



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

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### 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].

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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 hypothesize 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](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  $\geq 18$  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  $\geq 18$  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  $\geq 200$  mg/dL, or a fasting glucose level  $\geq 126$  mg/dL, or HbA1c  $\geq 6.5\%$  [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)  $\geq 140$  mm Hg, a mean diastolic BP (DBP)  $\geq 90$  mm Hg ( $\geq 130/80$  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 [ $GFR = 186 \times \text{serum creatinine}^{-1.154} \times \text{age}^{-0.23} \times (1.212 \text{ if black}) \times (0.742 \text{ if female})$ ], and CKD was defined as an estimated GFR  $< 60$  mL/min/1.73 m<sup>2</sup>. MS was defined  $\geq 3$  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<sup>2</sup> [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  $\geq 130/80$  mm Hg), LDL-C  $> 70$  mg/dL, obesity (BMI  $\geq 30$  kg/m<sup>2</sup>), 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  $\geq 2$  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  $68.36 \pm 12.57$  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 |
|---|------------------------|--------------------------|-----------------------------|---------|
| <b>Age(yrs), mean <math>\pm</math> SD</b>     | 68.36 $\pm$ 12.57      | 71.92 $\pm$ 12.21        | 67.14 $\pm$ 12.46           | <0.0001 |
| <b>Sex, n (%)</b>                             |                        |                          |                             | 0.42    |
| Male  | 1041 (54.62)           | 272 (56.20)              | 769 (54.08)                 |         |
| Female  | 865 (45.38)            | 212 (43.80)              | 653 (45.92)                 |         |
| <b>Race, n (%)</b>                            |                        |                          |                             | <0.0001 |
| Non-Hispanic White                            | 1024 (56.61)           | 288 (63.72)              | 736 (54.24)                 |         |
| Hispanic Non-Hispanic                         | 325 (17.97)            | 84 (18.58)               | 241 (17.76)                 |         |
| Black   | 460 (25.43)            | 80 (17.70)               | 380 (28.00)                 |         |
| <b>Socioeconomic Status, n (%)</b>            |                        |                          |                             | 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)                  |         |
| <b>Education Status, n (%)</b>                |                        |                          |                             | 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)                 |         |
| <b>Current Health Insurance Status, n (%)</b> |                        |                          |                             | 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)                 |         |
| <b>Risk Factor and Co-morbidities</b>         |                        |                          |                             |         |
| Hypertension, n (%)                           | 1539 (80.75)           | 316 (65.29)              | 1223 (86.01)                | <0.0001 |
| SBP (mmHg), mean $\pm$ SD                     | 132.30 $\pm$ 23.40     | 115.87 $\pm$ 16.18       | 135.83 $\pm$ 23.22          | <0.0001 |
| DBP (mmHg), mean $\pm$ SD                     | 66.30 $\pm$ 15.92      | 60.00 $\pm$ 14.10        | 67.66 $\pm$ 15.97           | 0.0001  |
| LDL-C (mg/dL), mean $\pm$ SD                  | 100.11 $\pm$ 37.89     | 73.04 $\pm$ 28.69        | 102.85 $\pm$ 37.66          | <0.0001 |
| HDL-C (mg/dL), mean $\pm$ SD                  | 49.14 $\pm$ 16.17      | 51.59 $\pm$ 17.77        | 48.69 $\pm$ 15.82           | 0.04    |
| TC (mg/dL), mean $\pm$ SD                     | 174.64 $\pm$ 45.27     | 159.35 $\pm$ 40.61       | 177.48 $\pm$ 45.54          | <0.0001 |
| Current smoking, n (%)                        | 391 (20.51)            | 19 (3.93)                | 372 (26.16)                 | <0.0001 |
| BMI $\geq$ 30 kg/m <sup>2</sup> , 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  $\pm$  standard deviation (SD).

