Right ventricular systolic function is associated with health-related quality of life: a cross-sectional study in community-dwelling populations

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Background: Considerable evidence has been presented that heart and health-related quality of life are directly linked in patients with various diseases. This exploratory study investigated whether cardiac structure and function were associated with health-related quality of life in the general population.

Methods: This cross-sectional study was performed in five villages of Shunyi, a suburban district of Beijing, from June 2013 to April 2016. All inhabitants aged 35 years or older living in five villages of Shunyi were invited to participate. Exclusion criteria were individuals who declined participation, who had incomplete Health-related quality of life (HRQoL) data, and who had suboptimal echocardiograms. HRQoL was evaluated by the Mandarin version of SF-36. The association between the echocardiography-derived cardiac structure and function and each domain of SF-36 was analyzed by the multivariate linear regression analysis after adjusted for conventional risk factors affecting HRQoL.

Results: The baseline data of 990 individuals were analyzed. The median age of the participants was 57 (50–63) years, and 367 (37.1%) were male, the average physical and mental component summary scores were 89.3 (79.8–94.3) and 90 (83.5–95) respectively. Tricuspid annular plane systolic excursion, an echocardiography-derived right ventricular parameter, was associated with all the subscales and summarized scores of SF-36 (all $P<0.05$). The independent association between tricuspid annular plane systolic excursion and physical/mental component summary scores remained after adjusting for age, gender, body mass index, education level, annual personal income, smoking and drinking status, and comorbidities ($\beta=0.65$, 95% confidence interval 0.30–1.01, $P<0.01$ and $\beta=0.49$, 95% confidence interval 0.23–0.76, $P<0.01$ for physical and mental component summary scores respectively). Compared with the participants with tricuspid annular plane systolic excursion ≥21 mm, the participants with tricuspid annular plane systolic excursion <21 mm had lower adjusted scores of physical and mental component summary scores (81.8 *vs.* 84.5, $P=0.015$, and 85.5 *vs.* 88.1, $P<0.01$ for physical and mental component summary scores respectively).

Conclusions: In this population-based study, right ventricular systolic function assessed by tricuspid annular plane systolic excursion was independently associated with health-related quality of life assessed by SF-36.

Keywords: Right ventricular function; health-related quality of life (HRQoL); general population

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Introduction

Quality of life is defined as a general concept that implies an evaluation of the effect of all aspects of life on general well-being and health-related quality of life (HRQoL) focuses on aspects of quality of life that are related to health (1). HRQoL is an important patient-reported outcome measures in patients with cardiovascular disease and HRQoL can predict the cardiovascular events, morbidity and mortality (2). The data that informs HRQoL, for example, any aspect of health or care, are directly elicited from individuals (3). HRQoL tools assess an individual's subjective perception of the impact of a disease they have and its treatment on their daily life; physical, psychological, and social functioning; and general well-being.

HRQoL has become an important clinical end-point, economic factor, and predictor of prognosis in studies of a wide range of diseases. Considerable evidence has been presented that the heart and HRQoL are directly linked in patients with heart failure (4-6), coronary artery disease (7), atrial fibrillation (8), hypertension (HTN) (9), pulmonary hypertension (10), and chronic obstructive pulmonary disease (COPD) (11). However, little is known regarding whether cardiac structure and function are associated with HRQoL in the general population.

HRQoL is composed of multiple domains that comprehensively measure the patient's experience of symptoms, functional status, and psychosocial elements (1). The Short-Form 36 Health Survey (SF-36) which is a generic HRQoL questionnaire is a validated 36-item health status instrument with eight dimensions and two component summary scales. One item assesses transition in health status over the past year. All items have a four-week recall and a five-option response category (1).

This exploratory study investigated whether the cardiac structure and function derived from echocardiography, were associated with HRQoL in the general population. We present the following article in accordance with the STROBE reporting checklist (available at http://dx.doi.org/10.21037/atm-20-6845).

Methods

Population

This cross-sectional study was part of the ongoing community-based Shunyi study in China, designed to investigate the risk factors of cardiovascular and age-related diseases. This study was conducted in five villages of Shunyi, a suburban district of Beijing. All the residents aged ≥35 years were invited to participate and the demographic data were recorded from June 2013 to April 2016. Exclusion criteria were individuals who declined participation, who had incomplete HRQoL data, and who had suboptimal echocardiograms.

The baseline data of the participants were analyzed to investigate the association between the echocardiography-derived cardiac structure and function and each domain of SF-36.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of the Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences (approval no. 009-2014, 031-2017).and informed consent was taken from all the patients.

HRQoL measurements

HRQoL was evaluated by the Mandarin version of SF-36, which has been proved reliable and valid in other surveys in China (12,13). The SF-36 questionnaires comprised eight domains: physical functioning (PF), role physical (RP), bodily pain (BP), general health (GH), vitality (VT), social functioning (SF), role emotional (RE), and mental health (MH). The scores for SF-36 were summarized into a physical component summary (PCS) score and mental component summary (MCS) score, from 0 (worst) to 100 (best).

To improve the quality of questionnaires, the interviewers were intensively trained about how to conduct the questionnaire survey, and standardized questionnaires were conducted face-to-face interview by the trained interviewers.

Assessment of conventional risk factors affecting HRQoL

Conventional factors affecting HRQoL status were selected and included in the analysis, based on medical knowledge and reports in the literature on age, gender, body mass index (BMI), smoking and alcohol-drinking status, educational level, annual personal income, and comorbidities, for example, HTN, diabetes mellitus (DM), history of coronary heart disease (CHD), and ischemic and hemorrhagic stroke. The total comorbidity score was calculated on an ordinal scale (0, 1, 2, or ≥3).

