International Journal of Cardiology Cardiovascular Risk and Prevention 13 (2022) 200128

Contents lists available at ScienceDirect

International Journal of Cardiology Cardiovascular Risk and Prevention

journal homepage: www.journals.elsevier.com/international-journal-of-cardiology-cardiovascular-risk-and-prevention

Risk factor control among heart failure patients in the United States: Results from the NHANES 1999–2018

Ying Tang [a], Jing Yan [a,b], Lijiang Tang [b,c,**], Xiaowei Liu [b,*]

[a] Geriatrics Research Institute of Zhejiang Province, Zhejiang Provincial Key Lab of Geriatrics, Zhejiang Hospital, Hangzhou, Zhejiang, 310013, PR China
[b] Department of Cardiology, Zhejiang Hospital, Hangzhou, Zhejiang, 310013, PR China
[c] Department of Medicine, School of Medicine, Zhejiang University of Traditional Chinese Medicine, Hangzhou, Zhejiang, 310000, PR China

ARTICLE INFO

Keywords:
Heart failure
Risk factor
Medication
Lifestyle modification

ABSTRACT

Background: Compliance with recommended pharmacological and non-pharmacological treatments to modify risk factors is associated with improved outcomes for patients with heart failure (HF).

Methods: We conducted an analysis of the National Health and Nutrition Examination Survey (NHANES) years 1999–2018 to evaluate the adequacy of risk factor control and compliance with recommended lifestyle and medications according to the clinical guidelines for the management of HF. Demographic, clinical, and healthcare-access factors associated with having risk factors uncontrolled or not receiving recommended medications were determined using logistic regression analyses.

Results: We collected 1906 participants aged 18 years or older with a self-reported history of HF. The majority were at target goals for blood pressure (45.07%), low-density lipoprotein cholesterol (22.04%), and glycated hemoglobin (72.15%), whereas only 19.09% and 27.38% were at targets for body mass index and waist circumference respectively. Besides, 79.49% and 67.23% of respondents reported smoking cessation and recommended alcohol consumption, whereas only 11.54% reported adequate physical activity. Proportion of taking beta blockers, angiotensin converting enzyme inhibitors/angiotensin receptor blockers (ACEIs/ARBs) and diuretics was 54.77%, 52.62% and 49.37%, respectively. Finally, the logistic regression analysis showed that metabolic syndrome and diabetes mellitus were associated with a higher likelihood of having risk factor uncontrolled, while metabolic syndrome, diabetes mellitus, and chronic kidney disease were predictors for not receiving recommended medications.

Conclusions: Risk factor control and adherence to recommended lifestyle and medications are non-ideal among HF patients in the USA. A systematic approach for risk factor optimization in people with HF is urgently needed.

1. Introduction

Heart failure (HF) is a major public health problem and a leading cause of morbidity and mortality worldwide. In the United States, HF affects approximately 6.5 million adults, with its prevalence continuing to rise [1]. As estimated, the lifetime risk of developing HF is 20% over 40 years of age, and the incidence of HF increases with age [2,3]. Since one in 5 Americans is projected to be >65 years of age by 2050 [4], the number of Americans with HF is expected to significantly worsen in the future. Although survival has improved, the absolute mortality rates for HF remain approximately 50% within 5 years of diagnosis [5,6]. While the progression of HF is irreversible, HF stages are associated with progressively worsening 5-year survival rates [7].

Although HF still has a poor outcome [8], the prognosis has improved considerably in the last decades by the achievements in pharmacological and non-pharmacological treatment aimed at modifying conditions or co-morbidities (e.g. hypertension, dyslipidemia, obesity, abdominal adiposity, and fasting hyperglycemia) that are important risk factors for HF [9,10]. Multiple medications should be prescribed to HF patients in order to control co-morbidities and symptoms, reduce rehospitalization, and improve survival. For example, long-term treatment of both systolic and diastolic hypertension, which may be the single most important risk factor of HF in the United States [4], reduces the risk of moving from stage A or B to stage C HF [11–14].

* Corresponding author. Department of Cardiology, Zhejiang Hospital, Lingyin Road No.12, Hangzhou, Zhejiang, 310013, PR China.
** Corresponding author. Department of Cardiology, Zhejiang Hospital, Lingyin Road No.12, Hangzhou, Zhejiang, 310013, PR China.
E-mail addresses: zjyytang@126.com (L. Tang), liuxiaowei144138@163.com (X. Liu).

https://doi.org/10.1016/j.ijcrp.2022.200128
Received 3 January 2022; Received in revised form 15 February 2022; Accepted 3 March 2022
Available online 12 March 2022

In addition, it is vital for HF patients to follow non-pharmacological recommendations on lifestyle modifications. Non-compliance with pharmacological or non-pharmacological recommendations in patients with HF is associated with a poor prognosis [15–17].

Despite the pharmacological and non-pharmacological treatments being widely recommended [4,18–21], previous studies have suggested inadequate adherence to national guidelines [22–28]. In a study focused on non-institutionalized U.S. adults with HF from the National Health and Nutrition Examination Survey (NHANES), Wong et al. [29] Comprehensively evaluated risk factor control according to the secondary prevention guidelines, and found inadequacy in risk factor control and adherence to recommended lifestyle and pharmacologic therapies. However, sample size of this study was small with participants included from two cycles of NHANES 2007–2010. We hypothesis that a large gap still exists between the secondary prevention guidelines and the real compliance in U.S. adults with HF. We also presume factors to potentially influence the achievement of targets for risk factor control and adherence to recommendations. In the present study, we evaluated the adequacy of risk factor control by estimating the proportions of subjects who achieve the target goals for physiological indices, and the degree of compliance with recommended lifestyle and medications in non-institutionalized U.S. adults with HF from the NHANES 1999–2018. Potential factors influencing the achievement of targets for risk factor control, adherence to recommended lifestyle modifications, and medical therapies were also analyzed.

