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# Age and sex disparities in blood pressure control and therapeutic inertia: Impact of a quality improvement program

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ABSTRACT

*Objective:* Hypertension quality improvement programs reduce uncontrolled blood pressure (BP) but impact may differ by sex and age.

*Methods:* This study examined uncontrolled BP, defined as a BP $\geq$ 140/90 mmHg, and therapeutic inertia, defined as absence of medication initiation or escalation during visits with uncontrolled BP, by sex and by age group (19–40, 41–65, 66–75, and 76+ years) during a 12 month follow-up period among 21, 861 patients with hypertension and $\geq$ two visits in primary care clinics enrolled in the American Medical Association (AMA) **M**easure Accurately, **A**ct Rapidly, and **P**artner with Patients (MAP) BP hypertension quality improvement program.

*Results:* The mean age was 64.8 years (standard deviation [SD 12.8]) and ranged from 19 to 87 years; 53.6% were female. In age groups 19–40, 41–65, 66–75, 76–87 years, uncontrolled BP at the first clinic visit was present in 51.5%, 42.5%, 37.5% and 36.6% of males, respectively, and in 40.0%, 38.0%, 36.0% and 39.6% of females, respectively. Based on vital signs at the first vs. last clinic visit, the proportion of patients with uncontrolled BP in age groups 19–40, 41–65, 66–75 years declined by 19.4%, 13.5%, 10.1% and 8.7% in males, respectively, and 14.4%, 12.5%, 9.3%, and 8.4%, among females, respectively. Therapeutic inertia ranged from 66.5% and 75.9% of clinic visits among males and females age 19–40 years, to 85.6% and 84.9% of clinic visits among males and females age 76–87 years, respectively. The proportion of clinic visits with therapeutic inertia was lower among males vs. females across all age groups until age 76–87 years.

*Conclusion:* A quality improvement program improves BP control but declines in uncontrolled BP are larger and therapeutic inertia is lower for younger vs. older age groups and for males vs. females. More interventions are needed to reduce sex and age disparities in hypertension management.

## 1. Introduction

Cardiovascular disease (CVD) remains the number one cause of death and disability for adults age 65 years and older and blood pressure (BP) control reduces CVD risk and may increase quality of life [1–6]. Recent data from the National Health and Nutrition Examination Survey shows that blood pressure (BP) control, defined as a systolic BP < 140 mmHg and a diastolic BP < 90 mmHg, has declined among U.S. adults age ≥75 years, and among females and non-Hispanic Blacks over the past decade [7]. This decline in BP control demonstrates an urgency in determining interventions to improve hypertension treatment. The association of BP with CVD, including myocardial infarction and heart failure, is stronger in females vs. males [8,9] and CVD risk in females begins at lower BP levels compared to males [10–12]. More than one-quarter of all heart failure (28%) cases among females is attributed to elevated BP compared to approximately one out of eight (13%) heart failure cases among males. While BP control rates increase with advancing age among males, the percentage of females with treated hypertension and BP control declines after age 65 years [13–15]. Because systolic BP increases more with advancing age among females

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**Table 1**
Characteristics of the 9560 males and 12,301 females a hypertension diagnosis by sex and by blood pressure control status based on vital signs at last clinic visit during January 1, 2019 –December, 31, 2019.

| | Males ($n$ = 9560) | | | Females ($n$ = 12, 301) | | |
|---|---|---|---|---|---|---|
| | Total | Uncontrolled BP ($n$ = 2764) | Controlled BP ($n$ = 6796) | Total | Uncontrolled BP ($n$ = 3340) | Controlled BP ($n$ = 8961) |
| ***Age (Mean)*** | 65.1 (12.8) | 64.9 (13.2) | 65.2 (12.6) | 64.4 (12.8) | 63.2 (20.8) | 65.3 (12.2)[a] |
| **Age group,% (n)** | | | | | | |
| 19–40 years | 4.3 (414) | 7.8 (133) | 4.1 (281) [a] | 4.8 (590) | 4.5 (151) | 4.9 (439) [a] |
| 41–65 years | 49.2 (4291) | 45.0 (1244) | 44.8 (3047) | 41.7 (5130) | 39.1 (1306) | 42.7 (3824) |
| 66–75 years | 30.1 (2876) | 28.5 (787) | 30.7 (2089) | 30.5 (3749) | 29.9 (999) | 30.7 (2750) |
| 76+ years | 20.7 (1979) | 21.7 (600) | 20.3 (1379) | 23.0 (2832) | 26.5 (884) | 21.7 (1948) |
| **Race/Ethnicity,% (n)** | | | | | | |
| NH White | 65.7 (6279) | 64.3 (1778) | 66.2 (4501)[a] | 56.7 (6974) | 54.8 (1831) | 57.4 (5143) [a] |
| NH Black | 16.2 (1552) | 18.5 (510) | 15.3 (1042) | 25.1 (3082) | 28.7 (957) | 23.7 (2125) |
| Hispanic | 10.4 (992) | 9.6 (266) | 10.7 (726) | 11.5 (1416) | 10.4 (348) | 11.9 (1068) |
| Other[b] | 5.4 (519) | 5.3 (148) | 5.5 (371) | 4.8 (589) | 4.2 (141) | 5.0 (448) |
| Unknown | 2.3 (218) | 2.2 (62) | 2.3 (156) | 2.0 (240) | 2.0 (63) | 2.0 (177) |
| ***BMI categories,% (n)*** | | | | | | |
| < 18.5 kg/m$^2$ | 0.8 (21) | 0.4 (11) | 0.2 (10)[a] | 0.8 (96) | 0.8 (28) | 0.8 (68)[a] |
| 18.5–24.9 kg/m$^2$ | 14.6 (1015) | 9.9 (274) | 10.9 (741) | 14.6 (1801) | 16.9 (565) | 13.8 (1236) |
| 25–29.9 kg/m$^2$ | 34.7 (3318) | 33.4 (923) | 35.2 (2395) | 27.2 (3408) | 29.0 (967) | 27.2 (2441) |
| ≥ 30 kg/m$^2$ | 54.3 (5191) | 56.0 (1548) | 53.6 (3643) | 56.6 (6966) | 53.0 (1770) | 58.0 (5196) |
| Missing/Unknown | 0.2 (15) | 0.3 (8) | 0.1 (7) | 0.2 (30) | 0.3 (10) | 0.2 (20) |
| ***Diabetes,% (n)*** | 38.1 (3638) | 37.4 (1034) | 38.3 (2604) | 31.8 (3917) | 31.7 (1057) | 31.9 (2860) |
| ***CVD,% (n)*** | 22.1 (2111) | 20.6 (569) | 22.7 (1542)[a] | 17.2 (2117) | 18.9 (630) | 16.6 (1487)[a] |
| ***Smoker,% (n)*** | 13.6 (1258) | 14.3 (395) | 12.7 (863)[a] | 9.4 (1154) | 10.5 (350) | 9.0 (804)[a] |

