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Blood pressure, sexual activity and erectile function in hypertensive men: baseline findings from the Systolic Blood Pressure Intervention Trial (SPRINT)

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Introduction

Sexual function is an important component of health-related quality of life (HRQL). Sexual dysfunction, defined by the World Health Organization as "the various ways in which an individual is unable to participate in a sexual relationship as he or she would wish" [1], presents challenges to life satisfaction [2], relationships and mood states [3]. In men, erectile

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dysfunction (ED), defined as " the persistent inability to attain and/or maintain penile erection sufficient for sexual intercourse" [4] affects 45% of men in their 60s, and over 70% of men aged 70 years or older [5], and is expected to increase in prevalence by 2025 [6]. While ED was previously dismissed as a disorder that was primarily psychogenic in origin [7], most researchers currently agree that ED may result from vascular [8], psychological, hormonal, neural or physiological factors [9].

The association between one physiological factor, blood pressure, and ED in men with hypertension remains unclear [7, 10]. While some studies have reported that over two-thirds of men with hypertension report having ED [11, 12, 13], earlier studies have not found a high prevalence of ED in hypertensive men [14]. Several possible mechanisms have been postulated to explain the possible association between blood pressure and ED, including one hypothesis that chronic hypertension may cause oxidative stress, which may result in endothelial dysfunction, which in turn may result in reduced ability of the arteries and small vessels of the corpus cavernosum to dilate properly [11]. Of note, antihypertensive medications themselves have been implicated as a possible cause of ED, with some earlier studies reporting associations between "oldgeneration" drugs (e.g. beta-blockers and diuretics) and ED [15], while other reports have not found these associations [14, 16]. In addition, the independent associations of systolic blood pressure (SBP) and diastolic blood pressure (DBP) with erectile function have not been extensively investigated.

In consideration of these issues, the purpose of this investigation was to examine the prevalence of ED, as well as the cross-sectional association between blood pressure measures and self-reported sexual activity and erectile function in male participants in the Systolic Blood Pressure Intervention Trial (SPRINT) Health-Related Quality of Life (HRQL) subsample. SPRINT afforded the opportunity to study this association in a large, multiethnic sample after adjustment for various demographic, medication, behavioral, psychosocial and clinical factors that may be associated with ED. We hypothesized that higher blood pressure would be associated with less favorable erectile function.

Material and Methods

Participants

SPRINT was a large, two-armed, multi-center randomized clinical trial designed to test whether treatment of systolic blood pressure (SBP) to a goal of <120 mmHg would reduce unfavorable cardiovascular, renal and cognitive outcomes compared to a treatment goal of <140 mmHg in a multiethnic sample of 9361 men and women with hypertension. Details regarding the design, recruitment, and objectives of SPRINT have been previously published [17]. The Institutional Review Boards at each clinical site approved the trial. The trial was registered with clinicaltrials.gov (NCT01206062) prior to participant recruitment, and all participants signed informed consent forms. Briefly, inclusion criteria for SPRINT are described in Table 1, with exclusion criteria provided in the publicly-available SPRINT protocol document[18]. SPRINT also included several subsamples, including a Health-Related Quality of Life (HRQL) subsample consisting of 1987 men and women participants who were selected using a probabilistic algorithm that preserved the randomization blocking and allowed the sampling fraction to vary by clinical site and over time. This investigation

involves the 1255 male participants in the SPRINT HRQL subsample who completed baseline assessments before the random assignments to standard or intensive blood pressure control began.

Measures

Outcome Measures

Sexual Activity and Erectile Function.: Sexual activity during the previous 4 weeks was assessed by the question, - "Have you engaged in sexual activity of any kind with a partner and/or by yourself (masturbation)?" Participants who answered "yes" then completed questions regarding erectile function during the past 4 weeks, using the 5-item version of International Index of Erectile Function (IIEF-5) questionnaire[19]. The IIEF-5 includes 4 questions on erectile function and 1 question on sexual satisfaction, with each question being scored on a 5-point scale. Total scores on the IIEF-5 range from 5 to 25, with lower scores indicating poorer function. As suggested by developers of the instrument, ED was operationally defined as a total IIEF-5 score of ≤21 [19]. As a note, phosphodiesterase type 5 inhibitor (PDE-5 inhibitor) use was not included in this definition, as some PDE-5 inhibitors (e.g. sildenafil) are approved by the FDA for treatment of other conditions, such as pulmonary arterial hypertension. In addition, PDE-5 inhibitors are gaining increased attention as possible treatments for cardiac, circulatory, and neurogenerative diseases [20]. However, as will be noted below, PDE-5 inhibitor use was included as a covariate in the fully adjusted linear and logistic regression analyses.