2. Materials and methods

2.1. Study design and population

The NHANES is a program of studies designed to assess the health and nutritional status of adults and children in the United States (https://www.cdc.gov/nchs/nhanes/about_nhanes.htm). Since 1999, NHANES has been conducted in 2-year cycles. For each cycle, it samples the non-institutionalized population of the United States by using a stratified multistage probability sample design, thus allowing the study to provide nationally representative population estimates of the United States. NHANES cycles can be combined to provide more stable prevalence estimates when needed. The present study was based on analysis of data for ten 2-year NHANES survey cycles: 1999–2000, 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, 2011–2012, 2013–2014, 2015–2016, and 2017–2018. Overall interview response rates for these years ranged from 57% to 84%, and examination response rates ranged from 54% to 80%. Eligibility criteria for this present study included 1) age ≥18 years; 2) a self-reported history of HF. Participants who missed the information about a self-reported history of HF or reported pregnancy were excluded. Of the 101,316 NHANES participants ≥18 years old who were interviewed and examined during the ten calendar periods, we excluded 45,592 participants who missed the answer to the question "Have you ever been told by a doctor or health professional you have HF?''. We then excluded 53,818 participants who did not self-report a prior diagnosis of HF. Finally, none of the remaining participants were pregnant, 1906 eligible participants were identified for the present study, and the missingness remained less than 10% per observation. Therefore, the missing values were deleted when analyzing the measurement data or count data.

2.2. Data collection

For this present study, data from the last 10 consecutive cycles of NHANES from 1999 to 2018 were surveyed. From a total of 101,316 participants, 1906 had a self-reported history of HF. A self-report of HF was defined as a positive answer to the question of "Have you ever been told by a doctor or health professional you have HF?'' Participants' age, sex, race/ethnicity, annual house income, education status and health insurance status were obtained by questionnaire during detailed in-person home interviews. Standardized physical examinations consisting of medical, dental, and physiological measurements were conducted in mobile examination centers (MECs). For prescription medications information, participants were asked if they had taken prescription medications in the past month. Those who answered "yes" were further asked to show containers for all medications taken during the time, and medication names were recorded. If no container was available, participants were asked to verbally report medication name. All blood pressure (BP) determinations (systolic and diastolic BP), waist circumference, and body mass index (BMI) were measured in the MECs according to the NHANES procedures. Serum cholesterol including low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C) and total cholesterol (TC), and glycated hemoglobin (HbA1c) were measured in laboratory according to the NHANES *Laboratory/Medical Technologists Procedures Manual*. Co-morbidities including metabolic syndrome (MS), stroke, coronary heart disease (CHD), diabetes mellitus (DM), and chronic kidney disease (CKD) were defined as described below.

2.3. Definition of Co-morbidities

DM was defined according to a non-fasting glucose level ≥200 mg/dL, or a fasting glucose level ≥126 mg/dL, or HbA1c≥6.5% [30], an affirmative response to the question "Because of your diabetes/high blood sugar, are you now taking prescribed medicine?", or a physician diagnosis of DM. Hypertension was defined as a mean systolic BP (SBP) ≥140 mm Hg, a mean diastolic BP (DBP) ≥90 mm Hg (≥130/80 mm Hg if DM) [31] or on anti-hypertensive medication. CHD was defined according to a physician diagnosis of angina, myocardial infarction (heart attack), or CHD. Glomerular filtration rate (GFR) was estimated with the use of the Modification of Diet in Renal Disease equation [GFR = 186 × serum creatinine-10,154 × age-0.2.3 × (1.212 if black]) × (0.742 if female)], and CKD was defined as an estimated GFR <60 mL/min/1.73 m^2. MS was defined ≥3 of the following [32]: (1) waist circumference >88 cm for women, >102 cm for men, (2) HDL-C <40 mg/dL (1.0 mmol/L) for men or <50 mg/dL (1.3 mmol/L) for women, (3) fasting TG >150 mg/dL (1.7 mmol/L), (4) BP of >130 mm Hg systolic or >85 mm Hg diastolic, or receiving treatment, and (5) impaired fasting glucose, defined as 100–125 mg/dL (5.55–6.99 mmol/L).

2.4. Physiological targets, prescribed lifestyles and pharmacological recommendations

Specific physiological goals were defined as follows: BP <130/80 mm Hg [4,33], LDL-C <70 mg/dL [4,19,33], BMI between 18.5 and 25 kg/m^2 [18], waist circumference <89 cm for women or <102 cm for men [18], and HbA1c <7% in those with DM [18]. Recommended lifestyle modifications included smoking cessation [18], moderate physical activity for at least 150 min per week or minimum 5 days per week at least 30 min/day [4,20], and alcohol consumption of no more than 2 drinks/day for men or 1 drink/day for women [18].

Uncontrolled blood pressure (BP ≥130/80 mm Hg), LDL-C >70 mg/dL, obesity (BMI ≥30 kg/m^2), current smoking, DM, and inadequate physical activity are conditions regarded as significant risk factors for HF [4,18]. Therefore, in this present study, we defined having risk factors uncontrolled as two or more of the guideline goals or recommendations for above conditions not achieved.

Failure at being compliant with pharmacological recommendations refers to the fact that HF patient do not take the recommended medication including beta blockers, ACEIs/ARBs, and diuretics.

2.5. Statistical analysis

Percentages of patients with ≥2 uncontrolled risk factors among sex, race/ethnicity (non-Hispanic White, Hispanic, and non-Hispanic Black), socioeconomic (annual house income <$35,000, $35,000~$75,000,

and >$75,000), education (<high school, high school diploma, and associated degree or higher) and current health insurance (uninsured, private, public Medicare, and public others) statuses were analyzed with Chi-square tests. BP (systolic and diastolic) as well as serum lipids (LDL-C, HDL-C and total cholesterol) between risk factor controlled and uncontrolled patients were compared using Student's t-tests. Uncontrolled rates between HF patients with or without co-morbidities including hypertension, obesity, MS, stroke, CHD, DM and CKD were measured with Chi-square tests.

For assessing proportions of patients achieving specific physiological targets including BP, serum LDL-C and HbA1c levels, BMI as well as waist circumference, participants were grouped by sex, age (<65 and ≥ 65), race/ethnicity, socioeconomic, education and health insurance statuses as indicated above. Then bivariate relationships between targets and groups were estimated with Chi-square tests. Percentages of patient adherent to lifestyle modifications including physical activity, alcohol consumption and non-smoking status, and proportions of taking recommended drugs including beta blockers, ACEIs/ARBs and diuretics were similarly estimated. In addition, differences in medication use between participants with or without co-morbidities including hypertension, MS, stroke, CHD, DM, and CKD were compared with Chi-square tests.

