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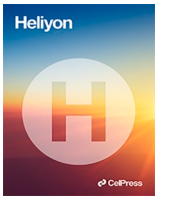

Research article

Associations between cardiac structure and function and depressive disorder: A centenarian study in China

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ABSTRACT

Background: Depressive disorder is a common comorbidity in patients with cardiovascular diseases and is associated with increased hospitalization and death rates. The relationships between cardiac structure and function and depressive disorder remains unclear in the older adults, especially in centenarians. Therefore, this study aimed to explore the possible associations between cardiac structure and function and depressive disorder among centenarians.

Methods: In the China Hainan Centenarian Cohort Study, the 15-item Geriatric Depression Scale scores and echocardiography were used to evaluate depressive disorder and cardiac structure and function, respectively. All information, including epidemiological questionnaires, physical examinations, and blood tests, was obtained following standardized procedures.

Results: A total of 682 centenarians were enrolled in the study (mean age: 102.35 ± 2.72 years). The prevalence of depressive disorder in centenarians is 26.2% (179 older adults), of whom 81.2% (554 older adults) are women. Centenarians with depressive disorder have significantly higher left ventricular ejection fraction (60.02 ± 3.10) and interventricular septum thickness (9.79 ± 1.54). Stepwise multiple linear regression analysis detected positive associations of left ventricular ejection fraction (Bets: 0.093) and interventricular septum thickness (Bets: 0.440) with Geriatric Depression Scale scores. Both left ventricular ejection fraction (odds ratio: 1.081) and interventricular septum thickness (odds ratio: 1.274) were independently associated with depressive disorder in multiple logistic regression analysis ($P < 0.05$, all).

Conclusions: The prevalence of depressive disorder remains very high, and associations were found between left ventricular ejection fraction, interventricular septum thickness, and

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depressive disorder in Chinese centenarians. Future studies should focus on their temporal relationships to improve cardiac structure and function, prevent depressive disorder, and achieve healthy aging by coordinating their relationships.

1. Introduction

Depressive disorder is a common comorbidity in patients with cardiovascular diseases and is associated with an increased risk of hospitalization and death rates [1,2]. In a meta-analysis [3] including 27 studies on participants with cardiovascular diseases, the average prevalence of depressive disorder was 22% (range: 9%–54%). However, the relationships between cardiac structure and function and depressive disorder remain unclear. Depressive disorder is believed to be associated with an increased risk of cardiovascular diseases and is extremely common in patients with reduced left ventricular ejection fraction (LVEF: 20%–42%) [4,5]. Study using a Bayesian cross-lagged structural equation model reported that worsening depressive disorder predicts a change in cardiac function [6]. On the contrary, studies have drawn different conclusions and shown that the occurrence of depressive disorder is largely independent of LVEF [7,8].

Centenarians are a particular group of people whose physical and mental health is related to healthy aging [9,10]. However, few studies have investigated the relationship between echocardiography findings and depressive disorder in centenarians. Hainan Province is an area with high levels of longevity, with the highest population density of centenarians in China. According to the latest demographic information reported by Hainan Provincial Health Commission in 2019, Hainan Province has a population of 1.4103 million people aged above 60 years, 308,100 people aged above 80 years, and approximately 2200 people aged above 100 years, of whom 20.52 per 100,000 people aged 100 years and above. The number of centenarians has far exceeded the United Nations' "Land of Longevity" standard of 7.5 centenarians per 100,000 people. The China Hainan Centenarian Cohort Study (CHCCS) provides a large population-based sample of centenarians, and research on healthy aging based on Hainan centenarians is of great clinical significance. Therefore, using the data from the CHCCS, this study aimed to address the associations between cardiac structure and function and depressive disorder to provide an epidemiological basis for the early detection of depressive disorder and explore potential risk factors for depressive disorder in Chinese centenarians.

