal migration and health in China. *International Journal of Public Health,* 57(4): 691–698. http://dx.doi.org/10.1007/s00038-011-0314-0

Lu Y and Qin L (2014). Healthy migrant and salmon bias hypotheses: A study of health and internal migration in China. *Social Science & Medicine,* 102: 41–48. https://doi.org/10.1016/j.socscimed.2013.11.040

Luo Y and Waite LJ (2005). The impact of childhood and adult SES on physical, mental, and cognitive well-being in later life. *The Journals of Gerontology: Series B*, 60(2): S93–S101. https://doi.org/10.1093/geronb/60.2.S93

Lynch J and Smith GD (2005). A life course approach to chronic disease epidemiology. *Annual Review of Public Health*, 26: 1–35. https://doi.org/10.1093/ije/31.2.285

Ministry of Human Resources and Social Security of China (2015). *Annual report of the China social insurance.* Beijing, China. [in Chinese]

National Bureau of Statistics of China (NBSC) (1984). *The tabulation of the 1982 population census of the People's Republic of China*. Beijing, China: China Statistics Press. [in Chinese]

——— (1992). *The tabulation of the 1990 population census of the People's Republic of China*. Beijing, China: China Statistics Press. [in Chinese]

——— (2002). *The tabulation of the 2000 population census of the People's Republic of China*. Beijing, China: China Statistics Press. [in Chinese]

——— (2012). *The tabulation of the 2010 population census of the People's Republic of China*. Beijing, China: China Statistics Press. [in Chinese]

——— (2016). *China Demographic and Employment Yearbook*. Beijing, China: China Statistics Press. [in Chinese]

National Health and Family Planning Commission (2016). *China floating population report: 2016*. Beijing, China: China Population Publishing House. [in Chinese]

Palloni A and Arias E (2004). Paradox lost: Explaining the Hispanic adult mortality advantage. *Demography,* 41(3): 385–415. https://doi.org/10.1353/dem.2004.0024

Popkin BM (1999). Urbanization, lifestyle changes and the nutrition transition. *World Development,* 1999; 27(11): 1905–1916. https://doi.org/10.1016/S0305-750X(99)00094-7

Popkin BM and Du SF (2003). Dynamics of the nutrition transition toward the animal foods sector in China and its implications: A worried perspective. *Journal of Nutrition,* 133(11): 3898S–3906S.

Purser JL, Feng Q, Zeng Y, *et al*. (2012). A new classification of function and disability in China: Subtypes based on performance-based and self-reported measures. *Journal of Aging and Health,* 24(5): 779–798. https://doi.org/10.1177/0898264312444310

Seybolt PJ (1975). The rustication of urban youth in China: A social experiment. New York, NY, USA: Routledge: Taylor & Francis Group.

Shankar A, Hamer M, McMunn A, *et al*. (2013) Social isolation and loneliness: Relationships with cognitive function during 4 years of follow-up in the English Longitudinal Study of Ageing. *Psychosomatic Medicine,* 75(2): 161–170. https://doi.org/10.1097/PSY.0b013e31827f09cd

Sorensen AB (1996). The structural basis of social inequality. *The American Journal of Sociology*, 101(5): 1333–1365. https://doi.org/10.1086/230825

State of Council of People's Republic of China (2014). *National new-type of urbanization plan (2014-2020)*. Beijing, China: State of Council. [in Chinese]

Tong Y and Piotrowski M (2012). Migration and health selectivity in the context of internal migration in China, 1997–2009. *Population Research and Policy Review,* 31(4): 497–543. https://doi.org/10.1007/s11113-012-9240-y

United Nations (2014). *The World Urbanization Prospects: The 2014 Revision*. New York, NY, USA: United Nations.

Vlahov D and Galea S (2002). Urbanization, urbanicity, and health. *Journal of Urban Health*. 79(4): S1–S12. https://doi.org/10.1093/jurban/79.suppl_1.S1

Wakabayashi C (2010). Effects of immigration and age on health of older people in the United States. *Journal of Applied Gerontology*, 29(6): 697–719. https://doi.org/10.1177/0733464809353602

Wang YH and Li LM (2008). A comparison of life expectancy between the urban and rural residents in China, 1990–2005. *Chinese Journal of Epidemiology*, 29(3): 262–266. [in Chinese]

Wen M, Hawkley LC, and Cacioppo JT (2006). Objective and perceived neighborhood environment, individual SES and psychosocial factors, and self-rated health: An analysis of older adults in Cook County, Illinois. *Social Science & Medicine,* 63(10): 2575–2590. https://doi.org/10.1016/j.socscimed.2006.06.025

Wen M and Gu D (2011). The effects of childhood, adult, and community socioeconomic conditions on health and mortality among older adults in China. *Demography*. 48(1): 153–181. https://doi.org/10.1007/s13524-010-0003-2

Winship C and Radbill L (1994). Sampling weights and regression analysis. *Sociological Methods and Research*, 23(2): 230–257. https://doi.org/10.1177/0049124194023002004