[a] $P<0.05$ compared to the same sex group with uncontrolled blood pressure.
[b] Other race/ethnicity includes Alaskan Native, American Indian, Asian, Multiracial, Native Hawaiian and Other Pacific Islander and Other; CVD = cardiovascular disease.

vs. males [14], older females may require more intensification of BP lowering medication to maintain BP control. Differences in BP control between males and females can then contribute to sex differences in subclinical and clinical CVD [16–18]. The reasons for lower BP control rates among females vs. males after age 65 years remains unclear but differences in co-morbidities including obesity and diabetes do not appear to account for sex differences in BP control among older adults [14].

Therapeutic inertia, or lack of initiating a new BP lowering medication or escalating an existing medication, increases with advancing age and may be more common in females [19–23] and contribute to lower BP control rates [20–23]. Intensifying medication when a patient's clinic BP is uncontrolled leads to significantly higher rates of BP control, even in patients with suboptimal medication adherence [24]. In a recent Scientific Statement, The American Heart Association and the American Medical Association emphasized the importance of addressing therapeutic inertia to improve BP control [25]. Hypertension quality improvement programs such as the American Medical Association (AMA) Measure Accurately (M), Act Rapidly (A), Partner with Patients (P) BP Program (MAP BP®) [26–28] address multiple aspects of hypertension management to reduce therapeutic inertia and improve BP control. The AMA MAP BP® is an evidence-based quality improvement program to improve BP control and includes process metrics aligned with M (confirmatory uncontrolled BP measurement), A (therapeutic inertia), and P (change in systolic BP after medication intensification), interprofessional clinic team training on accurate BP measurement using automated office BP (AOBP), treatment algorithms, support for constructing the process metrics, and feedback to reduce therapeutic inertia [26–29]. This study examined uncontrolled BP and therapeutic inertia by age group and by sex in primary care clinics enrolled in the AMA MAP BP® program and followed for 12 months. We hypothesized that BP control and therapeutic inertia would differ by sex and by age group.

## 2. Methods

### 2.1. Study population

This retrospective cohort study utilized electronic health record (EHR) data from patients with an ICD10 diagnosis of hypertension receiving care within fourteen large outpatient primary care clinics during January 1, 2019 through December 31, 2019. The study was reviewed by the Loyola University of Chicago Institutional Review Board and received a status of exempt. A total of 28,691 adults with an ICD10 diagnosis of hypertension with at least one primary care visit to one of the fourteen primary care outpatient clinics during the study period were identified. We excluded 6830 patients with less than two clinic visits during the study period leaving 21, 861 patients with a total of 77, 382 clinic visits included in the analyses. Data on race/ethnicity were missing in 458 patients (2.1%) and 30 patients (0.2%) (see Table 1) lacked documentation of body mass index (BMI). Due to the low amount of missing data, we did not exclude these patients and their clinic visits with these missing covariates.

### 2.2. Blood pressure measurement and control

All clinics were enrolled in the AMA MAP BP® and began staff training and establishing practice protocols for the program during the third quarter of 2018. The medication protocol encouraged fixed-dose combination medications and once daily dosed medications, which are available with minimal or no cost to patients. Goals of BP did not differ by age. Follow-up visit with a registered nurse within four-weeks of a clinic visit with confirmed BP ≥ 140/90 mmHg was encouraged. The program included monthly feedback via email to prescribing clinicians on rates of therapeutic inertia, BP control and documented follow-up (via telephone or face-to-face nurse visits) for patients with uncontrolled BP during clinic visits win the past 30 days with peer comparisons. Per protocol, measurement of BP was performed by clinic staff with patients seated and back supported using a digital BP monitor (Omron

