# RESEARCH

Risk of premature cardiovascular disease and all-cause mortality in young adults, association with risk factor prevalence early in life

Chenrui Zhu<sup>1†</sup>, Liuxin Li<sup>2,3†</sup>, Mingchen Zhao<sup>1</sup>, Jie Li<sup>4</sup>, Haibo Gao<sup>5</sup>, Huiying Li<sup>1</sup>, Yan Liu<sup>1</sup>, Chunpeng Ji<sup>1</sup> and Zhe Huang<sup>1\*</sup>

# Abstract

**Background** With the increase in risk factors and the emergence of unhealthy lifestyles in young adults, we need to pay more attention to the cardiovascular health of this group. This study aimed to assess the association of the degree of joint risk factor control with premature cardiovascular disease (CVD) and all-cause mortality in young people.

**Methods** *Kailuan Study* is a prospective cohort study based on a community population, which began in June 2006, and followed up every two years. A sample of 16,519 eligible participants in the *Kailuan* cohort was recruited in this current study and 15,948 was included in the final analysis, with an average age of  $32.34 \pm 5.19$  years, and a male proportion of 74.76%. Based on the control status of the risk factors, participants were divided into three groups: well-controlled group ( $\geq$  7 risk factors controlled), moderately controlled group ( $\leq$  4 risk factors controlled). Multivariate Cox proportional hazard model was used to analyse the relationship between the joint control of risk factors and onset of CVD and all-cause mortality.

**Results** During a mean follow-up period of 14.78±1.33 years, we identified 285 incident CVD cases and a total of 274 deaths from all causes. Compared to the well-controlled group, the moderately controlled group and poorly controlled group exhibited progressively higher risks of CVD and all-cause mortality. The adjusted hazard ratios (HRs) for CVD in the moderately controlled group and poorly controlled group were 2.24 (95% confidence interval [CI]: 1.66–3.02) and 3.09 (95% CI: 2.04–4.68), respectively. The adjusted HRs for all-cause mortality in these two groups were 1.53 (1.15–2.04) and 2.65 (1.79–3.92), respectively.

**Conclusions** We observed an inverse relationship between the degree of risk factor control and the risk of CVD and all-cause mortality in young adults, emphasizing the importance of actively controlling more risk factors in early life.

Keywords Cardiovascular disease, All-cause mortality, Young adult, Joint risk factor, Cohort study

<sup>†</sup>Chenrui Zhu and Liuxin Li contributed equally to this work.

\*Correspondence: Zhe Huang huangzhesky@163.com Full list of author information is available at the end of the article



© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.





# Introduction

A large number of studies have indicated that a favourable cardiovascular health (CVH) status in middle-aged and elderly population is significantly associated with a substantial reduction in cardiovascular disease (CVD) and mortality rates [1-4]. However, there has been limited research focusing on the CVH status of young people. Some studies suggested that CVH measured during adolescence or early adulthood is correlated with later subclinical disease markers, including increased carotid intima-media thickness, left ventricular hypertrophy and diastolic dysfunction [5, 6]. Although intimal-medial thickness [7], left ventricular hypertrophy [8, 9] and diastolic dysfunction [10, 11] are all related to cardiovascular events and mortality, there is still a lack of direct research on the relationship between CVH status and clinical outcomes in young people. This often leads to the neglect of cardiovascular health issues in this population. Early emergence of risk factors such as elevated blood pressure, blood glucose, lipid levels, increased body mass index (BMI), and unhealthy lifestyles within this group may significantly increase the risk of early-onset cardiovascular diseases in the future.

In order to alleviate the burden of CVD, the American Heart Association (AHA) formulated and updated the concept of CVH in 2022. They introduced the"Life's Simple 8"(LE8), which involves the simultaneous presence of four health behaviors (diet, physical activity, smoking, and sleep) and four health factors (BMI, blood lipid, blood glucose and blood pressure) [12, 13]. Studies have indicated that effective control of these factors can significantly reduce the incidence and mortality of CVD [1–3]. However, previous research has predominantly focused on the middle-aged and elderly population. Our study, on the other hand, examined the associations between the number of risk factors under control based on the LE8 in aged  $\leq$ 40 years young adults and the occurrence of premature CVD and all-cause mortality.

