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Research article

The secondary prevention of coronary heart disease in US adults 75 Years and older in daily practice: Results from the National Health and Nutrition Examination Survey 1999–2018 survey

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A R T I C L E I N F O

Keywords:
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A B S T R A C T

Background: Pharmacologic therapies, risk factor control, and lifestyle alterations were independently proven to reduce long-term cardiovascular events. However, comprehensive research examining the extent to which individuals aged 75 and above in the United States adhere to national guidelines for the secondary prevention of coronary heart disease is limited. Therefore, the primary objective of this study was to examine the current state of secondary prevention of coronary heart disease in persons 75 years of age and older in the United States and to examine the factors that contribute to inadequate drug utilization and poor control of numerous risk factors.
Methods: We identified patients over 75 years of age with coronary heart disease based on the National Health and Nutrition Examination Survey from 1999 to 2018 and analyzed the adequacy of risk factor control and adherence to lifestyle and medication recommendations to assess the effectiveness of coronary heart disease management. Logistic regression analysis was used to identify factors associated with uncontrolled risk factors or noncompliance with recommended medications.
Results: We collected information from 1566 known coronary heart disease patients aged ≥75 years of age. The majority were at target goals for blood pressure (58.88%), low-density lipoprotein cholesterol (66.85%), and glycated hemoglobin (76.12%). Only 27.8% and 36.06% were at targets for body mass index and waist circumference, respectively. 91.95% reported smoking cessation, 85.98% followed recommended alcohol consumption, whereas only 10.34% reported sufficient physical activity. For β blockers, angiotensin -converting enzyme inhibitors/angiotensin receptor blockers, statins, and antiplatelet drugs, the utilization of indicated therapy was 54.41%, 49.36%, 54.79%, and 19.03%, respectively (6.26% for all 4 medications). The results of the logistic regression analysis demonstrated that diabetes mellitus and metabolic syndrome were critical markers of numerous uncontrolled risk variables as well as noncompliance with medication regimens.

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Conclusions: A vast majority of coronary heart disease patients ≥75 years in the USA exhibited suboptimal overall control of critical coronary heart disease risk factors. For this patient population, more knowledge is necessary to enable patients to receive continuous support, guidance, and counseling.

1. Introduction

Advances in medical science have led to significant increases in life span, and adults aged 75 and older now form the fastest-growing segment of the population. By 2050, more than 45 million Americans are estimated to be 75 years and older [1]. Coronary heart disease (CHD) is the primary contributor to mortality among this population, and it also reduces quality of life and enhances medical expenditure [2]. Secondary prevention of CHD is defined as the prevention of occurrence of recurrent coronary events after clinical diagnosis [3], and the primary purpose of secondary prevention among CHD patients is to regulate the disease progression risk factors (RFs) like hypertension, dyslipidemia, diabetes mellitus (DM), overweight/obesity, and smoking to facilitate an overall healthy lifestyle [4]. Pharmacologic therapies, RF control, and lifestyle alterations were independently proven to reduce long-term cardiovascular events [5]. However, people aged over 75 years of age have typically been excluded from large-scale randomized controlled trials (RCTs). In RCTs of statins, for example, this patient group is often underrepresented, and patients participating in statin-focused RCTs do not necessarily accurately represent this age group [6]. A previous trial found that high-intensity statin therapy reduced cardiovascular events more than moderate-intensity statin therapy, but these trials enrolled few patients >75 years [7]. The 2013 American College of Cardiology/American Heart Association Task Force (ACC/AHA) guidelines on the treatment of blood cholesterol to reduce the risk of atherosclerotic cardiovascular disease in adults similarly states that there is not enough information to support moderate-intensity statin therapy use in people aged 75 years and older [8]. The practical application of secondary prevention of CHD in this group lacks clarity. Therefore, the purpose of this study was to investigate the actual situation of secondary prevention of coronary heart disease in adults aged 75 years and older in the USA, and to analyze the factors influencing the poor control of multiple risk factors and inadequate medication usage.

2. Methods

The National Health and Nutrition Examination Survey (NHANES) was a cross-sectional investigation carried out by the United States Centers for Disease Control and Prevention on non-institutionalized adults, and all data were obtained from the website of "https://www.cdc.gov/nchs/nhanes/about_nhanes.htm". The NHANES dataset is readily available to the public. The NHANES staff obtained all the primary data. The interviewers administered a survey and received comprehensive data, including the participants' age, race, socioeconomic status, and level of education, through questionnaires. The interviewers also conducted standardized physical examinations of the participants, including blood pressure (BP) values, waist circumference, BMI, etc. Low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and total cholesterol (TC)) and glycosylated hemoglobin (HbA1c) were measured in the uniform laboratory. Our research was a secondary analysis based on this dataset.

Data was collected from ten 2-year NHANES survey cycles from 1999 to 2018. In each cycle, the non-institutionalized population in the US was sampled using a stratified multi-stage probability sampling design. The inclusion criteria for this study were: 1) age ≥75 years old; and 2) self-reported history of CHD. Self-reported CHD was characterized as members having been told by a specialist that they had "angina, myocardial infraction (heart attack), or CHD". Patients younger than 75 years and/or who self-reported no prior history of CHD were excluded. Finally, from a total of 101,316 participants, 1566 eligible participants were identified.