BMI was calculated by the weight in kilograms indexed to the height in meters squared. Smoking and drinking were categorized as never-smokers or never-drinkers, ex-smokers or ex-drinkers, and current smokers (at least within the past month) or current drinkers (at least once per week within the past month). Educational level was self-reported and was divided into two groups: high school or above and junior high school or below. Annual personal income was divided into three levels: less than 10,000 renminbi (RMB), RMB 10,000–50,000 and over RMB 50,000. The presence of HTN and DM and the history of CHD was determined by using a method in our previous report (14). Self-reported history of ischemic and hemorrhagic stroke was also collected.

Echocardiography

Echocardiography was used to assess the cardiac structure and function, and it was performed by using commercially available equipment. All studies were performed and reviewed by cardiologists with advanced training in echocardiography.

The echocardiographic parameters about left ventricle (LV) included left ventricle end-diastolic volume (LVEDV), LV end-systolic volume (LVESV), LV ejection fraction (LVEF), LV mass (LVM), relative wall thickness (RWT) and left atrial volume index (LAVI), early and late diastolic velocity from mitral inflow profile (MVE and MVA), and E/A ratio. All the parameters were assessed according to the guideline of the American Society of Echocardiography (15). Tissue Doppler imaging (TDI) parameters included the mean value of peak systolic velocity and mean value of peak early diastolic velocity from the median and lateral mitral valve anulus (Sm and Em) and the ratio of E/Em (16,17). The measurement details of the above parameters were demonstrated in our previous report (14). The presence of LV diastolic dysfunction (LVDDF) was defined according to the recommendation from the American College of Cardiology (18).

Right ventricular (RV) structure and function were assessed by RV diameter (RVD), right ventricular wall thickness (RVWT), tricuspid annular plane systolic excursion (TAPSE), peak systolic velocity and peak early diastolic velocity from the lateral tricuspid valve anulus (Sm-R and Em-R), and inferior vena cava diameter according to the American Society of Echocardiography's guidelines (19). RVD was the diameter of the RV basal cavity obtained in the apical four-chamber view. RVWT was the end-diastolic RV wall thickness measured from the subcostal four-camber view. TDI was performed in the apical four-chamber view for the long-axis motion of the heart. The pulsed Doppler sample volume was placed at the lateral tricuspid valve annulus to obtain Sm-R and Em-R.

At least three consecutive beats were stored, and the images were analyzed offline by using EchoPAC version 6.3.6.

Statistical analysis

Deviations from a Gaussian distribution were analyzed by using the Kolmogorov-Smirnov test. Continuous variables were presented as mean ±Standard Deviation or median (25th to 75th percentiles). Categoric variables were expressed as percentages of the group from which they were derived. Missing data was not included in the analysis.

We used linear regression analysis to determine the relationships between the clinical data and echocardiographic parameters and HRQoL assessed by SF-36 including scores of eight subscales and two summarized scores. A further multivariate linear regression analysis selection criterion from the univariate analysis was a P value <0.05. To evaluate the association between the echocardiography-derived data and summarized HRQoL scores, multivariate linear regression analysis was performed in two models with entry and retention at a significance level of 0.05. Model 1 was adjusted for age, gender, BMI, educational level, and annual personal income; model 2 was adjusted for other conventional risk factors affecting HRQoL (model 1 + smoking and alcohol-drinking status, and comorbidity score). Because TAPSE has a strong independent relationship with both PCS and MCS, we divided the population into two groups according to the median value of TAPSE: individuals with a TAPSE <21 mm and individuals with a TAPSE ≥21 mm. The adjusted scores of PCS and MCS were compared between the two groups by using a univariate general linear model.

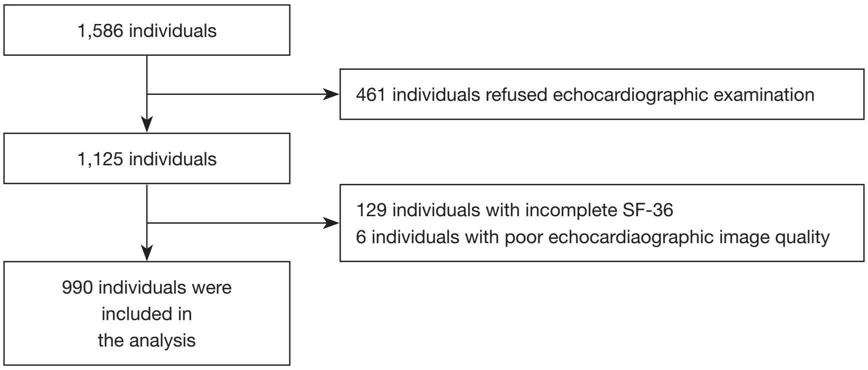

Figure 1 The participants' flow chart with respect to inclusion and exclusion. A total of 1,586 inhabitants aged 35 years or older were invited. Exclusion criteria included individuals who declined participation and who had incomplete data and suboptimal echocardiograms. Finally, 990 individuals were included in this study.

SPSS version 13.0 (SPSS Inc., Chicago, IL, USA) was used for the calculations. A P value <0.05 was considered statistically significant.

Results

From June 2013 to April 2016, a total of 1586 participants underwent baseline assessment including a physical examination and blood tests. All the participants were invited to undergo a baseline echocardiography examination. Among the participants, 461 refused the echocardiographic examination. Incomplete SF-36 questionnaires (129 individuals) and echocardiographic images of poor quality (6 individuals) were excluded. Thus, the final analysis was based on a sample of 990 participants (*Figure 1*).

Clinical, echocardiographic data and scores for HRQoL

The median age of the participants was 57 (50–63) years, 367 (37.1%) were male, and BMI was 26.6±3.8 kg/m^2. Among the participants, 701 (70.8%) were non-smokers, 733 (74%) were non-drinkers, 766 (77.4%) had one or more comorbidities (including HTN, DM, CHD, ischemic or hemorrhagic stroke), 136 (13.7%) had an educational level of high school or above, and 512 (51.8%) had an annual personal income less than RMB 10,000 (*Table 1*).

