Agreement Between China-PAR and ICVD-10 and Overlap of Cardiovascular High-Risk Identification Pathways Among Community-Screened Adults in Nanjing, Eastern China

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ABSTRACT

Objective: To describe the proportion of screened adults aged 35–79 years identified as being at high risk of cardiovascular disease (CVD) in five selected areas of Nanjing; compare classifications by the Prediction for ASCVD Risk in China (China-PAR) and the 10-year ischemic cardiovascular disease risk assessment for Chinese adults (ICVD-10) among participants without prior CVD; characterize the four prespecified identification sources and their overlap; and explore factors associated with multiple-source identification.

Methods: We analyzed cross-sectional screening data collected in 2020–2021. Of 38,488 eligible residents invited, 38,427 completed screening (response rate, 99.84%). High-risk identification was based on prior CVD, severe dyslipidemia, China-PAR risk ≥10%, or ICVD-10 risk ≥10%. Paired classifications and exact intersections were described. Confidence intervals, group comparisons, and an exploratory logistic regression of multiple-source identification used community-cluster robust variance.

Results: Among 38,427 screened participants, 8,905 were identified as being at high risk (23.17%; cluster-robust 95% confidence interval [CI] = 21.80%–24.61%). China-PAR classified 3,957 of 35,814 participants without prior CVD as high risk (11.05%), and ICVD-10 classified 3,966 of 35,815 as high risk (11.07%). Among 35,814 participants with both classifications, 30,660 were non-high risk by both tools, 2,768 were high risk by both, 1,189 were high risk only by China-PAR, and 1,197 were high risk only by ICVD-10; discordant classifications accounted for 46.29% of participants classified as high risk by either tool. Among 8,904 high-risk participants with complete source data, 2,980 (33.47%) met at least two criteria. In exploratory cluster-robust regression, male sex, older age, study area, and harmful alcohol use were associated with multiple-source identification; insufficient leisure-time physical activity was not statistically significant (adjusted odds ratio [aOR] = 1.14; 95% CI = 0.996–1.32; $P = 0.057$).

Conclusions: The four prespecified identification sources overlapped substantially in this screened sample. China-PAR and ICVD-10 produced similar overall high-risk proportions, but discordant classifications for nearly half of participants classified as high risk by either tool. Screening registries should retain the specific triggering source and the risk tool used to support appropriate verification and follow-up.

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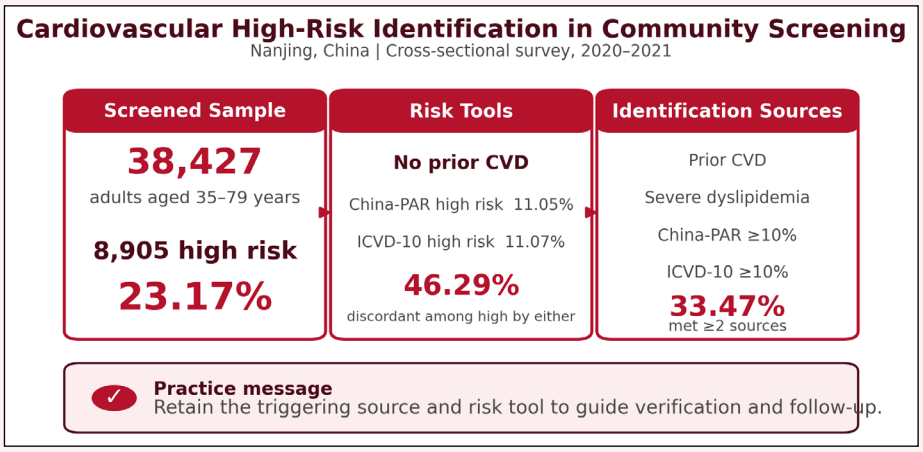
KEYWORDS:
cardiovascular disease; high-risk population; China-PAR; ICVD-10; cross-sectional study

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LAY SUMMARY

- Community screening may identify cardiovascular high risk from prior disease, very high cholesterol, or one of two Chinese risk tools.
- In five selected areas of Nanjing, 23.17% of screened adults were high risk; China-PAR and ICVD-10 gave similar totals, but nearly half of those high risk by either tool were classified differently.
- Recording why a person was labeled high risk—and which tool was used—can direct appropriate review and follow-up.

GRAPHICAL ABSTRACT



Cardiovascular high-risk identification pathways and key findings in community screening.

INTRODUCTION

Cardiovascular disease (CVD) is a leading cause of death and disease burden worldwide and in China (1, 2, 22). Prevention has therefore moved beyond single risk factors toward overall cardiovascular risk, which can guide intervention intensity and follow-up. The World Health Organization (WHO) CVD risk charts, HEARTS technical package, and European prevention guideline all support risk-based management in primary care, alongside intensified management for established CVD or markedly abnormal individual factors (3–5, 23, 31, 32).

The Prediction for ASCVD Risk in China (China-PAR) estimates 10-year atherosclerotic cardiovascular disease (ASCVD) risk from prospective Chinese cohorts (6), whereas ICVD-10 estimates 10-year fatal and nonfatal ischemic CVD risk in Chinese adults (7). Differences in derivation cohorts, outcomes, predictors, and risk mapping may produce different individual classifications despite similar population-level high-risk proportions (24, 25). Prior CVD and severe dyslipidemia provide two additional, clinically distinct high-risk pathways.

Chinese studies have mainly reported risk-category distributions, high-risk proportions from a single tool, or conventional risk-factor clustering (8–10). Evidence is limited on paired China-PAR and ICVD-10 classifications and their exact overlap with prior CVD and severe dyslipidemia. We examined these four prespecified sources and explored factors associated with multiple-source identification to inform post-screening verification and follow-up. The screening framework and principal findings are summarized in the Graphical Abstract.

