Journal of Psychosomatic Research 192 (2025) 112116

Contents lists available at ScienceDirect

Journal of Psychosomatic Research

journal homepage: www.elsevier.com/locate/jpsychores

Psychological resilience, cardiovascular disease, and mortality – Insights from the German Gutenberg Health Study

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ARTICLE INFO

Keywords:
Psychological resilience
Brief resilient coping scale
Stress
Cardiovascular disease
Mortality

ABSTRACT

Objective: Psychological distress is associated with a higher risk of cardiovascular disease (CVD) and mortality, whereas psychological resilience may confer a protective effect. However, evidence on these relationships remains limited. This study aimed to examine the associations between psychological resilience, CVD, and all-cause mortality within a large general population cohort.

Methods: Data from 12,675 participants in the German Gutenberg Health Study were analyzed. Psychological resilience was assessed using the Brief Resilient Coping Scale (BRCS). CVD prevalence and mortality data were obtained from medical records and registry updates. Logistic and Cox regression analyses examined the associations between resilience, CVD, and mortality, with adjustments for socio-demographics, lifestyle, and clinical factors.

Results: Cross-sectionally, lower resilience was linked to higher odds of any CVD (odds ratio (OR) 1.030, 95 % confidence interval [CI] 1.009–1.051). Participants with low resilience had 38 % higher odds of CVD and 61 % higher odds of peripheral artery disease compared to those with high resilience. Longitudinally, low resilience was associated with the highest all-cause mortality risk (log-rank test, $p < 0.0001$). This association remained significant in Cox models after adjusting for confounders (hazard ratio (HR) 1.362, 95 % CI 1.002–1.852).

Conclusions: Lower psychological resilience is associated with increased CVD prevalence and all-cause mortality. These findings highlight resilience as a potential target for cardiovascular risk assessment and intervention. Incorporating resilience measures in clinical practice may help identify vulnerable individuals who could benefit from strategies to enhance adaptive coping, improving cardiovascular and overall health outcomes.

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https://doi.org/10.1016/j.jpsychores.2025.112116
Received 27 January 2025; Received in revised form 24 March 2025; Accepted 27 March 2025
Available online 28 March 2025

1. Background

According to the American Psychological Association (APA), psychological resilience describes "the process and outcome of successfully adapting to difficult or challenging life experiences, especially through mental, emotional, and behavioral flexibility and adjustment to external and internal demands" [1]. Numerous studies indicate that psychological resilience is a critical factor in maintaining and enhancing mental health [2,3]. On a conceptual level, psychological resilience is interconnected with various psychological constructs such as posttraumatic growth [4], hardiness [5], coping [6], self-efficacy [7], emotional regulation [8], social support [9], optimism [10], and sense of coherence [11]. These constructs collectively influence the capacity to adapt to adversity, regulate emotional responses, utilize available resources, and maintain psychological well-being under stress.

Previous evidence has shown that maladaptive responses to stress are not only significant risk factors for mental health disorders, reduced quality of life, and premature mortality [12] but also demonstrate a strong association with cardiovascular diseases [13]. Consequently, psychological resilience is emerging as a potential target for assessing and reducing cardiovascular risk [14,15]. For instance, in a recent pooled analysis of two prospective cohorts ($N = 891$) with stable coronary heart disease, it was found that higher psychological distress scores (a combined measure of depression, anxiety, anger, perceived stress, and post-traumatic stress disorder) were associated with a greater risk of cardiovascular events over 5.9 years [16]. Patients in the highest tertile of distress scores had a 2.27-fold increased risk (95 % confidence interval (CI) 1.69–3.06) of cardiovascular death, nonfatal myocardial infarction, or hospitalization for heart failure, compared to those in the lowest tertile. Importantly, including the distress score in a traditional clinical risk model significantly improved the risk prediction for adverse cardiovascular events. The link between higher psychological distress and recurrent cardiovascular events or death is likely mediated, at least in part, by impaired psychological recovery after such traumatic events [17], as suggested by a study indicating that higher psychological resilience is associated with better psychological recovery over time in a cohort of women following a myocardial infarction [18]. In addition to these findings, there are also studies that specifically focus on the role of stress resilience in cardiovascular disease development. A prospective study of 237,980 Swedish men demonstrated that low stress resilience was associated with increased coronary heart disease risk (hazard ratio (HR) 1.17, 95 % CI 1.10–1.25) [19]. Interestingly, while higher physical fitness was protective against coronary heart disease, this benefit was attenuated in those with low stress resilience (p for interaction <0.001), suggesting that low stress resilience may modify the cardiovascular benefits of physical fitness. The role of lifetime trauma was analyzed in a study of 6596 older adults to determine how psychological resilience affects cardiometabolic health and mortality [20]. Higher levels of psychological resilience, defined as trauma burden and psychological health, i.e. low distress and high psychological well-being, were associated with a 9 % lower risk of developing any cardiometabolic disease (relative risk (RR) 0.91, 95 % CI 0.88–0.94) and a 27 % lower risk of all-cause mortality (RR 0.73, 95 % CI 0.63–0.86). However, a systematic review of 17 studies suggests that psychological resilience may be associated with cardiometabolic disturbances in a protective manner [15]. The overall conclusion is limited due to significant heterogeneity in the types of outcomes, populations studied, the small number of studies, and the various instruments used to assess psychological resilience.

