

BMJ Open Changes to cardiovascular risk factors over 7 years: a prospective cohort study of in situ urbanised residents in the Chaoyang District of Beijing

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ABSTRACT

Objectives To examine changes in cardiovascular risk factors of in situ urbanised residents between 2010 and 2017.

Design Population-based cohort study.

Setting The Chaoyang District of Beijing, China.

Participants A total of 942 in situ urbanised rural residents aged 35–64 who participated in the cardiovascular disease (CVD) risk factors study in China between 2010 and 2017.

Main outcome measures Lifestyles (smoking, drinking and effective exercise) and medical history (diabetes, hypertension, dyslipidaemia, overweight and obesity) were self-reported. New cases of diabetes, hypertension, dyslipidaemia, overweight and obesity were confirmed by physical examination or blood biochemical tests. Multiple linear regression and log-binomial models analyses adjusted for sociodemographic confounders were conducted to evaluate any changes of clinical indexes and to estimate prevalence rate ratios (PRRs), respectively.

Results During the study period of 2010–2017, diastolic blood pressure elevated by 3.55 mm Hg, central blood pressure increased by 4.39 mm Hg, total cholesterol decreased by 0.29 mmol/L and hypertension increased significantly (PRR=1.25, $p<0.05$) after adjusting for demographic, lifestyle and family history factors. Effective exercise rate (PRR=1.57), prevalence of diabetes (PRR=1.36) and dyslipidaemia (PRR=1.19) all increased from 2010 to 2017. However, these changes were not significant after adjusting for confounders ($p>0.05$). Prevalence of smoking, drinking, hypertension, overweight and obesity was significantly higher in males than females in both 2010 and 2017. In 2017, the 10-year risk of atherosclerotic CVD increased in 29.8% of participants and decreased in 6.1% of individuals.

Conclusions CVD risk factors augmented remarkably for in situ urbanised rural residents aged 35–64 in the Chaoyang District of Beijing, especially those indicators related to blood pressure. Awareness of the direction and magnitude of these risk factor changes may be beneficial in informing targeted strategies for preventing CVDs of in situ urbanised populations.

INTRODUCTION

Over the past three decades, China has experienced the largest acceleration of urbanisation

Strengths and limitations of this study

- This is a rare study which uses reliable clinical data to explore the changes in cardiovascular health risks in an in situ urbanised population.
- The longitudinal study design and use of standard protocols and instruments, data collection by trained interviewers, a vigorous quality control throughout the survey period as well as the rigorous statistical methods all enhance the reliability of the findings.
- The study cannot determine a causal relationship between in situ urbanisation and changes in cardiovascular risk factors since there is no control population.
- The information on lifestyles, medical history, family history and income were based on self-report, which may be subject to reporting bias and recall bias.
- As data from six participants with risk factors who died during the study period were not included in the analysis, the final results may be underestimated.

worldwide. China's proportion of urban population increased from 25.8% in 1990 to 59.6% in 2018.¹ It is estimated that one billion people will live in urban areas in China by 2030.² This urbanisation has emerged from two processes: migration from rural to urban areas and in situ urbanisation of rural areas.^{3–5} In addition to the social and economic alterations of the past few decades, China has experienced an epidemiological transition from predominantly infectious diseases to chronic non-communicable diseases, such as cardiovascular disease (CVD). The disease burden caused by CVD is a serious public health problem in China.^{6 7} It is suggested that this growing disease burden is driven by social macro factors^{8 9} such as urbanisation and ageing. Previous studies into the impact of urbanisation on health have focused on the health of migrants from rural to urban areas, but rarely on that of in situ urbanised rural residents. This is also true for risk factors associated with CVD. Therefore, research on

changes in CVD risk factors following the tracking of the health indicators for each in situ urbanised resident in China is needed.^{10–12}

In 2008, Beijing launched an unprecedented urbanisation project which involved the demolition and transformation of the urban–rural fringe area.¹³ The project involved nine districts, 108 villages and approximately 117 km². The intention was to demolish all old villages in 2–3 years. Chaoyang District is the largest urban area in Beijing, with a permanent population of 3.6 million. By the end of 2013, 102 000 households and 208 000 rural residents in the district's urban–rural fringe area moved into new high-rise residential communities, thus undergoing in situ urbanisation. Not only were living conditions improved, but income increased due to compensation, while considerable changes were made to lifestyles, such as the use of central heating instead of coal. Most residents were no longer engaged in agricultural work but instead relied on renting to make a profit, since the location of the capital increased housing values. Previously, villagers socialised by playing mahjong and drinking. However, to improve health literacy and enrich the cultural life of the residents who moved back, Chaoyang launched the 'citizenisation' of farmers project, which comprised fitness training courses, disease prevention, flower arrangement and handwork.

These changes in lifestyle and behaviour may effect CVD risk factors including hypertension diabetes, dyslipidaemia, obesity and physical activity. Previous studies confirmed that urbanisation is a double-edged sword for health.^{3 49–15} Urbanisation offers health benefits including access to services and education, higher incomes and living conditions. However, it also poses risks, such as pollution, transition to Western-style diets and sedentary lifestyles.

So what are the changes and characteristics in CVD risks during in situ urbanisation? This report expands the literature by using longitudinal data from 2010 to 2017 to depict changes and characteristics in CVD risks factors of in situ urbanised rural residents aged 35–64 in the Chaoyang District of Beijing.

MATERIALS AND METHODS

Study design and participants

Hongbo community in the Chaoyang District is located in the southeast of Beijing. It is a high-rise building community designed by Xiaohongmen Township in Chaoyang district for local land requisitioning and returning rural residents. Since 2002, the community has developed six subcommunities, of which area C was the first to be completed, in 2009. From January to June 2010, the first group of returning rural residents from the Xiaohongmen Township moved back to area C of the community, which was 2 km away from the original residence.