The patient's socioeconomic status was stratified as follows: annual household income <$35,000, low; $35,000 - $75,000, middle; >$75000, high. The educational status was based on the participant's highest degree: <high school, high school diploma, and associate degree or greater.

Based on the criteria proposed by the American Heart Association/American College of Cardiology Foundation (AHA/ACCF) on secondary prevention (SP) and risk reduction (RR) intervention for coronary artery disease and other atherosclerotic vascular disease-based patients [3], we classified SP into categories for analysis: RF management suggested lifestyle alterations, and pharmacological intervention. RF management included blood pressure (BP), blood lipid, smoking, body mass index (BMI), and centripetal obesity. Suggested lifestyle alterations included sports, reducing alcohol intake, and smoking cessation. Lastly, pharmacological interventions included β- Receptor blockers, angiotensin converting enzyme inhibitors (ACEIs)/angiotensin receptor blockers (ARB), statin, and/or antiplatelet drug usage [3].

Our RF goals or optimal levels were as follows: BP < 140/90 mmHg (130/80 mmHg for diabetic or chronic kidney disease [CKD] patients) [9], low-density lipoprotein cholesterol (LDL-C) <100 mg/dl, BMI 18.5–25 kg/m^2, female and male waist circumferences <89 and < 102 cm, respectively, and glycosylated hemoglobin in diabetic patients <7% [3]. Multiple uncontrolled RFs were defined as: ≥2 RFs not controlled (hypertension [BP ≥ 140/90 mm Hg or ≥130/80 mm Hg if diabetes or chronic kidney disease is present], LDL-C ≥100 mg/dl, DM, BMI: ≥25 kg/m^2, and waist circumference >102 cm for men or >88 cm for women).

Suggested lifestyle alterations included: physical activity (PA) for ≥150 min/week, or at least 5 days/week, exercise for ≥30 min/day; male and female alcohol intake ≤2 and ≤ 1 drink/day, respectively [3]; complete smoking cessation.

The pharmacological intervention was based on whether the patient consumed β receptor blockers, ACEI/ARB, statins, or antiplatelet drugs. Not receiving recommended medications was defined as not taking β blockers, ACEI/ARB, statins, or antiplatelet agents.

Data measurement: BP was assessed using a mercury sphygmomanometer. Four measurements were recorded, and an average value was calculated for analysis [10]. The total cholesterol and triglyceride levels were measured via a series of coupling reactions. The serum or plasma samples were treated with enzymes to produce hydrogen peroxide as a by-product. High-density lipoprotein cholesterol (HDL-C) was assessed from the serum. If the triglyceride levels were <400 mg/dl, the LDL-C content was computed using the Friedwald formula [11]. The automatic glycosylated hemoglobin analyzer was employed for glycosylated hemoglobin determination. The analyzer employed high-performance liquid chromatography (HPLC), with good long-term accuracy and <3.0% coefficient of variation between analyses. NHANES staff collected the specimen and data, and the collection protocols were described in the NHANES Laboratory/Medical Technician Procedures Manual [10].

Definition of comorbidities: diabetes was defined as the non-fasting blood glucose (BG) content ≥200 mg/dL, or fasting BG content ≥126 mg/dL, or glycosylated hemoglobin ≥6.5% [12], the patient taking prescribed medication for diabetes/elevated BG or a DM diagnosis by a certified physician. Hypertension was described as an average systolic BP (SBP) ≥140 mm Hg, an average diastolic BP (DBP) ≥90 mm Hg (≥130/80 mm Hg, if DM) [9], or a patient on anti-hypertensive medication.

Metabolic syndrome was described as having ≥3 of the following symptoms [13]: (1) male or female waist circumference >102 cm or >88 cm, respectively, (2) male or female HDL-C <40 mg/dL (1.0 mmol/L) or <50 mg/dL (1.3 mmol/L), respectively (3) fasting TG > 150 mg/dL (1.7 mmol/L), (4) SBP or DBP >130 mm Hg or >85 mm Hg, respectively, or undergoing intervention, and (5) dysregulated fasting BG range between 100–125 mg/dL (5.55–6.99 mmol/L). The glomerular filtration rate (GFR) was assessed via the diet correction equation in kidney disease [GFR = 186 × Circulating creatinine ˆ (-1.154) × age ˆ (−0.203) × (1.212 for Black people) × (0.742 for women)]. CKD was described as eGFR<60 mL/min/1.73 m2. Stroke was defined as newly developed symptoms and signs of vasogenic focal neurasthenia, with a duration of over 24 h and an anatomical basis, such as, MRI or CT. Heart failure (HF): answer "Yes" to the question "Have you ever been told by a doctor or health professional that you have heart failure?". Central obesity: waist circumferences >102 cm for men or >88 cm for women.

3. Statistical analysis

To better assess the patient population with particular physiological indicators, namely, BP, LDL-C, HbA1c, BMI, and waist circumference, subjects were classified based on their gender, race, socioeconomic, and education statuses, as shown in Table 1. Next, percentages of patients with different genders among age, race, socioeconomic status, education status, and comorbidities (including

Table 1
The basic information among US adults ≥75 years with coronary heart disease (n = 1566).