# Methods

# Study design and study population

Kailuan Study [14, 15] (Registration No.: ChiCTR-TNRC-11001489) is a prospective cohort study based on a community population in Tangshan, a city in northern China. From 2006 to 2007, all employees and retirees of Kailuan Group received the first physical examination in Kailuan General Hospital and its 11 affiliated hospitals. A total of 101,510 participants completed baseline survey between June 2006 and October 2007, 16,519 participants aged  $\leq$ 40 years were enrolled. After excluding participants with missing data (n= 548) and those with a history of stroke (n= 10) or myocardial infarction (n= 13), 15,948 individuals were included in the final analysis (Fig. 1).

The study was performed according to the guidelines of the Helsinki Declaration and was approved by the ethics committee of *Kailuan* General Hospital (2006–05). All participants provided written informed consent.



Fig. 1 Flow diagram of the participants selection

# Data collection

The data included questionnaire assessments, physical examinations, and laboratory tests, which were updated every two years. Standardized questionnaire data, including socio-demographic factors, health and medication status, and lifestyle information, were collected by trained professionals via face-to-face interviews. Height, weight, and blood pressure were measured by trained nurses. BMI was calculated as weight in kilograms divided by height in metres squared.

Fasting venous blood samples (5 ml) were collected from the cubital vein between 7:00 and 9:00 on the day of the examination. Biochemical indicators, including fasting blood glucose (FBG), total cholesterol (TC), and high-density lipoprotein cholesterol (HDL-C), were analysed by an automatic analyser (Hitachi 747; Hitachi, Japan) at the *Kailuan* Hospital Central Laboratory. Nonhigh-density lipoprotein cholesterol (non-HDL-C) was calculated by subtracting HDL-C from TC.

# Joint risk factor assessment and classification

In this study, we assessed eight important modifiable risk factors and developed the risk factor scoring criteria based on the AHA "LE8" standards (Table S1). The LE8 score includes four lifestyle factors (diet quality, physical activity, smoking status, and sleep quality), and four health factors (BMI, non-high density lipoprotein cholesterol [non-HDL cholesterol], blood glucose, and blood pressure). Due to the lack of detailed dietary data, we used the intake of salt, tea, and high-fat foods as surrogate indicators for dietary quality. Previous reports have confirmed the association of these indicators with the occurrence of CVD in the Chinese population [16–18]. Each of the eight risk factors is scored on a scale of 0 to 100.

Degree of risk factor control: each risk factor scoring  $\geq$  50 points was considered controlled, while risk factor scoring < 50 points was considered not controlled. In this current study, based on the control status of the eight risk factors, participants were divided into three groups: well-controlled group ( $\geq$  7 risk factors controlled), moderately controlled group (5–6 risk factors controlled), and poorly controlled group ( $\leq$  4 risk factors controlled).

# Assessment of outcomes

The primary outcomes of the study were incident CVD and all-cause mortality. The types of CVD included stroke (ischemic stroke and hemorrhagic stroke, ICD-10: I61-I64) and myocardial infarction (ICD-10: I21-I22). The outcomes in the prospective cohort were updated via medical insurance information and searching for hospital records until December 31, 2021. Stroke was diagnosed according to the World Health Organization's criteria, based on neurological signs, clinical symptoms, and neuroimaging examinations, including computerized tomography scans or magnetic resonance imaging [19]. Myocardial infarction was diagnosed referring to the 4th universal definition of myocardial infarction (2018) [20]. Mortality was collected from provincial vital statistics offices. All participants were followed up every two years to collect data on CVDs and mortality. The follow-up for deaths was not terminated by CVDs.