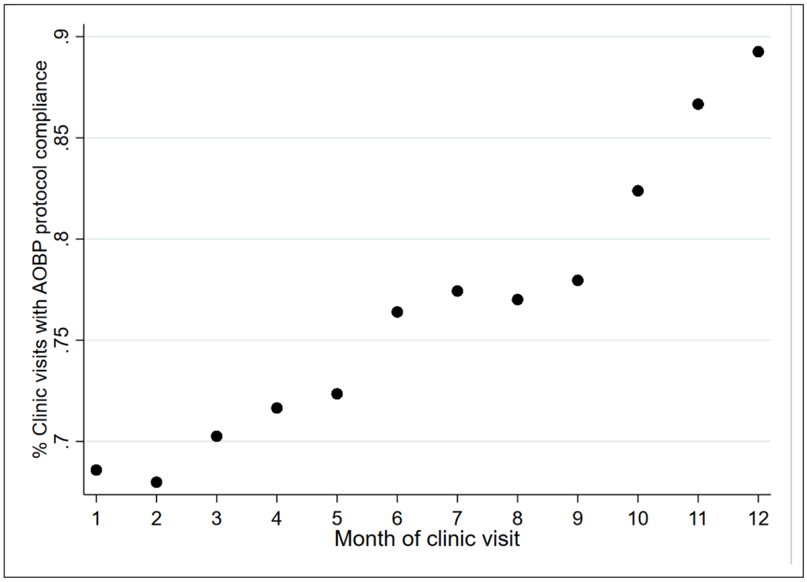



**Fig. 1.** Proportion of clinic visits with fidelity to automated office blood pressure (AOBP) measurement protocol by month during the study period. Fidelity to the AOBP protocol was defined as the percentage of clinic visits with a documented clinic systolic BP ≥ 140 and/or a diastolic BP ≥ 90 mmHg and documented AOBP measurement.

Model HEM-907XL or Welch Allyn 3400) and an appropriately sized cuff. When BP was ≥140/90 mmHg, clinic staff were instructed to complete unattended automated office BP (AOBP) whereby BP is measured three times in one-minute intervals using an Omron Model HEM-907XL device and the average of the three readings was recorded [30]. Fidelity to the AOBP protocol was defined as the percentage of clinic visits with a documented clinic systolic BP ≥ 140 and/or a diastolic BP ≥ 90 mmHg and documented AOBP measurement. Uncontrolled BP was defined as a systolic BP ≥ 140 and/or a diastolic BP ≥ 90 mmHg based on the last recorded clinic BP. Additional analyses examined uncontrolled BP defined as a systolic BP ≥ 130 mmHg and/or a diastolic BP ≥ 80 mmHg.

Therapeutic inertia was defined as the absence of a prescription for a new BP lowering medication or escalation of the dose of an existing antihypertensive medication class during a clinic visit with uncontrolled BP. Prior medication use was defined as medication use with a start date before the visit date and with a discontinuation date at or after the visit date. The lookback period to assess prior medication class use during a visit was restricted to one year before the visit date [27]. We repeated analyses of therapeutic inertia using a BP control defined as < 130/80 mmHg [31].

### 2.3. Demographics

Age was defined as the age at the first clinic visit and sex, race,/ ethnicity and tobacco use were self-reported. Race/ethnicity was categorized as non-Hispanic White, non-Hispanic Black, Hispanic, and non-Hispanic Other (Alaskan Native, American Indian, Asian, Muiltiracial, Native Hawaiian, and Other Pacific Islander and Other). BMI in kg/m$^2$ was calculated from height and weight measured during the clinic visit. Obesity was defined as a BMI ≥ 30 kg/m$^2$. Presence of diabetes and cardiovascular disease (CVD) *was* based on *ICD10* codes with a lookback of one year. BP lowering medications were categorized as diuretics (thiazide, loop and potassium sparing diuretics, and mineralcorticoid receptor antagonists), beta-blockers, calcium channel blockers, angiotensin-converting enzyme inhibitors or angiotensin-2 receptor blockers (ACEi/ARB), alpha agonists, vasodilators and other.

### 2.4. Statistical analysis

Chi-squared and independent group *t*-tests were used to compare patient characteristics by BP control status at the last clinic visit. Analyses of BP control was examined at the patient level by comparing proportion of patients with uncontrolled BP between the first and last clinic visit during the study period by sex and by age group. Change in uncontrolled BP was also examined at the visit level by determining the proportion of clinic visits with uncontrolled BP for each sex and age group by month of clinic visit during the study period and these data were plotted using locally-weighted scatterplot smoothing. Generalized linear mixed effects models for the binomial family with logit function were then used to examine the association of sex and age group with BP control status at a clinic visit. The adjusted models included demographics, BMI, tobacco use, presence of diabetes and CVD status, and month of clinic visit and accounted for the clustering within clinics and intra-individual correlations. An interaction term of sex * age group (19–40, 41–65, 65–75, ≥76 years) fitted in the fully adjusted model met statistical significance ($P = 0.045$) so analyses were stratified by sex. Marginal effects were then used to calculate the adjusted probability of BP control by sex and by age group and plotted.

The proportion of clinic visits with therapeutic inertia during clinic visit with uncontrolled BP was examined overall and by sex and by age group and plotted using locally-weighted scatterplot smoothing. Visits with uncontrolled BP were not included in the therapeutic inertia analyses. Generalized linear mixed effects models for the binomial family with logit function were used to examine the unadjusted and adjusted association of sex and age group with therapeutic inertia at a clinic visit with uncontrolled BP while accounting for the clustering within clinics and intra-individual correlations. The adjusted models accounted for the covariates in the models of uncontrolled BP but also adjusted for the systolic BP during the clinic visit fitted as categories < 130 mmHg, 130–149 mmHg, 150–159 mmHg and ≥160 mmHg with < 130 mmHg as referent group. An interaction term of sex * age group fitted in the fully adjusted model met statistical significance ($P = 0.04$) so analyses of therapeutic inertia were stratified by sex. Marginal effects were then used to calculate the adjusted probability of therapeutic inertia during a clinic visit with uncontrolled BP by sex and by age group. All statistical