Independent Variables

Blood Pressure.: Trained clinical staff measured blood pressures with an automated blood pressure device (Omron-HEM-907 XL, Omron Healthcare, Lake Forest, IL, USA) using standardized procedures [17, 18, 21, 22]. Blood pressure measurement requirements included measuring blood pressure early during the visit and not following stressful exam components such as blood draws, proper positioning of the participant in a chair with back support, and proper cuff size determination. The Manual of Procedures (MOP) stated that participants should be resting, not completing questionnaires, and not speaking with study staff during the 5-minute rest period or while BP measurements were being taken. Pulse Pressure (PP) was defined as systolic blood pressure – diastolic blood pressure.

Demographic, Behavioral, Clinical and Psychosocial Variables.: Using findings from literature and clinical judgment, we included several demographic characteristics and risk factors that may be associated with sexual activity and erectile function. Age, race/ethnicity (white, black, Hispanic and other), highest educational attainment, living arrangement (alone vs. with others), pack-years of smoking and alcohol consumption (typical drinks/week) were assessed by self-report. Use of beta-blockers, diuretics, calcium channel blockers, angiotensin converting enzyme inhibitors, angiotensin receptor blockers, PDE-5 inhibitors, or any cholesterol medications was assessed by trained personnel who referred to the US FDA lists of approved antihypertensive and cholesterol medications. Height and weight were directly measured according to standardized procedures, and Body Mass Index (BMI) was calculated as weight in kilograms / (height in meters)^2. Estimated glomerular filtration rate

(eGFR) was calculated using the four-variable MDRD formula [23], and expressed as mL/min/1.73m^2. Chronic Kidney Disease (CKD) was defined as eGFR <60 mL/min/1.73m^2. Cognitive function was assessed via standardized interview using the Montreal Cognitive Assessment (MoCA) total score [24]. Depressive symptoms were assessed via self-report using the Patient Health Questionnaire (PHQ-9) [25] total score. Total number of physical comorbidities were assessed via self-report using the sum of the Selim Comorbidity Index physical comorbidity score [26].

Statistical Analyses

Histograms and descriptive summary statistics were generated to determine the baseline characteristics for the sample. Variables that demonstrated distributions with skewness of an absolute value |>2|, or kurtosis of an absolute value |>7| were considered to be nonparametric [27]. Means and standard deviations were reported for continuous variables, percentages for categorical variables and median, 25th and 75th percentiles for nonparametric continuous variables. Descriptive statistics were partitioned by sexual activity status during the past 4 weeks (yes/no), and by categories of SBP (<140 mmHg, 140 to 160 mmHg, and >160 mmHg), and PP. To test bivariate associations, Pearson's chi-square tests were used and Student's t-tests or Kruskal-Wallis tests, as appropriate, were used to examine differences between groups depending on the variable distribution. P-values were reported.

The associations between baseline SBP and DBP (each in 5mmHg increments) and sexual activity were examined using unadjusted and adjusted logistic regression models in which odds ratios, 95% confidence intervals and p-values were calculated. The adjusted model examined the association between baseline SBP and DBP, and sexual activity, after adjustment for baseline *demographic factors* (age, race/ethnicity, education, and living arrangement), *behavioral risk factor and medication use variables* (pack-years of smoking, drinks per week of alcohol, class of antihypertensive medication, PDE-5 inhibitors and cholesterol medication), and *cardiometabolic and psychosocial variables* (BMI, eGFR, MoCA total score, PHQ-9 total score, and total number of physical comorbidities).

In addition, unadjusted and adjusted linear regression models were conducted using the same variables to examine the association between baseline blood pressure and erectile function (IIEF-5 total score), in which beta coefficients (β), 95% confidence intervals and p-values were calculated. The aforementioned unadjusted and adjusted logistic regression models were repeated to determine the association between baseline blood pressure and ED (IIEF-5 score ≤21).

Finally, in supplemental analyses, the aforesaid analyses examined the association between PP (in 5 mmHg increments) and erectile function. The a priori alpha level of significance for all analyses was set at 0.05, and all analyses were conducted using SAS version 9.4 (Cary, NC USA).

Results

Descriptive Analyses.