Thus, we used data from a large cohort of the German general population to investigate the association between psychological resilience, as measured by the Brief Resilient Coping Scale (BRCS), and various cardiovascular diseases, including myocardial infarction, stroke, atrial fibrillation, peripheral artery disease, coronary artery disease, and chronic heart failure, as well as all-cause mortality. We hypothesize that higher psychological resilience is associated with a lower risk of prevalent cardiovascular diseases and reduced all-cause mortality.

2. Methods

2.1. The Gutenberg health study

The Gutenberg Health Study (GHS) is an ongoing large-scale, prospective cohort study based at the University Medical Center in Mainz, Germany, and has been extensively described recently [21–23]. This study draws on a randomly selected cohort from local registries in Mainz city and the Mainz-Bingen district. A total of 15,010 individuals aged 35 to 74 were enrolled during the baseline phase, which spanned from April 2007 to April 2012 and included a comprehensive 5-h examination following standardized protocols consisting of various interviews and clinical tests. Participants underwent follow-up assessments at both 5 and 10 years after their initial enrollment (from 2012 to 2017 and 2017–2022, respectively), following procedures similar to those used at baseline. At the 10-year follow-up, psychological resilience questionnaires were incorporated into the test battery. Therefore, the present study uses cross-sectional data from this follow-up phase, along with longitudinal data on all-cause mortality to date ($N = 12,675$ participants in total, comprising 9088 returning participants from the baseline phase and 3673 newly recruited participants). The exact end date of the follow-up period was 2024/11/25 (median follow-up time was 4.52 years). The study received ethical approval from the Medical Chamber of Rhineland-Palatinate's ethics committee (reference number 837.020.07(5555)) as well as authorization from both local and federal data protection authorities. Criteria for exclusion included inadequate German language skills or any psychological or physical condition that could hinder participation. The study was conducted following the principles outlined in the revised Helsinki Declaration and the standards of Good Clinical and Epidemiological Practice. All participants provided written informed consent before joining the study.

2.2. Psychological resilience

The German version of the Brief Resilient Coping Scale (BRCS) [24–26] was used to measure psychological resilience. The BRCS assesses individuals' tendency for adaptive stress management. It specifically measures the extent to which individuals employ coping strategies that are flexible, persistent, and problem-focused, enabling them to navigate and resolve challenges even under stressful conditions. The scale consists of four items (e.g., "I look for creative ways to alter difficult situations"). Response options ranged from 1 ("does not describe me at all") to 5 ("describes me very well") and were summarized to a total sum score [4-20], with higher values indicating a higher degree of psychological resilience. Total sum score of 4–12 indicate low resilient coping, 13–16 medium resilient coping, and 17–20 high resilient coping. The internal consistency of the BRCS, as measured by Cronbach's alpha, was previously reported to be $\alpha = 0.78$ [25].

2.3. Cardiovascular disease, risk factors, and mortality

The presence of cardiovascular disease was ascertained by examining medical records for physician diagnoses or those made during study visits. This assessment included conditions such as atrial fibrillation, coronary artery disease, myocardial infarction, stroke, chronic heart failure, and peripheral artery disease. To ensure up-to-date mortality information, we performed quarterly updates from registry offices and the mortality registry in Rhineland-Palatinate, securing official death certificates for detailed review. Socioeconomic status was assessed using a validated scale that ranges from 3 to 21, incorporating factors such as education level, current employment, and income, higher scores reflect higher socioeconomic status [27]. Self-reported alcohol consumption was expressed in grams per day (g/d). Participants' smoking status was categorized into current smokers and non-smokers. Current