#### Statistical analyses

Continuous variables were described as means ±SD and were compared using ANOVAs. Categorical variables were described as percentages and were compared using  $\chi^2$  tests. Kaplan-Meier curves were drawn and cumulative incidence rates of CVD, all-cause mortality, stroke and myocardial infarction in different groups were observed. Multivariate Cox proportional hazard regression models were performed to analyse the association of different control levels of risk factors and each additional uncontrolled risk factor with CVD and all-cause mortality. The model corrected for age, gender, education, income, marital status, alcohol consumption and family history of CVD. The proportional hazards assumption for the Cox model was tested using the Schoenfeld residuals method, and no violations were observed. To test the robustness of the results, sensitivity analysis was undertaken. First, we excluded participants who experienced CVD or death within the two years of follow-up, and those who had a history of cancer at baseline or onset cancer during follow-up. Second, we postponed the occurrence of CVD or death by 2 years for further analysis to avoid the randomness of events.

All analyses were conducted using SAS version 9.3 (SAS Institute, Inc., Cary, NC). A two-sided p value < 0.05 was considered statistically significant in the current study.

# Results

#### **Baseline participant characteristics**

There were 15,948 individuals included in the final analysis, with 7,708 participants in the well-controlled group, 7,239 participants in the moderately controlled group, and 1,001 participants in the poorly controlled group. The average age was  $32.34 \pm 5.19$  years, with a male proportion of 74.76% and 47.16% having a senior high school education or above. In groups with fewer controlled risk factors, participants tended to be older and have lower incomes. Additionally, we observed greater proportions of males, individuals with a senior high school education or above, individuals who were married, and individuals with a family history of CVD in these groups, while the percentage of nondrinkers was lower in the poorly controlled group than in the other groups (Table 1).

# Associations between the degree of joint risk factor control and CVD and all-cause mortality

Dring a mean follow-up period of 14.78 ±1.33 years, 285 new CVD cases (231 cases of stroke and 59 cases of myocardial infarction) and a total of 274 deaths from all causes were observed. The incidence rates of CVD and all-cause mortality in the well-controlled group, moderately controlled group and poorly controlled group were 0.53 and 0.67, 1.72 and 1.42, 2.82 and 2.97 per 1000 person-years, respectively. (Fig. 2, log-rank test, p < 0.01). We observed significant inverse associations between the degree of risk factor control and the risk of incident CVD and all-cause mortality (Table 2). The risks of CVD in the moderately controlled group and poorly controlled group were 2.24 times (95% CI: 1.66–3.02) and 3.09 times (95% CI: 2.04–4.68) higher respectively compared to that of the well-controlled group. The risks of all-cause mortality

Table 1 Baseline characteristics of the study population

Characteristics	Total (N= 15,948)	Degree of Risk Factor Control			
		$\geq$ 7 Risk Factors (N = 7708)	5–6 Risk Factors (N = 7239)	$\leq$ 4 Risk Factors (N = 1001)	
Age (y)	32.34 ± 5.19	31.87 ± 5.19	32.64 ± 5.19	33.82 ± 5.19	< 0.001
Male (%)	11,923(74.76)	4541(58.91)	6406(88.49)	976(97.50)	< 0.001
Education level (%)					
Illiteracy or primary school	148(0.93)	34(0.44)	78(1.08)	36(3.60)	< 0.001
Junior high school	8279(51.91)	3567(46.28)	4109(56.76)	603(60.24)	< 0.001
Senior high school and above	7521(47.16)	4107(53.28)	3052(42.16)	721(72.03)	< 0.001
Income level, ¥/month (%)					
≤ 800	12,827(80.43)	6040(78.36)	5952(82.22)	835(83.42)	< 0.001
800–1000	1574(9.87)	753(9.77)	718(9.92)	103(10.29)	< 0.001
≥ 1000	1547(9.70)	915(11.87)	569(7.86)	63(6.29)	< 0.001
Alcohol consumption (%)					
Never	8168(51.22)	4807(62.36)	3106(42.91)	255(25.47)	< 0.001
Current drinker	7496(47.00)	2788(36.17)	3987(55.08)	25(2.50)	< 0.001
Past	284(1.78)	113(1.46)	146(2.01)	721(72.03)	< 0.001
Married individuals (%)	14,477(90.78)	6856(88.95)	6668(92.11)	953(95.20)	< 0.001
Family history of CVD (%)	816(5.12)	337(4.37)	388(5.36)	91(9.09)	< 0.001
Health factors under controlled (9	%)				
Blood glucose	15,540(97.44)	7697(99.86)	7003(96.74)	840(83.92)	< 0.001
Blood pressure	12,800(80.26)	7589(98.46)	4906(67.77)	305(30.47)	< 0.001
Blood lipids	13,459(84.39)	7522(97.59)	5546(76.61)	391(39.06)	< 0.001
Body mass index	14,557(91.28)	7632(99.01)	6348(87.69)	577(57.64)	< 0.001
Health behaviours under controlle	ed (%)				
Diet health	4582(28.73)	3063(39.74)	1372(18.95)	147(14.69)	< 0.001
Nicotine exposure	10,051(63.02)	6604(85.68)	3251(44.91)	196(19.58)	< 0.001
Physical activity	14,134(88.63)	7566(98.16)	6035(83.37)	533(53.25)	< 0.001
Sleep health	15,134(94.90)	7635(99.05)	6740(93.11)	759(75.82)	< 0.001