Uncontrolled:  $\geq$ 2 risk factors (including hypertension [blood pressure  $\geq$ 130/80 mm Hg], LDL-C  $\geq$ 70 mg/dL, obesity [body mass index  $\geq$ 30 kg/m<sup>2</sup>], 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  $\geq 2$  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 |
|--|---------------|--------------|-------------|--------------|---------------------|-------------|
| <b>Overall</b>                         | 45.07 (727)   | 22.04 (108)  | 72.15 (570) | 19.09 (309)  | 27.38 (406)         | 0.47 (9)    |
| <b>Sex</b>                             |               |              |             |              |                     |             |
| 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)    |
| <b>Age (yrs)</b>                       |               |              |             |              |                     |             |
| <65                                    | 47.86 (269)   | 14.75 (27)** | 68.91 (184) | 14.89 (84)** | 25.84 (138)         | 0.63 (4)    |
| $\geq 65$                              | 43.58 (458)   | 26.38 (81)   | 73.80 (386) | 21.33 (225)  | 28.24 (268)         | 0.39 (5)    |
| <b>Race</b>                            |               |              |             |              |                     |             |
| 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)    |
| <b>Socioeconomic Status</b>            |               |              |             |              |                     |             |
| <\$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)    |
| <b>Education Status</b>                |               |              |             |              |                     |             |
| <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)    |
| <b>Current Health Insurance Status</b> |               |              |             |              |                     |             |
| 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<sup>2</sup>, 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 |
|--|-------------------|---------------------|-------------------|
| <b>Overall</b>                         | 11.54 (220)       | 67.23 (400)         | 79.49 (1515)      |
| <b>Sex</b>                             |                   |                     |                   |
| Male                                   | 13.54 (141)**     | 69.07 (268)         | 75.79 (789)**     |
| Female                                 | 9.13 (79)         | 63.77 (132)         | 83.93 (726)       |
| <b>Age (yrs)</b>                       |                   |                     |                   |
| <65                                    | 13.70 (87)*       | 52.27 (138)**       | 63.78 (405)**     |
| ≥65                                    | 10.46 (133)       | 79.15 (262)         | 87.33 (1110)      |
| <b>Race</b>                            |                   |                     |                   |
| 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)       |
| <b>Socioeconomic Status</b>            |                   |                     |                   |
| <\$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)       |
| <b>Education Status</b>                |                   |                     |                   |
| <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)       |
| <b>Current Health Insurance Status</b> |                   |                     |                   |
| 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.

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

**Table 4**  
Medication use in HF patients.

| Group                                  | Beta blockers | ACEIs/ARBs   | Diuretics     | All 3 drugs   |
|--|---------------|--------------|---------------|---------------|
| <b>Overall</b>                         | 54.77 (1044)  | 52.62 (1003) | 49.37 (941)   | 20.36 (388)   |
| <b>Sex</b>                             |               |              |               |               |
| 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)   |
| <b>Age (yrs)</b>                       |               |              |               |               |
| <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)   |
| <b>Race</b>                            |               |              |               |               |
| 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)   |
| <b>Socioeconomic Status</b>            |               |              |               |               |
| <\$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)    |
| <b>Education Status</b>                |               |              |               |               |
| <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)   |
| <b>Current Health Insurance Status</b> |               |              |               |               |
| 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.

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   |
|---------------------|---------------|---------------|---------------|---------------|
| <b>Hypertension</b> |               |               |               |               |
| 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)    |
| <b>MS</b>           |               |               |               |               |
| 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)    |
| <b>Stroke</b>       |               |               |               |               |
| 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)   |
| <b>CHD</b>          |               |               |               |               |
| 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)   |
| <b>DM</b>           |               |               |               |               |
| 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)   |
| <b>CKD</b>          |               |               |               |               |
| 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 |
|--|------|------------|---------|
| <b>Age (yrs)</b>                       |      |            |         |
| 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  |
| <b>Sex</b>                             |      |            |         |
| Male                                   | 1    | reference  | –       |
| Female                                 | 1.75 | 0.87–3.54  | 0.12    |
| <b>Socioeconomic Status</b>            |      |            |         |
| <\$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    |
| <b>Current Health Insurance Status</b> |      |            |         |
| 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    |
| <b>MS</b>                              |      |            |         |
| Yes                                    | 1    | reference  | –       |
| No                                     | 0.18 | 0.09–0.36  | <0.0001 |
| <b>DM</b>                              |      |            |         |
| 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<sup>2</sup>], 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 |
|--|------|-----------|---------|
| <b>Age (yrs)</b>                       |      |           |         |
| 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  |
| <b>Current Health Insurance Status</b> |      |           |         |
| 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    |
| <b>MS</b>                              |      |           |         |
| Yes                                    | 1    | Reference | –       |
| No                                     | 2.84 | 1.53–5.25 | 0.0009  |
| <b>CHD</b>                             |      |           |         |
| Yes                                    | 1    | Reference | –       |
| No                                     | 1.53 | 0.84–2.77 | 0.16    |
| <b>DM</b>                              |      |           |         |
| Yes                                    | 1    | Reference | –       |
| No                                     | 2.06 | 1.03–4.11 | 0.04    |
| <b>CKD</b>                             |      |           |         |
| 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.

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### Declaration of competing interest

The authors declare no conflict of interest.

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