smokers were defined as individuals who smoked regularly or daily, with a consumption of at least one cigarette per day, seven cigarettes per week, or one pack per month for at least six months. Non-smokers included those who had never smoked, those who had quit smoking for more than six months, and occasional smokers [28]. Presence of diabetes mellitus was defined either as a physician's evaluation, use of antidiabetic medications, fasting blood glucose levels of 126 mg/dL or more, non-fasting blood glucose levels of 200 mg/dL or more, or an HbA1c level of 6.5 % or greater. Arterial hypertension was defined as taking antihypertensive medications or those with a resting systolic blood pressure of 140 mmHg or higher or a diastolic blood pressure of 90 mmHg or higher, averaged from the second and third readings after 8 and 11 min of rest. Obesity was defined as having a body mass index of 30 kg/m^2 or higher [29]. Dyslipidemia was identified through a physician's diagnosis, a low-density lipoprotein to high-density lipoprotein cholesterol ratio greater than 3.5, or triglyceride levels of 150 mg/dL or higher. A family history of myocardial infarction or stroke was recorded if a first-degree relative (female ≤65 years or male ≤60 years) had experienced such an event.

2.4. Statistical analysis

Participants with missing data on psychological resilience, i.e. the BRCS, were excluded from the analysis. Continuous variables are reported as means with standard deviations (SD). For variables exhibiting skewness greater than 1, data are described by medians (with first and third quartiles (Q1/Q3)). Binary variables at baseline are presented with both relative and absolute frequencies. *P* values are estimated using the *t*-test for mean (SD), the Mann-Whitney *U* test (Wilcoxon Rank Sum test) for median (Q1/Q3), and the Chi-squared test for binary variables. Intercorrelations among items of the BRCS were analyzed using the Spearman correlation coefficient. To assess the association between psychological resilience (per point increase in total sum score and groups of psychological resilience with high resilient coping being the reference category) and the prevalence of cardiovascular disease, binary logistic regression was used. Results are presented as odds ratios with 95 % CI and *p* values. Cox regression models were used to estimate HR and 95 % CI to evaluate the association between psychological resilience and the risk of all-cause mortality. The proportional hazards assumption for the fully adjusted all-cause mortality model was assessed using Schoenfeld residuals, which indicated no violations. In all regression analysis, the BRCS total sum score was inverted to facilitate the interpretation of risk estimates greater than 1. Kaplan-Meier survival analysis was employed to investigate the relationship between groups of psychological resilience and the risk of all-cause mortality with statistical significance determined by the log rank test. The analysis involved sequential model adjustments: Model 1 was adjusted for sex (binary), age (continuous), and socioeconomic status (continuous) and Model 2 was further adjusted for alcohol consumption (continuous), current smoking (binary), diabetes mellitus (binary), arterial hypertension (binary), obesity (binary), dyslipidemia (binary), and a family history of myocardial infarction or stroke (binary). *P* values were reported with precision as measures of evidence against the null hypothesis, with values below 0.05 considered statistically significant for descriptive reasons. All statistical analyses were performed using the R software package (http://www.r-project.org/).

3. Results

3.1. Sample characteristics

The study included 12,675 participants with a mean age and standard deviation of 58.0 ± 14.5 years and a sex distribution of 49.4 % women (n = 6261) (Table 1). Those with cardiovascular disease (n = 1156) were older and had lower socioeconomic status and psychological resilience scores compared to those without cardiovascular disease.

Table 1
Characteristics of the Gutenberg Health Study sample stratified by prevalent cardiovascular disease (N = 12,675).