The average PCS and MCS scores were 89.3 (79.8–94.3) and 90 (83.5–95), respectively. The scores for the eight subscales of the SF-36 are summarized in *Table 2*.

For the echocardiographic data, LVM was 122.7 (104.7–149.0) g, LVEDV was 68 (59–78) mL, LVEF was 70% (66–74%), RWT was 34.7% (31.1–38.5%) and Sm was 8 (7–9) cm/s. The parameters of LV diastolic function were as follows: LAVI was 24.3 (20–28.9) mL/m^2, MVE was 68 (57–81) cm/s, and E/A ratio was 0.84 (0.70–1.10). Em was 8 (7.0–9.5) cm/s, and E/e' was 8.7 (7.2–10.5). The number of individuals with LVDDF was 94 (9.9%). The structural and functional parameters of the right ventricle were as follows: RVD was 31 (29–34) mm, RVWT was 4 (3–4.25) mm, Sm-R was 13 (11–14) cm/s, TAPSE was 21 (19–23) mm, Em-R was 10 (8–11) cm/s, and IVC was 12 (11–14) mm. Other echocardiographic characteristics are presented in *Table 2*.

Univariate analysis of the relationship between the clinical echocardiographic data and the scores for HRQoL

The univariate analysis of the relationship between the clinical echocardiographic data and the scores for HRQoL are presented in *Tables 3*,*4*.

We used univariate linear regression analysis to correlate the echocardiographic-derived parameters, including E/e', Em, E/A ratio, Sm, LVDDF, TAPSE, Em-R, LAVI, MVA and RVD, with PCS; LVM, Em, Sm, LVDDF, TAPSE, Sm-R, and RVD were correlated with MCS (all P<0.05). Other parameters associated with the summarized scores of HRQoL were age, gender, smoking and drinking status, comorbidities, educational level, annual personal income for PCS, gender, smoking and drinking status, and comorbidities for MCS (all P<0.05).

TAPSE was associated with all the subscales and summarized scores of SF-36 (all P<0.05). The other data of the univariate linear regression analysis of the relationship between the clinical echocardiographic data and scores for

Table 1 Study population's clinical data

Clinical data	Value
Age (years)	57 (50–63)
gender (male), n (%)	367 (37.1)
BMI (kg/m^2)	26.6±3.8
Smoking status	
Never-smokers	701 (70.8%)
Ex-smokers	67 (6.8%)
Current-smokers	222 (22.4%)
Drinking status	
Never-drinkers	733 (74%)
Ex-drinkers	27 (2.7%)
Current-drinkers	230 (23.2%)
Comorbidities*	
0	224 (22.6%)
1	355 (35.9%)
2	281 (28.4%)
≥3	130 (13.1%)
Educational level	
High school or above	136 (13.7%)
Below high school	854 (86.3%)
Annual personal income	
RMB <10,000	513 (51.8%)
RMB 10,000–50,000	383 (38.7%)
RMB ≥50,000	30 (3.0%)
NA	64 (6.5%)

BMI, body mass index; *comorbidities were hypertension, diabetes mellitus, history of coronary heart disease, and ischemic and hemorrhagic stroke; NA, not available; RMB, renminbi.

Table 2 Echocardiographic data and the study population's SF-36 scores

Echocardiographic data	Value
LVM (g, N=988)	122.7 (104.7–149.0)
LVEDV (mL, N=981)	68 (59–78)
LVEF (N=981)	0.70 (0.66–0.74)
RWT (%, N=988)	34.7 (31.1–38.5)
Sm (cm/s, N=982)	8 (7–9)
LAVI (mL/m^2, N=952)	24.3 (20–28.9)
MVE (cm/s, N=984)	68 (57–81)
MVA (cm/s, N=974)	78 (66–91)
E/A (N=974)	0.84 (0.70–1.10)
Em (cm/s, N=982)	8.0 (7.0–9.5)
E/e' (N=977)	8.7 (7.2–10.5)
LVDDF (N=945, n, %)	94 (9.9%)
RVWT (mm, N=990)	4 (3–4.25)
Sm-R (cm/s, N=980)	13 (11–14)
TAPSE (ms, N=981)	21 (19–23)
Em-R (cm/s, N=980)	10 (8–11)
RVD (mm, N=983)	31 (29–34)
IVC (mm, N=981)	12 (11–14)
SF-36 scores	
PF	95 (85–100)
RP	100 (100–100)
BP	90 (90–90)
GH	80 (62–92)
VT	85 (75–95)
SF	100 (87–100)
RE	100 (100–100)
MH	80 (72–92)
PCS	89.3 (79.8–94.3)
MCS	90 (83.5–95)

LVM, left ventricular mass; LVEDV, left ventricular end-diastolic volume; LVEF, left ventricular ejection fraction; RWT, relative wall thickness; Sm, the mean value of the systolic peak velocity of the septal mitral annulus and lateral mitral annulus; LAVI, left atrial volume index; MVE, peak velocity of early diastolic transmitral flow; MVA, peak velocity of late diastolic transmitral flow; E/A, the ratio of E and A; Em, the mean value of the early diastolic velocity of the septal mitral annulus (Em-S) and lateral mitral annulus (Em-L); E/e', the mean value of E/Em-S and E/Em-L; LVDDF, left ventricular diastolic dysfunction; RVWT, right ventricular wall thickness; Sm-R, the systolic peak velocity of the lateral tricuspid annulus; TAPSE, tricuspid annular plane systolic excursion; Em-R, the early diastolic velocity of the lateral tricuspid annulus; RVD, the diameter of the right ventricular basal cavity; IVC, diameter of inferior vena cava; PF, physical functioning; RP, role physical; BP, bodily pain; GH, general health; VT, vitality; SF, social functioning; RE, role emotional; MH, mental health; PCS, physical component summary; MCS, mental component summary.