In 2010, China's national centre for CVD initiated a nationwide, multicentre study of cardiovascular risk factors for the middle-aged and elderly population. The

Xiaohongmen Township in Chaoyang District was a unique area for focusing on an urbanised population in this study. We used a cluster sampling method to select five out of nine buildings, the highest of which had 28 floors, in area C. We then surveyed 1000 returning residents aged 35–64 in July 2010. The detailed methods of this baseline survey have been described previously.¹⁶ A total of 942 (94.2%) residents provided complete baseline information in 2010. Of the 942 participants, 59 (6.3%) refused to participate in the follow-up study, 87 (9.2%) could not be contacted, 6 (0.6%) died before 2017, 790 (83.9%) participated in the follow-up survey (2017), 131 (13.9%) were excluded as they did not provide a blood specimen and attend a physical examination, and 19 (2.0%) were beyond the age range of the analysis. This resulted in a final sample of 640 (67.9%) participants who had provided complete data both at baseline and follow-up.

Data collection

The survey was conducted according to the unified implementation plan. Participants' demographic and clinical information, family history and lifestyles were collected by trained interviewers using internationally standardised methods.^{17 18} Written informed consent was obtained from each participant prior to data collection.

Physical examinations and blood specimens

Brachial blood pressure (BP) and central BP (CBP) were measured three times using a conventional mercury sphygmomanometer and the BPro device with A-Pulse CASP software (Health STATS, Singapore) after each participant rested for 5 min. The BPro device with A-Pulse CASP software showed an accurate agreement in CBP compared with invasively measured CBP.^{19 20} The mean of the three measurements was used for analysis. Height was measured to the nearest 0.5 cm without shoes, using a standard right-angle device and a fixed measurement tape. Body weight without heavy clothes, percentage body fat (PBF) and Visceral Fat Index (VFI) were measured using an Omron body fat and weight measurement device (V-body HbF-359, Omron, Kyoto, Japan). Methods of blood collection and testing have been described previously.¹⁶ Biochemical indexes involve total cholesterol (TC), triglyceride (TG), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C) and fasting plasma glucose (FPG).

Definitions

Hypertension was defined as a mean systolic BP ≥ 140 mm Hg or a mean diastolic BP ≥ 90 mm Hg or self-reported history of hypertension. Diabetes was defined as a fasting plasma glucose level of at least 7.0 mmol/L or self-reported diabetic history. Dyslipidaemia was defined according to the following measurements: TC ≥ 6.22 mmol/L, TG ≥ 2.26 mmol/L, HDL-C < 1.04 mmol/L or LDL-C ≥ 4.14 mmol/L. Body mass index (BMI: kg/m²)

Table 1 General characteristics of participants in 2010 and 2017

Characteristics	2010 (n=942)	2017 (n=640)	P value
Demographic characteristics			
Sex, n (%)			>0.05
Male	415 (44.1)	273 (42.7)	
Female	527 (55.9)	367 (57.3)	
Age groups, n (%)			<0.001
35–44	218 (23.1)	18 (2.8)	
45–54	369 (39.2)	170 (26.6)	
55–64	355 (37.7)	452 (70.6)	
Marital status, n (%)			>0.05
Married/living with partner	903 (95.9)	601 (93.9)	
Unmarried/not living with partner	39 (4.1)	39 (6.1)	
Education, n (%)			>0.05
Below high school graduation	767 (81.4)	535 (83.6)	
High school graduation and above	175 (18.6)	105 (16.4)	
Income, n (%)			<0.001
Below middle	644 (68.4)	108 (16.9)	
Middle and above	298 (31.6)	532 (83.1)	
Occupation, n (%)			<0.001
Professional/managerial	113 (12.0)	75 (11.7)	
Farmer	296 (31.4)	161 (25.2)	
Worker	36 (3.8)	8 (1.3)	
Unemployed	301 (32.0)	266 (41.6)	
Others	196 (20.8)	130 (20.3)	
Insurance, n (%)			<0.001
Urban basic medical insurance	219 (23.2)	236 (36.9)	
New Rural Cooperative Medical Scheme	606 (64.3)	395 (61.7)	
Others	117 (12.5)	9 (1.4)	
Lifestyles			
Smoking, n (%)	236 (25.1)	128 (20.0)	<0.05
Drinking, n (%)	184 (19.5)	127 (19.8)	>0.05
Effective exercise, n (%)	259 (27.5)	277 (43.3)	<0.001
Clinical index			
SBP, mm Hg, mean (SD)	131.97 (17.84)	134.72 (16.33)	<0.01
DBP, mm Hg, mean (SD)	83.03 (10.94)	84.97 (13.43)	<0.01
CBP, mm Hg, mean (SD)	121.69 (16.87)	127.66 (15.31)	<0.001
FPG, mmol/L, mean (SD)	5.79 (1.18)	6.19 (1.89)	>0.05
TC, mmol/L, mean (SD)	5.20 (0.98)	5.1 (1.27)	>0.05
TG, mmol/L, mean (SD)	1.39 (1.11)	1.81 (1.68)	>0.05
LDL-C, mmol/L, mean (SD)	3.10 (0.85)	3.08 (0.92)	>0.05
HDL-C, mmol/L, mean (SD)	1.32 (0.30)	1.37 (0.33)	<0.01
BMI, kg/m ² , mean (SD)	26.14 (3.57)	26.04 (3.59)	>0.05
PBF, %, mean (SD)	31.40 (5.89)	32.47 (5.65)	<0.001
VFI, mean (SD)	11.25 (4.93)	11.9 (5.07)	<0.05
Hypertension, n (%)	424 (45.0)	409 (63.9)	<0.001
Diabetes, n (%)	189 (20.1)	164 (25.6)	<0.01
Dyslipidaemia, n (%)	331 (35.1)	270 (42.2)	<0.01
Overweight and obesity, n (%)	697 (74.0)	471 (73.6)	>0.05