Characteristics	Overall (n = 1566)	Man (n = 930)	Women (n = 636)	P Value[a]
Age	79.88 ± 2.82	79.67 ± 2.84	80.19 ± 2.76	0.003
Race				
Non-Hispanic White	78.02 (1182)	81.27 (729)	73.30 (453)	0.0011
Hispanic	10.56 (160)	9.25 (83)	12.46 (77)	0.0011
Non-Hispanic Black	11.42 (173)	9.48 (85)	14.24 (88)	0.0011
Socioeconomic status				
low	54.60 (445)	48.90 (245)	63.69 (200)	<0.0001
middle	32.52 (265)	35.13 (176)	28.34 (89)	<0.0001
high	12.88 (105)	15.97 (80)	7.96 (25)	<0.0001
Education status				
<high school	37.23 (579)	34.92 (323)	40.63 (256)	<0.0001
High school diploma	24.31 (378)	21.08 (195)	29.05 (183)	<0.0001
AA or high	38.46 (598)	44.00 (407)	30.32 (191)	<0.0001
Risk Factor and co-morbidities				
Hypertension	79.37 (1243)	75.27 (700)	85.38 (543)	<0.0001
SBP (mm Hg)	138.24 ± 23.70	135.55 ± 22.36	142.53 ± 25.12	<0.0001
DBP (mm Hg)	61.24 ± 16.20	62.88 ± 15.02	58.63 ± 17.62	<0.0001
LDL-C(mg/dL)	92.61 ± 33.71	86.33 ± 29.42	102.20 ± 37.50	<0.0001
HDL-C (mg/dL)	51.29 ± 14.95	48.04 ± 12.95	56.88 ± 16.44	<0.0001
TC (mg/dL)	170.29 ± 40.39	161.07 ± 35.96	186.14 ± 42.65	<0.0001
Current smoking	8.05 (126)	9.78 (91)	5.50 (35)	<0.0001
BMI≥25 kg/m^2	72.20 (930)	71.77 (567)	72.89 (363)	0.6620
Central obesity	29.97 (386)	27.97 (221)	33.13 (165)	0.1349
Metabolic syndrome	54.45 (214)	47.20 (118)	67.13 (96)	0.0001
Stroke	19.80 (310)	18.39 (171)	21.86 (139)	0.0919
Heart failure	30.08 (471)	27.74 (258)	33.49 (213)	0.0151
Diabetes mellitus	28.61 (448)	27.20 (253)	30.66 (195)	0.138
Chronic kidney disease	44.81 (384)	39.52 (215)	53.99 (169)	<0.0001

Data are presented as % (n) or mean ± standard deviation (SD).
Central obesity: >102 cm for men or >88 cm for women.
Socioeconomic status: low, <$35,000; middle, $35,000-$75,000; high, >$75,000.
SBP = systolic blood pressure; DBP = diastolic blood pressure; LDL-C = low-density lipoprotein cholesterol; HDL = high-density lipoprotein; TC = total cholesterol; BMI = body mass index.
[a] Comparison of means or proportions between man and women.

obesity, metabolic syndrome [MS], stroke, HF, DM, CKD) were analyzed with Chi-square tests. BP (systolic BP [SBP] and diastolic BP [DBP]) and blood lipids (LDL-C, HDL-C, and TC) were compared across genders using the student *t*-test.

We grouped the patients by gender, race, socioeconomic status, and education status to evaluate the proportion of CHD patients achieving recommended risk factor goals. The chi-square test was used for analysis.

We also estimated the patient population who insisted on altering their lifestyle (such as PA, drinking, and non-smoking) and those who were on the recommended medications (like β-receptor blockers, ACEIs/ARB, statins, and antiplatelet drugs) similarly. We used multivariate logistic regression analysis to examine potential associations among gender, race, socioeconomic and educational statuses, complications, likelihood of BP and LDL-C regulation, several dysregulated RFs, and not partaking in the suggested pharmacological intervention. Systems statistical software version 9.4 (SAS Institute, Cary, North Carolina) was employed for all data analyses. For all analyses, statistical significance was set at $p < 0.05$.

4. Results

4.1. Sociodemographic Characteristics

The selected 1566 patients' baseline profiles are summarized in Table 1. Among those who responded were 930 males and 636 females, with a mean age of 79.88 ± 2.82 years. Most reported being non-Hispanic White people (78.02%), with an annual household income of <$35000 (54.60%). The difference in educational levels of lower than high school, high school diploma and associate degree (AA) or high were in the proportion of 37.23%, 24.31% and 38.46%, respectively. Approximately 8.05% of responders were current smokers and mostly men (9.78%, $p < 0.0001$). Most responders (72.20%) had a BMI ≥25 kg/m^2. Centripetal obesity accounted for 29.97% of the analyzed population. Hypertension (79.37%) accounted for more than half. In addition, stroke patients accounted for 19.80%, 18.39% of men and 21.86% of women, with no significant difference ($p = 0.0919$). The proportion of DM was 28.61%, and there was no significant difference between men and women ($p = 0.138$). MS accounted for more than half (54.45%) and was significantly higher in women than in men (67.13% vs 47.20%; $p < 0.0001$). There were also significant gender differences in HF and CKD patients; HF patients accounted for 30.08% (male 27.74%, female 33.49%, $p = 0.0151$), CKD patients accounted for 44.81% (male 39.52%, female 53.99%, $p < 0.0001$).