Table 3 Univariate analysis of the relationship between the clinical, echocardiographic data and the SF-36 scores (part I)

	PF		RP		BP		GH		VT	
	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P
Clinical data										
Age (10 years)	−6.37 (−7.55 to −5.19)	0	−6.25 (−8.45 to −4.05)	0	−1.64 (−2.67 to 0.61)	<0.01	−1.64 (−3.11 to −0.16)	0.03	−0.02 (−1.12 to 1.17)	0.97
Gender (male)	4.52 (2.18 to 6.86)	0	8.70 (4.50 to 12.89)	0	3.4 (1.45 to 5.34)	<0.01	2.6 (−0.20 to 5.40)	0.07	1.21 (−0.86 to 3.28)	0.25
BMI	−0.17 (−0.47 to 0.13)	0.47	−0.47 (−1.01 to 0.07)	0.13	−1.36 (−0.51 to −0.01)	0.04	0.28 (−0.07 to 0.64)	0.31	0.16 (−0.10 to 0.43)	0.31
Smoking	1.81 (0.45 to 3.16)	<0.01	3.40 (0.97 to 5.84)	<0.01	1.57 (0.44 to 2.7)	<0.01	1.7 (0.09 to 3.32)	0.04	−0.13 (−1.32 to 1.07)	0.84
Drinking	1.78 (0.44 to 3.13)	<0.01	4.29 (1.89 to 6.70)	0	1.19 (0.08 to 2.31)	0.04	1.14 (−0.46 to 2.74)	0.16	0.75 (−0.43 to 1.93)	0.21
Comorbidities	−3.73 (−4.88 to −2.57)	0	−3.66 (−5.76 to −1.55)	<0.01	−1.18 (−2.15 to −0.20)	0.02	−2.63 (−4.02 to 1.24)	0	−0.8 (−1.83 to 0.24)	0.13
Education	7.84 (4.56 to 11.12)	0	6.02 (0.09 to 11.94)	0.05	2.75 (0.01 to 5.49)	0.05	4.35 (0.42 to 8.28)	0.03	2.9 (0 to 5.81)	0.05
Annual income	8.27 (6.23 to 10.30)	0	8.39 (4.68 to 12.11)	0	2.27 (0.52 to 4.02)	0.11	3.69 (1.24 to 6.14)	<0.01	1.06 (−0.80 to 2.91)	0.26
Echocardiographic data										
LVM	−0.01 (−0.04 to 0.02)	0.51	0.03 (−0.03 to 0.09)	0.35	−0.01 (−0.04 to 0.02)	0.46	0.03 (0 to 0.07)	0.09	0.05 (0.02 to 0.08)	<0.01
LVEDV	−0.04 (−0.11 to 0.03)	0.32	0.05 (−0.08 to 0.18)	0.44	0.01 (−0.06 to 0.06)	0.94	−0.04 (−0.13 to 0.05)	0.35	−0.02 (−0.09 to 0.04)	0.48
LVEF	−0.09 (−0.18 to −0.01)	0.03	−0.12 (−0.27 to 0.03)	0.13	0.04 (−0.03 to 0.11)	0.27	−0.05 (−0.15 to 0.05)	0.32	0.03 (−0.05 to 0.10)	0.49
RWT	−16.9 (−36.91 to 3.08)	0.1	−13.50 (−49.52 to 22.60)	0.46	2.26 (−14.45 to 18.96)	0.79	−2.68 (−26.56 to 21.20)	0.83	10.93 (−6.63 to 28.50)	0.22
Sm	1.38 (0.63 to 2.14)	0	1.37 (0.02 to 2.72)	0.05	0.43 (−0.19 to 1.06)	0.17	0.17 (−0.72 to 1.07)	0.71	0.38 (−0.28 to 1.05)	0.26
LAVI	−0.21 (−0.35 to −0.08)	<0.01	−0.21 (−0.46 to 0.03)	0.09	−0.08 (−0.19 to 0.04)	0.18	−0.05 (−0.21 to 0.10)	0.5	−0.01 (−0.12 to 0.12)	0.96
E/e'	−0.75 (−0.11 to −0.39)	0	−1.10 (−1.73 to −0.46)	<0.01	−0.3 (−0.6 to 0)	0.05	−0.4 (−0.82 to 0.03)	0.07	−0.03 (−0.34 to 0.29)	0.88
Em	1.9 (1.37 to 2.43)	0	2.07 (1.10 to 3.04)	0	1.1 (0.65 to 1.54)	0	0.44 (−0.21 to 1.09)	0.18	0.08 (−0.40 to 0.56)	0.74
MVE	0.06 (0 to 0.13)	0.05	0.05 (−0.06 to 0.16)	0.37	0.06 (0 to 0.11)	0.32	−0.02 (−0.10 to 0.05)	0.59	0.01 (−0.05 to 0.06)	0.85
MVA	−0.15 (−0.21 to −0.10)	0	−0.21 (−0.31 to −0.11)	0	−0.06 (−0.11 to 0.02)	<0.01	−0.06 (−0.13 to 0.01)	0.07	0.02 (−0.03 to 0.07)	0.5
E/A	10.31 (6.67 to 14.0)	0	13.9 (7.31 to 20.48)	0	6.07 (3.02 to 9.12)	0	1.35 (−3.04 to 5.73)	0.55	−0.27 (−3.53 to 2.99)	0.87
LVDDF	−5.96 (−9.83 to −2.09)	<0.01	−7.94 (−15.0 to −0.92)	0.03	−1.69 (−4.89 to 1.52)	0.3	−2.99 (−7.56 to 1.58)	0.2	−2.39 (−5.82 to 1.04)	0.17
RVWT	−1.81 (−3.16 to −0.45)	0.01	−0.48 (−2.92 to 1.97)	0.7	1.02 (−2.15 to 0.11)	0.08	−0.11 (−1.73 to 1.51)	0.9	−0.34 (−1.54 to 0.86)	0.58
Sm-R	0.14 (−0.27 to 0.57)	0.51	0.59 (−0.16 to 1.34)	0.12	−0.11 (−0.46 to 0.24)	0.55	0.06 (−0.44 to 0.56)	0.83	0.26 (−0.11 to 0.63)	0.17
TAPSE	0.96 (0.59 to 1.33)	0	1.86 (1.20 to 2.53)	0	0.4 (0.08 to 0.71)	0.01	0.55 (0.10 to 0.99)	0.02	0.44 (0.11 to 0.77)	0.01
Em-R	0.79 (0.37 to 1.22)	0	1.07 (0.31 to 1.82)	<0.01	0.36 (0 to 0.71)	0.05	0.3 (−0.21 to 0.80)	0.25	−0.1 (−0.47 to 0.27)	0.6