	No cardiovascular disease (n = 11,519)	Cardiovascular disease (n = 1156)	*P* value
Social demographics			
Sex (women) – % (no.)	51.0 (5869)	33.9 (392)	**<0.0001**
Age (years) – mean ± SD	56.8 ± 14.2	70.3 ± 10.7	**<0.0001**
Socioeconomic status total sum score – mean ± SD	14.62 ± 4.16	13.12 ± 4.26	**<0.0001**
Psychological resilience			
BRCS total sum score – mean ± SD	15.24 ± 3.09	14.45 ± 3.49	**<0.0001**
Low resilient coping – % (no.)	17.4 (1951)	26.6 (299)	**<0.0001**
Medium resilient coping – % (no.)	48.0 (5400)	46.4 (521)	0.30
High resilient coping – % (no.)	34.6 (3891)	27.0 (303)	**<0.0001**
Item 1 (1–5) – median (Q1/Q3)	4.00 (4.00/5.00)	4.00 (3.00/4.00)	**<0.0001**
Item 2 (1–5) – mean ± SD	3.81 ± 0.86	3.78 ± 0.91	0.34
Item 3 (1–5) – median (Q1/Q3)	4.00 (4.00/5.00)	4.00 (3.00/4.00)	**<0.0001**
Item 4 (1–5) – mean ± SD	3.53 ± 1.20	3.39 ± 1.28	**0.00041**
Risk factors			
Alcohol consumption (g/d) – median (Q1/Q3)	3.77 (0/12.57)	4.40 (0/16.88)	**0.049**
Current smoking – % (no.)	13.6 (1559)	8.5 (94)	**<0.0001**
Diabetes mellitus – % (no.)	8.0 (913)	21.3 (245)	**<0.0001**
Arterial hypertension – % (no.)	46.2 (5312)	77.3 (891)	**<0.0001**
Obesity – % (no.)	24.4 (2808)	34.3 (396)	**<0.0001**
Dyslipidemia – % (no.)	24.6 (2828)	64.2 (742)	**<0.0001**
Family history of myocardial infarction or stroke – % (no.)	2.1 (245)	3.9 (45)	**0.00040**
Cardiovascular disease			
Atrial fibrillation – % (no.)	–	30.0 (344)	–
Coronary artery disease – % (no.)	–	26.0 (286)	–
Myocardial infarction – % (no.)	–	13.6 (156)	–
Stroke – % (no.)	–	15.8 (181)	–
Chronic heart failure – % (no.)	–	20.6 (228)	–
Peripheral artery disease – % (no.)	–	25.2 (285)	–

Continuous variables are described by mean values with standard deviation in brackets (SD) or median values with 1st and 3rd quantiles in brackets (Q1/Q3) if they are skewed (i.e., |skewness| > 1). Discrete variables are described by relative and absolute frequencies. *P*-values are estimated using the t-test for mean (SD), the Mann-Whitney U test (Wilcoxon Rank Sum test) for median (Q1/Q3), and the Chi-squared test for dichotomous variables.
Socioeconomic status total sum score can reach values from 3 to 21 with 21 indicating the highest and 3 the lowest socioeconomic status.
Brief Resilient Coping Scale (BRCS) total sum scores range from 4 to 20. Scores of 4–12 indicate low resilient coping, 13–16 indicate medium resilient coping, and 17–20 indicate high resilient coping.

Notably, 26.6 % of the cardiovascular disease group had low psychological resilience compared to 17.4 % of the non-cardiovascular disease group. Risk factors such as diabetes mellitus, arterial hypertension, obesity, and dyslipidemia were significantly more prevalent in the cardiovascular disease group. Fig. 1 displays the correlation coefficients of the BRCS Items indicating moderate intercorrelation.

3.2. Psychological resilience and cardiovascular disease

Lower psychological resilience (total sum score) was linked to a higher likelihood of any cardiovascular disease (OR 1.033, 95 % CI 1.014–1.054) in Model 1, which remained almost unattenuated after additional adjustment for risk factors (OR 1.030, 95 % CI 1.009–1.051) (Table 2). Low psychological resilience was associated with 61 % (OR 1.613, 95 % CI 1.120–2.324) and 38 % (OR 1.380, 95 % CI 1.135–1.677) higher odds of peripheral artery disease and any cardiovascular disease, respectively, compared to high resilience, after comprehensive adjustment (Table 3). Additionally, positive trends were observed across several other cardiovascular outcomes with respect to low psychological resilience. For instance, low psychological resilience showed a trend toward increased coronary artery disease risk (OR 1.379, 95 % CI 0.957–1.988, and a similar trend was observed for stroke (OR 1.301, 95 % CI 0.850–1.990) (Table 3).

3.3. Psychological resilience and mortality

Cumulative incidence plots of all-cause mortality, stratified by low, medium, and high psychological resilience using Kaplan-Meier survival analysis, demonstrated that low psychological resilience was associated with the highest mortality rates (p for log rank test <0.0001, Fig. 2). In Cox regression analysis, this association remained robust after adjustment for risk factors (HR 1.362, 95 % CI 1.002–1.852) (Table 4).