METHODS

STUDY POPULATION AND DATA SOURCE

A multistage stratified cluster sampling design was used. At the first stage, five areas of Nanjing—Jianye District, Pukou District, Lishui District, Gaochun District, and Jiangbei New Area—were purposively selected according to geographic location and economic development; this stage was not probability-proportional to the population of all Nanjing districts. Within

the selected areas, all subdistricts or townships were included. Four residents' committees or administrative villages were selected from each subdistrict or township by systematic random sampling after ranking by population size. Each selected community or village was divided into resident or villager groups containing at least 60 households; two groups were selected by simple random sampling, and 60 households were randomly selected from each group. All permanent residents aged 35–79 years who had lived locally for at least six months in the selected households were invited to participate (11). Of 38,488 eligible residents invited, 38,427 completed screening, giving a response rate of 99.84%; individual characteristics of nonrespondents were unavailable.

The study protocol was reviewed and approved by the Ethics Committee of the Nanjing Center for Disease Control and Prevention (approval no. PJ2020-B001-01). Written informed consent was obtained from all participants.

DATA COLLECTION AND DEFINITIONS

Questionnaire survey

A questionnaire designed by the National Center for Chronic and Noncommunicable Disease Control and Prevention and Chinese Center for Disease Control and Prevention was administered face-to-face by uniformly trained interviewers. Information was collected on sex, age, study area, education, smoking, alcohol consumption, sleep, diet, leisure-time physical activity, family history of CVD, and previous diagnoses and medication use. Current smoking was defined as smoking at the time of the survey and having smoked continuously or cumulatively for at least six months; former smokers were included with never smokers in the non-current-smoking category. Nighttime sleep duration was classified as short (<7 h), recommended (7 to <9 h), or long (≥9 h). The healthy-diet score assigned 1 point for each of six criteria: daily fresh fruit, daily fresh vegetables, daily whole grains, fish or other seafood at least one day per week, beans or bean products at least four days per week, and red meat fewer than seven days per week. Scores ranged from 0 to 6, and a score ≥4 defined a healthy diet (12). Sufficient leisure-time physical activity was defined as at least 150 minutes per week (13); this measure did not include occupational, transport, or household activity. Harmful alcohol use was defined as a mean daily alcohol intake of at least 61 g for men or at least 41 g for women.

Physical examination

Uniformly trained staff measured height, weight, waist circumference, and blood pressure. Height and weight were recorded to the nearest 0.1 cm and 0.1 kg, respectively. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Participants were categorized as underweight (BMI <18.5 kg/m^2), normal weight (18.5–23.9 kg/m^2), overweight (24.0–27.9 kg/m^2), or obese (≥28.0 kg/m^2). Waist circumference was measured midway between the anterior superior iliac crest and the lower border of the 12th rib. Central obesity was defined as a waist circumference of at least 90 cm in men or at least 85 cm in women (14). Participants were asked to avoid vigorous activity for 30 minutes before blood pressure measurement. Blood pressure was measured three times at one-minute intervals using an Omron HBP-1300 electronic monitor (Omron Corporation, Japan); the mean of the second and third readings was used. Hypertension was defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg, a previous diagnosis at a township health center, community health service center, or higher-level medical institution, or use of antihypertensive medication within the preceding two weeks (15).

Laboratory measurements

After an 8- to 12-h fast, 6 mL of venous blood was analyzed at each site's designated laboratory for fasting plasma glucose (FPG), glycated hemoglobin (HbA1c), total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C). HbA1c was unavailable in Lishui District. Diabetes was defined by physician diagnosis at a township health center/community health service center or higher-level institution, FPG ≥7.0 mmol/L, or, where available, HbA1c ≥6.5% (14). Dyslipidemia was TC ≥6.2 mmol/L, TG ≥2.3 mmol/L, LDL-C ≥4.1 mmol/L, HDL-C <1.0 mmol/L, or lipid-lowering treatment in the previous two weeks (16).

Identification of participants at high risk of CVD

Participants were classified as high risk if they met any criterion: (1) myocardial infarction or stroke diagnosed at a secondary-level or higher institution, or previous percutaneous coronary intervention or coronary artery bypass grafting; (2) fasting TC ≥7.2 mmol/L or LDL-C ≥4.9 mmol/L; (3) China-PAR 10-year risk ≥10%; or (4) ICVD-10 absolute risk ≥10% (11, 17). Diagnoses recorded only at township-level institutions did not meet the prior-CVD criterion.

Risk stratification and sources of high-risk identification

China-PAR and ICVD-10 were applied only to participants without prior CVD. Risks were classified as low (<5%), intermediate (5% to <10%), or high (≥10%) (6, 7, 17). After both assessments, prior CVD, severe dyslipidemia, China-PAR high risk, and ICVD-10 high risk constituted four identification sources. Exact mutually exclusive combinations and source counts (1 vs. ≥2) were examined; the source count was not treated as a prognostic score.

STATISTICAL ANALYSIS

Analyses used IBM SPSS Statistics 25.0 and Python 3.12. Continuous variables are mean ± standard deviation (SD) or median (25th–75th percentile), and categorical variables are *n* (%). Because first-stage area selection was nonprobability based and validated sampling weights were unavailable, estimates were unweighted. Community clusters were defined by area, subdistrict/township, community health service center, and residents' committee/administrative village; 151 clusters were represented. Proportion confidence intervals (CIs) used logit-scale cluster-robust variance. Group comparisons used cluster-robust Wald tests from linear, binary logistic, or multinomial logistic models; skewed risks were log-transformed.