To determine factors associated with having risk factors uncontrolled and not receiving recommended medications, we calculated odd ratios (ORs) and 95% confidence intervals (CIs) for each factor of interest using univariate logistic regression with likelihood ratio test. Having risk factors uncontrolled or not receiving recommended medications was modeled as the dichotomous dependent variable and the factors of sex, age (groups defined by 18–49 years, 50–59 years, 60–69 years, and ≥70 years), race/ethnicity, socioeconomic, education, and health insurance statuses, or co-morbidities were modeled as the independent variables. Then, the statistically different independent variables were selected to the subsequent multivariate logistic regression analysis. In this present study, age, sex, socioeconomic status, current health insurance status, MS, and DM were selected to the multivariate logistic regression for having risk factors uncontrolled. Meanwhile, age, current health insurance status, MS, CHD, DM, and CKD were selected to the multivariate logistic regression for not receiving recommended medications. Missingness remained less than 10% per observation.

For all analyses, statistical significance was set at $p < 0.05$. SAS statistical software (version 9.3; SAS Institute, Cary, NC, USA) was used for data management and analysis.

3. Results

The baseline characteristics of the final analytic sample of 1906 adults were shown in Table 1. Overall, the average age of respondents were 68.36 ± 12.57 years, and approximately 45% were female. The majority of respondents were non-Hispanic white (56.61%), with annual house income less than $35,000 (59.54%), and had public health insurance (86.30%). Approximately one-fifth of respondents reported current smoking. Besides, over 80% of respondents had hypertension, and more than half had obesity (50.65%), MS (63.57%), and CHD (62.07%). Specifically, prevalence of hypertension, obesity, MS, and DM were significantly higher in risk factor uncontrolled group.

Table 2 shows the adequacy of achieving recommended physiological targets. 45.07% of respondents were at the target BP goal, with males, Non-Hispanic Whites, higher annual house income group, and patients receiving higher education more likely to achieve this target. 22.04% of respondents were at the goal for LDL-C control, and older patients had significantly higher proportion achieving this target. 72.15% of participants were at the target level of HbA1c, and no difference was observed between groups. Only minority of participants achieved the goals for BMI (19.09%) and waist circumference (27.38%), with patients at younger age more likely failing at these goals.

The proportion of patients being completely compliant with

Table 1
Characteristics of the final analytic sample of participants ($n = 1906$).

Characteristics	Overall ($n = 1906$)	Controlled ($n = 484$)	Uncontrolled ($n = 1422$)	*P* Value
Age(yrs), mean ± SD	68.36 ± 12.57	71.92 ± 12.21	67.14 ± 12.46	<0.0001
Sex, *n* (%)				0.42
Male	1041 (54.62)	272 (56.20)	769 (54.08)	
Female	865 (45.38)	212 (43.80)	653 (45.92)	
Race, *n* (%)				<0.0001
Non-Hispanic White	1024 (56.61)	288 (63.72)	736 (54.24)	
Hispanic	325 (17.97)	84 (18.58)	241 (17.76)	
Non-Hispanic Black	460 (25.43)	80 (17.70)	380 (28.00)	
Socioeconomic Status, *n* (%)				0.02
<$35,000	649 (59.54)	114 (51.12)	535 (61.71)	
$35,000-$75,000	322 (29.54)	79 (35.43)	243 (28.03)	
>$75,000	119 (10.92)	30 (13.45)	89 (10.27)	
Education Status, *n* (%)				0.93
<High school	774 (40.78)	195 (40.63)	579 (40.83)	
High school diploma	460 (24.24)	114 (23.75)	346 (24.40)	
AA or high	664 (34.98)	171 (35.63)	493 (34.77)	
Current Health Insurance Status, *n* (%)				0.02
Uninsured	82 (6.07)	12 (4.26)	70 (6.55)	
Private	103 (7.62)	25 (8.87)	78 (7.30)	
Public Medicare	665 (49.22)	158 (56.03)	507 (47.43)	
Public others	501 (37.08)	87 (30.85)	414 (38.73)	
Risk Factor and Co-morbidities				
Hypertension, *n* (%)	1539 (80.75)	316 (65.29)	1223 (86.01)	<0.0001
SBP (mmHg), mean ± SD	132.30 ± 23.40	115.87 ± 16.18	135.83 ± 23.22	<0.0001
DBP (mmHg), mean ± SD	66.30 ± 15.92	60.00 ± 14.10	67.66 ± 15.97	0.0001
LDL-C (mg/dL), mean ± SD	100.11 ± 37.89	73.04 ± 28.69	102.85 ± 37.66	<0.0001
HDL-C (mg/dL), mean ± SD	49.14 ± 16.17	51.59 ± 17.77	48.69 ± 15.82	0.04
TC (mg/dL), mean ± SD	174.64 ± 45.27	159.35 ± 40.61	177.48 ± 45.54	<0.0001
Current smoking, *n* (%)	391 (20.51)	19 (3.93)	372 (26.16)	<0.0001
BMI ≥30 kg/m^2, *n* (%)	820 (50.65)	33 (11.54)	787 (59.04)	<0.0001
Central obesity	1077 (72.62)	133 (52.78)	944 (76.69)	<0.0001
MS, *n* (%)	328 (63.57)	21 (28.77)	307 (69.30)	<0.0001
Stroke, *n* (%)	403 (21.14)	104 (21.49)	299 (21.03)	0.83
CHD, *n* (%)	1183 (62.07)	291 (60.12)	892 (62.73)	0.31
DM, *n* (%)	790 (41.45)	140 (28.93)	650 (45.71)	<0.0001
CKD, *n* (%)	437 (39.33)	69 (41.32)	368 (38.98)	0.57

Data are presented as *n* (%) or mean ± standard deviation (SD).
Uncontrolled: ≥2 risk factors (including hypertension [blood pressure ≥130/80 mm Hg], LDL-C ≥70 mg/dL, obesity [body mass index ≥30 kg/m^2], current smoking, HbA1c >7% for those HF with DM, and inadequate physical activity [<5 days/week or <30 min/session]) not controlled.
Central obesity: waist circumference >102 cm for men or >88 cm for women.
AA: associate degree; SBP: systolic blood pressure; DBP: diastolic blood pressure; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol; TC: total cholesterol; BMI: body mass index; MS: metabolic syndrome; CHD: coronary heart disease; DM: diabetes mellitus; CKD: chronic kidney disease.