Table 3 (*continued*)

Table 3 (*continued*)

	PF		RP		BP		GH		VT	
	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P
RVD	0.13 (−0.14 to 0.38)	0.35	0.70 (0.23 to 1.16)	<0.01	0.06 (−0.16 to 0.27)	0.62	0.08 (−0.23 to 0.39)	0.61	0.21 (−0.02 to 0.44)	0.07
IVC	0.27 (−0.18 to 0.71)	0.24	0.12 (−0.68 to 0.92)	0.77	−0.19 (−0.56 to 0.19)	0.33	−0.1 (−0.63 to 0.44)	0.73	−0.38 (−0.77 to 0.01)	0.05

PF, physical functioning; RP, role physical; BP, bodily pain; GH, general health; VT, vitality; CI, confidence interval; LVM, left ventricular mass; LVEDV, left ventricular end-diastolic volume; LVEF, left ventricular ejection fraction; RWT, relative wall thickness; Sm, the mean value of the systolic peak velocity of the septal mitral annulus and lateral mitral annulus; LAVI, left atrial volume index; MVE, peak velocity of early diastolic transmitral flow; MVA, peak velocity of late diastolic transmitral flow; E/A, the ratio of E and A; Em, the mean value of the early diastolic velocity of the septal mitral annulus (Em-S) and lateral mitral annulus (Em-L); E/e', the mean value of E/Em-S and E/Em-L; LVDDF, left ventricular diastolic dysfunction; RVWT, right ventricular wall thickness; Sm-R, the systolic peak velocity of the lateral tricuspid annulus; TAPSE, tricuspid annular plane systolic excursion; Em-R, the early diastolic velocity of the lateral tricuspid annulus; RVD, the diameter of the right ventricular basal cavity; IVC, diameter of inferior vena cava.

Table 4 Univariate analysis of the relationship between the clinical, echocardiographic data and the SF-36 scores (part II)

	SF		RE		MH		PCS		MCS	
	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P
Clinical data										
Age (10 years)	−1.03 (−2.04 to −0.01)	0.05	−0.61 (−2.33 to 1.11)	0.49	1.12 (0.05 to 2.20)	0.04	−3.97 (−5.09 to −2.86)	0	−0.13 (−1.02 to 0.75)	0.77
gender(male)	2.19 (0.28 to 4.11)	0.03	5.72 (2.48 to 8.96)	<0.01	2.54 (0.51 to 4.57)	0.01	4.8 (2.66 to 6.95)	0	2.92 (1.26 to 4.58)	<0.01
BMI	−0.02 (−0.26 to 0.23)	0.66	−0.30 (−0.72 to 0.12)	0.05	0.09 (−0.18 to 0.35)	0.33	−0.16 (−0.43 to 0.12)	0.28	−0.02 (−0.23 to 0.20)	0.88
smoking status	1.33 (0.22 to 2.43)	0.02	2.28 (0.40 to 4.16)	0.02	0.46 (−0.71 to 1.64)	0.44	2.12 (0.88 to 3.37)	<0.01	0.99 (0.02 to 1.95)	0.05
drinking status	0.76 (−0.34 to 1.86)	0.17	2.86 (1 to 4.71)	<0.01	1.32 (0.16 to 2.48)	0.03	2.1 (0.87 to 3.33)	<0.01	1.423 (0.47 to 2.37)	<0.01
comorbidities	−1 (−1.86 to 0.06)	0.03	−2.31 (−3.94 to −0.69)	0.01	0.05 (−0.97 to 1.06)	0.93	−2.8 (−3.87 to −1.73)	0	−0.99 (−1.82 to −0.16)	0.02
education	−0.9 (−0.79 to 4.62)	0.07	−1.15 (−5.74 to 3.44)	0.62	0.93 (−1.92 to 3.78)	0.52	5.24 (2.22 to 8.26)	<0.01	1.15 (−1.20 to 3.50)	0.34
annual income	1.84 (0.12 to 3.55)	0.04	2.09 (−0.83 to 5.01)	0.16	0.22 (−1.61 to 2.04)	0.82	5.66 (3.76 to 7.55)	0	1.3 (−0.20 to 2.80)	0.09
Echocardiographic data										
LVM	0.17 (−0.01 to 0.04)	0.2	0.01 (−0.04 to 0.06)	0.7	0.05 (0.02 to 0.08)	<0.01	0.01 (−0.02 to 0.04)	0.5	0.03 (0.01 to 0.05)	<0.01
LVEDV	−0.04 (−0.10 to 0.02)	0.23	0.04 (−0.06 to 0.14)	0.46	−0.04 (−0.10 to 0.02)	0.19	−0.01 (−0.07 to 0.06)	0.86	−0.02 (−0.07 to 0.04)	0.55
LVEF	0.02 (−0.05 to 0.09)	0.61	−0.03 (−0.15 to 0.08)	0.58	0.01 (−0.06 to 0.08)	0.75	−0.06 (−0.13 to 0.02)	0.16	0.01 (−0.05 to 0.07)	0.85
RWT	−13.9 (−30.22 to 2.33)	0.09	−13 (−40.8 to 14.82)	0.36	10.7 (−6.53 to 27.87)	0.22	−7.7 (−26.14 to 10.74)	0.41	−1.33 (−15.52 to 12.86)	0.85
Sm	0.43 (−0.19 to 1.05)	0.17	0.71 (−0.34 to 1.75)	0.18	0.66 (0.01 to 1.31)	0.05	0.84 (0.15 to 1.53)	0.02	0.55 (0.01 to 1.08)	0.05