Sexual Activity.—Table 2 displays descriptive statistics for the total sample, partitioned by sexual activity status in the 1255 participants of the 1297 (96.8%) male participants in the HRQL subsample who answered the sexual activity question and completed the IIEF-5 questionnaire. The mean (sd) age of the sample was 66.9 (9.7) years. 857 participants (68.3%) reported being sexually active within the previous 4 weeks. The mean (sd) IIEF-5 score in sexually active participants was 18.0 (5.8), and 60% of the sample reported an IIEF-5 score ≤21. In addition, 10.5% of the sample reported taking PDE-5 inhibitors. Collectively, sexually active men (n=857) were younger, more likely to be African-American, more educated, and more likely to be living with others. They also had higher total cholesterol, were less likely to take anti-cholesterol medication, were more likely to take PDE-5 inhibitors, and had higher BMI, higher eGFR, higher MoCA and PHQ-9 scores, and reported fewer physical comorbidities than men who were not sexually active.

Systolic Blood Pressure.—Table 3 presents additional descriptive statistics that were partitioned by categories of systolic blood pressure. There were no differences in the baseline characteristics among blood pressure categories, except in total cholesterol, anti-cholesterol medications (marginal), and PDE-5 inhibitors, with participants in <140 mmHg categories having lower total cholesterol and being more likely to take anti-cholesterol medication and PDE-5 inhibitors than participants in the 140-160 mmHg and >160 mmHg categories.

Regression Analyses.

Blood Pressure and Sexual Activity.—Table 4 depicts the results of the unadjusted and adjusted logistic regression models to examine the baseline, cross-sectional association between blood pressure (expressed in 5 mmHg units) and being sexually active. In the unadjusted model, lower SBP ($p<0.0001$), and higher DBP ($p<0.0001$) were associated with higher odds of being sexually active. However, in the adjusted model, neither SBP nor DBP were significantly associated with sexual activity. Among covariates, younger age was associated with higher odds of being sexually active in all adjusted models ($p<0.001$). In the adjusted model, participants with less than high school education, and high school education or GED were less likely to be sexually active compared to participants who graduated from college ($p = 0.043$ and $p = 0.0313$, respectively). In addition, in the adjusted model, participants who lived with others were more likely to be sexually active compared to participants who lived alone ($p=0.004$). Also, in the adjusted model, use of PDE-5 inhibitors was associated with higher odds of being sexually active ($p<.0001$). Finally, in the adjusted model, lower (i.e. more favorable) PHQ-9 score was associated with higher odds of being sexually active ($p = 0.027$), as was lower number of total physical comorbidities ($p=0.015$).

Blood Pressure and IIEF-5 Scores.—Table 5 conveys the results of the simple and multiple linear regression models that investigated the association between blood pressure and erectile function using IIEF-5 total score. In the unadjusted and adjusted models, lower SBP, and higher DBP were significantly associated with higher (i.e. more favorable) IIEF- 5

score (p = 0.025 and p = 0.029 respectively). In the adjusted model, younger age was significantly associated with higher IIEF-5 score (p < 0.001). In the adjusted model, lower BMI was significantly associated with higher IIEF-5 score (p=0.032), as was lower (i.e. more favorable) PHQ-9 score (p<.0001), and fewer physical comorbidities (p = 0.020).

Table 6 exhibits the results of the unadjusted and adjusted logistic regression models assessing the association between baseline blood pressure and ED (IIEF-5 score ≤21). In the unadjusted model, higher SBP (p = 0.109) and lower DBP (p<0.001) were significantly associated with higher odds of ED. In the adjusted model, lower DBP was significantly associated with higher odds of ED (p=0.045). In the adjusted model, older age was associated with higher odds of ED (p<0.001). In addition, in the adjusted model, having a high school education or GED was significantly associated with higher odds of ED versus graduating from college (p<0.05). Also, participants who had less than a high school education, or had some post high school education both had higher odds of ED compared to participants who graduated from college (p = 0. 014). Poorer cognitive function, and higher (i.e. less favorable) PHQ-9 score were each significantly associated with higher odds of ED (p = 0.037 and p<.0001 respectively).

Supplemental Analyses of Pulse Pressure (PP) and IIEF-5 Scores

Pulse Pressure and Descriptive Analyses.—Table A.1 (Supplementary Appendix) provides descriptive statistics that were partitioned according to quartile of PP. Compared to Quartile 1 of PP, participants in Quartile 4 reported significantly lower IIEF-5 scores and higher percentages of ED, were older, had higher percentages of non-Hispanic white participants, reported higher use of beta-blockers and had higher total numbers of antihypertensive medications. In addition, participants in Quartile 4 had higher systolic blood pressure and lower diastolic blood pressure than participants in Quartile 1. Quartile 4 participants had lower total cholesterol, and had lower percentages of taking anti-cholesterol medication than participants in Quartile 1. In addition, participants in Quartile 4 had lower BMI, lower eGFR and lower PHQ-9 scores than participants in Quartile 1. Finally, participants in Quartile 4 reported higher total numbers of physical comorbidities. Interestingly, the quartiles did not significantly differ regarding PDE-5 use.