4.2. Risk factors

Table 2 describes the proportion of older CHD patients who achieved the desirable RF targets. 58.88% of responders exhibited

Table 2
Proportion of those with coronary heart disease achieving recommended risk factor goals.

Group	Blood pressure	LDL-C <100 mg/ml	HbA1c <7%	BMI	Waist circumference	All 5 Goals
Overall	58.88 (922)	66.85 (240)	76.12 (341)	27.80 (358)	36.06 (432)	1.02 (16)
Gender						
Male	60.86 (566)	76.96 (167)**	73.91 (187)	28.23 (223)	44.48 (333)**	1.40 (13)
Female	55.97 (356)	51.41 (73)	78.97 (154)	27.11 (136)	21.95 (99)	0.47 (3)
Race						
Non-Hispanic White	61.59 (728)**	68.50 (187)	78.88 (239)	28.07 (272)	35.51 (326)	1.02 (12)
Hispanic	50.00 (80)	52.63 (20)	64.71 (33)	22.39 (30)	34.96 (43)	0.00 (0)
Non-Hispanic Black	49.71 (86)	65.71 (23)	75.61 (62)	26.39 (38)	35.77 (44)	1.73 (3)
Socioeconomic status						
low	58.43 (260)	65.38 (102)	66.92 (89)	26.03 (101)	34.38 (121)	1.12 (5)
middle	55.85 (148)	65.98 (64)	64.89 (61)	25.00 (60)	31.31 (67)	1.89 (5)
high	64.76 (68)	73.53 (25)	65.79 (25)	23.16 (22)	39.08 (34)	2.86 (3)
Education status						
<high school	58.38 (338)	66.15 (86)	72.54 (140)	26.58 (126)	34.33 (149)	1.04 (6)
High school diploma	57.94 (219)	67.74 (63)	79.25 (84)	26.52 (83)	32.09 (95)	1.32 (5)
AA or high	59.70 (357)	66.91 (91)	78.23 (115)	29.58 (147)	39.78 (185)	0.84 (5)
Comorbidities						
MS	45.79 (98)**	59.71 (83)	65.96 (62)	7.58 (16)**	5.34 (11)**	0 (0)
Stroke	53.23 (165) *	62.32 (43)	77.27 (85)	27.16 (66)	34.39 (76)	0.32 (1)
HF	61.36 (289)	64.49 (69)	79.52 (132)	22.81 (86)**	30.56 (103)*	0.64 (3)
DM	42.86 (192)**	76.80 (96)**	76.12 (341)	15.65 (59)**	24.35 (84)**	0 (0)
CKD	53.13 (204)	62.75 (96)	61.94 (83)	22.71 (82)	29.39 (97)	0.26 (1)

Data are presented as % (*n*).
Blood pressure: <140/90 mm Hg or <130/80 mm Hg if diabetic or with chronic kidney disease.
BMI:18.5 ~ 24.99 kg/m^2; waist circumference <88 cm for women and <102 cm for men; socioeconomic status: low, <$35,000; middle, $35,000 ~ $75,000; high, >$75,000.
AA = associate degree; LDL-C = low-density lipoprotein cholesterol; HbA1c = glycated hemoglobin; BMI = body mass index; MS = metabolic syndrome; HF = heart failure; DM = diabetes mellitus; CKD = chronic kidney disease.
*$p < 0.05$ between gender, age, socioeconomic status, educational, current health groups, or comorbidities.
**$p < 0.01$ between gender, age, socioeconomic status, educational, current health groups, or comorbidities.

target BP, and 61.59% were of non-Hispanic White origin ($p < 0.01$). Most male (76.96%, $p < 0.01$) responders achieved desirable LDL-C control compared to females. 76.12% responders reached desirable HbA1c content. 27.80% of subjects achieved desirable BMI, with comparable values between men and women, but the result was not statistically significant ($p > 0.05$). Few responders reached desirable waist circumference (36.06%), with fewer females than males attaining this goal ($p < 0.01$). Even fewer people (1.02%) achieved all five goals. Among older CHD patients with MS, 45.79% of patients achieved the desirable BP ($p < 0.01$), only 7.58% of patients achieved the desirable BMI ($p < 0.01$), and 5.34% of patients reached the desirable waist circumference ($p < 0.01$). Among older CHD patients with stroke, more than half of the patients achieved the desirable BP (53.23%, $p < 0.05$). Among older CHD patients with HF, 22.81% of patients achieved desirable BMI ($p < 0.01$), and 30.56% achieved desirable waist circumference ($p < 0.05$). Among older CHD patients with DM, 42.86% of patients achieved the desirable BP ($p < 0.01$) , 76.80% achieved the LDL-C target (p < 0.01), only 15.65% of patients achieved the desirable BMI ($p < 0.01$), and 24.35% achieved desirable waist circumference ($p < 0.01$).