4. Discussion

The present study investigated the association between psychological resilience, cardiovascular disease, and all-cause mortality in a large cohort from the German general population. Our findings indicate that lower psychological resilience, as measured by the BRCS, is associated with an increased risk of prevalent cardiovascular disease, peripheral artery disease, and higher risk of all-cause mortality. In general, we found positive trends for the association between low psychological resilience and all cardiovascular outcomes, including coronary artery disease, stroke, myocardial infarction, atrial fibrillation, and chronic heart failure. These results align with and expand upon prior evidence suggesting that psychological resilience may play a protective role in cardiovascular health [15]. Our study demonstrated a robust association between lower psychological resilience and increased risk of any cardiovascular disease, which persisted even after adjusting for multiple covariates, including traditional cardiovascular risk factors, that could be potential pathway variables. Specifically, participants with low psychological resilience had a 38 % higher likelihood of having any cardiovascular disease compared to those with high resilience. This finding is consistent with previous research indicating that psychological distress and stress resilience significantly influences cardiovascular outcomes [16,19]. Furthermore, the association between psychological resilience and all-cause mortality, which was also confirmed in a previous study in Italy [30], is in line with findings that report a link between psychological well-being and reduced mortality risk, potentially mediated by behavioral factors, including adherence to health-promoting behaviors such as not smoking, regular physical activity, moderate or no alcohol consumption, and sufficient sleep quality as well as reduced engagement in other risky behaviors [31]. Additionally, psychological resilience may buffer stress-induced pathophysiological changes, such as systemic inflammation or endothelial dysfunction, both of which are critical in the pathophysiology of cardiovascular disease [13]. Herein, better psychological recovery in resilient individuals compared to less resilient, through the use of adaptive coping strategies and the fostering of more effective emotional regulation, may play an important role, as suggested by previous research [18]. Comprehensive evidence on the relationship between resilience and mortality comes from a Chinese study cohort of 4935 participants aged >65, which found that higher resilience was associated with lower all-cause mortality (HR 0.74, 95 % CI 0.67–0.82) and reduced risks of death from cardiovascular disease (HR 0.74, 95 % CI 0.59–0.93), respiratory diseases (HR 0.63, 95 % CI 0.45–0.87), and other non-cancer causes (HR 0.69, 95 % CI 0.60–0.78) [32]. Dose-response analysis revealed a steady decline in

Table 2
Cross-sectional association analysis between psychological resilience and cardiovascular disease (data from the Gutenberg Health Study 2017–2022).

	N	Model 1		Model 2	
		OR [95 % CI]	*P* value	OR [95 % CI]	*P* value
Any cardiovascular disease	11,814	1.033 [1.014; 1.054]	**0.00082**	1.030 [1.009; 1.051]	**0.0042**
Myocardial infarction	11,851	1.034 [0.985; 1.085]	0.18	1.026 [0.975; 1.080]	0.32
Stroke	11,857	1.034 [0.990; 1.079]	0.13	1.032 [0.987; 1.080]	0.17
Atrial fibrillation	11,849	1.025 [0.993; 1.059]	0.13	1.020 [0.986; 1.054]	0.25
Peripheral artery disease	11,760	1.039 [1.003; 1.077]	**0.035**	1.034 [0.996; 1.073]	0.079
Coronary artery disease	11,766	1.025 [0.989; 1.062]	0.17	1.018 [0.980; 1.057]	0.37
Chronic heart failure	11,753	1.009 [0.969; 1.051]	0.66	1.006 [0.965; 1.049]	0.78

Odds ratios and 95 % confidence intervals (CI) are derived from a logistic regression model modeling for prevalent cardiovascular disease with psychological resilience (Brief Resilient Coping Scale total sum score) being the independent variable. *N* denotes model 2.
Model 1 was adjusted for sex, age, and socioeconomic status.
Model 2 was additionally adjusted for alcohol consumption, current smoking, diabetes mellitus, arterial hypertension, obesity, dyslipidemia, and family history of myocardial infarction or stroke.

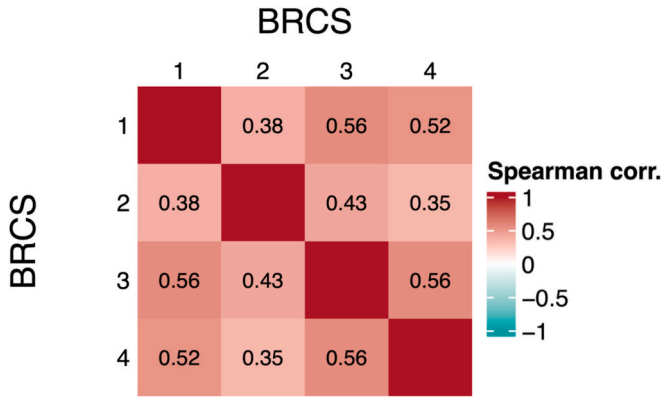

Fig. 1. Intercorrelations (Spearman correlation coefficient) of Brief Resilient Coping Scale (BRCS) Items. The items are the following: 1. I look for creative ways to alter difficult situations, 2. Regardless of what happens to me, I believe I can control my reaction to it, 3. I believe that I can grow in positive ways by dealing with difficult situations, 4. I actively look for ways to replace the losses I encounter in life.