in the moderately controlled group and poorly controlled group were also significantly increased, with HR values of 1.53 (95% CI:1.15–2.04) and 2.65 (95% CI:1.79–3.92), respectively. For each additional uncontrolled risk factor, the risks of CVD and all-cause mortality increased by 1.44 times (95% CI: 1.30–1.60) and 1.30 times (95% CI: 1.17–1.45), respectively (Table 2).

#### Subgroup analyses

We categorized CVD into stroke and myocardial infarction, and observed the association of varying degrees of risk factor control. As presented in Fig. 1, the incidence rates of stroke and myocardial infarction showed statistical differences among the three groups, with the lowest incidence rate observed in the well-controlled group. The risks of incident stroke and myocardial infarction in the moderately controlled and poorly controlled groups were both higher compared to those of the well-controlled group. Stroke was divided into ischemic stroke and hemorrhagic stroke, and the results were consistent with the



**Fig. 2** Kaplan–Meier curves for the incidence of CVD, all-cause mortality, stroke, and myocardial infarction and the degree of joint risk factor control. Caption:  $Q1: \ge 7$  risk factors controlled, Q2: 5-6 risk factors controlled,  $Q3: \le 4$  risk factors controlled. Cox model was adjusted for age, sex, education level, income level, marital status, alcohol consumption and family history of CVD. CVD, cardiovascular diseases

above. For each additional risk factor uncontrolled, the risks of stroke and myocardial infarction increased by 1.39 times (95% CI: 1.24–1.56) and 1.67 times (95% CI: 1.34–2.07), respectively (Table S2).

To clarify whether the effect of degrees of risk factors control on CVD and all-cause mortality is age- and sexdependent, Cox regression models were conducted after stratification by age and sex. As presented in Table S5, the interaction between age, sex, and control levels of risk factors was not statistically significant (*P* for interaction = 0.67 and 0.34, respectively). This suggests that the association between control levels of risk factors and cardiovascular disease (CVD) is independent of age and sex, implying that the impact of risk factor control on CVD outcomes does not vary significantly across different age groups or between males and females.

# Distinct effects of health factors and health behaviors on CVD and all-cause mortality

After categorizing all risk factors into health factors and health behaviors, our study found that health factors had a greater impact on outcomes compared to health behaviors (Table S3). For each reduction of a controlled health factor, the risk of CVD and all-cause mortality increased by 1.75 times (95% CI:1.55–1.98) and 1.38 times (95% CI:1.21–1.58), respectively, and the risks of stroke and myocardial infarction increased by 1.69 times (95% CI:1.47–1.93) and 2.10 times (95% CI:1.63–2.69),

	Degree of Risk Factors Control			P for trend	Each Additional	
	$\geq$ 7 Risk Factors (N = 7708)	5–6 Risk Factors ( <i>N</i> = 7239)	$\leq$ 4 Risk Factors (N = 1001)		Uncontrolled Risk Factor	
CVD						
Events/person-years	60/114140	184/106972	41/14556			
Incidence rate	0.53	1.72	2.82			
Model 1	1 (reference)	2.29(0.70-3.09)	3.15(2.07-4.73)	< 0.001		
Model 2	1 (reference)	2.24(1.66-3.02)	3.09(2.04-4.68)	< 0.001	1.44(1.30-1.60)	
All-cause mortality						
Events/person-years	77/114446	153/107832	44/14800			
Incidence rate	0.67	1.42	2.97			
Model 1	1 (reference)	1.58(1.19–2.10)	2.78(1.89-4.08)	< 0.001		
Model 2	1 (reference)	1.53(1.15–2.04)	2.65(1.79–3.92)	< 0.001	1.30(1.17–1.45)	