4.3. Lifestyle factors

Table 3 lists the number of older patients who strictly abided by the suggested lifestyle alterations (PA, alcohol intake, and smoking cessation). Only 10.34% of responders reported sufficient PA, and a markedly more significant number was amongst males (12.58%, $p < 0.01$) and those with higher education (13.04% for AA or high, $p < 0.05$). 85.98% of responders followed recommended alcohol consumption, with more chances of males (89.39%, $p < 0.01$), non-Hispanic White (90.30%, $p < 0.01$), and more educated individuals (89.83% for AA or high, $p < 0.01$) in achieving this goal. 91.95% of responders reported smoking cessation. The difference was noticeable when compared by gender and educational status; males (90.22%, $p < 0.01$) and those with lower education (88.77%, $p < 0.01$) exhibited reduced compliance. In terms of comorbidities, most patients followed the recommended alcohol consumption and reported smoking cessation, but the results were not statistically significant ($p > 0.05$). Only 6.45% of older CHD patients with stroke reported sufficient PA ($p < 0.01$).

4.4. Medical therapy

Medication usage among older CHD patients is summarized in Table 4. About 50% of responders consumed β-receptor blockers, ACEI/ARB, and statins, and 19.03% received antiplatelet drugs. Based on our analysis, females were less compliant with statins (48.27%, $p < 0.01$) and antiplatelet intake (15.72%, $p < 0.01$). Hispanic people (41.25%, $p < 0.01$) and high-income patients (52.38%, $p < 0.05$) consumed fewer receptor blockers. Patients with lower education levels often did not comply with medical therapies (20.55%, $p < 0.01$). The proportion of responders who used four drugs in combination was only 6.26%. In responders with DM, more than half of the responders consumed β blockers (58.93%, $p < 0.05$), ACEI/ARB (57.59%, $p < 0.01$), or statins (62.50%, $p < 0.01$). Only

Table 3
Proportion of those with coronary heart disease achieving recommended targets for lifestyle factors (physical activity, alcohol consumption and non-smoking status).

Group	Physical activity	Alcohol consumption	Non-smoking status
Overall	10.34 (162)	85.98 (411)	91.95 (1440)
Gender			
Male	12.58 (117)**	89.39 (295)**	90.22 (839)**
Female	7.08 (45)	78.38 (116)	94.50 (601)
Race			
Non-Hispanic White	10.91 (129)	90.30 (363)**	92.22 (1090)
Hispanic	7.50 (12)	67.57 (25)	92.50 (148)
Non-Hispanic Black	8.67 (15)	56.67 (17)	89.02 (154)
Socioeconomic status			
low	17.75 (79)	84.26 (91)	88.76 (395)
middle	17.74 (47)	88.42 (84)	91.32 (242)
high	25.71 (27)	88.10 (37)	90.48 (95)
Education status			
<high school	7.77 (45)*	77.69 (101)**	88.77 (514)**
High school diploma	10.32 (39)	87.50 (98)	93.92 (355)
AA or high	13.04 (78)	89.83 (212)	93.65 (560)
Comorbidities			
MS	14.95 (32)	88.24 (75)	92.06 (197)
Stroke	6.45 (20)**	88.14 (52)	93.23 (289)
HF	9.55 (45)	86.55 (103)	91.08 (429)
DM	8.48 (38)	81.65 (89)	91.07 (408)
CKD	15.10 (58)	85.5 (112)	89.32 (343)

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; socioeconomic status: low, <$35,000; middle, $35,000 ~ $75,000; high, >$75,000.
AA = associate degree; MS = metabolic syndrome; HF = heart failure; DM = diabetes mellitus; CKD = chronic kidney disease.
*$p < 0.05$ between gender, age, socioeconomic status, educational, current health groups, or comorbidities.
**$p < 0.01$ between gender, age, socioeconomic status, educational, current health groups, or comorbidities.

Table 4
Proportion of those with coronary heart disease who received recommended medical therapy.

Group	β blockers	ACEI/ARB	Statins	Antiplatelets	No drug	All 4 drugs
Overall	54.41 (852)	49.36 (773)	54.79 (858)	19.03 (298)	16.48 (258)	6.26 (98)
Gender						
Male	53.98 (502)	48.06 (447)	59.25 (551)**	21.29 (198)**	16.34 (152)	6.77 (63)
Female	55.03 (350)	51.26 (326)	48.27 (307)	15.72 (100)	16.67 (106)	5.50 (35)
Race						
Non-Hispanic White	56.18 (664)**	49.32 (583)	56.09 (663)	18.53 (219)	15.31 (181)	6.77 (80)
Hispanic	41.25 (66)	49.38 (79)	47.50 (76)	18.13 (29)	20.63 (33)	3.75 (6)
Non-Hispanic Black	54.91 (95)	48.55 (84)	50.29 (87)	22.54 (39)	20.23 (35)	4.62 (8)
Socioeconomic status						
low	66.07 (294)*	55.06 (245)	68.09 (303)	22.47 (100)	8.54 (38)	9.21 (41)
middle	61.51 (163)	59.25 (157)	71.32 (189)	24.91 (66)	6.04 (16)	7.92 (21)
high	52.38 (55)	55.24 (58)	71.43 (75)	20.95 (22)	6.67 (7)	9.52 (10)
Education status						
<high school	51.47 (298)	46.80 (271)	51.81 (300)	21.24 (123)	20.55 (119)**	7.60 (44)
High school diploma	56.08 (212)	52.91 (200)	56.08 (212)	15.87 (60)	13.23 (50)	5.03 (19)
AA or high	56.86 (340)	50.17 (300)	57.86 (346)	19.06 (114)	13.71 (82)	5.85 (35)
Comorbidities						
MS	69.63 (149)	64.95 (139)	67.76 (145)	22.90 (49)	6.07 (13)	8.88 (19)
Stroke	55.16 (171)	53.55 (166)	55.81 (173)	29.03 (90)	14.84 (46)	7.42 (23)
HF	59.24 (279)	52.23 (246)	53.93 (254)	19.53 (92)	15.71 (74)	6.37 (30)
DM	58.93 (264)*	57.59 (258)**	62.50 (280)**	24.55 (110)**	10.04 (45)**	9.15 (41)**
CKD	64.84 (249)	55.21 (212)	63.80 (245)	24.74 (95)	9.11 (35)	8.33 (32)