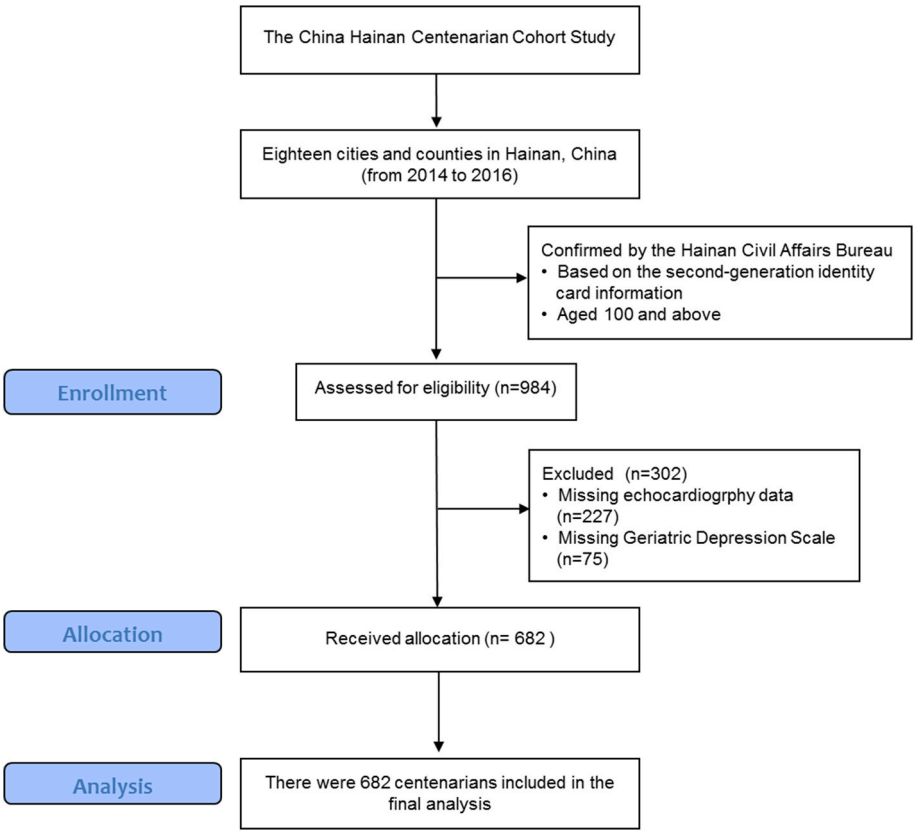

Fig. 1. Information of the China Hainan Centenarian Cohort Study (CHCCS) and flowchart of participant selection based on inclusion and exclusion criteria in this study (CONSORT 2010 Flow Diagram).

2. Materials and methods

2.1. Study population

As the centenarian survey with the largest sample size in China yet, the CHCCS was a project supported by Hainan Province. It commenced in 2014 and ended in 2016, and was conducted to survey all older individuals aged 100 years and above in 18 cities and counties in Hainan Province, China. During the study period, all older adults aged 100 years and above in Hainan Province were included in the survey. The Civil Affairs Bureau of Hainan confirmed their age based on the information on second-generation identity cards. Ultimately, among 984 participants, 302 older adults were excluded because of missing values and 682 centenarians were finally included in this analysis. The information on the CHCCS and the flowchart of participant selection are presented in Fig. 1. The research was conducted in the form of a household survey, and the investigation methods of the CHCCS are outlined previously [11–13]. The present study was approved by the Ethics Committee of Hainan Hospital of Chinese People's Liberation Army General Hospital (Sanya, Hainan, No. 301HNLL-2016-01), with written informed consent obtained from all participants.

2.2. Depressive disorder

A home interview was implemented following standard procedures by a professional medical team, including internists, geriatricians, cardiologists, endocrinologists, nephrologists, neurologists, psychiatrists, psychologists, and nurses. Depressive disorder was diagnosed by psychiatrists and psychologists based on the 15-item Geriatric Depression Scale (GDS-15) scores in combination with the clinical symptoms of these participants and clear communication with family members. With good reliability and validity in the Chinese older individuals [14–16], GDS-15 scores contain 15 dichotomous items and required all participants to answer. Scores of >6 (range: 0–15) and >10 were considered to indicate a depressive disorder and major depression, respectively, with a higher GDS-15 score indicating a more severe depressive disorder [17,18]. Although no centenarians were found to use regular antidepressants in our investigations, our experts informed participants diagnosed with depressive disorder and their family members of the necessary antidepressive treatment available from our hospital or other professional medical institutions.

2.3. Echocardiography

Echocardiography was performed by a well-trained cardiac sonographer using a CX50 ultrasound system (Philips Medical Systems, Andover, Massachusetts, USA). The participants were placed in the partial left decubitus position, and a 1–5-MHz cardiac transducer (S5-1; Phillips Medical Systems) was used for cardiac ultrasound. Cardiac structure and function parameters assessed included LVEF, aortic diameter, left ventricular end-diastolic diameter, interventricular septum thickness (IVST), left ventricular posterior wall thickness (LVPWT), left atrial end-systolic diameter, right ventricular end-diastolic diameter, right atrial end-systolic diameter, and pulmonary artery diameter.

2.4. Covariates

Baseline data mainly included a questionnaire survey, physical examination, specimen collection, and laboratory examination. The questionnaire was conducted through a face-to-face family interview by local doctors and nurses who had undergone systematic training. A calibrated desktop sphygmomanometer (Yuwell medical equipment and supply Co., Ltd., Jiangsu, China) was used to measure the systolic and diastolic blood pressures of older adults while seated. Each parameter was measured twice and averaged by different investigators, with at least 1-min interval between two measurements. Body mass index (BMI) was computed using the standard formula: BMI = weight/height^2 (km/m^2). Venous blood samples were obtained and transported within 4 h in cold storage (4 °C) to our central laboratory. Hemoglobin levels were measured with a blood autoanalyzer (SYSMEX XS-800I). Total cholesterol (TC), triglyceride (TG), low-density lipoprotein cholesterol (LDL-C), fasting blood glucose (FBG), and serum creatinine levels were measured by enzyme colorimetry (Roche Products Ltd., Basel, Switzerland) on a fully automatic biochemical autoanalyzer (COBAS c702; Roche Products Ltd). All data were cross-checked and recorded by two researchers.

Cognitive status was assessed by neurologists based on the Mini-Mental State Examination score, and a score of $\leq$17 (range: 0–30) was considered to indicate cognitive impairment [19]. Physical ability was assessed based on the Activity of Daily Living score, and a score of $<$40 (range: 0–100) was considered to indicate physical disability [20,21]. Hyperlipidemia was defined as a TC level of $\geq$6.22 mmol/L, TG level of $\geq$2.26 mmol/L, LDL-C level of $\geq$4.14 mmol/L, or use of hypolipidemic drugs. Hypertension was defined as systolic blood pressure of $\geq$140 mmHg, diastolic blood pressure of $\geq$90 mmHg, or use of anti-hypertensive drugs. Diabetes mellitus was defined as a FBG level of $\geq$7.0 mmol/L or use of anti-diabetic drugs. Renal disease was defined as a serum creatinine level of $>$110 μmol/L.