P value indicates comparison of means or proportions between controlled and uncontrolled groups.

recommended lifestyle modifications were shown in Table 3. 79.49% of participants reported smoking cessation, with higher compliance in women and older patients, and difference was observed between patients grouped by race, house income, education status, as well as current health insurance. Only 11.54% of respondents took enough physical activity, with significantly higher proportion in males, younger patients, and patients receiving higher education. Almost two thirds (67.23%) of participants followed recommended alcohol consumption, with significant differences observed between patients grouped by age, race, house income, education status, and current health insurance.

Table 4 describes the medications use in HF patients. Approximately one half of participants received beta blockers, ACEIs/ARBs, or diuretics. There were significant differences in medication use between groups. In brief, females tended to have lower ratio of compliance with beta blockers and ACEIs/ARBs. Younger patients tended to have lower ratio of compliance with beta blockers and diuretics. Hispanics, patients receiving lower education, and those without health insurance were less likely to be compliant with medical therapies. Compliance with medication use in HF patients with co-morbidities is shown in Table 5. On the whole, patients with co-morbidities had higher ratio of compliance with beta blockers, ACEIs/ARBs and diuretics.

Table 6 and Table 7 illustrate potential determinants of having ≥2 risk factors uncontrolled and not receiving recommended medications, respectively. The univariate logistic regression was first performed to determine variables for subsequent multivariate logistic regression analyses. After univariate logistic regression, age, gender, socioeconomic status, current health insurance status, MS, and DM were selected to the multivariate logistic regression for having risk factors uncontrolled. On the other hand, age, current health insurance status, MS, CHD, DM, and CKD were selected to the multivariate logistic regression for not receiving recommended medications. The multivariate logistic regression analysis showed that MS and DM were significant predictors for having risk factor uncontrolled. While, in terms of not receiving recommended medications, MS, DM, and CKD were predictors.

4. Discussion

Hypertension, dyslipidemia, obesity, smoking, DM, and may other relevant conditions are important risk factors for HF [4]. Appropriate treatment and control of these risk factors can significantly reduce and delay the progress of HF. However, the data presented here suggest inadequate risk factor control among HF patients in the United States, with only 0.47% of participants achieving all 5 target goals for BP, LDL-C, HbA1c (if DM), BMI and waist circumference (Table 2). Important disparities in therapeutic goal achievement and compliance with clinical recommendations exist in demographic subgroups.

The overall prevalence of hypertension in HF patients is over 80% according to our study (Table 1), in similar with previous studies showing hypertension as the most common co-morbidity with HF [29,34]. The management of hypertension in patients with HF is challenging [35], and only approximately 45% of participants are at the target goal for BP control (Table 2). In particular, female gender, Hispanic and non-Hispanic black, having annual house income <$35,000, and receiving education less than high school are associated with lower proportion achieving this goal. Further, the overall taking beta blockers, ACEIs/ARBs, and diuretics, the first-line agents to control hypertension in HF [4,35], is about 54%, 52% and 49%, respectively (Table 4). This is similar to the NHANES 2007–2010 studied by Lama Tamang. A greater proportion of HF patients were taking individual drug such as beta blockers (61%), a similar proportion were taking diuretics (50%), and a lower proportion were taking ACEIs/ARBs (49%). These compliance rates are suboptimal, even though earlier studies with smaller sample size describe higher rates over 70% [36–40]. In addition, although this present study suggests significantly higher ratio of compliance in older participants with beta blockers and diuretics, a previous study describes

Table 2
Achievement of recommended physiological targets in HF patients.

Group	BP	LDL-C	HbA1c	BMI	Waist Circumference	All 5 Goals
Overall	45.07 (727)	22.04 (108)	72.15 (570)	19.09 (309)	27.38 (406)	0.47 (9)
Sex						
Male	49.34 (451)**	23.55 (61)	71.05 (297)	20.24 (183)	35.40 (302)	0.67 (7)
Female	39.48 (276)	20.35 (47)	73.39 (273)	17.62 (126)	16.51 (104)	0.23 (2)
Age (yrs)						
<65	47.86 (269)	14.75 (27)**	68.91 (184)	14.89 (84)**	25.84 (138)	0.63 (4)
≥65	43.58 (458)	26.38 (81)	73.80 (386)	21.33 (225)	28.24 (268)	0.39 (5)
Race						
Non-Hispanic White	47.62 (411)**	19.85 (53)	75.34 (278)	19.60 (168)	26.78 (214)	0.68 (7)
Hispanic	42.20 (119)	32.56 (28)	68.42 (104)	14.08 (40)	28.74 (75)	0.00 (0)
Non-Hispanic Black	40..05 (155)	20.00 (23)	73.28 (170)	16.88 (67)	23.36 (82)	0.43 (2)
Socioeconomic Status						
<$35,000	44.75 (260)**	22.59 (54)	62.13 (187)	17.50 (102)	26.40 (141)	0.62 (4)
$35,000-$75,000	49.65 (141)	22.94 (25)	65.65 (86)	18.88 (54)	25.00 (63)	0.62 (2)
>$75,000	59.81 (64)	14.63 (6)	64.91 (37)	19.63 (21)	27.55 (27)	0.84 (1)
Education Status						
<High school	40.40 (261)**	21.13 (41)	74.55 (249)	21.27 (137)*	28.21 (167)	0.78 (6)
High school diploma	47.19 (185)	18.80 (22)	65.24 (122)	15.19 (60)	23.37 (86)	0.22 (1)
AA or high	49.04 (280)	25.28 (45)	73.86 (195)	19.24 (111)	29.17 (152)	0.30 (2)
Current Health Insurance Status						
Uninsured	41.56 (32)	14.29 (4)	64.29 (18)	16.88 (13)	24.36 (19)	1.22 (1)
Private	48.31 (43)	23.53 (8)	64.29 (27)	20.43 (19)	27.06 (23)	0.97 (1)
Public Medicare	47.83 (276)	21.69 (54)	65.25 (199)	20.41 (120)	27.20 (145)	0.60 (4)
Public others	48.21 (215)	23.73 (42)	61.57 (141)	15.19 (67)	25.07 (95)	0.60 (3)

Data are presented as %(n).
Physiological targets: blood pressure <130/80 mm Hg, LDL-C <70 mg/mL, HbA1c <7% for HF patients with DM, body mass index (BMI) 18.5–25 kg/m^2, waist circumference <89 cm for women and <102 cm for men.
*p<0.05, **p<0.01 between sex, age, socioeconomic, educational, or current health insurance statuses.