<b>Fable 2</b> Association between the deg	ree of joint ri	sk factor control a	and incident CVD an	d all-cause mortality
--	-----------------	---------------------	---------------------	-----------------------

Incidence rate: per 1000 person-years

Model 1: adjusted for age, sex

Model 2: Model 1 + education level, income level, marital status, alcohol consumption and family history of CVD

respectively. For each reduction of a controlled health behavior, only the risk of all-cause mortality increased by 18%.

# Sensitivity analyses

In the sensitivity analyses, HRs for CVD and all-cause mortality associated with the different groups remained robust after excluding participants with CVD events or deaths within the first 2 years of follow-up, and participants with a history of cancer at baseline or cancer onset during follow-up. We also conducted a 2-year lag analysis for associations of duration of adherence, and the results remained consistent with the primary analysis (Table S4). In the existing population, we redefined the degree of risk factor control for sensitivity analysis. Each risk factor scoring  $\geq 80$  points was considered controlled, while risk factor scoring < 80 points was considered not controlled. We observed no change in the conclusion that the worse the control of risk factors, the higher the risk of incident cardiovascular disease and all-cause mortality (Table S8). Then we utilized a logistic regression model to calculate the overall estimated propensity scores for eight indicators. Based on these propensity scores, we further computed the inverse probability weighting (IPW) and applied this weighting to the weighted Cox regression analysis to balance the influence of each risk factor, and the results remained consistent with the primary analysis (Table S9).

# Discussion

In this prospective cohort study, we found an inverse relationship between the degree of risk factor control and the risk of premature CVD and all-cause mortality in young adults. The greater the number of controlled factors, the lower the risk of early-onset CVD and all-cause mortality. Our results underscore the importance of better controlling risk factors in the early stages of life to prevent premature cardiovascular events and all-cause mortality.

During 14.8-year follow-up, this current study revealed that in the young population, participants with  $\leq 4$  controlled risk factors face a 2.09-fold higher risk of cardiovascular events and a 1.65-fold higher risk of all-cause mortality compared to those with  $\geq 7$  controlled risk factors. Additionally, among participants with 5-6 controlled risk factors, the risks of cardiovascular events and all-cause mortality still increased by 1.24 times and 53%, respectively, compared to those in the well-controlled group. In the subgroup analysis, a close association was observed between the degree of risk factor control and the incidence of stroke and myocardial infarction in the young population. With each additional uncontrolled factor, the risk of cardiovascular events increased by 44%, and the risk of all-cause mortality increased by 30%. Other studies have found that there is a negative correlation between CVH scores and the intima-media thickness of the carotid artery [5, 21], and higher baseline CVH scores are associated with lower risks of early-onset CVD and mortality [22, 23], in young adults. This current study updated the CVH standards from AHA and classified based on the number of risk factors under control, providing new evidence for exploring the relationship between CVH in young populations and early-onset CVD.

We also found that, in the young population, with each exclusion of a controlled health factor (blood pressure,

non-HDL-C, FBG, and BMI), there is a significant increase in the risk of CVD, all-cause mortality, stroke and myocardial infarction. A prospective cohort study in the United States, encompassing six large communities, indicated that elevated blood pressure and low-density lipoprotein cholesterol in young adults are associated with an increased risk of late-life cardiovascular diseases [24]. Coronary Artery Risk Development in Young Adults (CARDIA) study also found that higher baseline triglyceride-glucose (TyG) index levels and higher longterm trajectory of TyG index during young adulthood are significantly associated with an increased risk of incident CVD events and all-cause mortality in later life [25]. A UK-based case-control study also indicated that, in a population with an average age of 33, the all-cause mortality rate is significantly higher in individuals with diabetes compared to those without [26]. Another study suggested that weight gain in aged 18-35 group is associated with coronary artery calcification in midlife, indicating a causal association between weight gain in young individuals and subsequent cardiovascular diseases [27]. We also observed that with each exclusion of a controlled health behavior, there is an increased risk of all-cause mortality, without a corresponding increase in the risk of CVD. Possible reasons may be that health behavior were more likely to be impacted by modern work and lifestyle, such as long work time and extensive use of social media, and the effect of behaviour on CVD may be modified by risk factors.