2.5. Statistical analyses

Continuous variables are expressed as mean ± standard deviation; the Student's t-test and one-way analysis of variance were performed for normally distributed variables and a non-parametric test for non-normally distributed variables. The Chi-square test assessed the differences in categorical variables, and the results are presented as count and percentage. Enter and stepwise multiple linear regression analyses were performed to analyze independent associations between cardiac function and structure and GDS-15

scores, with age, sex, BMI, smoking, drinking, cognitive impairment, physical disability, hemoglobin, hyperlipidemia, diabetes mellitus, hypertension, and renal disease as adjusted covariates. Similarly, multiple logistic regression analyses were performed to analyze independent associations between cardiac function and structure and depressive disorder or major depressive disorder, with age, sex, BMI, smoking, drinking, cognitive impairment, physical disability, hemoglobin, hyperlipidemia, diabetes mellitus, hypertension, and renal disease as adjusted covariates. Statistic Package for Social Science version 17.0 was used for statistical analyses (Chicago, IL, USA). A P-value of <0.05 was considered to indicate statistical significance.

3. Results

The baseline characteristics of participants with and without depressive disorder are presented in Table 1. A total of 682 centenarians were enrolled; their mean age was 102.35 ± 2.72 years (range: 100–116 years). Among them, 81.2% were women (554 centenarians), and 179 centenarians (26.2%) had depressive disorder [95% confidence interval (CI): 0.229 to 0.296]. The mean GDS-15 score was 4.64 ± 3.48. Among centenarians with depressive disorder, there were more women, more participants with lower BMI, cognitive impairment, physical disabilities, and higher LVEF (Fig. 2A) and IVST (Fig. 2B; $P < 0.05$, all). LVEF of centenarians with (Fig. 2C) and without (Fig. 2D) depressive disorder was shown in echocardiography, respectively. IVST of centenarians with (Fig. 2E) and without (Fig. 2F) depressive disorder was shown in apical four-chamber view of echocardiography, respectively. IVST of centenarians with (Fig. 2G) and without (Fig. 2H) depressive disorder was shown in left ventricular long-axis view of echocardiography, respectively.

As shown in Table 2, enter multiple linear regression analysis found that participants with lower BMI (beta: −0.044; 95% CI: −0.080 to −0.007), smoking habit (beta: 2.665; 95% CI: 0.821 to 4.489), cognitive impairment (beta: 2.022; 95% CI: 1.435 to 2.610), higher LVEF (beta: 0.107; 95% CI: 0.025 to 0.190) and IVST (beta: 0.420; 95% CI: 0.148 to 0.691), and lower LVPWT (beta: −0.312; 95% CI: −0.598 to −0.025) tended to have higher GDS-15 scores ($P < 0.05$, all). Stepwise multiple linear regression analysis suggested that participants with lower BMI (beta: −0.051; 95% CI: −0.084 to −0.018), smoking habit (beta: 2.347; 95% CI: 0.563 to 4.132), cognitive impairment (beta: 2.051; 95% CI: 1.489 to 2.613), higher LVEF (beta: 0.093; 95% CI: 0.014 to 0.173) and IVST (beta: 0.440; 95% CI: 0.177 to 0.704), and lower LVPWT (beta: −0.306; 95% CI: −0.587 to −0.025), tended to have higher GDS-15 scores ($P < 0.05$, all; Fig. 3).

Multiple logistic regression analysis showed that participants with lower BMI (0.973; 95% CI: 0.948 to 0.999), smoking habit (5.519; 95% CI: 1.550 to 19.649), cognitive impairment (3.296; 95% CI: 2.067 to 5.255), physical disability (2.045; 95% CI: 1.279 to

Table 1
Characteristics of centenarians with and without depressive disorder.

Variables	Whole population (n = 682)	Without depressive disorder (n = 503)	With depressive disorder			P_1	P_2
			Total (n = 179)	Mild (n = 126)	Major (n = 53)		
Demography							
Age (year)	102.35 ± 2.72	102.32 ± 2.66	102.44 ± 2.87	102.25 ± 2.85	102.91 ± 2.94	0.610	0.301
Females (%)	554 (81.2%)	397 (78.9%)	157 (87.7%)	109 (86.5%)	48 (90.6%)	0.010	0.029
BMI (kg/m^2)	14.01 ± 8.28	14.72 ± 7.96	12.02 ± 8.84	12.85 ± 8.78	10.05 ± 8.79	<0.001	<0.001
Lifestyle							
Smoking (%)	16 (2.3%)	9 (1.7%)	7 (3.9%)	4 (3.2%)	3 (5.7%)	0.107	0.165
Drinking (%)	73 (10.7%)	53 (10.5%)	20 (11.1%)	14 (11.1%)	6 (11.3%)	0.813	0.972
Comorbidity							
Cognitive impairment (%)	382 (56%)	256 (50.8%)	126 (70.3%)	89 (70.6%)	37 (69.8%)	<0.001	<0.001
Physical disability (%)	250 (36.6%)	165 (32.8%)	85 (47.4%)	56 (44.4%)	29 (54.7%)	<0.001	0.001
Hemoglobin (g/L)	112.88 ± 16.18	113.60 ± 15.52	110.80 ± 17.85	110.59 ± 18.65	111.33 ± 15.90	0.051	0.144
Hyperlipidemia (%)	79 (11.6%)	59 (11.7%)	20 (11.1%)	14 (11.1%)	6 (11.3%)	0.910	0.986
Diabetes mellitus (%)	69 (10.1%)	51 (10.1%)	18 (10.1%)	10 (7.9%)	8 (15.1%)	0.975	0.349
Hypertension (%)	432 (63.3%)	317 (63.0%)	115 (64.2%)	79 (62.6%)	36 (67.9%)	0.770	0.770
Renal disease (%)	113 (16.57%)	86 (17.1%)	27 (15.1%)	19 (15.1%)	8 (15.1%)	0.534	0.824
Echocardiography							
LVEF (%)	59.41 ± 3.50	59.19 ± 3.61	60.02 ± 3.10	59.84 ± 3.09	60.48 ± 3.13	0.010	0.020
AOD (mm)	29.75 ± 3.91	29.78 ± 3.87	29.68 ± 4.03	29.51 ± 3.88	30.09 ± 4.41	0.768	
LVEDD (mm)	37.83 ± 4.91	37.89 ± 5.05	37.65 ± 4.51	38.16 ± 4.37	36.42 ± 4.66	0.565	
IVST (mm)	9.56 ± 1.51	9.48 ± 1.49	9.79 ± 1.54	9.69 ± 1.60	10.06 ± 1.39	0.016	0.018
LVPWT (mm)	9.25 ± 1.96	9.24 ± 2.13	9.30 ± 1.39	9.28 ± 1.44	9.38 ± 1.27	0.735	0.631
LAESD (mm)	29.78 ± 4.87	29.84 ± 4.88	29.61 ± 4.87	29.90 ± 5.00	28.94 ± 4.54	0.592	0.425
RVEDD (mm)	28.74 ± 3.91	28.74 ± 4.05	28.74 ± 3.48	28.64 ± 3.46	29.00 ± 3.57	0.998	0.085
RAESD (mm)	28.69 ± 4.20	28.72 ± 4.22	28.60 ± 4.14	28.64 ± 4.14	28.51 ± 4.21	0.741	0.930
PAD (mm)	19.87 ± 2.59	19.82 ± 2.51	20.01 ± 2.81	20.03 ± 2.71	19.98 ± 3.07	0.426	0.724