Paired cross-tabulations compared China-PAR and ICVD-10. Secondary agreement measures were linear weighted κ for three categories and unweighted κ for binary high-risk classification; CIs were obtained by resampling clusters. The paired difference in high-risk proportions used cluster-robust variance. A sensitivity analysis excluded ages 75–79 years. Exact intersections were displayed in an UpSet plot. Exploratory logistic regression compared ≥2 with one source among high-risk participants, with Huber–White standard errors clustered by community (149 clusters). Covariates were sex, age, education, study area, sleep, healthy diet, leisure-time physical activity, and harmful alcohol use. *P* values were not adjusted for multiple comparisons and were interpreted with adjusted odds ratios (aORs) and 95% CIs. Tests were two-sided with $P < 0.05$.

RESULTS

PARTICIPANT CHARACTERISTICS AND COMPARISONS BY SEX

Among 38,427 participants, 17,969 (46.76%) were men and 20,458 (53.24%) were women; mean age was 56.03 ± 10.01 years. Mean age and area distribution did not differ by sex, whereas age group, education, sleep, and BMI distributions did (Table 1). Overweight, obesity, central obesity, hypertension, diabetes, and dyslipidemia affected 41.90%, 16.29%, 40.90%, 49.54%, 18.32%, and 39.02%, respectively. These characteristics, current smoking, and harmful alcohol use were more frequent in men (all $P < 0.001$). Healthy diet, family CVD history, and sufficient leisure-time physical activity were more frequent in women. Prior CVD affected 6.80% and did not differ by sex ($P = 0.657$).

Table 1 Characteristics of screened participants aged 35–79 years in five areas of Nanjing.

Note: Age is presented as mean ± SD; all other variables are *n* (%). *P* values are from community-cluster robust Wald tests. BMI, body mass index; CVD, cardiovascular disease; SD, standard deviation.

CHARACTERISTICS	OVERALL (*n* = 38,427)	MALE (*n* = 17,969)	FEMALE (*n* = 20,458)	CLUSTER-ADJUSTED WALD χ^2	*P* VALUE
Age (mean ± SD), years	56.03 ± 10.01	56.07 ± 10.23	55.98 ± 9.82	0.188	0.665
Age group, years					
35–44	5,151 (13.40)	2,525 (14.05)	2,626 (12.84)	30.336	<0.001
45–54	11,997 (31.22)	5,506 (30.64)	6,491 (31.73)		
55–64	12,693 (33.03)	5,761 (32.06)	6,932 (33.88)		
65–74	7,305 (19.01)	3,512 (19.54)	3,793 (18.54)		
75–79	1,281 (3.33)	665 (3.70)	616 (3.01)		

(Contd.)

CHARACTERISTICS	OVERALL (*n* = 38,427)	MALE (*n* = 17,969)	FEMALE (*n* = 20,458)	CLUSTER-ADJUSTED WALD χ^2	*P* VALUE
Education					
Primary school or below	15,828 (41.19)	5,376 (29.92)	10,452 (51.09)	304.051	<0.001
Middle/high school	19,594 (50.99)	10,865 (60.47)	8,729 (42.67)		
College or above	3,005 (7.82)	1,728 (9.62)	1,277 (6.24)		
Study area					
Jianye District	6,951 (18.09)	3,009 (16.75)	3,942 (19.27)	4.668	0.323
Pukou District	7,354 (19.14)	3,301 (18.37)	4,053 (19.81)		
Lishui District	7,627 (19.85)	3,689 (20.53)	3,938 (19.25)		
Gaochun District	8,457 (22.01)	4,062 (22.61)	4,395 (21.48)		
Jiangbei New Area	8,038 (20.92)	3,908 (21.75)	4,130 (20.19)		
Nighttime sleep duration					
Short	11,273 (29.34)	4,842 (26.95)	6,431 (31.44)	55.181	<0.001
Recommended	23,751 (61.81)	11,355 (63.19)	12,396 (60.59)		
Long	3,403 (8.86)	1,772 (9.86)	1,631 (7.97)		
BMI category					
Underweight	643 (1.67)	293 (1.63)	350 (1.71)	103.121	<0.001
Normal weight	15,424 (40.14)	6,449 (35.89)	8,975 (43.87)		
Overweight	16,100 (41.90)	8,122 (45.20)	7,978 (39.00)		
Obesity	6,260 (16.29)	3,105 (17.28)	3,155 (15.42)		
Current smoking	8,695 (22.63)	8,516 (47.39)	179 (0.87)	1,185.438	<0.001
Harmful alcohol use	1,595 (4.15)	1,513 (8.42)	82 (0.40)	700.496	<0.001
Healthy diet	10,945 (28.48)	4,276 (23.80)	6,669 (32.60)	166.148	<0.001
Sufficient leisure-time physical activity	7,203 (18.74)	3,255 (18.11)	3,948 (19.30)	4.635	0.031
Central obesity	15,718 (40.90)	7,677 (42.72)	8,041 (39.30)	14.511	<0.001
Hypertension	19,038 (49.54)	9,733 (54.17)	9,305 (45.48)	158.122	<0.001
Diabetes	7,040 (18.32)	3,739 (20.81)	3,301 (16.14)	75.049	<0.001
Dyslipidemia	14,995 (39.02)	7,384 (41.09)	7,611 (37.20)	20.790	<0.001
History of CVD	2,612 (6.80)	1,235 (6.87)	1,377 (6.73)	0.197	0.657
Family history of CVD	6,422 (16.71)	2,667 (14.84)	3,755 (18.35)	43.211	<0.001

CHINA-PAR AND ICVD-10 RISK STRATIFICATION AND AGREEMENT

Among participants without prior CVD, 35,814 had China-PAR results: the median risk was 3.61% (25th–75th percentile, 1.73%–6.72%), and 63.03%, 25.92%, and 11.05% were at low, intermediate, and high risk. Among 35,815 with ICVD-10 results, the mean score was 6.04 ± 3.65, the median absolute risk was 2.90% (1.10%–7.30%), and 64.94%, 23.99%, and 11.07% were at low, intermediate, and high risk, respectively. For both tools, estimates and categories differed by sex and age (all $P < 0.001$), and high-risk proportions rose from <1% at 35–44 years to approximately 70% at 75–79 years (Tables 2 and 3).