Data are presented as % (*n*).
Socioeconomic status: low, <$35,000; middle, $35,000 ~ $75,000; high, >$75,000.
AA = associate degree; ACEI = angiotensin converting enzyme inhibitor; ARB = angiotensin receptor blocker; MS = metabolic syndrome; HF = heart failure; DM = diabetes mellitus; CKD = chronic kidney disease.
*$p < 0.05$ between gender, age, socioeconomic status, educational, current health groups, or comorbidities.
**$p < 0.01$ between gender, age, socioeconomic status, educational, current health groups, or comorbidities.

24.55% of them received antiplatelet drugs ($p < 0.01$), about one in 10 responders did not take any drug at all (10.04%, $p < 0.01$), and fewer than 10% of responders took all 4 drugs (9.15%, $p < 0.01$).

4.5. Adjusted odds ratios

Table 5 lists the potential determinants of RF dysregulation and medication noncompliance. Multiple factor logistic regression analyses involving gender, race, economic status, education status, MS, stroke, HF, DM, CKD, and so on were conducted in both groups. We demonstrated that MS and DM were essential indicators of multiple uncontrolled RFs (OR = 2.84, CI: 1.53–5.25; OR = 2.27, CI:1.79–2.87) and medication noncompliance (OR = 0.42, CI: 0.21–0.85; OR = 0.47, CI:0.34–0.67).

Table 5
Adjusted odds ratios for risk factor control and lack of medication use.

Characteristics	Multiple Uncontrolled Risk Factors		Not Receiving Recommended Medications	
	OR	95% *CI*	*OR*	95% *CI*
Gender				
Female vs male	1.38	1.13–1.70**	1.02	0.78–1.34
Race				
Hispanic vs white	1.40	0.99–1.97	1.44	0.95–2.18
Non-Hispanic black vs white	1.03	0.75–1.42	1.40	0.94–2.10
Socioeconomic status				
Middle vs low	1.23	0.89–1.69	0.69	0.38–1.26
High vs low	0.98	0.63–1.51	0.77	0.33–1.77
Education status				
High school diploma vs less than high school	1.02	0.78–1.32	0.59	0.41–0.84**
AA or high vs less than high school	0.85	0.67–1.07	0.61	0.45–0.84**
Co-morbidities				
Metabolic syndrome (yes vs no)	2.84	1.53–5.25**	0.42	0.21–0.85*
Stroke (yes vs no)	0.94	0.73–1.21	0.86	0.61–1.21
Heart failure (yes vs no)	1.01	0.81–1.26	0.92	0.69–1.24
Diabetes mellitus (yes vs no)	2.27	1.79–2.87**	0.47	0.34–0.67**
Chronic kidney disease (yes vs no)	1.17	0.87–1.57	1.18	0.73–1.92

AA = associate degree; CI = confidence interval; OR = odds ratio.
*$p < 0.05$.
**$p < 0.01$.

5. Discussion

The primary purpose of CHD treatment is to appropriately regulate RFs of disease progression like hypertension, dyslipidemia, diabetes, overweight/obesity, smoking, and so on, to achieve a comprehensive and healthy lifestyle [14]. However, our study revealed that many older CHD patients did not reach the RF control recommended by the US AHA/ACCF SP and RR in the US. Only 1.02% of responders completed all five RF goals: BP, LDL-C, HbA1c, BMI, and waist circumference (Table 2).

A European study showed similar results. The study [15] used a cross-sectional epidemiological study, and showed that older adults in Croatia were not able to objectively assess their own cardiovascular disease (CVD) risk objectively, their general knowledge about CVD risk factors and CVD prevention was also unsatisfactory as a result, and they were not able to appropriately target and deal with their CVD risk and implement prevention measures.

5.1. Hypertension

Hypertension is an RF that affects all age groups, including older people, and has a higher incidence among the older population [16]. In EUROASPIRE II and III, the hypertension prevalence was 89.9% and 81.4%, with 50% and 44% of patients achieving the target BP, respectively [17,18]. A study by Salih Kilic et al. reported a 73.4% hypertension prevalence and 66.1% BP attainment among older CHD patients [19]. Herein, we observed a hypertension prevalence of 79.37%, comparable to the aforementioned reports. Target BP was achieved in 58.88% of patients, and a higher proportion of non-Hispanic White people achieved this BP. In addition, the total rates of β blockers and ACEIs/ARBs consumption were 54.41% and 49.36%, respectively, which corroborated with the 2005–2006 NHANES report by Dusko Vulic [20], who revealed a comparable number of β receptor blocker consumers, and lower quantity of ACEI/ARB consumers. A prior prospective epidemiological survey study [21] demonstrated that, worldwide, the pharmacotherapeutic usage was confirmed to be relatively low, and it differed between low- and high-income countries. In high-income countries, the prevalence of medication usage was 40% for receptor blockers and 50% for ACEIs/ARBs, which is consistent with the results of this study. However, this study demonstrated a higher prevalence of receptor blocker usage [16–21].