Notes: P_1, without depressive disorder versus with depressive disorder; P_2, without depressive disorder versus with mild depressive disorder versus with major depressive disorder.

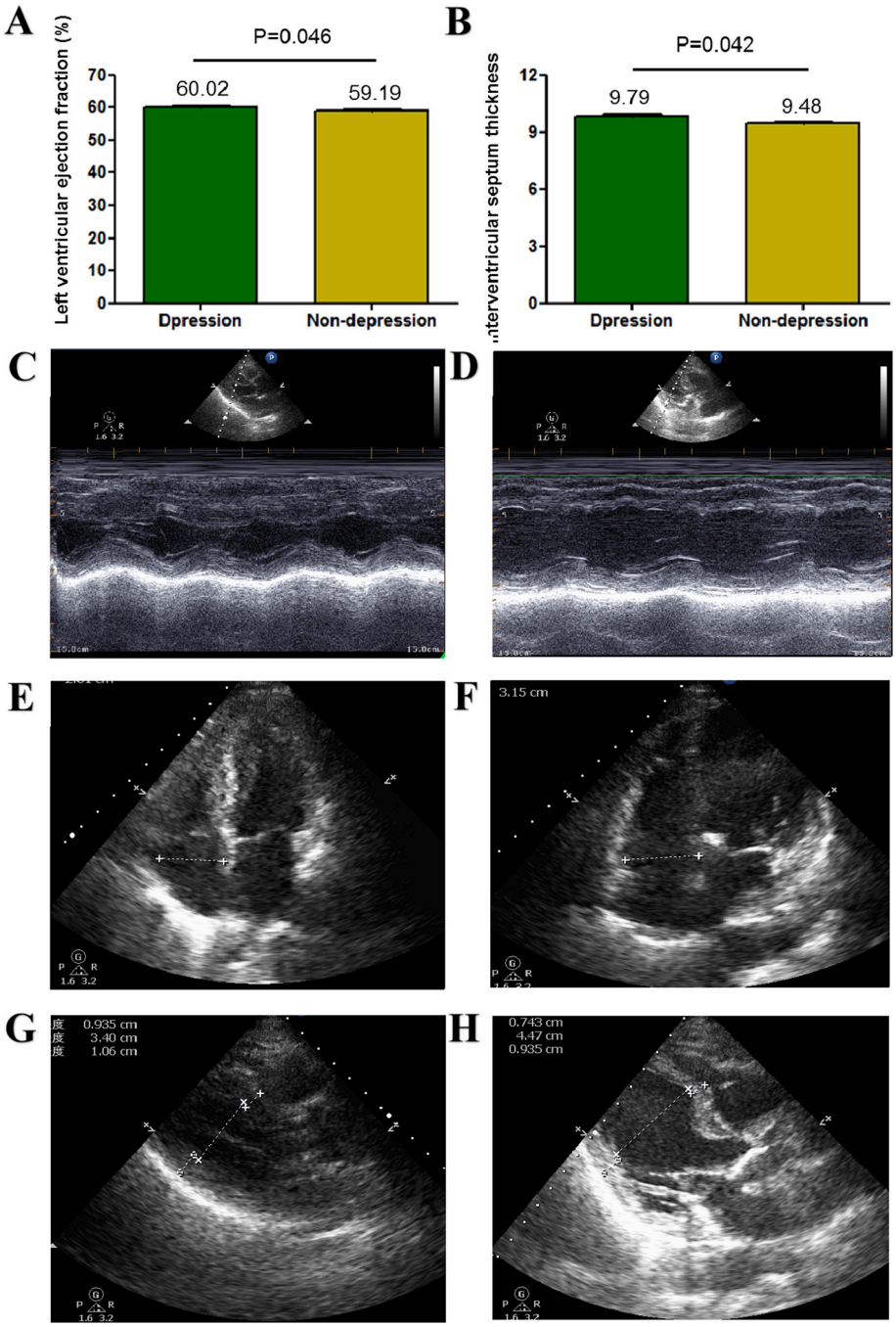

Fig. 2. Left ventricular ejection fraction (LVEF) of centenarians with and without depressive disorder (A); Interventricular septum thickness (IVST) of centenarians with and without depressive disorder (B); LVEF of centenarians with depressive disorder in echocardiography (C); LVEF of centenarians without depressive disorder in echocardiography (D); IVST of centenarians with depressive disorder in apical four-chamber view of echocardiography (E); IVST of centenarians without depressive disorder in apical four-chamber view of echocardiography (F); IVST of centenarians with depressive disorder in left ventricular long-axis view of echocardiography (G); IVST of centenarians without depressive disorder in left ventricular long-axis view of echocardiography (H).