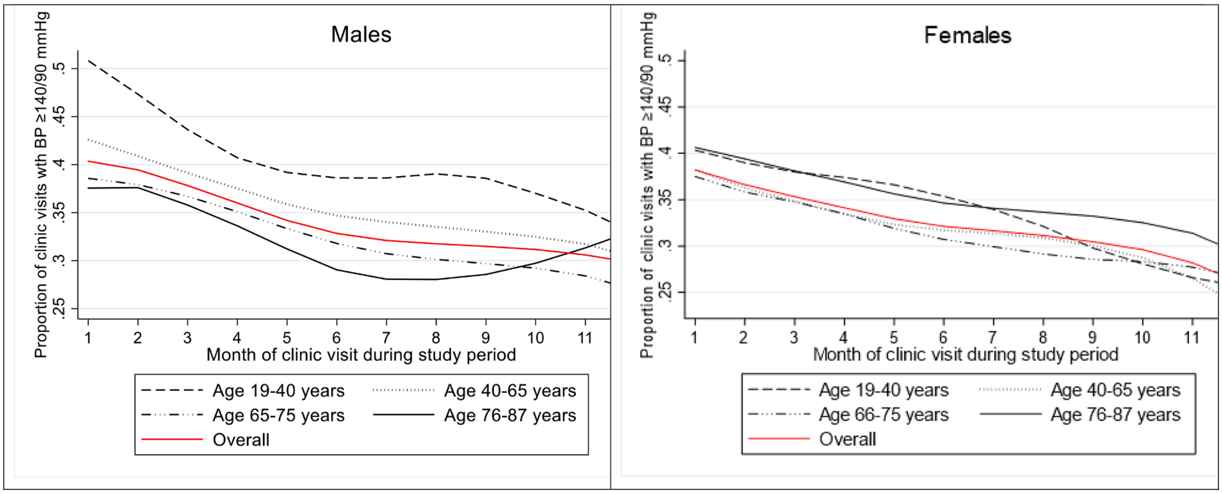



**Fig. 2.** Proportion of clinic visits with uncontrolled blood pressure (BP) defined as a systolic BP ≥ 140 mmHg and/or a diastolic BP ≥ 90 mmHg during a clinic visit by month and by age group in males (left panel) and in females (right panel). The proportion of clinic visits with uncontrolled BP during the study period are plotted for each month by sex and by age group using locally-weighed scatterplot smoothing.

**Table 2**
Proportion of patients with controlled and uncontrolled blood pressure (≥ 140/90 mmHg) by treatment status at first and last visit during the study period by sex and by age group.

| Age Group Males ($n$ = 9560) | First Visit Treated controlled | Last Visit Treated controlled | First Visit Treated uncontrolled | Last Visit Treated uncontrolled | First Visit Untreated controlled | Last Visit Untreated controlled | First Visit Untreated uncontrolled | Last Visit Untreated uncontrolled |
|---|---|---|---|---|---|---|---|---|
| **Overall,% n** | 40.0 (3821) | 51.4 (4916) | 23.7 (2266) | 20.2 (1931) | 19.9 (1902) | 19.7 (1880) | 16.4 (1571) | 8.7 (833) |
| **19–40 years,% n ($n$ = 414)** | 25.5 (103) | 43.0 (178) | 17.9 (74) | 18.1 (75) | 23.7 (98) | 24.0 (103) | 33.6 (139) | 14.0 (58) |
| **41–65 years,% n ($n$ = 4291)** | 39.8 (1709) | 54.1 (2320) | 24.1 (1036) | 20.6 (882) | 17.7 (760) | 16.9 (727) | 18.3 (786) | 8.4 (362) |
| **66–75 years,% n ($n$ = 2876)** | 42.9 (1235) | 53.7 (1544) | 24.1 (692) | 19.6 (563) | 19.6 (563) | 18.9 (545) | 13.4 (386) | 7.8 (224) |
| **76–87 years,% n ($n$ = 1979)** | 39.2 (776) | 44.2 (874) | 23.4 (464) | 20.8 (411) | 24.3 (481) | 25.5 (505) | 13.1 (260) | 9.6 (189) |
| **Age Group Females ($n$ = 12,301)** | **First Visit Treated controlled** | **Last Visit Treated controlled** | **First Visit Treated uncontrolled** | **Last Visit Treated uncontrolled** | **First Visit Untreated controlled** | **Last Visit Untreated controlled** | **First Visit Untreated uncontrolled** | **Last Visit Untreated uncontrolled** |
| **Overall,% (n)** | 42.6 (5246) | 53.5 (6576) | 23.2 (2859) | 19.7 (2422) | 19.5 (2396) | 19.4 (2385) | 14.6 (1800) | 7.5 (918) |
| **19–40 years,% n ($n$ = 590)** | 22.0 (130) | 33.9 (200) | 13.7 (81) | 12.7 (75) | 38.0 (224) | 40.5 (239) | 26.3 (155) | 12.9 (76) |
| **41–65 years,% n ($n$ = 5130)** | 42.2 (2167) | 55.3 (2838) | 21.8 (1118) | 17.9 (919) | 19.7 (1012) | 19.2 (986) | 16.2 (833) | 7.5 (387) |
| **66–75 years,% n ($n$ = 3749)** | 46.7 (1752) | 56.3 (2110) | 23.4 (877) | 21.0 (786) | 36.9 (646) | 17.1 (640) | 12.6 (474) | 5.7 (213) |
| **76–87 years,% n ($n$ = 2832)** | 42.3 (1197) | 50.4 (1428) | 27.6 (783) | 22.7 (642) | 18.1 (514) | 18.4 (520) | 11.9 (338) | 8.5 (242) |

analyses were performed with Stata v 17.0. Statistical significance was assessed at the alpha level of 0.05.