Table 3
Cross-sectional association analysis between groups of psychological resilience and cardiovascular disease (data from the Gutenberg Health Study 2017–2022).

	N	Model 1		Model 2	
		OR [95 % CI]	*P* value	OR [95 % CI]	*P* value
Any cardiovascular disease					
Low (vs. high) resilient coping	11,814	1.423 [1.181; 1.716]	**0.00021**	1.380 [1.135; 1.677]	**0.0012**
Medium (vs. high) resilient coping		1.81 [1.007; 1.385]	**0.041**	1.138 [0.964; 1.343]	0.13
Myocardial infarction					
Low (vs. high) resilient coping	11,851	1.358 [0.826; 2.231]	0.23	1.243 [0.748; 2.065]	0.40
Medium (vs. high) resilient coping		1.334 [0.871; 2.044]	0.18	1.115 [0.718; 1.729]	0.63
Stroke					
Low (vs. high) resilient coping	11,857	1.323 [0.880; 1.989]	0.18	1.301 [0.850; 1.990]	0.61
Medium (vs. high) resilient coping		0.864 [0.593; 1.261]	0.45	0.772 [0.519; 1.150]	0.20
Atrial fibrillation					
Low (vs. high) resilient coping	11,849	1.291 [0.938; 1.777]	0.12	1.224 [0.880; 1.702]	0.23
Medium (vs. high) resilient coping		1.130 [0.853; 1.495]	0.39	1.102 [0.827; 1.469]	0.51
Peripheral artery disease					
Low (vs. high) resilient coping	11,760	1.642 [1.153; 2.339]	**0.0060**	1.613 [1.120; 2.324]	**0.010**
Medium (vs. high) resilient coping		1.323 [0.971; 1.804]	0.076	1.293 [0.941; 1.778]	0.11
Coronary artery disease					
Low (vs. high) resilient coping	11,766	1.485 [1.050; 2.101]	**0.025**	1.379 [0.957; 1.988]	0.084
Medium (vs. high) resilient coping		1.216 [0.899; 1.645]	0.20	1.132 [0.826; 1.551]	0.44
Chronic heart failure					
Low (vs. high) resilient coping	11,753	1.107 [0.737; 1.663]	0.62	1.106 [0.730; 1.676]	0.63
Medium (vs. high) resilient coping		1.267 [0.912; 1.761]	0.16	1.212 [0.864; 1.699]	0.27

Odds ratios and 95 % confidence intervals (CI) are derived from a logistic regression model modeling for prevalent cardiovascular disease with low and medium (vs. high) resilient coping being the independent variables. *N* denotes model 2.
Model 1 was adjusted for sex, age, and socioeconomic status.
Model 2 was additionally adjusted for alcohol consumption, current smoking, diabetes mellitus, arterial hypertension, obesity, dyslipidemia, and family history of myocardial infarction or stroke.

mortality risk with increasing resilience scores.

The current findings contribute to a growing body of evidence that underscores the importance of psychological factors in cardiovascular health. While previous studies have primarily focused on psychological distress as a risk factor for cardiovascular disease, our study emphasizes the protective role of psychological resilience, which is likely shaped by a complex interplay between stress and adaptive coping or stress management and accompanied by specific neurobiological, neuroendocrine, and immune responses [33]. Interestingly, a study of 1433 Black residents in Atlanta, GA, USA, found that those living in low-risk neighborhoods (with lower-than-expected rates of cardiovascular events) reported higher psychological well-being compared to those in high-risk neighborhoods (with higher-than-expected rates) [34]. This greater psychological well-being was linked to lower cardiovascular risk, despite similar rates of traditional risk factors, suggesting it may enhance cardiovascular resilience. More comprehensively, another study found suggestive evidence of an association between resilience resources (optimism, social support, and neighborhood social cohesion) and cardiovascular disease incidence in three US cohort studies [35]. Herein, high optimism (HR 0.94, 95 % CI 0.78–1.13) and high social support (HR 0.88, 95 % CI 0.74–1.04) were linked to lower cardiovascular disease incidence, while neighborhood social cohesion showed no clear association (HR 1.10, 95 % CI 0.94–1.29). Importantly, psychosocial risk factors modified these associations indicating that social support was protective only in those without depression (HR 0.86 vs. 1.17) and optimism lowered cardiovascular disease risk in low- but not high-deprivation neighborhoods (HR 0.82 vs. 1.24).