This current study has significant clinical implications from the perspectives of predictive, preventive and precision medicine. Early control of CVD-risk factors in young adults can effectively reduce the risk of premature CVD and all-cause mortality, and greatly alleviate the burden on individuals and the society on the occasion of an aging society. Therefore, it is crucial to emphasize the monitoring and treatment of existing or newly emerging risk factors in the young population, strengthen health education tailored for young individuals, and promote lifestyle improvements. Furthermore, the degree of control of risk factors in the young population may serve as an effective intermediate or surrogate indicator for determining the factors contributing to premature CVD. Given the observed associations between diet, lifestyle, and health outcomes in the cohort, there may be opportunities for public health interventions targeted at improving dietary patterns and promoting healthier lifestyles in young population. For example, policies aimed at increasing access to healthy foods, promoting physical activity, and reducing occupational stress could contribute to improving overall health outcomes. Future research should investigate the mechanisms through which dietary patterns influence health, such as through gut microbiota, targeted interventions. Additionally, investigating how different social determinants of health, such as income, education, and healthcare access, interact with dietary behaviors to impact health outcomes will provide a more comprehensive understanding of the factors that contribute to health disparities.

The limitations of this study need to be addressed. Firstly, the cohort in this study is composed of employees from the Kailuan Group, which may limit the generalizability of the findings to the broader young adult population. This limitation arises from the specific demographic and occupational characteristics of the Kailuan Group employees, which may not reflect the diversity in lifestyle, socio-economic status, or health behaviors found in the general population. The validation in another cohort from different settings would benefit the generalization of the outcomes of the current study. Secondly, there was a lack of representativeness of females in this cohort. This Kailuan cohort study will provide further evidence in the follow-up investigation. Third, for dietary indices, due to the lack of corresponding items in the questionnaire, we opted for salt, tea, and high-fat diet closely associated with Chinese cardiovascular health as substitute indicators for the DASH-style diet [4, 18, 28, 29]. The accuracy of dietary contributions to CVD risk is thus potentially compromised by the use of these limited indicators. However, the findings of this study can be served as a starting point for further research using more detailed and comprehensive dietary data. Lastly, due to the extended follow-up period, potential for participant attrition exists. However, the Kailuan study will deploy an expert panel to review annual discharge records from 11 local hospitals to identify suspected cases of CVD among Kailuan study participants. This measure aims to mitigate the potential impact of participant relocation during the study period on the research outcomes.

#### Conclusions

The current study found a clear inverse relationship between the degree of control of risk factors and the risk of CVD as well as all-cause mortality in young adults. Individuals with fewer controlled risk factors are associated with a higher risk of CVD and all-cause mortality. The findings suggested that implementing aggressive primordial preventive strategies to control more risk factors may help to prevent such adverse events in young adults.

## Abbreviations

CVD	Cardiovascular disease
HR	Hazard ratio
CI	Confidence interval
CVH	Cardiovascular health
BMI	Body mass index
AHA	American Heart Association

LE8	Life's Simple 8
FBG	Fasting blood glucose
TC	Total cholesterol
HDL-C	High-density lipoprotein cholesterol
non-HDL-C	Non-high-density lipoprotein cholesterol

# **Supplementary Information**

The online version contains supplementary material available at https://doi. org/10.1186/s12872-025-04814-5.

Supplementary Material 1.

#### Acknowledgements

We sincerely express our gratitude to all the staff and participants of the *Kailuan* Cohort for their invaluable contributions.

#### **Conflict of interest**

The authors declare no competing interests.

## Clinical trial number

Not applicable.