Continued

Table 1 Continued

Characteristics	2010 (n=942)	2017 (n=640)	P value
Family history			
Family history of hypertension, n (%)	476 (50.5)	330 (51.6)	>0.05
Family history of dyslipidaemia, n (%)	119 (12.6)	79 (12.3)	>0.05
Family history of diabetes, n (%)	184 (19.5)	126 (19.7)	>0.05

BMI, body mass index; CBP, central blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; PBF, percentage body fat; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride; VFI, visceral fat index.

was categorised according to Chinese-specific criteria (overweight: ≥ 24 and < 28 kg/m²; obesity: ≥ 28 kg/m²).²¹

Smoking was defined as the use of at least 20 packets of cigarettes or 0.5 kg leaf tobacco in participants' lifetime or smoking at least one cigarette per day at least for 1 year. Drinking was defined as drinking alcohol once a week. Effective exercise was defined as leisure-time exercise of at least 30 min per day, 5 days a week. Family history of hypertension, dyslipidaemia or diabetes was defined as with the following condition: First-degree relatives (parents, children, brothers or sisters) were definitely diagnosed with hypertension, dyslipidaemia or diabetes.

Statistical analysis

Descriptive analysis was undertaken to summarise demographic characteristics, lifestyle, clinical information and history of family illness. Variables were described according to their nature, using means (SD), frequency (percentages) or percentages (95% CI) for each subgroup. Differences in continuous variables were analysed using t-test, and prevalence values for categorical variables were compared using χ^2 test. Multiple linear regression analyses adjusted for sex, age group, marital status, education, income, occupation, insurance, lifestyle and family history were conducted to evaluate any changes to clinical indexes. Log-binomial models, adjusted for the variables mentioned above, were used to estimate prevalence rate ratios (PRRs).^{22–23} Overall risk was assessed based on the 10-year risk assessment method for atherosclerotic CVD (ASCVD), following the 2017 Chinese guidelines for CVD prevention.²⁴ As an additional analysis, we compared the main baseline characteristics of the samples not included (n=302) and included (n=640) in the final analysis. All tests of significance were two tailed and p values of < 0.05 were regarded as significant. Analyses were carried out using SAS V.9.3.

Patient and public involvement

Patients were not involved in setting the research questions, the design, outcome measures or implementation of the study. They were not asked to advise on interpretation or writing up of results. No patients were advised on dissemination of the study or its main results.

RESULTS

Sociodemographic, lifestyles and clinical characteristics

Table 1 shows that the proportion of women was higher than men both in 2010 and 2017. The proportion of residents aged 55–64 increased from 37.7% to 70.6%. Participants who married or were living with partner made up the majority of the group. Less than 20% of residents had a high school degree or above. Farmers, workers and the unemployed accounted for nearly two-thirds of this population. More than 60% were enrolled in the New Rural Cooperative Medical Scheme. The proportion of those with medium or greater levels of income rose from 31.6% in 2010 to 83.1% in 2017 ($p < 0.001$). Smoking rates in 2017 were lower than in 2010 ($p < 0.05$). Effective exercise rate and prevalence of hypertension, diabetes and dyslipidaemia were higher than in 2010 ($p < 0.01$), but there were no significant changes to overweight, obesity or drinking rates ($p > 0.05$). Differences in other clinical data or family history between 2010 and 2017 are also shown in table 1.

Prevalence of risk factors in different demographic groups

Detailed statistics relating to the prevalence of risk factors in different demographic groups are displayed in table 2. Overall, smoking rates among those with different demographic characteristics declined after 7 years. Drinking rates increased in the following populations: males; those aged 45–54; those who were married or living with partner; those receiving middle income and above; farmers; the unemployed and those with urban basic medical insurance. Effective exercise rates rose in all demographic characteristic subgroups. The prevalence of hypertension, diabetes and dyslipidaemia went up in all the subgroups aside from those who were unmarried/not living with partner and those with below middle income. Overweight and obesity rates showed a downward trend among females, the 45–64 age group, those of different marital statuses and education levels, farmers, people with below middle income and those who were enrolled in the New Rural Cooperative Medical Scheme. The differences in prevalence between subgroups of each sociodemographic feature are also shown in table 2. It is worth mentioning that both in 2010 and 2017, smoking, drinking, hypertension, and overweight and obesity rates were significantly higher in males than females ($p < 0.05$).

Table 2 Prevalence (95% CI) of risk factors in different demographic groups in 2010 (n=942) and 2017 (n=640)