Among 35,814 participants with both classifications, 30,660 were non-high risk by both tools, 2,768 high risk by both, 1,189 high risk only by China-PAR, and 1,197 high risk only by ICVD-10 (Table 4). The 2,386 discordant classifications represented 46.29% of 5,154 participants at high risk by either tool. Agreement measures appear in Supplementary Table S1. In the sensitivity analysis of 34,778 participants aged 35–74 years, high-risk proportions were 9.29% and 9.39%; discordance remained 48.95% among those high risk by either tool (Supplementary Table S2).

CHARACTERISTICS	10-YEAR RISK, MEDIAN (P25–P75), %	CLUSTER-ADJUSTED WALD χ^2	*P* VALUE	LOW RISK, <5%	INTERMEDIATE RISK, 5%–<10%	HIGH RISK, ≥10%	CLUSTER-ADJUSTED WALD χ^2	*P* VALUE
Overall	3.61 (1.73–6.72)			22,575 (63.03)	9,282 (25.92)	3,957 (11.05)		
Sex								
Male	4.51 (2.29–7.79)	431.461	<0.001	9,096 (54.36)	5,200 (31.07)	2,438 (14.57)	312.378	<0.001
Female	2.94 (1.38–5.62)			13,479 (70.64)	4,082 (21.39)	1,519 (7.96)		
Age group, years								
35–44	0.68 (0.39–1.28)	17,787.634	<0.001	4,983 (97.25)	112 (2.19)	29 (0.57)	4,346.945	<0.001
45–54	2.21 (1.40–3.60)			10,133 (86.30)	1,355 (11.54)	254 (2.16)		
55–64	4.48 (3.08–6.59)			6,745 (57.37)	4,095 (34.83)	918 (7.81)		
65–74	8.22 (6.23–11.02)			711 (11.55)	3,412 (55.44)	2,031 (33.00)		
75–79	11.74 (9.54–14.90)			3 (0.29)	308 (29.73)	725 (69.98)		

Table 2 China-PAR 10-year risk estimates and categories among participants without prior CVD.

Note: Risk estimates are median (P25, P75); categories are *n* (%). Wald tests used community-cluster robust variance; continuous risk was log-transformed for comparison (*N* = 35,814). CVD, cardiovascular disease; China-PAR, Prediction for ASCVD Risk in China.

CHARACTERISTICS	TOTAL SCORE, MEAN ± SD	CLUSTER-ADJUSTED WALD χ^2	*P* VALUE	ABSOLUTE RISK, MEDIAN (P25–P75), %	CLUSTER-ADJUSTED WALD χ^2	*P* VALUE	LOW RISK, <5%	INTER-MEDIATE RISK, 5%–<10%	HIGH RISK, ≥10%	CLUSTER-ADJUSTED WALD χ^2	*P* VALUE
Overall	6.04 ± 3.65			2.90 (1.10–7.30)			23,257 (64.94)	8,592 (23.99)	3,966 (11.07)		
Sex											
Male	6.85 ± 3.53	515.662	<0.001	3.90 (1.50–7.30)	940.456	<0.001	9,690 (57.91)	4,594 (27.45)	2,450 (14.64)	281.243	<0.001
Female	5.33 ± 3.61			2.10 (0.50–5.40)			13,567 (71.10)	3,998 (20.95)	1,516 (7.95)		
Age group, years											
35–44	1.66 ± 2.62	13,546.899	<0.001	0.50 (0.20–1.10)	12,127.904	<0.001	5,012 (97.81)	96 (1.87)	16 (0.31)	4,297.905	<0.001
45–54	4.66 ± 2.65			2.10 (0.50–2.90)			10,110 (86.10)	1,412 (12.03)	220 (1.87)		
55–64	6.99 ± 2.56			3.90 (2.10–7.30)			6,881 (58.52)	3,986 (33.90)	891 (7.58)		
65–74	9.59 ± 2.49			9.70 (5.40–12.80)			1,206 (19.59)	2,809 (45.64)	2,140 (34.77)		
75–79	11.48 ± 2.37			12.80 (9.70–21.70)			48 (4.63)	289 (27.90)	699 (67.47)		

Table 3 ICVD-10 scores, absolute risks, and categories among participants without prior CVD.

Note: Total scores are mean ± SD, absolute risks are median (P25, P75), and categories are *n* (%). Wald tests used community-cluster robust variance; absolute risk was log-transformed for comparison (*N* = 35,815). CVD, cardiovascular disease; ICVD, 10-year ischemic cardiovascular disease risk assessment for Chinese adults.

CHINA-PAR CATEGORY	ICVD-10 LOW RISK	ICVD-10 INTERMEDIATE RISK	ICVD-10 HIGH RISK	TOTAL
Low risk	20,881	1,678	16	22,575
Intermediate risk	2,317	5,784	1,181	9,282
High risk	59	1,130	2,768	3,957
Total	23,257	8,592	3,965	35,814

Table 4 Paired cross-classification of China-PAR and ICVD-10 risk categories among participants without prior CVD.

Note: *N* = 35,814. Agreement coefficients and the cluster-adjusted paired comparison are reported in Supplementary Table S1. China-PAR, Prediction for ASCVD Risk in China; CVD, cardiovascular disease; ICVD, 10-year ischemic cardiovascular disease risk assessment for Chinese adults.