Woods R (2003). Urban-rural mortality differentials: An unresolved debate. *Population and Development Review*, 29(1): 29–46. https://doi.org/10.1111/j.1728-4457.2003.00029.x

Wu W and Wang G (2014). Together but unequal: Citizenship rights for migrants and locals in urban China. *Urban Affairs Review*, 50(6): 781–805. https://doi.org/10.1177/1078087413518172

Xu H, Luo J and Wu B (2015). Self-reported diabetes treatment among Chinese middle-aged and older adults with diabetes: Comparison of urban residents, migrants in urban settings, and rural residents. *International Journal of Nursing Science.* 2(1): 9–14. https://doi.org/10.1016/j.ijnss.2015.01.005

Xu H, Dupre ME, Gu D, *et al*. (2017) The impact of residential status on cognitive decline among older adults in China: Results from a longitudinal study. *BMC Geriatrics*, 17(107): 1–11. https://doi.org/10.1186/s12877-017-0501-9

Xu Y, Li J and Jiao S (2015). Impacts of Chinese urbanization on farmers' social networks: Evidence from the urbanization led by farmland requisition in Shanghai. *Journal of Urban Planning and Development*, 142(2): 1–8. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000302

Yang G, Wang Y, Zeng Y, *et al*. (2013) Rapid health transition in China, 1990–2010: Findings from the Global Burden of Disease Study 2010. *The Lancet*, 381(9882): 1987–2015. http://dx.doi.org/10.1016/S0140-6736(13)61097-1

Yang G and Zeng S (2016). The comparison of trust structure between urban and rural residents in China. *American Journal of Industrial and Business Management*, 6(5): 665–673. http://dx.doi.org/10.4236/ajibm.2016.65062

Yip WC-M, Hsiao WC, Chen W, *et al*. (2012). Early appraisal of China's huge and complex health-care reforms. *The Lancet*, 379(9818): 833–842. http://dx.doi.org/10.1016/S0140-6736(11)61880-1

Zeng Y, Gu D and Land KC (2007). Association of childhood socioeconomic with healthy longevity at oldest-older ages in China. *Demography,* 44(3): 497–518. https://doi.org/10.1353/dem.2007.0033

Zeng Y, Gu D, Purser J, *et al.* (2010) Associations of environmental factors with elderly health and mortality in China. *American Journal of Public Health*, 100(2): 298–305. https://doi.org/10.2105/AJPH.2008.154971

Zhang H (2007). Who will care for our parents? Changing boundaries of family and public roles in providing care for the aged in urban China. *Care Management Journal*, 8(1): 39–46. http://dx.doi.org/10.1891/152109807780494087

Zhang X, Dupre ME, Qiu L, *et al*. (2017) Urban-rural differences in the association between access to healthcare and health outcomes among older adults in China. *BMC Geriatrics*, 17(151): 1–11. https://doi.org/10.1186/s12877-017-0538-9

Zhang Z, Gu D and Hayward M (2008). Early-life influences on cognitive impairment among oldest old Chinese. *Journal of Gerontology: Series B*, 63(1): S25–S33. https://doi.org/10.1093/geronb/63.1.S25

Zhao Y, Sautter JM, Qiu L, *et al.* (2017) Self-perceived uselessness and associated factors among older adults in China. *BMR Geriatrics*, 17(12): 1–19. https://doi.org/10.1186/s12877-016-0406-z

Zheng S and Kahn ME (2017). A new era of pollution progress in urban China? *Journal of Economic Perspectives*, 31(1): 71–92. https://doi.org/10.1257/jep.31.1.71

Zhu H and Xie Y (2007). Socioeconomic differentials in mortality among the oldest old in China. *Research on Aging*, 29(2): 125–143. https://doi.org/10.1177/0164027506296758

Zhu W, Chi A and Sun Y (2016). Physical activity among older Chinese adults living in urban and rural areas: A review. *Journal of Sport and Health Science*, 5(3): 281–286. https://doi.org/10.1016/j.jshs.2016.07.004

Zhu Y (2014). *In situ* urbanization in China: Process, contributing factors, and policy implications. *World Migration Report 2015.* Newark, NJ, USA: International Organization for Migration.

Zimmer Z, Kaneda T and Spess L (2007). An examination of urban versus rural mortality in China using community and individual data. *Journal of Gerontology: Social Sciences,* 62(5): S349–S357.
https://doi.org/10.1093/geronb/62.5.S349

Zimmer Z, Kaneda T, Tang Z, *et al*. (2010) Explaining late life urban vs. rural health discrepancies in Beijing. *Social Force*, 88(4): 1885–1908.
https://doi.org/10.1353/sof.2010.0000

Zimmer Z, Wen M and Kaneda T (2010). A multi-level analysis of urban/rural and socioeconomic differences in functional health status transition among older Chinese. *Social Science & Medicine*, 71(3): 559–567.
https://doi.org/10.1016/j.socscimed.2010.03.048