Characteristics	Smoking		Drinking		Effective exercise		Hypertension	
	2010	2017	2010	2017	2010	2017	2010	2017
Sex								
Male	50.1 (45.3 to 54.9)	42.5 (36.6 to 48.4)	41.0 (36.3 to 45.7)	44.0 (38.1 to 49.9)	28.7 (24.3 to 33.1)	41.8 (35.9 to 47.7)	50.1 (45.3 to 54.9)	70.7 (65.3 to 76.1)
Female	5.3 (3.4 to 7.2)	3.3 (1.5 to 5.1)	2.7 (1.3 to 4.1)	1.9 (0.5 to 3.3)	26.6 (22.8 to 30.4)	44.4 (39.3 to 49.5)	41.0 (36.8 to 45.2)	58.9 (53.9 to 63.9)
P value	<0.001	<0.001	<0.001	<0.001	>0.05	>0.05	<0.01	<0.01
Age groups								
35–44	25.2 (19.4 to 31.0)	22.2 (6.0 to 48.0)	21.1 (15.7 to 26.5)	11.1 (1.0 to 35.0)	19.7 (14.4 to 25.0)	22.0 (6.0 to 48.0)	30.3 (24.2 to 36.4)	44.4 (21.4 to 67.4)
45–54	25.5 (21.1 to 29.9)	25.3 (18.8 to 31.8)	18.7 (14.7 to 22.7)	22.4 (16.1 to 28.7)	23.0 (18.7 to 27.3)	30.0 (23.1 to 36.9)	45.8 (40.7 to 50.9)	49.4 (41.9 to 56.9)
55–64	24.5 (20.0 to 29.0)	17.9 (14.4 to 21.4)	19.4 (15.3 to 23.5)	19.2 (15.6 to 22.8)	36.9 (31.9 to 41.9)	49.1 (44.5 to 53.7)	53.2 (48.0 to 58.4)	70.1 (65.9 to 74.3)
P value	>0.05	>0.05	>0.05	>0.05	<0.001	<0.001	<0.001	<0.001
Marital status								
Married/living with partner	25.7 (22.8 to 28.6)	21.1 (17.8 to 24.4)	20.0 (17.4 to 22.6)	21.0 (17.7 to 24.3)	27.4 (24.5 to 30.3)	43.3 (39.3 to 47.3)	45.3 (42.1 to 48.5)	64.1 (60.3 to 67.9)
Unmarried/not living with partner	10.3 (3.0 to 24.0)	2.6 (0.0 to 13.0)	7.7 (2.0 to 21.0)	2.6 (0.0 to 13.0)	30.8 (16.3 to 45.3)	43.6 (28.0 to 59.2)	38.5 (23.2 to 53.8)	61.5 (46.2 to 76.8)
P value	<0.05	<0.01	>0.05	<0.01	>0.05	>0.05	>0.05	>0.05
Education								
Below high school graduation	26.2 (23.1 to 29.3)	21.3 (17.8 to 24.8)	20.5 (17.6 to 23.4)	20.6 (17.2 to 24)	28.9 (25.7 to 32.1)	45.8 (41.6 to 50.0)	46.8 (43.3 to 50.3)	66.4 (62.4 to 70.4)
High school graduation and above	20.0 (14.1 to 25.9)	13.3 (6.8 to 19.8)	15.4 (10.1 to 20.7)	16.2 (9.2 to 23.2)	21.1 (15.1 to 27.1)	30.5 (21.7 to 39.3)	37.1 (29.9 to 44.3)	51.4 (41.8 to 61.0)
P value	>0.05	>0.05	>0.05	>0.05	<0.05	<0.01	<0.05	<0.01
Income								
Below middle	25.0 (21.7 to 28.3)	15.7 (8.8 to 22.6)	19.6 (16.5 to 22.7)	9.3 (3.8 to 14.8)	25.5 (22.1 to 28.9)	34.3 (25.3 to 43.3)	43.9 (40.1 to 47.7)	69.4 (60.7 to 78.1)
Middle and above	25.2 (20.3 to 30.1)	20.9 (17.4 to 24.4)	19.5 (15.0 to 24.0)	22 (18.5 to 25.5)	31.9 (26.6 to 37.2)	45.1 (40.9 to 49.3)	47.3 (41.6 to 53.0)	62.8 (58.7 to 66.9)
P value	>0.05	>0.05	>0.05	<0.01	<0.05	<0.05	>0.05	>0.05
Occupation								
Professional/managerial	31.0 (22.5 to 39.5)	28.0 (17.8 to 38.2)	29.2 (20.8 to 37.6)	28.0 (17.8 to 38.2)	6.2 (1.8 to 10.6)	17.3 (8.7 to 25.9)	38.9 (29.9 to 47.9)	53.3 (42.0 to 64.6)
Farmer	23.6 (18.8 to 28.4)	18.0 (12.1 to 23.9)	19.3 (14.8 to 23.8)	21.1 (14.8 to 27.4)	71.6 (66.5 to 76.7)	73.9 (67.1 to 80.7)	49.3 (43.6 to 55.0)	70.8 (63.8 to 77.8)
Worker	55.6 (39.4 to 71.8)	75.0 (35.0 to 97.0)	44.4 (28.2 to 60.6)	37.5 (9.0 to 76.0)	30.6 (15.5 to 45.7)	25.0 (3.0 to 65.0)	55.6 (39.4 to 71.8)	62.5 (24.0 to 91.0)
Unemployed	17.3 (13.0 to 21.6)	10.2 (6.6 to 13.8)	11.0 (7.5 to 14.5)	13.9 (9.7 to 18.1)	0 (0)	39.8 (33.9 to 45.7)	44.5 (38.9 to 50.1)	65.4 (59.7 to 71.1)
Others	30.1 (23.7 to 36.5)	34.6 (26.4 to 42.8)	23.0 (17.1 to 28.9)	24.6 (17.2 to 32.0)	14.8 (9.8 to 19.8)	28.5 (20.7 to 36.3)	40.8 (33.9 to 47.7)	58.5 (50.0 to 67.0)
P value	<0.001	<0.001	<0.001	<0.01	<0.001	<0.001	>0.05	<0.05
Insurance								