Table 4 (*continued*)

Table 4 (*continued*)

	SF		RE		MH		PCS		MCS	
	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P
LAVI	−0.03 (−0.14 to 0.09)	0.66	−0.09 (−0.28 to 0.10)	0.33	0.03 (−0.09 to 0.14)	0.64	−0.14 (−0.26 to −0.12)	0.03	−0.02 (−0.12 to 0.07)	0.63
E/e'	−0.07 (−0.36 to 0.23)	0.66	−0.18 (−0.68 to 0.31)	0.47	−0.13 (−0.44 to 0.18)	0.41	−0.64 (−0.9 to −0.31)	0	−0.1 (−0.36 to 0.15)	0.43
Em	0.61 (0.16 to 1.05)	<0.01	0.75 (−0.01 to 1.50)	0.05	−0.12 (−0.36 to 0.59)	0.63	1.38 (0.88 to 1.87)	0	0.39 (0 to 0.77)	0.05
MVE	0.04 (−0.01 to 0.09)	0.12	0.03 (−0.06 to 0.11)	0.56	−0.04 (−0.09 to 0.02)	0.19	0.04 (−0.02 to 0.10)	0.2	0.01 (−0.04 to 0.05)	0.7
MVA	−0.03 (−0.08 to 0.02)	0.18	−0.09 (−0.17 to −0.01)	0.03	0.03 (−0.02 to 0.08)	0.22	−0.12 (−0.18 to −0.07)	0	−0.02 (−0.06 to 0.02)	0.4
E/A	2.84 (−0.18 to 5.86)	0.07	5.29 (0.15 to 10.42)	0.04	−2.42 (−5.60 to 0.77)	0.14	7.91 (4.54 to 11.27)	0	1.36 (−1.27 to 4.0)	0.31
LVDDF	−3.78 (−6.98 to 0.57)	0.02	−5.6 (−11.08 to −0.13)	0.05	−0.44 (−3.78 to 2.91)	0.8	−4.64 (−9.22 to −1.07)	0.01	−0.31 (−5.84 to −0.27)	0.03
RVWT	−0.49 (−1.60 to 0.62)	0.39	−1.33 (−3.21 to 0.56)	0.17	0.33 (−0.85 to 1.50)	0.59	−0.85 (−2.10 to 0.40)	0.18	−0.46 (−1.42 to 0.51)	0.35
Sm-R	0.26 (−0.08 to 0.61)	0.13	0.57 (−0.01 to 1.15)	0.06	0.55 (0.19 to 0.92)	<0.01	0.17 (−0.22 to 0.56)	0.39	0.41 (0.11 to 0.71)	<0.01
TAPSE	0.35 (0.04 to 0.65)	0.03	1.06 (0.54 to 1.58)	0	0.34 (0.02 to 0.67)	0.04	0.94 (0.60 to 1.28)	0	0.55 (0.28 to 0.81)	0
Em-R	0.27 (−0.07 to 0.62)	0.12	0.36 (−0.23 to 0.94)	0.24	0.18 (−0.19 to 0.54)	0.35	0.63 (0.24 to 1.02)	<0.01	0.18 (−0.13 to 0.48)	0.25
RVD	0.44 (0.23 to 0.65)	0	0.48 (0.12 to 0.84)	0.01	0.26 (0.03 to 0.48)	0.02	0.24 (0 to 0.48)	0.05	0.35 (0.16 to 0.53)	0
IVC	0.13 (−0.23 to 0.49)	0.48	0.12 (−0.49 to 0.73)	0.7	−0.22 (−0.60 to 0.16)	0.26	0.03 (−0.38 to 0.44)	0.9	−0.09 (−0.40 to 0.22)	0.58

PF, physical functioning; RP, role physical; BP, bodily pain; GH, general health; VT, vitality; CI, confidence interval; LVM, left ventricular mass; LVEDV, left ventricular end-diastolic volume; LVEF, left ventricular ejection fraction; RWT, relative wall thickness; Sm, the mean value of the systolic peak velocity of the septal mitral annulus and lateral mitral annulus; LAVI, left atrial volume index; MVE, peak velocity of early diastolic transmitral flow; MVA, peak velocity of late diastolic transmitral flow; E/A, the ratio of E and A; Em, the mean value of the early diastolic velocity of the septal mitral annulus (Em-S) and lateral mitral annulus (Em-L); E/e', the mean value of E/Em-S and E/Em-L; LVDDF, left ventricular diastolic dysfunction; RVWT, right ventricular wall thickness; Sm-R, the systolic peak velocity of the lateral tricuspid annulus; TAPSE, tricuspid annular plane systolic excursion; Em-R, the early diastolic velocity of the lateral tricuspid annulus; RVD, the diameter of the right ventricular basal cavity; IVC, diameter of inferior vena cava.

the eight subscales of the SF-36 are in *Tables 3,4*.