#### Authors' contributions

Z.H. and C.Z. contributed to the conception or design of the work. C.Z., L.L., M.Z., J.L., H.G., H.L., Y.L. and C.J. contributed to the acquisition, analysis, or interpretation of data for the work. C.Z. drafted the manuscript. Z.H. critically revised the manuscript. All authors reviewed the manuscript.

#### Funding

This *Kailuan* cohort has been supported by the *Kailuan* General Hospital internal grant.

#### Data availability

No datasets were generated or analysed during the current study.

# Declarations

#### Ethics approval and consent to participate

The protocol and informed consent document were approved by the ethics committee of *Kailuan* General Hospital (2006–05), and informed consent was signed by the participants or the participant's legally authorized representative prior to participation.

#### **Consent for publication**

Not applicable.

#### **Competing interests**

The authors declare no competing interests.

#### Author details

<sup>1</sup>Department of Cardiology, Kailuan General Hospital, 57 Xinhua East Road, Tangshan 063000, China. <sup>2</sup>Department of Clinical Epidemiology, Shengjing Hospital of China Medical University, Shenyang, China. <sup>3</sup>Liaoning Key Laboratory of Precision Medical Research On Major Chronic Disease, Shenyang, China. <sup>4</sup>Department of General Practice, Kailuan General Hospital, 57 Xinhua East Road, Tangshan 063000, China. <sup>5</sup>Department of Cardiology, The Affiliated Hospital of North China University of Science and Technology, Tangshan 063000, China.

Received: 19 December 2024 Accepted: 2 May 2025 Published online: 07 May 2025

#### References

- Folsom AR, Yatsuya H, Nettleton JA, et al. Community prevalence of ideal cardiovascular health, by the American Heart Association definition, and relationship with cardiovascular disease incidence. J Am Coll Cardiol. 2011;57(16):1690–6.
- Yang Q, Cogswell ME, Flanders WD, et al. Trends in cardiovascular health metrics and associations with all-cause and CVD mortality among US adults. JAMA. 2012;307(12):1273–83.
- Virani SS, Alonso A, Benjamin EJ, et al. Heart Disease and Stroke Statistics-2020 Update: A Report From the American Heart Association. Circulation. 2020;141(9):e139–596.
- Di Daniele N, Marrone G, Di Lauro M, et al. Effects of Caloric Restriction Diet on Arterial Hypertension and Endothelial Dysfunction. Nutrients. 2021;13(1):274.
- Chavoshi V, Barzin M, Ebadinejad A, et al. Association of ideal cardiovascular health with carotid intima-media thickness (cIMT) in a young adult population. Sci Rep. 2022;12(1):10056.
- Desai CS, Ning H, Liu K, et al. Cardiovascular Health in Young Adulthood and Association with Left Ventricular Structure and Function Later in Life: The Coronary Artery Risk Development in Young Adults Study. J Am Soc Echocardiogr. 2015;28(12):1452–61.
- van den Oord SC, Sijbrands EJ, ten Kate GL, et al. Carotid intima-media thickness for cardiovascular risk assessment: systematic review and metaanalysis. Atherosclerosis. 2013;228(1):1–11.
- Anstey DE, Tanner RM, Booth JN 3rd, et al. Inappropriate Left Ventricular Mass and Cardiovascular Disease Events and Mortality in Blacks: The Jackson Heart Study. J Am Heart Assoc. 2019;8(16):e011897.
- Bombelli M, Vanoli J, Facchetti R, et al. Impact of the Increase in Left Ventricular Mass on the Risk of Long-Term Cardiovascular Mortality: A Prospective Cohort Study. Hypertension. 2023;80(6):1321–30.
- Desai CS, Colangelo LA, Liu K, et al. Prevalence, prospective risk markers, and prognosis associated with the presence of left ventricular diastolic dysfunction in young adults: the coronary artery risk development in young adults study. Am J Epidemiol. 2013;177(1):20–32.
- Echouffo-Tcheugui JB, Erqou S, Butler J, et al. Assessing the Risk of Progression From Asymptomatic Left Ventricular Dysfunction to Overt Heart Failure: A Systematic Overview and Meta-Analysis. JACC Heart Fail. 2016;4(4):237–48.
- Lloyd-Jones DM, Allen NB, Anderson CAM, et al. Life's Essential 8: Updating and Enhancing the American Heart Association's Construct of Cardiovascular Health: A Presidential Advisory From the American Heart Association. Circulation. 2022;146(5):e18–43.
- Lloyd-Jones DM, Ning H, Labarthe D, et al. Status of Cardiovascular Health in US Adults and Children Using the American Heart Association's New "Life's Essential 8" Metrics: Prevalence Estimates From the National Health and Nutrition Examination Survey (NHANES), 2013 Through 2018. Circulation. 2022;146(11):822–35.
- 14. Zheng M, Zhang X, Chen S, et al. Arterial Stiffness Preceding Diabetes: A Longitudinal Study. Circ Res. 2020;127(12):1491–8.
- Zhao M, Song L, Sun L, et al. Associations of Type 2 Diabetes Onset Age With Cardiovascular Disease and Mortality: The Kailuan Study. Diabetes Care. 2021;44(6):1426–32.
- Wu S, Huang Z, Yang X, et al. Prevalence of ideal cardiovascular health and its relationship with the 4-year cardiovascular events in a northern Chinese industrial city. Circ Cardiovasc Qual Outcomes. 2012;5(4):487–93.
- Zhang Q, Zhou Y, Gao X, et al. Ideal cardiovascular health metrics and the risks of ischemic and intracerebral hemorrhagic stroke. Stroke. 2013;44(9):2451–6.
- Liu X, Cui L, Wang A, et al. Cumulative Exposure to Ideal Cardiovascular Health and Incident Diabetes in a Chinese Population: The Kailuan Study. J Am Heart Assoc. 2016;5(9):e004132.
- Stroke–1989. Recommendations on stroke prevention, diagnosis, and therapy. Report of the WHO Task Force on Stroke and other Cerebrovascular Disorders. Stroke. 1989;20(10):1407–31.
- Thygesen K, Alpert JS, Jaffe AS, et al. Fourth Universal Definition of Myocardial Infarction (2018). Circulation. 2018;138(20):e618–51.
- Guo F, Chen X, Howland S, et al. Association Between Cardiovascular Health and Subclinical Atherosclerosis Among Young Adults Using the American Heart Association's "Life's Essential 8" Metrics. J Am Heart Assoc. 2024;13(15):e033990.