Continued

Table 2 Continued								
Characteristics	Smoking		Drinking		Effective exercise		Hypertension	
	2010	2017	2010	2017	2010	2017	2010	2017
Urban basic medical insurance	29.7 (23.6 to 35.8)	30.5 (24.6 to 36.4)	24.7 (19.0 to 30.4)	30.9 (25.0 to 36.8)	24.2 (18.5 to 29.9)	41.5 (35.2 to 47.8)	45.7 (39.1 to 52.3)	61.9 (55.7 to 68.1)
New Rural Cooperative Medical Scheme	23.2 (19.8 to 26.6)	13.7 (10.3 to 17.1)	16.2 (13.3 to 19.1)	13.4 (10.0 to 16.8)	32.3 (28.6 to 36.0)	43.8 (38.9 to 48.7)	46.7 (42.7 to 50.7)	65.1 (60.4 to 69.8)
Others	25.3 (17.4 to 33.2)	22.2 (3.0 to 60.0)	24.1 (16.4 to 31.8)	11.1 (0.0 to 48.0)	15.4 (8.9 to 21.9)	66.7 (30.0 to 93.0)	38.3 (29.5 to 47.1)	66.7 (30.0 to 93.0)
P value	>0.05	<0.001	<0.01	<0.001	<0.001	>0.05	>0.05	>0.05
Characteristics	Diabetes		Dyslipidaemia		Overweight and obesity			
Sex	2010	2017	2010	2017	2010	2017	2010	2017
Male	24.1 (20.0 to 28.2)	27.8 (22.5 to 33.1)	41.4 (36.7 to 46.1)	45.4 (39.5 to 51.3)	78.1 (74.1 to 82.1)	79.1 (74.3 to 83.9)	78.1 (74.1 to 82.1)	79.1 (74.3 to 83.9)
Female	16.9 (13.7 to 20.1)	24.0 (19.6 to 28.4)	30.2 (26.3 to 34.1)	39.8 (34.8 to 44.8)	70.8 (66.9 to 74.7)	69.5 (64.8 to 74.2)	70.8 (66.9 to 74.7)	69.5 (64.8 to 74.2)
P value	<0.01	>0.05	<0.001	>0.05	<0.05	>0.05	<0.05	<0.01
Age groups								
35–44	10.1 (6.1 to 14.1)	27.8 (7.1 to 48.5)	31.7 (25.5 to 37.9)	38.9 (16.4 to 61.4)	64.2 (57.8 to 70.6)	83.3 (66.1 to 100.0)	64.2 (57.8 to 70.6)	83.3 (66.1 to 100.0)
45–54	22.0 (17.8 to 26.2)	15.3 (9.9 to 20.7)	40.7 (35.7 to 45.7)	48.8 (41.3 to 56.3)	77.0 (72.7 to 81.3)	69.4 (62.5 to 76.3)	77.0 (72.7 to 81.3)	69.4 (62.5 to 76.3)
55–64	24.2 (19.7 to 28.7)	29.4 (25.2 to 33.6)	31.5 (26.7 to 36.3)	39.8 (35.3 to 44.3)	76.9 (72.5 to 81.3)	74.8 (70.8 to 78.8)	76.9 (72.5 to 81.3)	74.8 (70.8 to 78.8)
P value	<0.001	<0.01	<0.05	>0.05	<0.001	>0.05	<0.001	>0.05
Marital status								
Married/living with partner	19.6 (17.0 to 22.2)	25.5 (22.0 to 29.0)	35.2 (32.1 to 38.3)	42.9 (38.9 to 46.9)	73.5 (70.6 to 76.4)	73.0 (69.5 to 76.5)	73.5 (70.6 to 76.4)	73.0 (69.5 to 76.5)
Unmarried/not living with partner	30.8 (16.3 to 45.3)	28.2 (14.1 to 42.3)	33.3 (18.5 to 48.1)	30.8 (16.3 to 45.3)	84.6 (73.3 to 95.9)	82.1 (70.1 to 94.1)	84.6 (73.3 to 95.9)	82.1 (70.1 to 94.1)
P value	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
Education								
Below high school graduation	21.0 (18.1 to 23.9)	26.5 (22.8 to 30.2)	35.1 (31.7 to 38.5)	39.6 (35.5 to 43.7)	76.3 (73.3 to 79.3)	75.7 (72.1 to 79.3)	76.3 (73.3 to 79.3)	75.7 (72.1 to 79.3)
High school graduation and above	16.0 (10.6 to 21.4)	21.0 (13.2 to 28.8)	35.4 (28.3 to 42.5)	55.2 (45.7 to 64.7)	64.0 (56.9 to 71.1)	62.9 (53.7 to 72.1)	64.0 (56.9 to 71.1)	62.9 (53.7 to 72.1)
P value	>0.05	>0.05	>0.05	<0.01	<0.001	<0.01	<0.001	<0.01
Income								
Below middle	22.2 (19.0 to 25.4)	23.1 (15.2 to 31.0)	34.9 (31.2 to 38.6)	33.3 (24.4 to 42.2)	75.8 (72.5 to 79.1)	73.1 (64.7 to 81.5)	75.8 (72.5 to 79.1)	73.1 (64.7 to 81.5)
Middle and above	15.4 (11.3 to 19.5)	26.1 (22.4 to 29.8)	35.6 (30.2 to 41.0)	44.0 (39.8 to 48.2)	70.1 (64.9 to 75.3)	73.7 (70.0 to 77.4)	70.1 (64.9 to 75.3)	73.7 (70.0 to 77.4)
P value	<0.05	>0.05	>0.05	<0.05	>0.05	<0.05	>0.05	>0.05
Occupation								
Professional/managerial	19.5 (12.2 to 26.8)	21.3 (12 to 30.6)	38.9 (29.9 to 47.9)	57.3 (46.1 to 68.5)	69.9 (61.4 to 78.4)	77.3 (67.8 to 86.8)	69.9 (61.4 to 78.4)	77.3 (67.8 to 86.8)
Farmer	22 (17.3 to 26.7)	31.1 (23.9 to 38.3)	33.1 (27.7 to 38.5)	36 (28.6 to 43.4)	77.7 (73 to 82.4)	75.8 (69.2 to 82.4)	77.7 (73 to 82.4)	75.8 (69.2 to 82.4)