OVERALL HIGH-RISK PROPORTION AND THE FOUR IDENTIFICATION SOURCES

Among 38,427 participants, 8,905 were high risk (23.17%; cluster-robust 95% CI = 21.80%–24.61%). Source-specific proportions were 11.05% for China-PAR, 11.07% for ICVD-10, 6.80% for prior CVD, and 3.99% for severe dyslipidemia. Overall and model-based high-risk proportions were higher in men, whereas severe dyslipidemia was more frequent in women; prior CVD did not differ by sex. All indicators differed by age and education (Tables 5 and 6). Overall high risk rose from 4.04% at 35–44 years to 86.18% at 75–79 years; the corresponding proportions were 30.60%, 18.97%, and 11.45% among participants with primary education or less, middle or high school education, and college education or above, respectively.

CHARACTERISTIC	OVERALL CVD HIGH RISK	HIGH BY CHINA-PAR	HIGH BY ICVD-10	HISTORY OF CVD	SEVERE DYSLIPIDEMIA
Overall	8,905 (23.17)	3,957 (11.05)	3,966 (11.07)	2,612 (6.80)	1,534 (3.99)
Sex					
Male	4,910 (27.32)	2,438 (14.57)	2,450 (14.64)	1,235 (6.87)	607 (3.38)
Female	3,995 (19.53)	1,519 (7.96)	1,516 (7.95)	1,377 (6.73)	927 (4.53)
Age group, years					
35–44	208 (4.04)	29 (0.57)	16 (0.31)	27 (0.52)	146 (2.83)
45–54	1,042 (8.69)	254 (2.16)	220 (1.87)	255 (2.13)	480 (4.00)
55–64	2,631 (20.73)	918 (7.81)	891 (7.58)	935 (7.37)	566 (4.46)
65–74	3,920 (53.66)	2,031 (33.00)	2,140 (34.77)	1,150 (15.74)	282 (3.86)
75–79	1,104 (86.18)	725 (69.98)	699 (67.47)	245 (19.13)	60 (4.68)
Education					
Primary school or below	4,844 (30.60)	2,371 (16.35)	2,416 (16.66)	1,323 (8.36)	718 (4.54)
Middle/high school	3,717 (18.97)	1,453 (7.89)	1,427 (7.75)	1,186 (6.05)	736 (3.76)
College or above	344 (11.45)	133 (4.58)	123 (4.24)	103 (3.43)	80 (2.66)

Table 5 Overall CVD high risk and four identification sources by participant characteristics, *n* (%).

Note: Column denominators were 38,427 for overall high-risk classification, 35,814 for China-PAR, 35,815 for ICVD-10, and 38,427 for prior CVD and severe dyslipidemia. Within each stratum, percentages were calculated among participants with an applicable and available result for the corresponding identification indicator. China-PAR, Prediction for ASCVD Risk in China; CVD, cardiovascular disease; ICVD, 10-year ischemic cardiovascular disease risk assessment for Chinese adults.

CHARACTERISTICS	OVERALL CVD HIGH RISK	HIGH BY CHINA-PAR	HIGH BY ICVD-10	HISTORY OF CVD	SEVERE DYSLIPIDEMIA
Sex	149.556 (<0.001)	211.185 (<0.001)	232.678 (<0.001)	0.197 (0.657)	20.776 (<0.001)
Age group	4,210.029 (<0.001)	4,470.515 (<0.001)	2,726.921 (<0.001)	740.512 (<0.001)	22.421 (<0.001)
Education	200.794 (<0.001)	205.056 (<0.001)	160.836 (<0.001)	41.129 (<0.001)	17.461 (<0.001)

Table 6 Community-cluster adjusted comparisons of overall CVD high risk and four identification sources.

Note: Cells show cluster-adjusted Wald χ^2 statistics, with *P* values in parentheses. China-PAR, Prediction for ASCVD Risk in China; CVD, cardiovascular disease; ICVD, 10-year ischemic cardiovascular disease risk assessment for Chinese adults.

OVERLAP AMONG THE FOUR SOURCES OF HIGH-RISK IDENTIFICATION

Of 8,905 high-risk participants, 8,904 had complete source data: 5,924 (66.53%) met one criterion, 2,796 (31.40%) met two, and 184 (2.07%) met three; thus, 2,980 (33.47%) had multiple sources. Multiple-source identification was more frequent in men, increased from 4.33% at ages 35–44 years to 53.35% at 75–79 years, and differed by education (Table 7).

The most frequent exact intersection was joint China-PAR and ICVD-10 high risk without prior CVD or severe dyslipidemia (2,584; 29.02%), followed by prior CVD alone (2,512; 28.21%). Severe dyslipidemia alone, China-PAR alone, and ICVD-10 alone each accounted for approximately 13%. Another 184 participants met both model criteria and had severe dyslipidemia, giving 2,768 participants at high risk by both tools (Figure 1).

FACTORS ASSOCIATED WITH IDENTIFICATION THROUGH MULTIPLE SOURCES

The exploratory regression included 8,904 high-risk participants in 149 clusters. Men had greater odds of multiple-source identification than women (aOR = 1.24; 95% CI = 1.11–1.38; $P < 0.001$). Relative to ages 35–44 years, aORs rose from 3.67 at 45–54 years to 26.42 at 75–79 years (all $P < 0.001$).

CHARACTERISTICS	NUMBER AT HIGH RISK	1 SOURCE	2 SOURCES	3 SOURCES	CLUSTER-ADJUSTED WALD χ^2	*P* VALUE
Overall	8,904	5,924 (66.53)	2,796 (31.40)	184 (2.07)		
Sex						
Male	4,910	3,189 (64.95)	1,622 (33.03)	99 (2.02)	11.548	0.003
Female	3,994	2,735 (68.48)	1,174 (29.39)	85 (2.13)		
Age group, years						
35–44	208	199 (95.67)	8 (3.85)	1 (0.48)	435.645	<0.001
45–54	1,042	888 (85.22)	141 (13.53)	13 (1.25)		
55–64	2,631	2,000 (76.02)	583 (22.16)	48 (1.82)		
65–74	3,919	2,322 (59.25)	1,511 (38.56)	86 (2.19)		
75–79	1,104	515 (46.65)	553 (50.09)	36 (3.26)		
Education						
Primary school or below	4,843	2,973 (61.39)	1,756 (36.26)	114 (2.35)	68.636	<0.001
Middle/high school	3,717	2,698 (72.59)	953 (25.64)	66 (1.78)		
College or above	344	253 (73.55)	87 (25.29)	4 (1.16)		

Table 7 Number of high-risk identification sources among participants at high risk of CVD, *n* (%).