Table 3
Lifestyle modifications in HF patients.

Group	Physical activity	Alcohol consumption	Smoking cessation
Overall	11.54 (220)	67.23 (400)	79.49 (1515)
Sex			
Male	13.54 (141)**	69.07 (268)	75.79 (789)**
Female	9.13 (79)	63.77 (132)	83.93 (726)
Age (yrs)			
<65	13.70 (87)*	52.27 (138)**	63.78 (405)**
≥65	10.46 (133)	79.15 (262)	87.33 (1110)
Race			
Non-Hispanic White	10.94 (112)	76.15 (249)**	81.35 (833)**
Hispanic	13.85 (45)	55.05 (60)	84.62 (275)
Non-Hispanic Black	9.57 (44)	55.07 (76)	72.17 (332)
Socioeconomic Status			
<$35,000	17.26 (112)	60.41 (119)*	74.11 (481)**
$35,000-$75,000	20.81 (67)	69.44 (75)	81.68 (263)
>$75,000	22.69 (27)	80.49 (33)	84.87 (101)
Education Status			
<High school	8.14 (63)**	60.11 (107)*	78.04 (604)**
High school diploma	13.70 (63)	67.81 (99)	76.09 (350)
AA or high	14.16 (94)	71.59 (194)	83.28 (553)
Current Health Insurance Status			
Uninsured	19.51 (16)	51.22 (21)**	65.85 (54)**
Private	19.42 (20)	59.46 (22)	77.67 (80)
Public Medicare	15.94 (106)	74.59 (138)	82.26 (547)
Public others	15.37 (77)	59.76 (101)	15.19 (67)

Data are presented as % (*n*).
Physical activity: ≥5 days/week and ≥30 min/session; alcohol consumption: ≤2 drinks/day for men and ≤1 drink/day for women; non-smoking status: never smoked or quit smoking after event.
*$p<0.05$, **$p<0.01$ between sex, age, socioeconomic, educational, or current health insurance statuses.

Table 4
Medication use in HF patients.

Group	Beta blockers	ACEIs/ ARBs	Diuretics	All 3 drugs
Overall	54.77 (1044)	52.62 (1003)	49.37 (941)	20.36 (388)
Sex				
Male	57.83 (602)**	53.70 (559)	46.01 (479)**	22.38 (233)*
Female	51.10 (442)	51.33 (444)	53.41 (462)	17.92 (155)
Age (yrs)				
<65	50.24 (319)**	52.76 (335)	38.43 (244)**	19.84 (126)
≥65	57.04 (725)	52.56 (668)	54.84 (697)	20.61 (262)
Race				
Non-Hispanic White	57.23 (586)**	51.27 (525)	52.83 (541)**	21.19 (217)**
Hispanic	47.08 (153)	56.00 (182)	33.54 (109)	13.23 (43)
Non-Hispanic Black	54.35 (250)	54.13 (249)	56.22 (254)	24.57 (113)
Socioeconomic Status				
<$35,000	63.79 (414)	53.31 (346)	50.85 (330)	22.34 (145)
$35,000-$75,000	67.39 (217)	58.70 (189)	52.48 (169)	27.33 (88)
>$75,000	66.39 (79)	57.14 (68)	42.02 (50)	18.49 (22)
Education Status				
<High school	50.00 (387)**	53.23 (412)	48.32 (374)	18.35 (142)
High school diploma	58.26 (268)	49.13 (226)	52.61 (242)	19.78 (91)
AA or high	58.43 (388)	54.82 (364)	48.80 (324)	23.19 (154)
Current Health Insurance Status				
Uninsured	51.22 (42)**	46.34 (38)	26.83 (22)**	18.29 (15)
Private	60.19 (62)	58.25 (60)	35.92 (37)	21.36 (22)
Public Medicare	69.02 (459)	55.34 (368)	58.50 (389)	25.86 (172)
Public others	59.08 (296)	55.29 (277)	47.11 (236)	22.16 (111)

Data are presented as % (*n*).
ACEIs/ARBs: angiotensin converting enzyme inhibitors/angiotensin receptor blockers.
*$p<0.05$, **$p<0.01$ between sex, age, socioeconomic, educational, or current health insurance statuses.

the underuse of certain recommended medications in older persons with HF [41]. In agree with the previous study [42], older patients are more likely to use antihypertensive medications but less likely to meet BP goals than younger patients (Tables 2 and 4 &7). Finally, medication use in HF patients was also influenced by co-morbidities such as MS, DM, or CKD (Table 7).

Being overweight or obese has been repeatedly linked to an increased risk for HF [43–45]. Most recent results from the 2017–2018 NHANES indicate that nearly 40% of U.S. adults aged 20 and over have obesity (BMI ≥30.0) and 76.1% are overweight (BMI 25.0–29.9) [46]. Our present study suggests even higher prevalence of obesity in patients with HF (51%) than general population (Table 1). In addition, nearly 73% of participants have central obesity (measured as waist circumference) according to our data (Table 1). Correspondingly, only about 19% and 27%, respectively, are at the targets for BMI and waist circumference (Table 2), which is similar to a previous NHANES 2007–2010 study [29], suggesting poor weight control among HF patients in the United States. Weight management in patients with already-established HF should be meticulous considering the previously described obesity paradox [47], in that obese patients with established cardiovascular diseases appear to have a more favorable clinical prognosis than do their leaner counterparts with the same cardiovascular diseases. Despite this, the major HF societies recommend intentional weight reduction interventions in HF [47]. Regarding adherence to smoking cessation, our study reported one-fifth of HF patients are currently smoking, which is similar to a previous NHANES 2005–2006 and NHANES 2007–2010 studies with lower rates in males and minority ethnic groups smoking cessation [29,48].