Continued

Table 2 Continued

Characteristics	Diabetes		Dyslipidaemia		Overweight and obesity	
	2010	2017	2010	2017	2010	2017
Worker	2.8 (0.0 to 15.0)	12.5 (0.0 to 53.0)	27.8 (13.2 to 42.4)	50 (16.0 to 84.0)	63.9 (48.2 to 79.6)	75.0 (35.0 to 97.0)
Unemployed	21.3 (16.7 to 25.9)	24.4 (19.2 to 29.6)	36.5 (31.1 to 41.9)	41.4 (35.5 to 47.3)	75.1 (70.2 to 80)	75.2 (70 to 80.4)
Others	18.9 (13.4 to 24.4)	24.6 (17.2 to 32)	35.2 (28.5 to 41.9)	42.3 (33.8 to 50.8)	70.9 (64.5 to 77.3)	65.4 (57.2 to 73.6)
P value	>0.05	>0.05	>0.05	<0.05	>0.05	>0.05
Insurance						
Urban basic medical insurance	16.9 (11.9 to 21.9)	26.7 (21.1 to 32.3)	33.3 (27.1 to 39.5)	44.1 (37.8 to 50.4)	71.7 (65.7 to 77.7)	76.7 (71.3 to 82.1)
New Rural Cooperative Medical Scheme	20.9 (17.7 to 24.1)	25.1 (20.8 to 29.4)	36.9 (33.1 to 40.7)	41.8 (36.9 to 46.7)	74.9 (71.4 to 78.4)	71.4 (66.9 to 75.9)
Others	21.6 (14.1 to 29.1)	22.2 (3.0 to 60.0)	31.5 (23.1 to 39.9)	11.1 (0.0 to 48.0)	74.1 (66.2 to 82)	88.9 (52.0 to 100.0)
P value	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05

Changes of CVD risk factors from 2010 to 2017

Table 3 shows that SBP, DBP, CBP, HDL-C, PBF and VFI all rose after 7 years when only considering time. Multiple linear regression suggested that after adjusting for demographic and family history factors, DBP was elevated by a mean of 3.55 mm Hg, CBP increased by a mean of 4.39 mm Hg, while TC decreased by a mean of 0.29 mmol/L.

Table 4 demonstrates that when compared with 2010, the 2017 prevalence of hypertension (PRR=1.41), diabetes (PRR=1.36), dyslipidaemia (PRR=1.19) and effective exercise (PRR=1.57) increased markedly when only time was considered. Log-binomial models results indicated that after adjusting for demographic factors, lifestyles and family histories, the PRR of hypertension between 2017 and 2010 was 1.25 ($p<0.05$), while other risk factors were not significantly changed.

Overall risk assessment of ASCVD

In 2017, the 10-year risk of ASCVD was increased in 29.8% of individuals and decreased in 6.1% of individuals. In addition, 20.6% of the original low-risk people, 36.3% of the original moderate-risk participants and 11.5% of the original high-risk individuals went up to high or extremely high-risk level. In contrast, 20.4% of the original moderate-risk people and 8.4% of the original high-risk participants went down to lower levels. For those with an original moderate or high risk, the proportion of people with an increased risk was higher than that of people with a reduced risk (see table 5).

Drop-out effects

Table 6 shows the analysis of the baseline characteristics of the valid ($n=640$) and invalid samples ($n=302$) in 2017. There were no statistical differences in the distribution of socioeconomic characteristics, lifestyles or disease characteristics between the two samples ($p>0.05$), indicating that 302 participants not included in final analysis had a similar CVD risk patterns as those who were in the follow-up study.

DISCUSSION

This is a rare longitudinal study which uses reliable clinical data to explore the changes in cardiovascular health risks of in situ urbanised rural residents. The research provides valuable evidence regarding changes in CVD risk factors over 7 years in an understudied population from the aspects of clinical indicators, prevalence rates and overall risk. Our study demonstrated that in addition to changes in living conditions and ageing, income levels improved significantly over past 7 years. Results revealed that serum biochemicals and physical examination indexes of research population had markedly changed. This is mainly reflected in increases of BP (DBP, CBP) and improved TC. The increased overall risks of CVD, especially the prevalence of hypertension, were major health issues for this population.

Table 3 Changes of serum biochemicals and physical examination indexes during 7 years

Indexes	Mean		Differences (95% CI)	Adjusted differences (95% CI)
	2010 (n=640)	2017 (n=640)		
SBP, mm Hg	132.16	134.72	2.55 (0.68 to 4.42)*	1.46 (-0.90 to 3.82)
DBP, mm Hg	83.27	84.97	1.70 (0.36 to 3.03)*	3.55 (1.86 to 5.23)*
CBP, mm Hg	121.86	127.66	5.80 (4.04 to 7.55)*	4.39 (2.17 to 6.61)*
FPG, mmol/L	6.28	6.19	-0.09 (-0.29 to 0.11)	-0.16 (-0.41 to 0.10)
TC, mmol/L	5.22	5.10	-0.13 (-0.25 to 0.01)	-0.29 (-0.46 to -0.13)*
TG, mmol/L	1.76	1.81	0.06 (-0.11 to 0.23)	0.02 (-0.24 to 0.20)
LDL-C, mmol/L	3.12	3.08	-0.04 (-0.14 to 0.06)	-0.13 (-0.26 to 0.01)
HDL-C, mmol/L	1.33	1.37	0.05 (0.01 to 0.08)*	0.03 (-0.01 to 0.07)
BMI, kg/m ²	26.17	26.04	-0.13 (-0.52 to 2.56)	-0.28 (-0.78 to 0.23)
PBF, %	31.67	32.47	0.80 (0.16 to 1.43)*	-0.01 (-0.61 to 0.61)
VFI	11.34	11.90	0.57 (0.02 to 1.11)*	0.04 (-0.59 to 0.67)

Models were adjusted for time (2017=1, 2010=0), sex (male=1, female=0), age groups (35–44=1, 45–54=2, 55–64=3), marital status (married/living with partner=1, unmarried/not living with partner=0), education (\geq high school graduation=1, <high school graduation=0), income (middle and above=1, below middle=0), professional/managerial (yes=1, no=0), farmer (yes=1, no=0), worker (yes=1, no=0), unemployed (yes=1, no=0), Urban Basic Medical Insurance (yes=1, no=0), New Rural Cooperative Medical Scheme (yes=1, no=0), smoking (yes=1, no=0), drinking (yes=1, no=0), effective exercise (yes=1, no=0), overweight and obesity (yes=1, no=0), family history of hypertension (yes=1, no=0), family history of dyslipidaemia (yes=1, no=0), family history of diabetes (Yes=1, No=0).