## 3. Results

The characteristics of patients who were and were not included in the analyses are shown in Supplemental Table 1. Compared to the 9560 male and 12, 301 female patients included in the analyses, excluded patients were younger (61.1 standard deviation [SD] 12.5 vs. 64.8 SD 12.0; $P < 0.05$) and more likely to have uncontrolled BP (32.0% vs. 27.9%). Among the 9560 males with a total of 32, 532 clinic visits and 12, 301 females with a total of 44, 850 clinic visits, the mean age was 64.8 years (standard deviation [SD 12.8] and ranged from 19 to 87 years; race and ethnicity were reported as NH White in 66.5%, NH Black in 21.1%, Hispanic in 10.9% and Other in 5.0%. Co-morbidities included 44.4% with obesity, 34.6% with diabetes, and 19.3% with CVD. The median number of clinic visits was 4 (Interquartile range 3,6). Table 1 shows the characteristics of the study participants by sex and by BP control status based on the vital signs at the patient's last clinic visit during the study period. Among males and females, patients with uncontrolled BP were more likely to report NH Black race/ethnicity and not have a diabetes diagnosis.

Fidelity to the AOBP protocol increased from 65% of clinic visits during month 1 to 89% of clinic visits during month 12 (Fig. 1). Overall, the proportion of clinic visits with uncontrolled BP declined by 9% among males and by 12% among females from first to last month of the study period but declines differed by age group for both males and females with the largest decline noted in males age 19–40 years (Fig. 2). Based on the percentage of patients with BP control at the first and last clinic visit during the study period, the percentage of patients with uncontrolled BP during the study period showed a decline in all sex and age groups (Fig. 2). Among age groups 19–40, 41–65, 66–75 and 76–87 years, uncontrolled BP declined by 19.4%, 13.5%, 10.1% and 8.7%, respectively, among males and 14.4%, 12.5%, 9.3%, and 8.4%, respectively, among females based on first vs. last clinic visit (Table 2).

Comparing first to last clinic visit, treatment with at least one BP

**Table 3**
Unadjusted and adjusted odds of uncontrolled blood pressure at a clinic visit by sex.

| | **Males** (32, 532 visits) | | **Females** (44, 850 visits) | |
|---|---|---|---|---|
| | **Unadjusted OR (95% CI)** | **Adjusted OR (95% CI)** | **Unadjusted OR (95% CI)** | **Adjusted OR (95% CI)** |
| ***Age group*** | | | | |
| 19–40 years | 1.0 (Referent) | 1.0 (Referent) | 1.0 (Referent) | 1.0 (Referent) |
| 41–65 years | 0.72 (0.60, 0.89) | 0.80 (0.66, 0.98) | 1.01 (0.85, 1.19) | 1.02 (0.86, 1.21) |
| 66–75 years | 0.62 (0.50, 0.76) | 0.75 (0.61, 0.92) | 1.00 (0.84, 1.18) | 1.04 (0.97, 1.24) |
| 76–87 years | 0.62 (0.50, 0.77) | 0.82 (0.66, 1.01) | 1.28 (1.07, 1.52) | 1.32 (1.10, 1.59) |
| **Race/*Ethnicity*** | | | | |
| Non-Hispanic White | 1.0 (Referent) | 1.0 (Referent) | 1.0 (Referent) | 1.0 (Referent) |
| Non-Hispanic Black | 1.52 (1.34, 1.71) | 1.48 (1.32, 1.68) | 1.50 (1.37, 1.64) | 1.62 (1.48, 1.78) |
| Hispanic | 1.18 (1.02, 1.35) | 1.13 (0.97, 1.30) | 0.96 (0.85, 1.08) | 1.04 (0.92, 1.17) |
| Non-Hispanic Other[a] | 0.93 (0.77, 1.11) | 0.97 (0.81, 1.16) | 0.88 (0.75, 1.04) | 1.04 (0.92, 1.17) |
| Unknown | 1.36 (1.04, 1.79) | 1.31 (1.00, 1.73) | 1.33 (1.03, 1.73) | 0.89 (0.75, 1.06) |
| **BMI categories** | | | | |
| 18.5 –24.9 kg/m$^2$ | 1.0 (Referent) | 1.0 (Referent) | 1.0 (Referent) | 1.0 (Referent) |
| $<$ 18.5 kg/m$^2$ | 1.39 (0.61, 3.19) | 1.07 (0.56, 2.97) | 1.10 (0.75, 1.60) | 1.05 (0.72, 1.54) |
| 25.0–29.9 kg/m$^2$ | 1.07 (0.93, 1.23) | 1.07 (0.93, 1.23) | 0.87 (0.78, 0.97) | 0.86 (0.77, 0.96) |
| $\geq$ 30.0 kg/m$^2$ | 1.22 (1.07, 1.40) | 1.22 (1.06, 1.41) | 0.76 (0.69, 0.84) | 0.76 (0.69, 0.85) |
| Missing/Unknown | 1.95 (0.71, 5.40) | 1.84 (0.66, 5.14) | 0.73 (0.34, 1.57) | 0.77 (0.36, 1.65) |
| **CVD** | 0.72 (0.66, 0.79) | 0.74 (0.68, 0.83) | 1.05 (0.96, 1.15) | 1.00 (0.91, 1.10) |
| **Diabetes** | 0.84 (0.77, 0.91) | 0.84 (0.78, 0.92) | 0.89 (0.82, 0.95) | 0.91 (0.84, 0.98) |
| **Current smoker** | 1.17 (1.04, 1.32) | 1.16 (1.03, 1.31) | 1.11 (0.99, 1.25) | 1.35 (1.04, 1.78) |
| **Month of visit** | 0.94 (0.93, 0.96) | 0.94 (0.93, 0.95) | 0.93 (0.92, 0.95) | 0.94 (0.93, 0.95) |

[a] Other race/ethnicity includes Alaskan Native, American Indian, Asian, Multiracial, Native Hawaiian and Other Pacific Islander and Other. CVD = cardiovascular disease. Fully adjusted model includes all variables in table.

lowering medication class increased from 64.0% to 71.6% in males and from 65.9% to 73.1% among females (see Table 2). The increase in treatment with at least one medication class between the first and last clinic visit differed by age group. Among individuals with untreated and uncontrolled BP at the first visit, 47.0% of males and 49.0% of females were prescribed BP lowering medications by the last visit during the study period. However, the proportion of patients with untreated and uncontrolled Bp at the first clinic visit who remained untreated at the last clinic visit was higher in the older vs. younger age groups (see Table 2).