3.270), and higher LVEF (1.081; 95% CI: 1.009 to 1.158) and IVST (1.274; 95% CI: 1.037 to 1.566) tended to have a higher odds ratio for depressive disorder ($P < 0.05$, all; Table 3). Multiple logistic regression analysis suggested that participants with lower BMI (0.942; 95% CI: 0.901 to 0.984), smoking habit (8.250; 95% CI: 1.764 to 38.572), drinking habit (2.886; 95% CI: 1.014 to 8.216), cognitive impairment (2.947; 95% CI: 1.316 to 6.599), and higher LVEF (1.127; 95% CI: 1.004 to 1.264) and IVST (1.725; 95% CI: 1.218 to 2.445), tended to have a higher odds ratio for major depressive disorder ($P < 0.05$, all; Table 4).

Table 2
Enter multiple linear regression analysis with GDS-15.

Variables	Beta	95% CI	P
Demography			
Age	0.020	−0.077 to 0.118	0.682
Females	0.499	−0.281 to 1.279	0.210
BMI	−0.044	−0.080 to −0.007	0.018
Lifestyle			
Smoking	2.655	0.821 to 4.489	0.005
Drinking	0.485	−0.403 to 1.373	0.284
Comorbidity			
Cognitive impairment	2.022	1.435 to 2.610	<0.001
Physical disability	0.228	−0.402 to 0.858	0.478
Hemoglobin	−0.015	−0.034 to 0.004	0.126
Hyperlipidemia	0.287	−0.587 to 1.161	0.519
Diabetes mellitus	0.076	−0.882 to 1.034	0.876
Hypertension	−0.006	−0.596 to 0.585	0.985
Renal disease	0.124	−0.664 to 0.912	0.757
Echocardiography			
LVEF	0.107	0.025 to 0.190	0.011
AOD	0.002	−0.076 to 0.079	0.969
LVEDD	0.001	−0.065 to 0.067	0.985
IVST	0.420	0.148 to 0.691	0.002
LVPWT	−0.312	−0.598 to −0.025	0.033
LAESD	0.010	−0.058 to 0.078	0.777
RVEDD	0.060	−0.026 to 0.146	0.172
RAESD	−0.077	−0.161 to 0.007	0.071
PAD	0.066	−0.059 to 0.191	0.302

Notes: adjusted for age, sex, BMI, smoking, drinking, cognitive impairment, physical disability, hemoglobin, hyperlipidemia, diabetes mellitus, hypertension, renal disease, LVEF, AOD, LVEDD, IVST, LVPWT, LAESD, RVEDD, RAESD, and PAD.

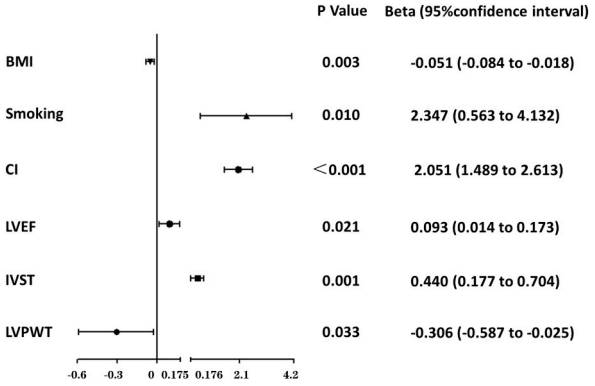

Fig. 3. Stepwise multiple linear regression analysis based on the GDS-15 scores. Note: adjusted for age, sex, BMI, smoking, drinking, CI, physical disability, hemoglobin, hyperlipidemia, diabetes mellitus, hypertension, renal disease, LVEF, aortic diameter, left ventricular end-diastolic diameter, IVST, LVPWT, left atrial end-systolic diameter, right ventricular end-diastolic diameter, right atrial end-systolic diameter, and pulmonary artery diameter. Abbreviations: GDS-15: Geriatric Depression Scale; BMI, body mass index; CI, cognitive impairment; LVEF, left ventricular ejection fraction; IVST, interventricular septum thickness; LVPWT, left ventricular posterior wall thickness.

4. Discussion

In this study, we found higher LVEF and IVST in centenarians with depressive disorder than in those without depressive disorder. GDS-15 scores were also positively associated with LVEF and IVST after adjusting for potential covariates. Based on this research, we determined significant and independent relationships between cardiac structure and function and depressive disorder. It is clinically significant to avoid the potential risk of depressive disorder in older adults.

Cardiac structure and function, as well as depressive disorder, are important factors that affect the long-term process of healthy aging [22,23]. Previous studies have found that cardiac structure and function are closely related to depressive disorder [24,25]. Haider et al. [26] reported that in patients aged above 60 years with heart failure, the probability of depressive disorder was significantly higher in patients with LVEF >45% than in those with LVEF <45%. Tarek et al. [27] found that patients with heart failure with preserved LVEF had significantly more severe depressive disorder than those with heart failure with reduced LVEF. However, some studies have found inconsistent conclusions. The findings reported by Hsiang et al. [28] showed that heart failure patients with

Table 3
Multiple logistic regression analysis with depressive disorder.