5.2. Dyslipidemia

Dyslipidemia treatment is the cornerstone of CHD treatment owing to its reduction of CHD SP-related mortality [22]. The intricate link between LDL-C content and cardiovascular events continues into old age, despite a decrease in total and LDL-C contents with age, particularly after 70 years of age [23,24]. However, according to our study, the LDL-C compliance rate among older CHD patients was not ideal at 66.85% (Table 2). In particular, women achieved relatively lower goal value completion, similar to the findings of the 2007–2010 NHANES [25]. Although published data demonstrated the efficacy of statins among the older population, many older patients fail to receive this treatment during hospital discharge or follow-up assessment [23,24,26]. However, according to the EUROASPIRE III [18] findings, the proportion of statin usage was 78%. The present study revealed that the statin usage was 54.79%, and relatively lower in females, which was probably explained by the fact that physicians could not use optimal drugs in older people due to the polypharmacy combination therapy, drug interactions, and potential side effects [27].

5.3. Co-morbidities

DM is one of the most significant RFs for cardiovascular disease. The present study found that 448 (28.61%) of patients with CHD patients also had DM, with slightly more men than women. Approximately 76.12% of patients achieved the target HbA1c. A previous study [28] reported that at least 45% of people with type 2 diabetes fail to achieve adequate blood glucose control (HbA1c $< 7\%$). In addition, using logistic regression analysis, we demonstrated that DM is an important influencing factor for multiple uncontrolled RFs and medication noncompliance ($OR = 2.27$, CI: 1.79–2.87;$OR = 0.47$, CI: 0.34–0.67), which is consistent with a previous study that reported poor medication adherence in type 2 diabetes [28]. However, most current evidence on DM medication adherence is based on retrospective or observational studies, with data primarily collected from databases. In addition, due to different research methods, the incidence of reported poor drug compliance in DM patients varies greatly, ranging from 38% to 93% [29], suggesting that further research is needed to elucidate the specific barriers to medication adherence in DM.

MS refers to multiple cardiovascular RFs in the same individual [30]. Its prevalence is increasing rapidly in newly wealthy countries in Asia, South America, and Eastern Europe [31]. In our results, 54.45% (214) of patients with CHD had MS. A Spanish study showed a close association between MS and CHD, and the risk of CHD in working men is significantly increased in MS patients ($OR = 4.03$; 95% CI: 2.98 ,5.45) [32]. NHANES III described a cross-sectional association of the syndrome with myocardial infarction ($OR = 2.01$) [33]. The present analysis demonstrated that MS significantly contributed to multiple uncontrolled RFs and not receiving recommended medications ($OR = 31.60$, CI: 16.03–62.27; $OR = 0.42$, CI: 0.21–0.85).

CKD is a public health threat that impacts cardiovascular risk [34] and is common in patients with CHD [35]. An epidemiological survey of 24 European countries showed that one in five patients with CHD had CKD [36]. In the present study, 44.81% of patients (384) had CKD, including a significantly higher proportion of women ($P < 0.01$). In people without CHD, the magnitude of the increased risk for CKD approached that for DM [37]. A study in 2013 found an association between the presence of CKD and risk for recurrent CHD events or mortality that equaled or exceeded the risk associated with DM, MS, or current cigarette smoking [38]. Our results showed that the ORs of CKD with uncontrolled multiple RFs and not receiving recommended medications were 1.17 (CI: 0.87–1.57) and 1.18 (CI: 0.73–1.92), although the difference was insignificant. Therefore, we should pay attention to the role of CKD in patients with CHD and seek more active methods to reduce the risk of cardiovascular disease in these patients.

5.4. Obesity

The NHANES 1999–2006 investigation involving obesity and CHD risk revealed that the 10-year CHD risk computed via the Framingham risk score increased significantly with rising BMI [39]. Herein, we demonstrated that 29.97% of patients were centripetally obese, and 72.20% exhibited BMI $\geq$25 kg/m^2. Meanwhile, only 27.80% and 36.06% achieved the recommended BMI and abdominal circumference, similar to the previous NHANES 2007–2010 study [25]. This indicated that the CHD patients in the US had suboptimal weight control.

5.5. Lifestyle factors

Regarding PA, we observed that only 10.34% of patients achieved the recommended targets. Among them, women and those with low education were less likely to comply with PA, which corroborated with the findings of NHANES 1999–2018 [40]. However, notably, the PA of older CHD patients must be adjusted according to the specific symptoms and personal conditions. Without precise cardiac function grading, there may be certain limitations in using a simple threshold to define PA. Smoking is a significant preventable RF for mortality [41], and in the EUROASPIRE III study [42], the prevalence of persistent smoking was 17.2% among the European Group and 23.1% among the Turkish group. Herein, we revealed that the proportion of older CHD patients who still smoked was 8.05%, which was lower than the results of prior studies from NHANES 2005–2006 and NHANES 2007–2010 [20,40]. We also observed that 85.98% of patients achieved the appropriate alcohol consumption target.