Note: The analysis included 8,904 high-risk participants with complete data for all four sources. Risk tools were not counted as sources for participants with prior CVD; no participant met all four sources. *P* values are from community-cluster robust multinomial Wald tests. CVD, cardiovascular disease.

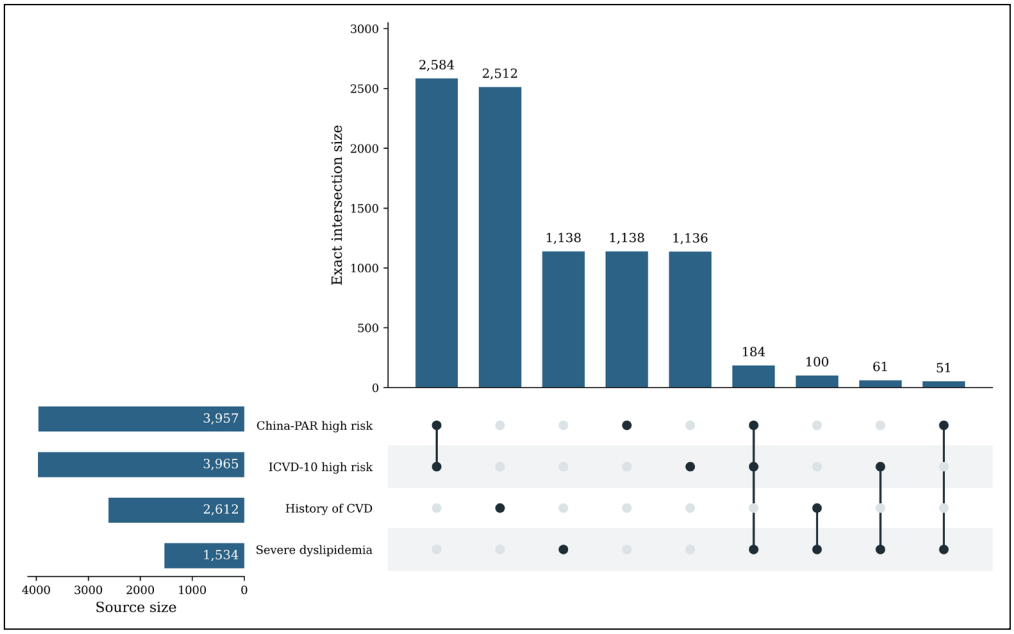


Figure 1 Exact intersections among four cardiovascular high-risk identification sources (*N* = 8,904).

Note: Vertical bars show the number of participants in each exact, mutually exclusive combination of the four high-risk identification sources; horizontal bars show the total number meeting each source. In the complete-source analysis, 3,965 participants met the ICVD-10 high-risk criterion; one additional participant classified as high risk by ICVD-10 was excluded because the China-PAR source was unavailable. CVD, cardiovascular disease; ICVD-10, 10-year ischemic cardiovascular disease risk assessment for Chinese adults.

Compared with Jianye, odds were lower in Pukou (aOR = 0.77; *P* = 0.023) and Jiangbei New Area (aOR = 0.76; *P* = 0.031), similar in Lishui (aOR = 0.91; *P* = 0.412), and higher in Gaochun (aOR = 2.01; *P* < 0.001). Harmful alcohol use was associated with multiple-source identification (aOR = 1.33; 95% CI = 1.10–1.61; *P* = 0.003). Leisure-time physical inactivity was not statistically significant (aOR = 1.14; 95% CI = 0.996–1.32; *P* = 0.057); education, sleep, and healthy diet were also not associated (Table 8).

CHARACTERISTIC	CLUSTER-ADJUSTED WALD χ^2	*P* VALUE	aOR (95% CI)
Sex			
Female	—	—	1.00
Male	14.799	<0.001	1.24 (1.11–1.38)
Age group, years			
35–44	—	—	1.00
45–54	11.622	<0.001	3.67 (1.74–7.75)

(Contd.)

Table 8 Exploratory factors associated with multiple-source identification among participants at high risk of CVD.

Note: Outcome: multiple-source identification (≥2 versus 1 source). Huber–White standard errors were clustered by community (149 clusters). Because the analysis was exploratory, P values were not adjusted for multiple comparisons. aOR, adjusted odds ratio; CI, confidence interval; CVD, cardiovascular disease.

CHARACTERISTIC	CLUSTER-ADJUSTED WALD χ^2	*P* VALUE	aOR (95% CI)
55–64	28.330	<0.001	7.57 (3.59–15.94)
65–74	53.204	<0.001	16.43 (7.74–34.85)
75–79	68.885	<0.001	26.42 (12.20–57.26)
Education			
College or above	—	—	1.00
Primary school or below	0.221	0.638	1.07 (0.80–1.45)
Middle/high school	0.055	0.814	1.03 (0.78–1.37)
Study area			
Jianye District	—	—	1.00
Pukou District	5.181	0.023	0.77 (0.62–0.96)
Lishui District	0.674	0.412	0.91 (0.73–1.14)
Gaochun District	46.461	<0.001	2.01 (1.64–2.45)
Jiangbei New Area	4.666	0.031	0.76 (0.59–0.97)
Sleep duration			
Recommended (7–<9 h)	—	—	1.00
Short (<7 h)	0.035	0.851	0.99 (0.89–1.10)
Long (≥9 h)	1.207	0.272	1.09 (0.93–1.27)
Healthy diet			
Yes	—	—	1.00
No	0.300	0.584	1.03 (0.93–1.14)
Leisure-time physical activity			
Sufficient	—	—	1.00
Insufficient	3.612	0.057	1.14 (0.996–1.32)
Harmful alcohol use			
No	—	—	1.00
Yes	8.529	0.003	1.33 (1.10–1.61)