Variables	Beta	OR	95% CI	P
Demography				
Age	0.035	1.036	0.966 to 1.111	0.325
Females	0.617	1.853	0.971 to 3.538	0.061
BMI	−0.027	0.973	0.948 to 0.999	0.042
Lifestyle				
Smoking	1.708	5.519	1.550 to 19.649	0.008
Drinking	0.450	1.569	0.813 to 3.027	0.179
Comorbidity				
Cognitive impairment	1.193	3.296	2.067 to 5.255	<0.001
Physical disability	0.715	2.045	1.279 to 3.270	0.003
Hemoglobin	−0.004	0.996	0.981 to 1.010	0.560
Hyperlipidemia	0.060	1.062	0.557 to 2.025	0.856
Diabetes mellitus	−0.213	0.808	0.378 to 1.729	0.583
Hypertension	−0.016	0.984	0.632 to 1.534	0.944
Renal disease	−0.013	0.987	0.548 to 1.777	0.965
Echocardiography				
LVEF	0.078	1.081	1.009 to 1.158	0.026
AOD	0.014	1.014	0.957 to 1.074	0.637
LVEDD	0.007	1.007	0.958 to 1.057	0.795
IVST	0.242	1.274	1.037 to 1.566	0.021
LVPWT	−0.151	0.860	0.685 to 1.080	0.195
LAESD	0.021	1.021	0.971 to 1.074	0.408
RVEDD	0.021	1.021	0.956 to 1.091	0.536
RAESD	−0.041	0.960	0.899 to 1.025	0.222
PAD	0.014	1.014	0.926 to 1.111	0.760

Notes: adjusted for age, gender, BMI, smoking, drinking, cognitive impairment, physical disability, hemoglobin, hyperlipidemia, diabetes mellitus, hypertension, renal disease, LVEF, AOD, LVEDD, IVST, LVPWT, LAESD, RVEDD, RAESD, and PAD.

Table 4
Multiple logistic regression analysis with major depressive disorder.

Variables	Beta	OR	95% CI	P
Demography				
Age	0.081	1.084	0.975 to 1.206	0.135
Females	0.420	1.522	0.483 to 4.800	0.473
BMI	−0.060	0.942	0.901 to 0.984	0.008
Lifestyle				
Smoking	2.110	8.250	1.764 to 38.572	0.007
Drinking	1.060	2.886	1.014 to 8.216	0.047
Comorbidity				
Cognitive impairment	1.081	2.947	1.316 to 6.599	0.009
Physical disability	0.439	1.552	0.713 to 3.377	0.268
Hyperlipidemia	0.115	1.121	0.378 to 3.325	0.836
Hemoglobin	−0.013	0.987	0.963 to 1.012	0.314
Diabetes mellitus	0.338	1.402	0.490 to 4.014	0.528
Hypertension	0.092	1.096	0.518 to 2.321	0.810
Renal disease	0.173	1.189	0.460 to 3.076	0.721
Echocardiography				
LVEF	0.119	1.127	1.004 to 1.264	0.043
AOD	0.146	1.157	1.051 to 1.274	0.003
LVEDD	−0.063	0.939	0.863 to 1.021	0.138
IVST	0.545	1.725	1.218 to 2.445	0.002
LVPWT	−0.503	0.605	0.404 to 0.904	0.014
LAESD	0.005	1.005	0.923 to 1.094	0.912
RVEDD	0.048	1.049	0.931 to 1.182	0.433
RAESD	−0.072	0.930	0.827 to 1.047	0.230
PAD	0.000	1.000	0.861 to 1.161	0.996

Notes: adjusted for age, gender, BMI, smoking, drinking, cognitive impairment, physical disability, hemoglobin, hyperlipidemia, diabetes mellitus, hypertension, renal disease, LVEF, AOD, LVEDD, IVST, LVPWT, LAESD, RVEDD, RAESD, and PAD.

LVEF <30% were more likely to develop severe depressive disorder. In 100 patients with heart failure, LVEF was found to be an independent predictor of depressive disorder after adjusting for other potential confounding factors [29]. However, no relevant data support associations between cardiac structure and function and depressive disorder in centenarians. We found both LVEF and IVST to be positively correlated with depressive disorder in centenarians, and we believe that this result can promote early screening of depressive disorder among centenarians.

The mechanisms underlying the association of depressive disorder with LVEF remain unclear. In a single-center cross-sectional study, Pedro et al. [30] found that LVEF affects depressive disorder by mediating the level of N-terminal pro-brain natriuretic peptide, which was considered a significant predictor of depressive disorder. In addition, Masaru et al. [31] has found that the cardiac reserve in patients with preserved LVEF is suppressed with reduced myocardial oxygen supply, and the reduced aerobic capacity of the body may be an important factor leading to depressive disorder. These studies explored the interaction between LVEF and depressive disorder, providing reliable ideas and potential pathways for further in-depth research [32].

4.1. Strengths and limitations

To the best of our knowledge, this is the first study to demonstrate significant associations between cardiac structure and function and depressive disorders in older adults aged 100 years and above, which is of great significance for the realization of a healthy aging population. While highlighting this study's findings, two limitations should be mentioned. First, due to the cross-sectional design, there was no temporal relationship between cardiac structure and function and the duration of depressive disorder in this study. Second, this study was conducted in the Hainan Province of China, so generalizing the findings across the country should be done with caution.