This study has several strengths and is novel in examining a large general population cohort in Germany, simultaneously assessing both cardiovascular disease and all-cause mortality risk within the same study, analyzing specific cardiovascular disease subtypes in addition to a composite endpoint, using the validated BRCS, and rigorously adjusting for socioeconomic, lifestyle, and clinical risk factors. However, some limitations should be acknowledged. The partly cross-sectional and observational nature of the study limit the ability to draw definitive conclusions about causality. While we adjusted for several known risk factors, residual confounding may still be present. The self-reported nature of key confounders, such as alcohol consumption and smoking status, introduces a potential risk of misclassification. The possibility of reverse causality cannot be entirely excluded. However, psychological resilience is generally considered a stable construct that forms early in life [36]. Previous research has used varying constructs and assessments of psychological resilience, whereas we specifically focused on the well-studied aspect of resilient coping—defined as individuals tendency for adaptive stress management. While psychological resilience is conceptually linked to stress and adversity, our study did not assess these factors. We found only suggestive evidence of an association between psychological resilience and specific cardiovascular outcomes, likely due to limited statistical power. Additionally, no data were available on cardiovascular mortality. Lastly, the study population is limited to residents of Mainz and the Mainz-Bingen district, which may affect the generalizability of the findings to other populations.

5. Conclusions

In conclusion, this study provides evidence that lower psychological resilience is associated with an increased risk of prevalent cardiovascular disease and all-cause mortality in a large general population cohort. The findings from this study have important implications for clinical practice and public health. Psychological resilience appears to be an emerging target for cardiovascular risk assessment and management. Incorporating resilience measures into clinical risk assessments could help identify individuals at higher risk for cardiovascular disease and mortality who might benefit from targeted interventions [16]. Interventions designed to enhance resilience, such as cognitive-behavioral therapy, mindfulness-based stress reduction, or resilience training