DISCUSSION

PRINCIPAL FINDINGS

This study compared China-PAR and ICVD-10 and four high-risk identification sources among 38,427 screened adults. Overall, 8,905 participants (23.17%) met at least one criterion. Among participants without prior CVD, each tool identified approximately 11% as high risk, yet 2,386 were high risk by only one tool. Of 8,904 high-risk participants with complete source data, 2,980 (33.47%) met at least two criteria; the most frequent exact combination was high risk by both tools. Multiple-source identification was associated with male sex, older age, harmful alcohol use, and study area.

Conventional risk-factor clustering describes the coexistence of hypertension, diabetes, dyslipidemia, obesity, smoking, and related exposures (18). Prospective international studies likewise show that a limited set of metabolic and behavioral factors accounts for a large proportion of CVD events and deaths (23, 31, 32). Here, multiple-source identification instead indicates whether prior CVD, severe dyslipidemia, and two risk tools identified the same participant through different pathways. Exact intersections revealed combinations hidden by marginal source proportions or a single overall label. Retaining the source supports verification of history, laboratory findings, and calculated risk and distinguishes primary- from secondary-prevention needs.

AGREEMENT BETWEEN CHINA-PAR AND ICVD-10 AND IMPLICATIONS FOR USE

China-PAR was developed and validated in Chinese populations to estimate first ASCVD events, whereas ICVD-10 estimates fatal and nonfatal ischemic CVD (6, 7). Consistent with their intended use in primary prevention, the comparison was restricted to participants without prior CVD. The tools share several predictors, including age, sex, smoking, blood pressure, cholesterol, and diabetes, which may partly explain their similar overall high-risk proportions and substantial agreement. Nevertheless, among the 5,154 participants classified as high risk by at least one tool, 2,386 (46.29%) had discordant classifications. Thus, similar group-level proportions did not make the tools interchangeable for individual classification. Differences in predicted outcomes, development periods, model coefficients, and risk-mapping procedures may shift some individuals across the 10% threshold. Single-visit blood pressure and differential availability of HbA1c may also have influenced classification because blood pressure and diabetes status contribute to both tools. Neither tool was validated against observed cardiovascular events in this sample; event follow-up is needed to assess calibration and prognostic performance.

A previous Nanjing study reported an ICVD high-risk proportion of 12.6% (8), close to the 11.07% observed here; a Xuzhou study reported a China-PAR proportion of 37.73% (9), compared with 11.05% here. Survey period, age range, participant composition, and handling of prior CVD can affect these estimates, so unadjusted proportions should not rank regions. Large national surveys have also documented substantial variation in hypertension detection and control and an increase in diabetes prevalence in China, underscoring how participant composition and measurement definitions can influence local risk distributions (26, 27). High-risk classification by both tools increased with age. After excluding ages 75–79 years, overall proportions remained similar, but discordance was 48.95% among participants high risk by either tool, showing that the oldest group did not solely explain individual disagreement. Repeated screening should prespecify and consistently apply the tool, review inputs in discordant cases, and retain the version, estimated risk, and category.

OVERLAP AMONG THE FOUR IDENTIFICATION SOURCES AND MANAGEMENT IMPLICATIONS

The four identification sources correspond to different clinical and public health tasks. Participants with prior CVD have entered secondary prevention. Severe dyslipidemia warrants repeat measurement and clinical assessment even when predicted risk is below 10%. Participants without prior CVD who are classified as high risk by China-PAR or ICVD-10 are primary-prevention candidates whose combined risk exceeds the prespecified threshold. Risk tools can identify people without a clinical event whose individual measurements do not reach the severe-abnormality threshold but whose combined risk is high; the prior-CVD and severe-dyslipidemia criteria, in turn, identify participants who have already entered secondary prevention or who have markedly abnormal lipid results. Parallel use of the four sources therefore preserves information that cannot be fully represented by a single risk tool or an isolated measurement.

Exact intersection analysis showed that no single pathway represented all high-risk participants. The exact combination of high-risk classification by both China-PAR and ICVD-10, with neither prior CVD nor severe dyslipidemia, accounted for 29.02% of the complete-source high-risk group. Prior CVD alone accounted for 28.21%, while severe dyslipidemia alone and high-risk classification by only one tool each accounted for approximately 13%. Overall, 33.47% of high-risk participants met at least two criteria. If a registry retains only a final high-risk/non-high-risk result, these pathways and combinations are lost. Recording prior-CVD status, the severe-lipid trigger, China-PAR classification, and ICVD-10 classification separately would preserve the information needed for post-screening verification and for differentiating primary- and secondary-prevention management.

Post-screening review can be organized by identification source: verify the diagnosis and current secondary-prevention treatment for participants with prior CVD; repeat fasting lipid measurements and arrange clinical assessment for those with markedly elevated TC or LDL-C; and verify model inputs, communicate overall risk, and manage modifiable factors for participants identified by a risk tool. Participants meeting multiple criteria require completion of the verification tasks indicated by each source. WHO HEARTS emphasizes risk-based

assessment, standardized protocols, and ongoing monitoring for CVD management in primary care (4). Evidence that blood-pressure lowering and LDL-C lowering reduce major cardiovascular events, together with contemporary cardiovascular-health frameworks, further supports linking source-specific screening results to appropriate clinical verification and comprehensive risk-factor management (19, 20, 32).