At the last clinic visit, a mean of 1.8 BP lowering medication classes was prescribed to both males and females (Supplemental Table 2). Use of ACEi/ARB was significantly higher among men vs. women with treated and controlled (74.1% vs. 65.0%; $P$ <0.05) and with treated and uncontrolled BP (72.9% vs. 64.9%; $P < 0.05$). In contrast, thiazide diuretic use was lower among men vs. women with treated and uncontrolled (34.5% vs. 40.8%; $P < 0.05$) and with treated and controlled BP (37.0% vs. 46.5%; $P < 0.05$).

Table 3 shows the unadjusted and adjusted associations of demographic factors and comorbidities with BP control status at a clinic visit stratified by sex. For both males and females, each advancing month during the study period was associated with lower adjusted odds of uncontrolled BP at a clinic visit. Among male patients, adjusted odds of uncontrolled BP were lower among age groups > 40 years vs. 19–40

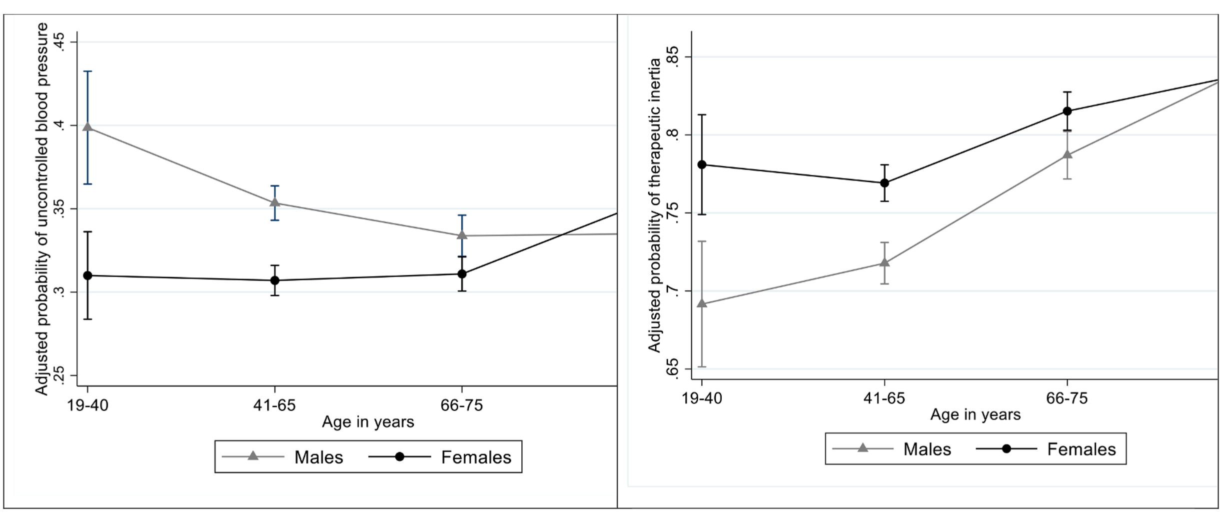



**Fig. 3.** Adjusted probability of uncontrolled blood pressure (BP) defined as a systolic BP ≥ 140 mmHg and/or a diastolic BP ≥ 90 mmHg (left panel) and therapeutic inertia (right panel) during a clinic visit by age group and by sex. Adjusted probability of uncontrolled BP was determined using generalized linear mixed effects models for the binomial family with logit function and marginal effects. Models accounted for the clustering within clinics and intra-individual correlations and adjusted for demographics, body mass index, current smoking, presence of diabetes and cardiovascular disease, and month of clinic visit. Therapeutic inertia was defined as absence of escalation or initiation of new BP lowering medication during a clinic visit with uncontrolled BP. Adjusted probability of therapeutic inertia was determined using generalized linear mixed effects models for the binomial family with logit function and marginal effects and accounted for same variables in models as uncontrolled BP but also accounted for the systolic BP at the clinic visit.

**Table 4**
Unadjusted and adjusted odds of therapeutic inertia during a clinic visit with blood pressure ≥ 140/90 mmHg by sex.