When analyzing physical activity in this present study, we find only about 11% of participants are compliant with recommendation, with female gender, being older than 65, and receiving education less than high school being less likely compliant with physical activities (Table 3). However, it is worth noticing that physical activity should be adapted in individual HF patient to symptom status and personal circumstances. In the absence of details about HF phenotype or stage from NHANES, it is one of our limitations to use only a simple threshold to define inadequate physical activity.

The control of LDL-C and DM is not ideal, with approximately 22% and 72% of participants, respectively, at the target goals for LDL-C and HbA1c (Table 2). Specifically, participants being younger than 65 are at lower proportion achieving target LDL-C level. In addition, we find DM as a significant predictor of having ≥2 risk factors uncontrolled (Table 6) and a significant determinant of not receiving recommended medications (Table 7), which is in similar with a previous study reporting poor medication adherence in type 2 diabetes [49].

The major strength of our present study is that the NHANES data provide a nationally representative sample of the non-institutionalized U.S. population. Additionally, our relatively larger sample size makes our estimates more precise than previous studies. However, several potential limitations of study should be noted. First, survey participants were asked to recall medications used in the past month to minimize recall bias, thus participants who used medications at any time before the recall period are classified as nonusers. Second, NHANES measurements are performed only at a single point in time, making it possible that some subjects were misclassified to control or uncontrolled status. Third, participants were only defined as compliant with a specific recommendation when they followed that recommendation totally,

Table 5
Proportion of HF patients with co-morbidities receiving recommended medical therapy.

Group	Beta blockers	ACEIs/ARBs	Diuretics	All 3 drugs
Hypertension				
Yes	58.48 (900)**	58.15 (895)**	51.98 (800)**	89.43 (347)**
No	39.24 (144)	29.43 (108)	38.42 (141)	10.57 (41)
MS				
Yes	67.68 (222)**	62.50 (205)**	57.93 (190)**	76.34 (100)**
No	52.09 (822)	50.57 (798)	47.59 (751)	23.66 (31)
Stroke				
Yes	53.85 (217)	51.12 (206)	52.11 (210)	19.07 (74)
No	55.02 (827)	53.03 (797)	48.64 (731)	21.67 (329)
CHD				
Yes	59.51 (704)**	55.20 (653)**	48.86 (578)	67.01 (260)**
No	47.03 (340)	48.41 (350)	50.21 (363)	32.99 (128)
DM				
Yes	62.03 (490)**	60.13 (475)**	56.58 (447)**	51.55 (200)*
No	49.64 (554)	47.31 (528)	44.27 (494)	48.45 (188)
CKD				
Yes	72.54 (317)**	55.84 (244)	66.82 (292)**	49.63 (133)
No	49.49 (727)	51.67 (759)	44.18 (649)	50.37 (135)

Data are presented as % (*n*).
MS: metabolic syndrome; CHD: coronary heart disease; DM: diabetes mellitus; CKD: chronic kidney disease.
ACEIs/ARBs: angiotensin converting enzyme inhibitors/angiotensin receptor blockers.
*$p<0.05$, **$p<0.01$ between groups with or without co-morbidities.

Table 6
Odds ratios by multivariate logistic regression for having risk factors uncontrolled.

	OR	95% *CI*	*P* value
Age (yrs)			
18–49	1	reference	–
50–59	2.49	0.25–24.34	0.43
60–69	0.31	0.09–1.09	0.07
>70	0.14	0.04–0.51	0.0025
Sex			
Male	1	reference	–
Female	1.75	0.87–3.54	0.12
Socioeconomic Status			
<$35,000	1	reference	–
$35,000-$75,000	0.72	0.35–1.48	0.37
>$75,000	0.33	0.13–0.85	0.02
Current Health Insurance Status			
Uninsured	1	reference	–
Private	0.61	0.10–3.60	0.59
Public Medicare	2.12	0.48–9.36	0.32
Public others	1.47	0.33–6.58	0.61
MS			
Yes	1	reference	–
No	0.18	0.09–0.36	<0.0001
DM			
Yes	1	reference	–
No	0.41	0.20–0.88	0.02

Uncontrolled: ≥2 risk factors (including hypertension [blood pressure ≥130/80 mm Hg], LDL-C ≥70 mg/dL, obesity [body mass index ≥30 kg/m^2], current smoking, HbA1c >7% for those HF with DM, and inadequate physical activity [<5 days/week or <30 min/session]) not controlled.
MS: metabolic syndrome; DM: diabetes mellitus; CI: confidence interval; OR: odds ratio.

leading to the lack of information on partially compliance. Fourth, as already mentioned above when discussing physical activity, participants were unable to be classified based on their ejection fraction or stage since thus information were unavailable from NHANES. Finally, a recent

Table 7
Odds ratios by multivariate logistic regression for not receiving recommended medications.

	OR	95% *CI*	*P* value
Age (yrs)			
18–39	1	Reference	–
40–49	0.48	0.14–1.70	0.25
50–59	0.48	0.15–1.60	0.23
60–69	0.12	0.04–0.42	0.0008
>70	0.10	0.03–0.36	0.0004
Current Health Insurance Status			
Uninsured	1	Reference	–
Private	0.97	0.29–3.31	0.97
Public Medicare	0.77	0.25–2.31	0.64
Public others	0.72	0.26–1.97	0.52
MS			
Yes	1	Reference	–
No	2.84	1.53–5.25	0.0009
CHD			
Yes	1	Reference	
No	1.53	0.84–2.77	0.16
DM			
Yes	1	Reference	–
No	2.06	1.03–4.11	0.04
CKD			
Yes	1	Reference	
No	3.69	1.56–8.74	0.003

Not receiving recommended medications: not taking any of beta blockers, ACEIs/ARBs, or diuretics.
MS: metabolic syndrome; CHD: coronary heart disease; DM: diabetes mellitus; CKD: chronic kidney disease. CI: confidence interval; OR: odds ratio.

study reported that mobile health applications (e.g. smart phones and mobile devices) may be useful in improving adherence to medical therapy and lifestyle behaviors in HF patients [50]. However, the use of mobile health information is not available in NHANES. Otherwise, we could analyze its application in United States among HF patients, and determine whether it can increase the use of recommended medications and modify some lifestyle behaviors.

In summary, the overall control of important risk factors of HF among patients in the United State is suboptimal, partly due to inadequate compliance with pharmacological and non-pharmacological treatment aimed at modifying these factors. Further investigations on direct associations between noncompliance with recommendations and failure to achieve specific risk factor control target, and on factors related to the patients in nature that independently contributing to non-ideal risk factor control will provide valuable information for optimizing prognosis in HF patients.