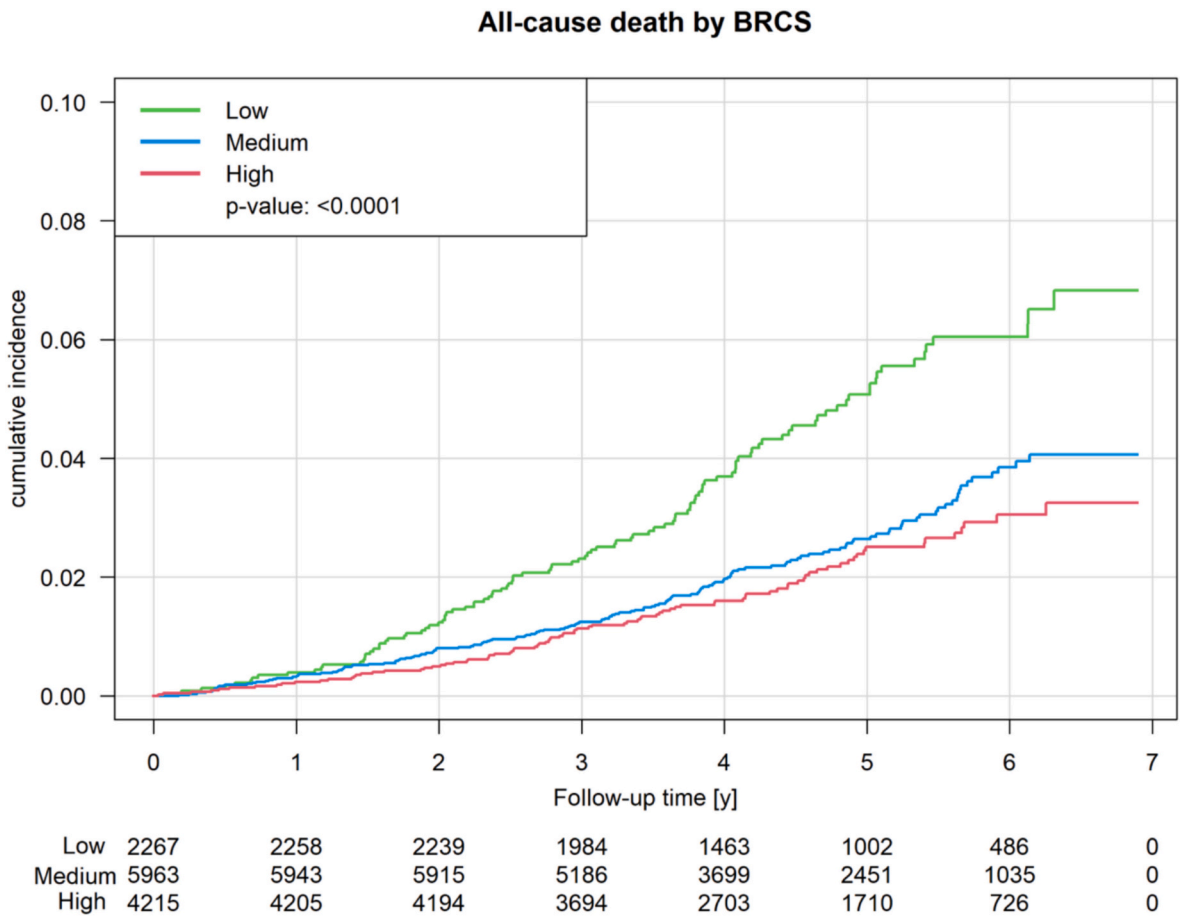

Fig. 2. Cumulative incidence plots of all-cause death stratified by low, medium, and high resilient coping based on Brief Resilient Coping Scale (BRCS). *P* value refers to log rank test.

Table 4
Association analysis between psychological resilience and all-cause mortality (data from the Gutenberg Health Study 2017–2024).

	N/ Events	Model 1		Model 2	
		Hazard ratio [95 % CI]	*P* value	Hazard ratio [95 % CI]	*P* value
BRCS total sum score	11,880/ 308	1.039 [1.010; 1.070]	**0.0086**	1.033 [1.002; 1.065]	**0.037**
Low (vs. high) resilient coping		1.443 [1.074; 1.937]	**0.015**	1.362 [1.002; 1.852]	**0.049**
Medium (vs. high) resilient coping		1.127 [0.860; 1.475]	0.39	1.071 [0.810; 1.416]	0.63

Hazard ratios and 95 % confidence intervals (CI) are derived from a Cox proportional hazard regression model modeling for all-cause mortality (dependent variable) with psychological resilience (Brief Resilient Coping Scale (BRCS)) being the independent variable). *N*/Events denotes model 2.
Model 1 was adjusted for sex, age, and socioeconomic status.
Model 2 was additionally adjusted for alcohol consumption, current smoking, diabetes mellitus, arterial hypertension, obesity, dyslipidemia, and family history of myocardial infarction or stroke.

programs, could potentially mitigate cardiovascular risk, although further research is needed to confirm the efficacy of these approaches [37].

CRediT authorship contribution statement

Omar Hahad: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Jasmin Ghaemi Kerahrodi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Conceptualization. **Elmar Brähler:** Writing – review & editing. **Klaus Lieb:** Writing – review & editing. **Donya Gilan:** Writing – review & editing. **Daniela Zahn:** Writing – review & editing. **Katja Petrowski:** Writing – review & editing. **Anna Celine Reinwarth:** Writing – review & editing. **Konstantin Kontohow-Beckers:** Writing – review & editing, Formal analysis. **Alexander K. Schuster:** Writing – review & editing. **Markus Schepers:** Writing – review & editing. **Karl Lackner:** Writing – review & editing. **Peter R. Galle:** Writing – review & editing. **Stavros Konstantinides:** Writing – review & editing. **Philipp Wild:** Writing – review & editing. **Andreas Daiber:** Writing – review & editing. **Matthias Michal:** Writing – review & editing. **Thomas Münzel:** Writing – review & editing. **Manfred Beutel:** Writing – review & editing, Writing – original draft.

Funding

None.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The Gutenberg Health Study is funded through the Government of Rhineland-Palatinate ('Stiftung Rheinland-Pfalz für Innovation', contract AZ 961-386261/733), the research programmes 'Wissen schafft Zukunft' and 'Center for Translational Vascular Biology (CTVB)' of the Johannes Gutenberg-University of Mainz, and its contract with Boehringer Ingelheim and PHILIPS Medical Systems, including an unrestricted grant for the Gutenberg Health Study and by the Foundation Heart of Mainz. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. Omar Hahad is a Young Scientist and Thomas Münzel and Philipp Wild are PI's of the DZHK (German Center for Cardiovascular Research), Partner Site Rhine-Main, Mainz, Germany.

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