Multivariate analysis of the relationship between the echocardiographic data and the summarized scores for HRQoL

The relationship between the echocardiographic data and the summarized scores for HRQoL was analyzed in two models (*Table 5*).

The first model was adjusted for age, gender, BMI, educational level, and annual personal income, TAPSE which reflected the RV longitudinal systolic function, showed a strong independent association with both MCS [β=0.53 95% confidence interval (CI): 0.26–0.79, P<0.01] and PCS (β=0.67 95% CI: 0.32–1.03, P<0.01). The other echocardiographic parameters independently associated with MCS were RVD, Sm-R, and LVDDF (all P<0.05). Em and the E/A ratio were independently associated with PCS (all P<0.05). The independent associations between TAPSE and the summarized scores for HRQoL remained even after adjusting for smoking and drinking status and comorbidities in model 2 (β=0.49 95% CI: 0.23–0.76, P<0.01 for MCS and β=0.65 95% CI: 0.30–1.01, P<0.01 for PCS). Other echocardiography-derived parameters of RV independently associated with MCS were LVM, RVD, and Sm-R (all P<0.05) in model 2; no other echocardiography parameter was independently associated with PCS.

Comparation of the summarized scores for HRQoL between different TAPSE groups

Because TAPSE was independently associated with both MCS and PCS, the participants were divided according to the median of TAPSE (21 mm). In *Figure 2*, compared with the participants with TAPSE ≥21 mm, the participants with TAPSE <21 mm had the lower scores for MCS and PCS (85.5 *vs*. 88.1, P<0.01 for MCS, and 81.8 *vs*. 84.5, P=0.015 for PCS) after adjusting for age, gender, BMI, education level, annual personal income, smoking and drinking status, and comorbidities.

Discussion

In this cross-sectional population-based study of the general Chinese population, we assessed the relationship between the echocardiography-derived cardiac structure and function and HRQoL assessed by SF-36. Our major findings were that RV long-axis myocardial contraction assessed by TAPSE was independently associated with two summarized scores for HRQoL and those with lower TAPSE had lower summarized scores of HRQoL assessed by SF-36.

The patients with isolated LV diastolic dysfunction present decreases in HRQoL scores similar to those with LV systolic dysfunction, and that both of them are worse in comparison to controls (20). In another study (9), HRQoL was associated with LV function assessed by TDI echocardiography in patients with HTN without overt heart failure after adjusted for age, gender and BMI especially in the subgroup with dyspnoea. In other studies which were performed in patients with cardiovascular diseases (7,8), LV function was also found to be associated with HRQoL. But most of the previous research about the association between cardiac function and HRQoL was performed in patients with cardiovascular diseases. The study about the role of cardiac function, especially RV function, in HRQoL in general population is lacking. In our study, we found in general population, after adjusted for the comorbidities (including HTN), RV function but not LV function was independently associated with HRQoL.

Studies of the relation between RV function and HRQoL have been performed in populations with certain diseases. Tannus-Silva *et al*. (11) found RV dysfunction was associated with impairment in HRQoL in patients with COPD, and a similar association was found in patients with pulmonary hypertension (21) and end-stage heart failure (22). In our study, RV long-axis myocardial contraction assessed by TAPSE was associated with all subscales and summarized scores of SF-36. The association between TAPSE and the summarized scores for HRQoL remained even after adjusting for the conventional factors affecting HRQoL.

The LV that plays the central role in defining arterial pressure has been considered by cardiologists as the essential ventricle for the maintenance of effective circulation. However, it is important to realize that overall cardiac performance is determined by both RV and LV in series (23). The RV is also important in maintaining CO, particularly during exercise, as shown indirectly by a 30% to 50% decrease in predicted maximum oxygen uptake in healthy Fontan patients (24).

The potential explanation for the independent association between RV function and HRQoL was that RV plays an important role in CO augmentation during exercise. The relative increases in afterload were greater for the pulmonary circulation than for the systemic circulation during exercise. The limited reserve for decreases in

Table 5 Multivariate analysis of the relationship between the echocardiographic data and the summarized scores for SF-36

	MCS		PCS	
	β (95% CI)	P	β (95% CI)	P
Model 1				
LVM	0.02 (0 to 0.05)	0.07		
Sm	0.45 (−0.09 to 0.98)	0.1	0.43 (−0.28 to 1.13)	0.24
LAVI			−0.03 (−0.16 to 0.09)	0.6
E/e'			−0.28 (−0.62 to 0.06)	0.11
Em	0.38 (0 to 0.77)	0.05	0.72 (0.15 to 1.30)	0.01
MVA			−0.05 (−0.10 to 0.01)	0.1
E/A			4.3 (0.42 to 8.12)	0.03
Sm-R	0.37 (0.07 to 0.67)	0.02		
TAPSE	0.53 (0.26 to 0.79)	0	0.67 (0.32 to 1.03)	0
Em-R			0.33 (−0.07 to 0.74)	0.11
RV	0.27 (0.08 to 0.47)	<0.01	0.01 (−0.25 to 0.25)	0.98
LVDDF	−2.83 (−5.6 to −0.05)	0.05	−2.37 (−6.05 to 1.32)	0.21
Model 2				
LVM	0.03 (0 to 0.05)	0.03		
Sm	0.38 (−0.16 to 0.92)	0.17	0.38 (−0.32 to 1.09)	0.29
LAVI			−0.04 (−0.17 to 0.09)	0.53
E/e'			−0.19 (−0.53 to 0.15)	0.27
Em	0.27 (−0.14 to 0.67)	0.19	0.56 (−0.03 to 1.14)	0.06
MVA			−0.03 (−0.09 to 0.03)	0.29
E/A			3.54 (−0.36 to 7.45)	0.08
Sm-R	0.37 (0.07 to 0.67)	0.02		
TAPSE	0.49 (0.23 to 0.76)	0	0.65 (0.30 to 1.01)	0
Em-R			0.26 (−0.14 to 0.67)	0.2
RV	0.26 (0.06 to 0.45)	0.01	−0.01 (−0.26 to 0.24)	0.91
LVDDF	−2.69 (−5.57 to 0.08)	0.06	−2.29 (−6.0 to 1.39)	0.22