5.6. Socioeconomic status

Socioeconomic status is recognized as an essential factor affecting cardiovascular and CHD morbidity and mortality. It comprises many variables, with education, income, and occupation being the most critical measures [43]. According to a study of 7937 patients with CHD, there was significantly better control of RFs in individuals with a higher level of education, specifically about current smoking, overweight and obesity, low PA, and low HDL-C in men, and obesity, high BP, low PA, diabetes, and low HDL-C in women [44]. This is consistent with our results that showed that individuals with degrees or high school education showed better control of RFs such as BP, LDL-C, HbA1C, BMI, waist circumference, PA, alcohol consumption, and smoking cessation compared with those with educational qualifications below high school (Table 2) and especially in terms of achieving recommended targets for lifestyle factors, those with less than a high school education performed significantly worse ($P < 0.05$) (Table 3). Thus, specific risk communication is needed to prevent secondary CHD in patients with lower educational status.

Income status is another important factor affecting CHD morbidity and mortality. Landon BE et al. [45] compared the treatment patterns and outcomes in patients with acute myocardial infarction in six countries' low- and high-income populations, observing significantly better survival outcomes in high-income populations in almost all countries. However, the present study did not identify differences in RF control and lifestyle-associated factors concerning income, and there were no statistical differences between the groups (Tables 2 and 3).

In terms of medical treatment, apart from the "No drug" proportion being higher in people with lower educational status, no significant differences were observed in medication adherence concerning academic status (Table 4). The results were similar across different income groups, even the low-income group had significantly higher usage of β-blockers than other income groups (Table 4). One study investigating medication usage for secondary prevention found no significant differences in medication usage regarding educational level [46].

The results of our study are not encouraging. Older people with CHD in the United States do not perform well in secondary prevention as recommended by the guidelines. This may be related to older people's lack of knowledge about secondary risk factors prevention. A European study [15] demonstrated that older individuals with CHD exhibited inadequate prevention due to a lack of understanding regarding CVD risk factors. Factors such as low access to health care, socioeconomic issues, cognitive status and hearing or visual impairment, lack of drug knowledge, lack of education for the families and their caregivers, etc., can affect patients' performance in secondary prevention of CHD [47,48].

5.7. Strengths and limitations

Our study has several strengths and limitations. The NHANES data provides a nationally representative sample of the US non-medical institutional population. Second, our relatively large patient sample population augmented the precision of our conclusions, as opposed to prior studies. Third, our investigation utilized standard RF measurement and medical history evaluation protocols. Among our limitations was that our sample population was restricted to CHD survivors who participated in the NHANES survey. Thus, the patient population may not completely represent all CHD patients. Secondary, treatment evaluations were done on self-reported ACE/ARB, receptor antagonists, antiplatelet agents, and statin usage. Thirdly, treatment was based on self-reported ACE/ARB, receptor antagonists, antiplatelet agents, and statin usage, and did not include any dietary modification efforts or dietary supplements that subjects may have been prescribed to lower BP and LDL-C levels. Fourthly, our study was cross-sectional research, and the data came from an observational survey, so our analysis and interpretation cannot demonstrate the causation but only the association. Lastly, due to the use of secondary data in the study, relevant data may have been missed due to different purposes and data collection methods.

Through our study, it can be found that the use of secondary prevention drugs is not satisfactory overall, and many factors affect the use of secondary prevention drugs in older CHD patients. Conducting comprehensive future research is valuable to investigate the precise reasons and influencing elements that may impact patients' drug use rate. This will enable the development of focused intervention techniques to help patients maximize their utilization of preventative drugs. As for other risk factors, many factors also affect their control. For example, in addition to the patient factor, there is also the physician factor. Although most physicians support using the guidelines, their understanding of them is unsatisfactory [49], which may prevent them from better managing risk factors. Therefore, we must also explore other causes and develop countermeasures to help patients strengthen their disease prevention.

6. Conclusion

Based on our analysis of the NHANES 1999–2018 database, a vast majority of US CHD patients aged ≥75 years exhibited sub-optimal overall control of critical CHD RFs. Thus, their treatments were not optimal, particularly concerning BP, lipid, and glycated hemoglobin levels. While the individual goals demonstrated progress compared to previous reports, further education is necessary for this patient population to enhance the provision of ongoing guidance, assistance, and counseling to patients.

7. Recommendations

These results indicate an urgent need for more public action. Policymakers should increase the publicity for the treatment and prevention of CHD and enhance the awareness of CVD risk factors in older people. Healthcare institutions should be responsible for organizing various types of educational lectures to improve understanding of risk factors and prevention of CHD. Health workers should strengthen the follow-up of patients, manage patients for regular review, and adjust medication and lifestyle according to the review results. Older people are more dependent on the support of family members. Hence, patients and their family members and caregivers must proactively acquire expertise in disease rehabilitation and prevention. They should also provide assistance and supervision to older patients with CHD to facilitate the adjustment of their unhealthy lifestyle.

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Data availability statement

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

CRediT authorship contribution statement

Zhi Zhang: Writing – original draft, Methodology. **Changqing Du:** Software, Formal analysis. **Xin Zhong:** Investigation, Data curation. **Ruilin Wang:** Investigation, Data curation. **Lijiang Tang:** Writing – review & editing, Validation, Resources, Project administration. **Xiaowei Liu:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

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

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