FACTORS ASSOCIATED WITH MULTIPLE-SOURCE IDENTIFICATION AND PUBLIC HEALTH IMPLICATIONS

Male sex and older age were strongly associated with multiple-source identification. This pattern was consistent with both the structure of China-PAR and ICVD-10 and the observed risk-factor distribution: men had higher proportions of current smoking, harmful alcohol use, hypertension, diabetes, and dyslipidemia, while increasing age was accompanied by marked increases in high-risk classification by both tools and in prior CVD. The marked sex difference in current smoking is consistent with nationwide prospective evidence showing substantially greater tobacco exposure and tobacco-attributable mortality among men in China (28). Notably, recorded prior CVD was similar in men and women (6.87% vs. 6.73%; $P = 0.657$), despite higher model-based high-risk proportions among men. This unexpected finding may partly reflect the composite history criterion combining myocardial infarction, stroke, PCI, and CABG; the requirement for diagnosis or treatment at a secondary-level or higher medical institution; and possible sex differences in previous diagnosis or screening participation.

Multiple-source identification varied across study areas after community-cluster adjustment: compared with Jianye, the odds were higher in Gaochun, lower in Pukou and Jiangbei New Area, and not statistically different in Lishui. The observed differences may reflect variation in participant age and risk-factor profiles, previous detection of chronic disease, survey participation, and site-level testing conditions. HbA1c was not measured in Lishui District, which may have influenced diabetes ascertainment and the corresponding risk classification. Because the study areas were purposively selected at the first stage and the estimates were unweighted, these findings describe variation within the screened sample and should not be used to rank population cardiovascular risk across Nanjing districts. Consistent measurement procedures and risk algorithms are important when interpreting local screening results.

Harmful alcohol use remained associated with multiple-source identification after cluster adjustment (aOR = 1.33; 95% CI = 1.10–1.61; $P = 0.003$). The direction of this association is consistent with prospective evidence from Chinese adults linking higher alcohol intake with increased blood pressure and stroke risk (21). The outcome in this study, however, was the concurrence of screening criteria rather than incident CVD; the estimate therefore describes the statistical association between harmful alcohol use and overlap of identification sources. Post-screening review may include alcohol frequency and intake and interpret these data together with the specific triggering source and verified risk factors.

After cluster adjustment, insufficient leisure-time physical activity was not statistically associated with multiple-source identification (aOR = 1.14; 95% CI = 0.996–1.32; $P = 0.057$); healthy diet, sleep duration, and education were also not associated. These results concern overlap among the four high-risk identification sources and do not estimate the relationships of these factors with incident cardiovascular events. Prospective studies have separately associated physical activity, dietary components, and sleep duration with cardiovascular events or mortality (29, 30, 33).

STRENGTHS AND LIMITATIONS

Strengths include the large sample, paired China-PAR and ICVD-10 classification among participants without prior CVD, and reconstruction of mutually exclusive combinations across four sources. The analysis distinguished source overlap from conventional risk-factor clustering, cross-checked continuous risks against categories, and incorporated community clustering into confidence intervals, group comparisons, and regression.

Five areas were purposively selected by geography and economic development; validated sampling weights and individual nonrespondent characteristics were unavailable. The reported proportions therefore describe the screened sample rather than all Nanjing adults aged 35–79 years.

Blood pressure was measured at one visit, with incomplete documentation of rest, arm, cuff size, and device calibration. Site laboratories performed biochemical testing, but analyzer, assay, and external quality-assessment details were unavailable. Lipid-lowering treatment may have reduced TC or LDL-C below severe-dyslipidemia thresholds. HbA1c was unavailable in Lishui, and oral glucose tolerance testing was not performed, potentially affecting diabetes classification.

Medical history and lifestyle measures were partly self-reported. Leisure-time physical activity excluded occupational, transport, and household activity, and harmful alcohol thresholds were relatively high. Requiring prior CVD diagnosis at a secondary-level or higher institution or revascularization may have missed events documented only at township facilities. Cross-sectional data cannot establish temporal ordering. Because sex and age enter both tools, their associations partly reflect the rules. Without incident CVD events, calibration, prognosis, and long-term value of source combinations could not be assessed.

CONCLUSIONS

Among screened participants from five selected areas of Nanjing, 23.17% met at least one prespecified CVD high-risk criterion; among high-risk participants with complete data for all four sources, 33.47% met at least two criteria. China-PAR and ICVD-10 yielded similar overall high-risk proportions, but classifications were discordant for 46.29% of participants identified as high risk by either tool.

Community screening programs should retain the specific high-risk identification source and the risk tool used, verify medical history and markedly abnormal lipid results, and distinguish primary- from secondary-prevention needs according to the pathway of identification.

DATA ACCESSIBILITY STATEMENT

The datasets generated during and/or analyzed during the current study are not publicly available due to privacy or ethical restrictions but are available from the corresponding author on reasonable request. Supplementary Tables S1 and S2 are provided as an additional file.

ADDITIONAL FILE

The additional file for this article can be found as follows:

- **Supplementary Files.** Tables S1 and S2. DOI: https://doi.org/10.5334/gh.1604.s1

ETHICS AND CONSENT

The study protocol was reviewed and approved by the Ethics Committee of the Nanjing Center for Disease Control and Prevention (approval no. PJ2020-B001-01). Written informed consent was obtained from all participants.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

GM conceived and designed the study, performed the statistical analysis, interpreted the findings, and drafted the manuscript. XW contributed to the methodology and participated in drafting and critically revising the manuscript. TZ and ZF contributed to data collection,

data curation, and interpretation of the findings. LZ contributed to data acquisition, project coordination, and critical revision of the manuscript. WL contributed to the conception and design of the study, supervised the work, and critically revised the manuscript. All authors read and approved the final manuscript.

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