| | **Males** (11, 028 visits) | | **Females** (14, 980 visits) | |
|---|---|---|---|---|
| ***Characteristics*** | **Unadjusted OR (95% CI)** | **Adjusted OR (95% CI)** | **Unadjusted OR (95% CI)** | **Adjusted OR (95% CI)** |
| ***Age group*** | | | | |
| 19–40 years | 1.0 (Referent) | 1.0 (Referent) | 1.0 (Referent) | 1.0 (Referent) |
| 41–65 years | 1.27 (1.01, 1.58) | 1.30 (1.04, 1.63) | 1.03 (0.084, 1.26) | 1.23 (1.00, 1.52) |
| 66–75 years | 2.09 (1.66, 2.64) | 2.16 (1.69, 2.75) | 1.49 (1.21, 1.86) | 1.88 (1.50, 2.36) |
| 76–87 years | 3.49 (3.03, 4.48) | 3.40 (2.60, 4.43) | 1.92 (1.53, 2.39) | 2.43 (1.92, 3.08) |
| ***Race and ethnicity*** | | | | |
| *NH White* | 1.0 (Referent) | 1.0 (Referent) | 1.0 (Referent) | 1.0 (Referent) |
| *NH Black* | 0.85 (0.73, 0.98) | 1.05 (0.90, 1.21) | 0.85 (0.76, 0.95) | 1.00 (0.89, 1.13) |
| *Hispanic* | 0.83 (0.70, 0.99) | 0.95 (0.79, 1.13) | 0.72 (0.63, 0.84) | 0.77 (0.66, 0.90) |
| *NH Other* [a] | 0.88 (0.69, 1.11) | 0.90 (0.71, 1.14) | 0.91 (0.72, 1.15) | 0.96 (0.76, 1.22) |
| *Unknown* | 0.69 (0.50, 0.97) | 0.78 (0.56, 1.09) | 0.83 (0.59, 1.15) | 0.96 (0.68, 1.34) |
| ***BMI categories*** | | | | |
| 18.5 –24.9 kg/m$^2$ | 1.0 (Referent) | 1.0 (Referent) | 1.0 (Referent) | 1.0 (Referent) |
| < 18.5 kg/m$^2$ | 6.62 (0.82, 54.0) | 6.88 (0.85, 56.02) | 1.16 (0.70, 1.93) | 0.99 (0.60, 1.53) |
| 25–29.9 kg/m$^2$ | 0.73 (0.60, 0.82) | 0.81 (0.67, 0.99) | 0.97 (0.84, 1.07) | 0.97 (0.84, 1.12) |
| ≥ 30 kg/m$^2$ | 0.68 (0.57, 0.82) | 0.88 (0.73, 1.07) | 0.94 (0.82, 1.07) | 1.02 (0.89, 1.17) |
| Unknown | 4.13 (0.49, 35.5) | 4.34 (0.51, 36.7) | 0.79 (0.28, 2.14) | 0.79 (0.29, 2.19) |
| ***CVD*** | 1.86 (1.63, 2.13) | 1.56 (1.36, 1.80) | 1.68 (1.49, 1.90) | 1.50 (1.40, 1.81) |
| **Diabetes** | 1.29 (1.11, 1.43) | 1.32 (1.18, 1.47) | 1.34 (1.21, 1.48) | 1.36 (1.22, 1.51) |
| **Current smoking** | 0.72 (0.62, 0.83) | 0.81 (0.71, 0.94) | 0.86 (0.74, 0.99) | 0.95 (0.82, 1.10) |
| **Month of clinic visit** | 1.00 (0.98, 1.01) | 0.99 (0.98, 1.00) | 1.00 (0.99, 1.01) | 1.00 (0.99, 1.01) |
| **SBP categories** | | | | |
| SBP < 130 mmHg | Referent | Referent | | Referent |
| SBP 130–139 mmHg | 0.82 (0.51, 1.34) | 0.83 (0.52, 1.35) | 0.56 (0.34, 0.91) | 0.55 (0.34, 0.89) |
| SBP 140–149 mmHg | 0.94 (0.60, 1.47) | 0.71 (0.46, 1.11) | 0.63 (0.40, 0.98) | 0.49 (0.31, 0.76) |
| SBP 150–159 mmHg | 0.49 (0.31, 0.76) | 0.36 (0.24, 0.57) | 0.35 (0.22, 0.54) | 0.27 (0.17, 0.42) |
| SBP ≥ 160 mmHg | 0.42 (0.26, 0.66) | 0.31 (0.20, 0.48) | 0.24 (0.16, 0.39) | 0.19 (0.11, 0.29) |
| # Medication Classes | 0.83 (0.79, 0.87) | 0.82 (0.78, 0.86) | 0.85 (0.81, 0.88) | 0.81 (0.77, 0.84) |

[a] Other race/ethnicity includes Alaskan Native, American Indian, Asian, Multiracial, Native Hawaiian and Other Pacific Islander and Other. CVD = cardiovascular disease. Fully adjusted model includes all variables in table.

years while among female patients, odds of uncontrolled BP were higher in age group 76–87 years (OR 1.32; 95% CI 1.10, 1.59) vs. age 19–40 years. Similar findings were noted with uncontrolled BP defined as ≥ 130/80 mmHg (see Supplemental Table 3). Other factors associated with higher odds of uncontrolled BP among males and females included NH Black race and current smoking. Fig. 3 (left panel) shows the adjusted probability of uncontrolled BP at a clinic visit by sex and by age group. Among males, the adjusted probability of uncontrolled BP declined with advancing age until age > 65 years. Among females, the adjusted probability of uncontrolled BP increased after age 65 years.

Among the 25, 574 clinic visits with uncontrolled BP (11, 035 male and 14, 539 female), therapeutic inertia occurred in 78.4% overall and in 76.3% of male visits and 80.1% of female visits. Therapeutic inertia increased with advancing age in both males and females (see Supplemental Figure 2) and ranged from 66.5% and 75.9% in males and females age 19–40 years, respectively, to 85.6% and 84.9% in males and females age 76–87 years, respectively. Change in medication class occurred in 16.3% of visits with uncontrolled BP overall and in 17.9% of male visits with uncontrolled BP and 15.1% of female visits with uncontrolled BP. A dose change occurred in 5.6% of visits with uncontrolled BP overall and in 6.3% of male visits and 5.1% of female visits with uncontrolled BP, respectively. For both males and females, adjusted odds of therapeutic inertia at a clinic visit with uncontrolled BP were significantly higher with age groups > 65 years vs. age 19–40 years (Table 4). Adjusted odds of therapeutic inertia during visits with uncontrolled BP were higher in age group 76–87 years vs. 19–40 years in both men (OR 3.40; 95% CI 2.60, 4.43) and women (OR 2.43; 95% CI 1.92, 3.08) . Non-White race and Hispanic ethnicity were not significantly associated with higher odds of therapeutic inertia. No significant association was noted with month of visit and odds of therapeutic inertia for males or females. Similar findings were noted when therapeutic inertia was examined during clinic visits with BP ≥ 130/80 mmHg (see Supplemental Table 4).