- 22. Perak AM, Ning H, Khan SS, et al. Associations of Late Adolescent or Young Adult Cardiovascular Health With Premature Cardiovascular Disease and Mortality. J Am Coll Cardiol. 2020;76(23):2695–707.
- Bundy JD, Ning H, Zhong VW, et al. Cardiovascular Health Score and Lifetime Risk of Cardiovascular Disease: The Cardiovascular Lifetime Risk Pooling Project. Circ Cardiovasc Qual Outcomes. 2020;13(7):e006450.
- 24. Zhang Y, Vittinghoff E, Pletcher MJ, et al. Associations of Blood Pressure and Cholesterol Levels During Young Adulthood With Later Cardiovascular Events. J Am Coll Cardiol. 2019;74(3):330–41.
- Xu X, Huang R, Lin Y, et al. High triglyceride-glucose index in young adulthood is associated with incident cardiovascular disease and mortality in later life: insight from the CARDIA study. Cardiovasc Diabetol. 2022;21(1):155.
- 26. Soedamah-Muthu SS, Fuller JH, Mulnier HE, et al. All-cause mortality rates in patients with type 1 diabetes mellitus compared with a non-diabetic population from the UK general practice research database, 1992–1999. Diabetologia. 2006;49(4):660–6.
- Batch BC, Tyson C, Bagwell J, et al. Weight loss intervention for young adults using mobile technology: design and rationale of a randomized controlled trial - Cell Phone Intervention for You (CITY). Contemp Clin Trials. 2014;37(2):333–41.
- Li CH, Yang YC, Wu JS, et al. Increased tea consumption is associated with decreased arterial stiffness in a Chinese population. PLoS ONE. 2014;9(1):e86022.
- 29. Bailey MA. Dhaun N Salt Sensitivity: Causes, Consequences, and Recent Advances. Hypertension. 2024;81(3):476–89.

# **Publisher's Note**

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.