*Differences between 2017 and 2010, significant at $p < 0.05$, the reference group was baseline in 2010.

BMI, body mass index; CBP, central blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; PBF, percentage body fat; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride; VFI, visceral fat index.

As a part of multicentre research, the survey followed the unified implementation plan for data collection and quality control, ensuring the data's reliability. Related studies^{25–27} have shown that standardised prevalence rates of hypertension, hyperglycaemia, obesity and high TC among the people of Hongbo community in Chaoyang District were in first or second place when compared with other subgroups in the multicentre study, indicating a high risk of CVD for this population. This is also

supported by comparisons with other national surveys in China.^{28–31}

Another finding is that compared with an investigation of 9-year changes of metabolic syndrome in a newly formed urban community in Shanghai, same upward trends in prevalence of hypertension and diabetes were observed and the increase of hypertension in our study is higher than that in Shanghai. However, there were also obvious differences in trends of FPG, BP and TG between the two

Table 4 Changes of prevalence of main risk factors during 7 years

Outcomes	Prevalence		PRR (95% CI)	Adjusted PRR (95% CI)
	2010 (n=640)	2017 (n=640)		
Smoking, %	23.60	20.00	0.85 (0.69 to 1.04)	0.92 (0.73 to 1.16)
Drinking, %	18.00	19.80	1.10 (0.88 to 1.39)	1.08 (0.87 to 1.35)
Effective exercise, %	27.50	43.30	1.57 (1.35 to 1.84)*	0.98 (0.83 to 1.15)
Hypertension, %	45.30	63.90	1.41 (1.27 to 1.56)*	1.25 (1.10 to 1.42)*
Diabetes, %	18.90	25.60	1.36 (1.10 to 1.67)*	1.28 (0.99 to 1.64)
Dyslipidaemia, %	35.50	42.20	1.19 (1.04 to 1.37)*	1.11 (0.93 to 1.32)
Overweight and obesity, %	74.40	73.60	0.99 (0.93 to 1.06)	0.95 (0.88 to 1.03)

Models were adjusted for time (2017=1, 2010=0), sex (male=1, female=0), age groups (35–44=1, 45–54=2, 55–64=3), marital status (married/living with partner=1, unmarried/not living with partner=0), education (\geq high school graduation=1, <high school graduation=0), income (middle and above=1, below middle=0), professional/managerial (yes=1, no=0), farmer (yes=1, no=0), worker (yes=1, no=0), unemployed (yes=1, no=0), Urban Basic Medical Insurance (yes=1, no=0), New Rural Cooperative Medical Scheme (yes=1, no=0), smoking (yes=1, no=0), drinking (yes=1, no=0), effective exercise (yes=1, no=0), overweight and obesity (yes=1, no=0), family history of hypertension (yes=1, no=0), family history of dyslipidaemia (yes=1, no=0), family history of diabetes (Yes=1, No=0).

*PRR between 2017 and 2010 significant at $p < 0.05$, the reference group was baseline in 2010.

PRR, prevalence rate ratio.

Table 5 The changes in the risk level of ASCVD from 2010 to 2017

Risk level in 2010	Risk level in 2017							
	Low		Moderate		High		Extremely high	
	N	% (95% CI)	N	% (95% CI)	N	% (95% CI)	N	% (95% CI)
Low	187	59.4 (53.9 to 64.8)	63	20.0 (15.6 to 24.4)	55	17.5 (13.1 to 21.7)	10	3.2 (1.2 to 5.1)
Moderate	23	20.4 (12.9 to 27.8)	49	43.4 (34.2 to 52.5)	27	23.9 (16.0 to 31.8)	14	12.4 (6.3 to 18.5)
High	7	3.7 (1.0 to 6.3)	9	4.7 (1.7 to 7.7)	153	80.1 (74.4 to 85.8)	22	11.5 (7.0 to 16.0)
Extremely high	0	0.0 (0.0 to 16.0)	0	0.0 (0.0 to 16.0)	0	0.0 (0.0 to 16.0)	21	100

ASCVD, atherosclerotic cardiovascular disease.

studies. The regional differences of major cardiovascular risk factors in China had been confirmed by numerous researchers, which indicated that diversity was closely related to the natural geographical environment, social and economic development level, lifestyle choices (such as dietary habits) and the national cultural characteristics of different groups.^{27–29 32 33} Our findings also show that although FPG did not demonstrate a significant change, the prevalence of diabetes dramatically increased. This suggests that the increased prevalence is mainly due to the increased number of self-reported patients and their higher treatment rates, which is closely related to their greater ability to access high-quality health services in recent years.³⁴

Moreover, we found that CBP increased more than peripheral BP. There was evidence that the heart, kidneys and cerebral arteries are primarily related to aortic pressure rather than brachial arteries. This means that CBP is more closely related to cardiovascular risk than brachial artery pressure.³⁵ CBP may be a more direct predictor of cardiovascular events and target-organ damage than brachial BP, which tends to independently predict CVD.^{36 37} Strong Heart research has also suggested that CBP is a better predictor of future cardiovascular events in healthy individuals than brachial artery pressure.³⁸ A follow-up study of 9.5 years demonstrated that people with elevated brachial artery BP and low CBP did not have a high cardiovascular risk, known as ‘pseudohypertension’.³⁹ Therefore, the value of applying CBP for identifying true and false hypertension in young people has been included in the European hypertension guidelines of 2013.^{40 41} Authors of future Chinese hypertension guidelines should also pay attention to CBP. Based on the evidence above, we believe that the risk of CVD for in situ urbanised residents rose faster than expected.