Fig. 3 (right panel) shows the adjusted probability of therapeutic inertia at a clinic visit with uncontrolled BP by sex and by age group. While the adjusted probability of therapeutic inertia increased with advancing age among both males and females, adjusted probability of therapeutic inertia was consistently higher among females until age group 76–87 years.

## 4. Discussion

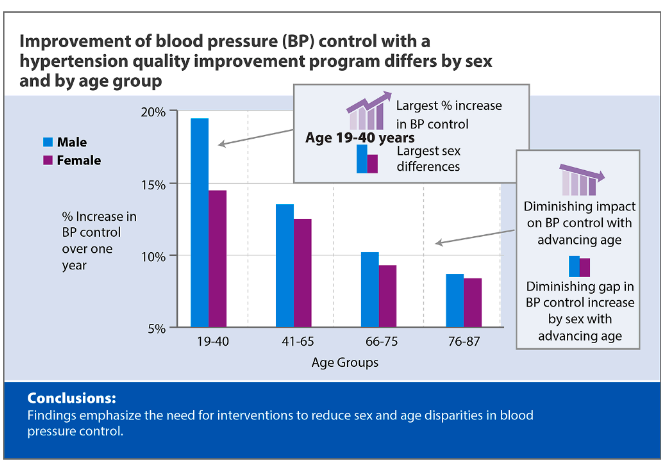
This study examined BP control and therapeutic inertia in a large cohort of hypertensive adults ages 19 to 87 years receiving care in primary care clinics enrolled in the AMA MAP BP® Program. Our analyses showed that uncontrolled BP declined after implementation of the AMA MAP BP® program by 11.2% among males and 10.7% among females during the 12 month period based on vital signs during the first and last clinic visit. Across the entire study period, the adjusted probability of uncontrolled BP was noted to be lower with advancing age among males, but higher among females after age 65 years. These findings are similar to previous studies which examined BP control in cohort studies [14,32], health systems [15,24], and in the non-institutionalized U.S. population [13,33]. Our study also showed larger declines in uncontrolled BP in younger vs. older age groups with implementation of the hypertension quality improvement program regardless of sex.

The reasons for sex and age differences in BP control have not been fully elucidated, and our study aimed to explore the role of therapeutic inertia as a possible contributing factor. Similar to previous studies [13–15,19], our study found higher odds of therapeutic inertia with advancing age among both males and females but therapeutic inertia was consistently higher among females until age 76 years. We did not see significant declines in therapeutic inertia in any sex or age group by time. These findings demonstrate a need to develop and implement interventions that specifically focus on reducing therapeutic inertia, especially among older adults, and female patients. Interventions could include use of self-monitoring of BP, which when paired with other tools, may help reduce therapeutic inertia and improve BP control [34, 35]. Female patients were less likely to be prescribed maximum doses of calcium channel blockers while use of maximum doses of thiazide diuretics and ACEi/ARB did not differ by sex. A previous analysis of the 2005–2011 National Ambulatory Care Survey data showed no significant sex differences in the initiation of antihypertensive therapy during a clinic visit with uncontrolled BP after controlling for demographics, comorbidities and insurance status [15]. However, this study did not examine sex differences in therapeutic inertia by age group.

Our findings are unique because clinics were participating in the AMA MAP BP® program and the patient cohort age ranged from 19 to 87 years. Our analyses adjusted for demographics and comorbidities which can influence BP control and possibly decisions to intensify BP lowering medications. Limitations of the study include the reliance on clinic BP to define BP control and lack of home BP measurements. Our analyses also did not include data on patient reported adverse effects to medications, total number of medications, insurance status, education attainment, diet or physical activity. Lastly, the study includes a relatively short follow-up period. More studies are needed to examine contextual factors at the clinic or provider level that can be addressed to reduce therapeutic inertia and improve BP control.

In conclusion, this study utilized data from patients receiving care within outpatient clinics enrolled in the AMA MAP BP® program. Results from early implementation of the program showed improvement in BP control rates for both male and female patients but age and sex disparities in BP control persisted. More research is needed to determine reasons for age and sex differences in BP control and therapeutic inertia to improve CVD prevention among older adults.

Central illustration




Improvements in blood pressure control differ by sex and by age group with implementation of a hypertension quality improvement program.

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None.

## Disclosures

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## Disclaimer

The content is solely the responsibility of the authors and does not necessarily represent the official views of the American Medical Association.

## CRediT authorship contribution statement

**Olivia Myers:** Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **Talar Markossian:** Conceptualization, Formal analysis, Methodology, Writing – review & editing. **Beatrice Probst:** Data curation, Project administration, Writing – review & editing. **Grant Hiura:** Data curation, Formal analysis, Writing – review & editing. **Katherine Habicht:** Data curation, Project administration, Writing – review & editing. **Brent Egan:** Formal analysis, Writing – review & editing. **Holly Kramer:** Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Holly Kramer reports a relationship with Bayshore Pharmaceuticals LLC that includes: consulting or advisory. Holly Kramer reports a relationship with Vifor Pharma Ltd that includes: consulting or advisory. Dr. Egan is employed by the American Medical Association

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ajpc.2023.100632.

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