5. Conclusions

The present study demonstrated that the prevalence of depressive disorder remains very high, and associations were found between LVEF, IVST, and depressive disorder in Chinese centenarians. Future studies should focus on their temporal relationships to improve cardiac structure and function, prevent depressive disorder and achieve healthy aging by coordinating their relationships.

Ethics approval and consent to participate

The current study received approval from the Ethics Committee of Hainan Hospital of Chinese People's Liberation Army General Hospital (Sanya, Hainan; Number: 301HNLL-2016-01). Prior to the current study, written informed consent was required from all participants.

Author contribution statement

Zhigao Sun; Ping Ping; Pei Zhang; Yao Yao; Zhenjun Huang; Yali Zhao; Leiming Luo; Shihui Fu: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data included in article/supp. material/referenced in article.

Declaration of interest's statement

The authors declare no competing interests.

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Abbreviations

OR	odds ratio
CI	confidence interval
BMI	body mass index
LVEF	left ventricular ejection fraction
AOD	aortic diameter
LVEDD	left ventricular end-diastolic diameter
IVST	interventricular septum thickness
LVPWT	left ventricular posterior wall thickness
LAESD	left atrial end-systolic diameter

RVEDD right ventricular end-diastolic diameter
RAESD right atrial end-systolic diameter
PAD pulmonary artery diameter

Appendix B. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.heliyon.2023.e13233.