There is also a bright side to our findings. We observed a favourable trend in effective exercise rate regardless of other factors. In fact, improvements to living conditions not only included housing conditions, but also surrounding supporting facilities. In the newly built community, fitness paths, health trails, gyms, health education activity rooms and other facilities provided a better supportive environment for residents to engage in regular physical activity. Findings from the Pan-European Study⁴² indicated that people who live close to a park

are more likely to exercise than those who do not. Built environment characteristics are, therefore, important correlates of physical activity.⁴³

Another finding was connected to the limitation⁴⁴ of BMI in CVD risk assessment. Results showed that PBF and VFI may rise significantly without any change in BMI, which is an indirect measure of body fat mass and may not accurately reflect cardiovascular risks. However, PBF is a robust measure of obesity and a better indicator of cardiovascular risk factor than BMI for both adults and adolescents.^{45 46} VFI is also a precise, dependable predictor for evaluating visceral adiposity.⁴⁷ Generally, visceral deposits of body fat are considered to play a vital role in CVD. Our research indicated that there was ‘invisible obesity’ in the research population.

Several limitations of our study should be considered. First, the true burden of risk factors in the research population may be underestimated, since inclusion of individuals in a cohort study might elevate the level of attention those people pay to health risks. Second, the issue of whether differences of changes and characteristics in our results come from in situ urbanisation has not been discussed. A suitable control group is needed for in-depth analysis. Third, as data from six participants with risk factors who died during the course of the study were not included in the analysis, this could mean that final results were underestimated. In addition, dietary factors were not included and information on lifestyles, family history and income was based on self-report, which may be subject to reporting bias and recall bias. Authors of future research should consider these factors. Finally, we acknowledge the limitations of cluster sampling and extrapolation.

In situ urbanisation is one of the most important forms of urbanisation in China. With the acceleration of urbanisation, the in situ urbanised population is increasing rapidly. Unlike our research, most studies about the changes of CVD risk factors focus on rural-to-urban migration and rarely on in situ urbanised rural residents.^{10–12} Our research puts more emphasis on objective indicators, meaning our results have increased objectivity and authenticity compared with research based on self-reports of health status.^{48–50} In addition, the naturalistic, longitudinal study design, the availability of data over an extended observation period as well as the rigorous

Table 6 Main baseline characteristics of the valid and invalid samples in 2017

Characteristics	Invalid samples in 2017 (n=302)	Valid samples in 2017 (n=640)	P value
Demographic characteristics			
Sex, n (%)			>0.05
Male	160 (53.0)	367 (57.3)	
Female	142 (47.0)	273 (42.7)	
Age groups, n (%)			>0.05
35–44	78 (25.8)	140 (21.9)	
45–54	107 (35.4)	262 (40.9)	
55–64	117 (38.7)	238 (37.2)	
Marital status, n (%)			>0.05
Married/living with partner	289 (95.7)	614 (95.9)	
Unmarried/not living with partner	13 (4.3)	26 (4.1)	
Education, n (%)			>0.05
Below high school graduation	242 (80.1)	525 (82.0)	
High school graduation and above	60 (19.9)	115 (18.0)	
Income, n (%)			>0.05
Below middle	195 (64.6)	449 (70.2)	
Middle and above	107 (35.4)	191 (29.8)	
Occupation, n (%)			>0.05
Professional/managerial	35 (11.6)	78 (12.2)	
Farmer	89 (29.5)	207 (32.3)	
Worker	11 (3.6)	25 (3.9)	
Unemployed	93 (30.8)	208 (32.5)	
Others	74 (24.5)	122 (19.1)	
Insurance, n (%)			>0.05
Urban Basic Medical Insurance	69 (22.8)	150 (23.4)	
New Rural Cooperative Medical Scheme	203 (67.2)	403 (63.0)	
Others	30 (10.0)	87 (13.6)	
Lifestyles			
Smoking, n (%)	85 (28.1)	151 (23.6)	>0.05
Drinking, n (%)	69 (22.8)	115 (18.0)	>0.05
Effective exercise, n (%)	83 (27.5)	176 (27.5)	>0.05
Hypertension, n (%)	134 (44.4)	290 (45.3)	>0.05
Diabetes, n (%)	68 (22.5)	121 (18.9)	>0.05
Dyslipidaemia, n (%)	104 (34.4)	227 (35.5)	>0.05
Overweight and obesity, n (%)	221 (73.2)	476 (74.4)	>0.05
Family history			
Family history of hypertension, n (%)	146 (48.3)	330 (51.6)	>0.05

Continued

Table 6 Continued

Characteristics	Invalid samples in 2017 (n=302)	Valid samples in 2017 (n=640)	P value
Family history of dyslipidaemia, n (%)	40 (13.2)	79 (12.3)	>0.05
Family history of diabetes, n (%)	58 (19.2)	126 (19.7)	>0.05

statistical methods all enhance the dependability of our findings. Additionally, this research is also a part of the National Key Research and Development Program of China. In the future, we will conduct research to assess the influence of social determinants on cardiovascular risk factors. Changes in CVD risk are easily influenced by social determinants, such as socioeconomic status (SES) and residential environments. In different stages of urbanisation, CVD risks level could be distinct since risk response capacity varies among urbanised residents with different SES. In addition, whether residential environments characterised by increased socioeconomic resources, access to healthy foods and more resources for physical activity have a measurable effect on CVD and the density of CVD risk factors is also worth exploring.

CONCLUSIONS

Based on a prospective study design, we found that CVD risk was markedly augmented for in situ urbanised rural residents aged 35–64 years in the Chaoyang District of Beijing. Risk factors for CVD are becoming more prevalent. Between 2010 and 2017, BP levels and the increase of hypertension among this population should be further explored. Further steps for CVD risk factor control among this population should be emphasised. Additionally, macro social determinants which may predict differences in CVD risk should be addressed.

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