Credit author statement

Ying Tang: Data curation, writing original draft, Writing - review & editing, Visualization, Project administration. **Jing Yan:** Conceptualization, Investigation, Resources. **Lijiang Tang:** Conceptualization, Writing – review & editing, Funding acquisition, Supervision. **Xiaowei Liu:** Conceptualization, Methodology, Formal analysis, writing original draft, Writing – review & editing, Supervision, Funding acquisition.

Funding

This study was supported by the Scientific and Technological Projects for Medicine and Health of Zhejiang Province (Grant No. 2022481190&2015128660); the Major Research and Development Projects for the Zhejiang Science and Technology Agency (Grant No. 2017C03034); the National Natural Science Foundation of China (Grant No. 81500284&81770475&81701386); the Public Projects of Technology in Zhejiang Province (Grant No. LGJ18H020001); the Scientific and

Technological Projects for Traditional Chinese Medicine of Zhejiang Province (Grant No. 2021ZQ007).

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgements

We thank all the staffs of the NHANES.

References

[1] E.J. Benjamin, M.J. Blaha, S.E. Chiuve, et al., Heart disease and stroke statistics-2017 update: a report from the American heart association[J], Circulation 135 (10) (2017) e146–e603.
[2] L. Djousse, J.A. Driver, J.M. Gaziano, Relation between modifiable lifestyle factors and lifetime risk of heart failure[J], JAMA 302 (4) (2009) 394–400.
[3] P. Ponikowski, S.D. Anker, K.F. Alhabib, et al., Heart failure: preventing disease and death worldwide[J], ESC Heart Fail 1 (1) (2014) 4–25.
[4] C.W. Yancy, M. Jessup, B. Bozkurt, et al., ACCF/AHA guideline for the management of heart failure: a report of the American college of cardiology foundation/American heart association task force on practice guidelines[J], J. Am. Coll. Cardiol. 62 (16) (2013) e147–e239.
[5] V.L. Roger, S.A. Weston, M.M. Redfield, et al., Trends in heart failure incidence and survival in a community-based population[J], JAMA 292 (3) (2004) 344–350.
[6] D. Levy, S. Kenchaiah, M.G. Larson, et al., Long-term trends in the incidence of and survival with heart failure[J], N. Engl. J. Med. 347 (18) (2002) 1397–1402.
[7] K.A. Ammar, S.J. Jacobsen, D.W. Mahoney, et al., Prevalence and prognostic significance of heart failure stages: application of the American College of Cardiology/American Heart Association heart failure staging criteria in the community[J], Circulation 115 (12) (2007) 1563–1570.
[8] S. Stewart, K. Macintyre, D.J. Hole, et al., More 'malignant' than cancer? Five-year survival following a first admission for heart failure[J], Eur. J. Heart Fail. 3 (3) (2001) 315–322.
[9] K. Dickstein, A. Cohen-Solal, G. Filippatos, et al., ESC guidelines for the diagnosis and treatment of acute and chronic heart failure 2008: the Task Force for the diagnosis and treatment of acute and chronic heart failure 2008 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association of the ESC (HFA) and endorsed by the European Society of Intensive Care Medicine (ESICM)[J], Eur. J. Heart Fail. 10 (10) (2008) 933–989.
[10] F.S.O.A. Heart, HFSA 2006 comprehensive heart failure practice guideline[J], J. Card. Fail. 12 (1) (2006) e1–e2.
[11] Effects of treatment on morbidity in hypertension. II. Results in patients with diastolic blood pressure averaging 90 through 114 mm Hg[J], JAMA 213 (7) (1970) 1143–1152.
[12] J.B. Kostis, B.R. Davis, J. Cutler, et al., Prevention of heart failure by antihypertensive drug treatment in older persons with isolated systolic hypertension. SHEP Cooperative Research Group[J], JAMA 278 (3) (1997) 212–216.
[13] M.F. O'Rourke, M. Namasivayam, A. Adji, Treatment of hypertension in patients 80 years of age or older[J], Minerva Med 100 (1) (2009) 25–38.
[14] S. Yusuf, P. Sleight, J. Pogue, et al., Effects of an angiotensin-converting-enzyme inhibitor, ramipril, on cardiovascular events in high-risk patients[J], N. Engl. J. Med. 342 (3) (2000) 145–153.
[15] B.B. Granger, K. Swedberg, I. Ekman, et al., Adherence to candesartan and placebo and outcomes in chronic heart failure in the CHARM programme: double-blind, randomised, controlled clinical trial[J], Lancet 366 (9502) (2005) 2005–2011.
[16] J.R. Wu, D.K. Moser, M.L. Chung, et al., Objectively measured, but not self-reported, medication adherence independently predicts event-free survival in patients with heart failure[J], J. Card. Fail. 14 (3) (2008) 203–210.
[17] M.H. van der Wal, D.J. van Veldhuisen, N.J. Veeger, et al., Compliance with non-pharmacological recommendations and outcome in heart failure patients[J], Eur. Heart J. 31 (12) (2010) 1486–1493.
[18] S.J. Smith, E.J. Benjamin, R.O. Bonow, et al., AHA/ACCF secondary prevention and risk reduction therapy for patients with coronary and other atherosclerotic vascular disease: 2011 update: a guideline from the American heart association and American college of cardiology foundation[J], Circulation 124 (22) (2011) 2458–2473.
[19] Executive summary of the third report of the national cholesterol education program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III)[J], JAMA 285 (19) (2001) 2486–2497.
[20] I.L. Pina, C.S. Apstein, G.J. Balady, et al., Exercise and heart failure: a statement from the American Heart Association Committee on exercise, rehabilitation, and prevention[J], Circulation 107 (8) (2003) 1210–1225.
[21] A.V. Chobanian, G.L. Bakris, H.R. Black, et al., The seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure: the JNC 7 report[J], JAMA 289 (19) (2003) 2560–2572.