References

[1] Bhautesh Dinesh Jani, Frances S. Mair, Veronique L. Roger, Susan A. Weston, Ruoxiang Jiang, Alanna M Chamberlain, Comorbid depression and heart failure: a community cohort study, PLoS One 11 (6) (2016), e0158570.
[2] Jian Liu, Zejun Guo, Meida Fan, Weihao Liang, Xin He, Dexi Wu, et al., Major depression and clinical outcomes in patients with heart failure with preserved ejection fraction, Eur. J. Clin. Invest. 51 (3) (2021), e13401.
[3] Thomas Rutledge, Veronica A. Reis, Sarah E. Linke, Barry H. Greenberg, Paul J. Mills, Depression in heart failure a meta-analytic review of prevalence, intervention effects, and associations with crlinical outcomes, J. Am. Coll. Cardiol. 48 (8) (2006) 1527–1537.
[4] Silvia Raquel Soares Ouakinin, Anxiety as a risk factor for cardiovascular diseases, Front. Psychiatr. 7 (2016) 25.
[5] Rebecca F. Gottesman, Maura A. Grega, Maryanne M. Bailey, Scott L. Zeger, William A. Baumgartner, Guy M. McKhann, Ola A. Selnes, Association between hypotension, low ejection fraction and cognitive performance in cardiac patients, Behav. Neurol. 22 (1–2) (2010) 63–71.
[6] Nicole Lossnitzer, Manuel Feisst, Beate Wild, Hugo A. Katus, Jobst-Hendrik Schultz, Frankenstein Lutz, Christian Stock, Cross-lagged analyses of the bidirectional relationship between depression and markers of chronic heart failure, Depress. Anxiety 37 (9) (2020) 898–907.
[7] Alvin Chandra, Michael AD. Alcala, Brian Claggett, Akshay S Desai, James C. Fang, John F. Heitner, et al., Associations between depressive symptoms and HFpEF-related outcomes, JACC Heart Fail 8 (12) (2020) 1009–1020.
[8] Dikic Aleksandar, Ljiljana Radmilo, Zeljko Zivanovic, Goran Kekovic, Slobodan Sekulic, Zoran Kovacic, Ruza Radmilo, Cognitive impairment and depression after acute myocardial infarction: associations with ejection fraction and demographic characteristics, Acta Neurol. Belg. 121 (6) (2021) 1615–1622.
[9] Oscar Ribeiro, Natália Duarte, Laetitia Teixeira, Constança Paúl, Frailty and depression in centenarians, Int. Psychogeriatr. 30 (1) (2018) 115–124.
[10] Calogero Caruso, Aiello Anna, Giulia Accardi, Ciaglia Elena, Monica Cattaneo, Annibale Puca, Genetic signatures of centenarians: implications for achieving successful aging, Curr. Pharmaceut. Des. 25 (39) (2019) 4133–4138.
[11] L. Feng, Z. Chu, X. Quan, Y. Zhang, W. Yuan, Y. Yao, Y. Zhao, S. Fu, Malnutrition is positively associated with cognitive decline in centenarians and oldest-old adults: a cross-sectional study, EClinicalMedicine 47 (2022), 101336.
[12] Shihui Fu, Ping Ping, Yulong Li, B. Li, Yali Zhao, Yao Yao, Pei Zhang, Centenarian longevity had inverse relationships with nutritional status and abdominal obesity and positive relationships with sex hormones and bone turnover in the oldest females, J. Transl. Med. 19 (1) (2021) 436.
[13] Zhigao Sun, Jieqiong Lin, Yujie Zhang, Yao Yao, Zhenjun Huang, Yali Zhao, et al., Association between immunoglobulin A and depression in Chinese older adults: findings from a cross-sectional study, Immun. Ageing 19 (1) (2022) 21.
[14] Chi Zhang, Hao Zhang, Minghao Zhao, Chen Chen, Zhongquan Li, Deping Liu, et al., Psychometric properties and modification of the 15-item geriatric depression scale among Chinese oldest-old and centenarians: a mixed-methods study, BMC Geriatr. 22 (1) (2022) 144.
[15] Ma Shwe Zin Nyunt, Calvin Fones, Mathew Niti, Tze-Pin Ng, Criterion-based validity and reliability of the Geriatric Depression Screening Scale (GDS-15) in a large validation sample of community-living Asian older adults, Aging Ment. Health 13 (3) (2009) 376–382.
[16] Lijuan Dong, N. Liu, Xiaoyu Tian, Xiaoxia Qiao, Robbert JJ. Gobbens, Robert L. Kane, Cuili Wang, Reliability and validity of the Tilburg Frailty Indicator (TFI) among Chinese community-dwelling older people, Arch. Gerontol. Geriatr. 73 (2017) 21–28.
[17] Yao Yao, Shihui Fu, Hao Zhang, Nan Li, Zhu Qiao, F. Zhang, et al., The prevalence of depressive symptoms in Chinese longevous persons and its correlation with vitamin D status, BMC Geriatr. 18 (1) (2018) 198.
[18] Cheolmin Shin, Moon Ho Park, Seung-Hoon Lee, Young-Hoon Ko, Yong-Ku Kim, Kyu-Man Han, et al., Usefulness of the 15-item geriatric depression scale (GDS-15) for classifying minor and major depressive disorders among community-dwelling elders, J. Affect. Disord. 259 (2019) 370–375.
[19] Sam T. Creavin, Susanna Wisniewski, Anna H. Noel-Storr, Clare M. Trevelyan, Thomas Hampton, Dane Rayment, et al., Mini-Mental State Examination (MMSE) for the detection of dementia in clinically unevaluated people aged 65 and over in community and primary care populations, Cochrane Database Syst. Rev. 2016 (1) (2016) CD011145.
[20] Fang Liu, Raymond Cc Tsang, Jing Zhou, Mingchao Zhou, Fubing Zha, Jianjun Long, Yulong Wang, Relationship of barthel index and its short form with the modified rankin scale in acute stroke patients, J. Stroke Cerebrovasc. Dis. 29 (9) (2020), 105033.
[21] Victor Figueiredo Leite, Danielle Bianchini Rampim, Valeria Conceição Jorge, M.D.C.C. de Lima, Leandro Gonçalves Cezarino, Cleber Nunes da Rocha, et al., Persistent symptoms and disability after COVID-19 hospitalization: data from a comprehensive telerehabilitation program, Arch. Phys. Med. Rehabil. 102 (7) (2021) 1308–1316.
[22] Bianca A. Lever-van Milligen, E Verhoeven Josine, Lianne Schmaal, Laura S van Velzen, Dóra Révész, Catherine N. Black, et al., The impact of depression and anxiety treatment on biological aging and metabolic stress: study protocol of the MOod treatment with antidepressants or running (MOTAR) study, BMC Psychiatr. 19 (1) (2019) 425.
[23] Haobo Li, Margaret H. Hastings, James Rhee, Lena E Trager, Jason D. Roh, Anthony Rosenzweig, Targeting age-related pathways in heart failure, Circ. Res. 126 (4) (2020) 533–551.
[24] Kenneth E. Freedland, Robert M. Carney, Michael W. Rich, Brian C. Steinmeyer, Eugene H. Rubin, Cognitive behavior therapy for depression and self-care in heart failure patients: a randomized clinical trial, JAMA Intern. Med. 175 (11) (2015) 1773–1782.
[25] Heather Lett, Sadia Ali, Mary Whooley, Depression and cardiac function in patients with stable coronary heart disease: findings from the Heart and Soul Study, Psychosom. Med. 70 (4) (2008) 444–449.
[26] Haider J. Warraich, Dalane W. Kitzman, David J. Whellan, Pamela W. Duncan, Robert J. Mentz, Amy M. Pastva, et al., Physical function, frailty, cognition, depression, and quality of life in hospitalized adults ≥60 years with acute decompensated heart failure with preserved versus reduced ejection fraction, Circ Heart Fail 11 (11) (2018), e005254.
[27] Tarek Bekfani, Nisser Jenny, Steffen Derlien, Hamadanchi Ali, Elisabeth Fröb, Gudrun Dannberg, et al., Psychosocial factors, mental health, and coordination capacity in patients with heart failure with preserved ejection fraction compared with heart failure with reduced ejection fraction, ESC Heart Fail 8 (4) (2021) 3268–3278.
[28] Hsiang-Fen Yeh, Jung-Hua Shao, Depression in community-dwelling elderly patients with heart failure, Arch. Psychiatr. Nurs. 32 (2) (2018) 248–255.
[29] Hakan Altay, Zorlu Ali, Halil Tolga Kocum, Senol Demircan, Nuryil Yilmaz, Mehmet Birhan Yilmaz, Relationship between parathyroid hormone and depression in heart failure, Arq. Bras. Cardiol. 99 (4) (2012) 915–923.

[30] Pedro Zuzarte, Gustavo Scola, Angela Duong, Kari Kostiw, Maria L. Figueira, Atilio Costa-Vitali, NT-proBNP is a potential mediator between reduced ejection fraction and depression in patients with heart failure, J. Psychiatr. Res. 104 (2018) 8–15.
[31] Masaru Obokata, Yogesh NV. Reddy, Vojtech Melenovsky, Garvan C. Kane, Thomas P. Olson, Petr Jarolim, Barry A. Borlaug, Myocardial injury and cardiac reserve in patients with heart failure and preserved ejection fraction, J. Am. Coll. Cardiol. 72 (1) (2018) 29–40.
[32] Hien Luong, Sarojini Singh, Mallikarjun Patil, Prasanna Krishnamurthy, Cardiac glycosaminoglycans and structural alterations during chronic stress-induced depression-like behavior in mice, Am. J. Physiol. Heart Circ. Physiol. 320 (5) (2021) H2044–H2057.