PCS, physical component summary; MCS, mental component summary; LVM, left ventricular mass; Em, the mean value of the early diastolic velocity of the septal mitral annulus (Em-S) and lateral mitral annulus (Em-L); E/e', the mean value of E/Em-S and E/Em-L; MVA, peak velocity of late diastolic transmitral flow; E/A, the ratio of E and A; LVDDF, left ventricular diastolic dysfunction; Sm-R, the systolic peak velocity of the lateral tricuspid annulus; Em-R, the early diastolic velocity of the lateral tricuspid annulus.

resistance in pulmonary vasculature and more increases in downstream venous pressure during exercise were the mayor physiological bases (23,25,26).

Furthermore, RV was more sensitive to the increase of afterload. Because RV coronary blood flow is supplied mostly during systole but also during diastole, right ventricular coronary flow is more susceptible to changes in afterload during exercise (27). Evidence supporting that the right ventricle plays an important role in CO augmentation during exercise in both health and disease is increasing (23). In our study, RV function was associated with PCS and MCS scores in the general population, which might add new evidence to

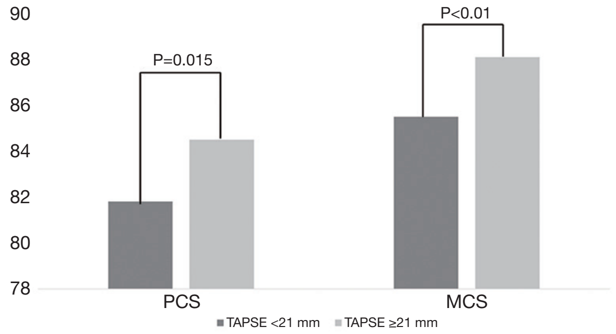

Figure 2 Compared with the participants with TAPSE ≥21 mm, the participants with TAPSE <21 mm had the lower scores of both MCS and PCS (85.5 *vs.* 88.1, P<0.01 for MCS, and 81.8 *vs.* 84.5, P=0.015 for PCS) after adjusting for age, gender, BMI, educational level, annual personal income, smoking and drinking status, and comorbidities. PCS, physical component summary; MCS, mental component summary.

the contribution of RV to normal circulation.

In this study, LV function was not independently associated with HRQoL, the possible explanation was that: this study was conducted in general population, the participants had relatively "normal" LV systolic and diastolic function as shown in *Table 2*. Although LV plays the central role in cardiac performance, RV is also important in maintaining CO especially in the general population with relatively "normal" LV function.

Assessing RV function is complex, and no single, commonly accepted parameter is available (28). Cardiac magnetic resonance imaging (CMR) is considered the clinical gold standard to evaluate RV function but is expensive and has limited availability. The main echocardiography-derived parameters of RV structure and systolic function include RVD, TAPSE, Sm-R, RV fractional area change (RVFAC), myocardial performance index (MPI), RV ejection fraction (RVEF), and RV strain (19). Among these parameters used to assess RV systolic function, TAPSE was the easiest to obtain, and TAPSE has been found to correlate well with RVFAC and RVEF (29). Because of the predominance of longitudinal subendocardial myocytes, longitudinal shortening accounts for approximately 75% of RV contraction (30). and TAPSE was the parameter that reflected the RV longitudinal contraction. In our study, TAPSE was the only parameter that related to all the subscales and summarized scores of HRQoL assessed by SF-36, which indicated that TAPSE might be a useful, easily available echocardiography-derived RV parameter in population-based studies.

The strengths of the study are its population-based and prospective design, the acquisition of the baseline parameters and echocardiographic data are standardized. A limitation is that: this is cross-sectional study, it is unknown how the HRQoL changed during the follow-up period, only cross-sectional analysis cannot prove a causal relationship between TAPSE and HRQoL. The follow-up of this cohort is ongoing and the change of the HRQoL and RV function will be revaluated during the follow-up. Another limitation is that: 1,586 participants were enrolled, but finally 990 participants were included in this study, leading to a possibility of selection bias. To mitigate the limitation, a two-step multivariate analysis was performed and after adjusting for the conventional factors influencing HRQoL, the relationship between RV function and HRQoL remained. The third limitation is that, only Chinese population is included in this study, our results could not be extrapolated to other ethnic populations. The fourth limitation is that, TAPSE is a regional parameter that only measures longitudinal shortening in the lateral free wall of the right ventricle, in patients with regional dysfunction in the outlet part of the right ventricle, TAPSE cannot correctly assess the global RV function. But this study is Population-based, and even after adjusting for the history of myocardial infarction, TAPSE remains independently associated with HRQoL.

Conclusions

In this study, we found that in the Chinese general population aged 35 years and older, RV systolic function derived from echocardiography (TAPSE) was independently associated with HRQoL assessed by SF-36. These findings add new evidence to the contribution of RV function to HRQoL. However, if the RV function has the prognostic value in the change of HRQoL in the general population, and what is the real mechanism of the association between RV and HRQoL; all these topics warrant further investigation.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist Available at http://dx.doi.org/10.21037/atm-20-6845

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of the Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences (approval no. 009-2014, 031-2017) and informed consent was taken from all the patients.

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