[22] M.S. Chow, Assessing the treatment of congestive heart failure: diuretics, vasodilators, and angiotensin-converting enzyme inhibitors[J], Pharmacotherapy 13 (5 Pt 2) (1993) 82S–87S.
[23] B. Pitt, F. Zannad, W.J. Remme, et al., The effect of spironolactone on morbidity and mortality in patients with severe heart failure. Randomized Aldactone Evaluation Study Investigators[J], N. Engl. J. Med. 341 (10) (1999) 709–717.
[24] H. Fukuta, T. Goto, K. Wakami, et al., Effects of exercise training on cardiac function, exercise capacity, and quality of life in heart failure with preserved ejection fraction: a meta-analysis of randomized controlled trials[J], Heart Fail. Rev. 24 (4) (2019) 535–547.
[25] J. Wu, D.D. Sin, Improved patient outcome with smoking cessation: when is it too late?[J], Int. J. Chronic Obstr. Pulm. Dis. 6 (2011) 259–267.
[26] R. Garg, S. Yusuf, Overview of randomized trials of angiotensin-converting enzyme inhibitors on mortality and morbidity in patients with heart failure. Collaborative Group on ACE Inhibitor Trials[J], JAMA 273 (18) (1995) 1450–1456.
[27] J. He, L.G. Ogden, L.A. Bazzano, et al., Risk factors for congestive heart failure in US men and women: NHANES I epidemiologic follow-up study[J], Arch. Intern. Med. 161 (7) (2001) 996–1002.
[28] M.R. Macdonald, D.T. Eurich, S.R. Majumdar, et al., Treatment of type 2 diabetes and outcomes in patients with heart failure: a nested case-control study from the U. K. General Practice Research Database[J], Diabetes Care 33 (6) (2010) 1213–1218.
[29] T.T. Lama, L. Tang, J. Chuang, et al., Examining risk factor goal attainment and adherence to treatment among US heart failure patients: the National Health and Nutrition Examination Survey 2007-2010[J], Am. J. Cardiovasc. Drugs 14 (1) (2014) 41–49.
[30] B. Draznin, V.R. Aroda, G. Bakris, et al., 2. Classification and diagnosis of diabetes: standards of medical care in diabetes-2022[J], Diabetes Care 45 (Supplement_1) (2022) S17–S38.
[31] T. Unger, C. Borghi, F. Charchar, et al., International society of hypertension global hypertension practice guidelines[J], Hypertension 75 (6) (2020) 1334–1357.
[32] S.M. Grundy, J.I. Cleeman, S.R. Daniels, et al., Diagnosis and management of the metabolic syndrome: an American heart association/national heart, lung, and blood Institute scientific statement[J], Circulation 112 (17) (2005) 2735–2752.
[33] T.A. Mcdonagh, M. Metra, M. Adamo, et al., ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure[J], Eur. Heart J. 42 (36) (2021) 3599–3726.
[34] R. Lopert, J.S. Shoemaker, A. Davidoff, et al., Medication adherence and Medicare expenditure among beneficiaries with heart failure[J], Am. J. Manag. Care 18 (9) (2012) 556–563.
[35] S. Manickavasagam, R. Merla, M.M. Koerner, et al., Management of hypertension in chronic heart failure[J], Expert Rev. Cardiovasc Ther. 7 (4) (2009) 423–433.
[36] N.T. Artinian, M. Magnan, M. Sloan, et al., Self-care behaviors among patients with heart failure[J], Heart Lung 31 (3) (2002) 161–172.
[37] J.D. Welsh, R.M. Heiser, M.P. Schooler, et al., Characteristics and treatment of patients with heart failure in the emergency department[J], J. Emerg. Nurs. 28 (2) (2002) 126–131.
[38] P. Bohachick, L.E. Burke, S. Sereika, et al., Adherence to angiotensin-converting enzyme inhibitor therapy for heart failure[J], Prog. Cardiovasc. Nurs. 17 (4) (2002) 160–166.
[39] M.A. Chui, M. Deer, S.J. Bennett, et al., Association between adherence to diuretic therapy and health care utilization in patients with heart failure[J], Pharmacotherapy 23 (3) (2003) 326–332.
[40] K.A. Schwarz, C.S. Elman, Identification of factors predictive of hospital readmissions for patients with heart failure[J], Heart Lung 32 (2) (2003) 88–99.
[41] P. Abete, G. Testa, D. Della-Morte, et al., Treatment for chronic heart failure in the elderly: current practice and problems[J], Heart Fail. Rev. 18 (4) (2013) 529–551.
[42] Q. Gu, V.L. Burt, C.F. Dillon, et al., Trends in antihypertensive medication use and blood pressure control among United States adults with hypertension: the National Health and Nutrition Examination Survey, 2001 to 2010[J], Circulation 126 (17) (2012) 2105–2114.
[43] S. Kenchaiah, J.C. Evans, D. Levy, et al., Obesity and the risk of heart failure[J], N. Engl. J. Med. 347 (5) (2002) 305–313.
[44] S. Kenchaiah, H.D. Sesso, J.M. Gaziano, Body mass index and vigorous physical activity and the risk of heart failure among men[J], Circulation 119 (1) (2009) 44–52.
[45] D.S. Lee, J.M. Massaro, T.J. Wang, et al., Antecedent blood pressure, body mass index, and the risk of incident heart failure in later life[J], Hypertension 50 (5) (2007) 869–876.
[46] C.M. Hales, M.D. Carroll, C.D. Fryar, et al., Prevalence of obesity and severe obesity among adults: United States, 2017-2018[J], NCHS Data Brief (360) (2020) 1–8.
[47] C.J. Lavie, M.A. Alpert, R. Arena, et al., Impact of obesity and the obesity paradox on prevalence and prognosis in heart failure[J], JACC Heart Fail 1 (2) (2013) 93–102.
[48] D. Vulic, B.T. Lee, J. Dede, et al., Extent of control of cardiovascular risk factors and adherence to recommended therapies in US multiethnic adults with coronary heart disease: from a 2005-2006 national survey[J], Am. J. Cardiovasc. Drugs 10 (2) (2010) 109–114.
[49] W.H. Polonsky, R.R. Henry, Poor medication adherence in type 2 diabetes: recognizing the scope of the problem and its key contributors[J], Patient Prefer. Adherence 10 (2016) 1299–1307.
[50] C. Sarwar, M. Vaduganathan, S.D. Anker, et al., Mobile health applications in cardiovascular research[J], Int. J. Cardiol. 269 (2018) 265–271.