Pulse Pressure and Sexual Activity.—Table A.2 (Supplementary Appendix) displays the results of the unadjusted and logistic regression analyses that examined the association between baseline PP and sexual activity. In the unadjusted model, lower PP was significantly associated with increased odds of being sexually active (p<0.001).

Pulse Pressure and IIEF-5 Scores.—Table A.3 (Supplementary Appendix) presents the results of the simple and multivariable linear models assessing the association between baseline PP and IIEF-5 scores in sexually active participants. In the multivariable model, lower PP was significantly associated with higher IIEF-5 scores (p = 0.02).

Finally, in Table A.4 (Supplementary Appendix), the results of the unadjusted and adjusted logistic regression models examining the association between baseline PP and ED in sexually active participants are presented. In the adjusted model, PP was not significantly associated with ED.

Discussion

The primary purpose of this investigation was to assess whether baseline blood pressure was associated with sexual activity or with erectile function in a sample of middle-aged and older men with hypertension, after adjustment for several demographic, behavioral and clinical variables and risk factors. Collectively, we found in adjusted analyses that neither SBP nor DBP was significantly associated with sexual activity. However, lower SBP was associated with better erectile function, even after adjustment for several relevant demographic, behavioral, medication and clinical factors. Interestingly, higher DBP, and lower PP were each associated with better erectile function (higher IIEF-5 total scores), and lower DBP was associated with lower odds of ED (defined as IIEF-5 total score of ≤21) in unadjusted and adjusted analyses.

Descriptive analyses revealed that 68.3% of participants had reported engaging in sexual activity over the previous 4 weeks, which is similar to other reports. Spatz et al. [28], in analyses from the National Social Health, Life and Aging study, found that the unweighted prevalence of sexual activity in treated and untreated men with hypertension was 66.5% and 75.9%, respectively. We also found that ED, as assessed using the IIEF-5, was highly prevalent (59.9%) in this hypertensive sample. Indeed, if PDE-5 inhibitor use had been included in our operational definition of ED, the prevalence of ED in this sample may have been higher. Burchardt et al.[12], studying 104 hypertensive male patients who responded to a mailing of the original 15-item version of IIEF, found that 68.3% of participants reported erectile dysfunction. Giuliano et al. [13] studying 3906 male patients with hypertension, found that 67% of participants reported ED, defined in that investigation as IIEF-5 scores <21, which is slightly different that our definition of IIEF-5 scores ≤21. The high prevalence of ED, coupled with the low percentages of ED patients who ask for medical advice [29] support the beneficial role that clinicians can play in the regular and proactive assessment of erectile function in patients [30].

In adjusted logistic regression analyses, blood pressure was not associated with sexual activity. However, consistent with our hypothesis, in the primary linear regression analyses, higher systolic blood pressure was significantly associated with lower IIEF-5 scores, and this association remained significant after adjustment for several relevant covariates This finding is in accordance with the aforementioned studies [12, 13], which found that ED is highly prevalent among men with hypertension, but is in contrast with recent findings by Korhonen et al.[31], who, studying 924 men at risk for CVD or diabetes, found that hypertension was not associated with ED after adjustment for age, cohabitating status, waist circumference or education. Our finding contributes to the literature by suggesting that even within a hypertensive sample, higher SBP may be associated with poorer erectile function. This association between blood pressure and erectile function is biologically plausible, as it is hypothesized that increased blood pressure may result in structural and functional damage to penile arteries, including smooth muscle tissue hypertrophy and stenosis that may lead to reduced blood flow, as well as reduced nitric oxide release which may impair endothelial tissue function [32].

Curiously, we found that higher DBP shared a robust association with more favorable IIEF-5 scores and with lower log odds of ED in our adjusted analyses. Korhonen et al.[31] state that DBP and ED may share a U-shaped association, with the odds of ED being lowest at approximately 90 mmHg. In simple and multiple linear regression analyses, we found that lower pulse pressure was associated with more favorable IIEF-5 scores. These results are similar to the findings of Corona et al. [33], who found that among 1093 men with ED, but without hypertension, participants in higher quartiles of pulse pressure had worse erectile function, as measured by the structured interview on erectile dysfunction. Pulse pressure is a measure of arterial stiffness, which is a risk factor for cardiovascular disease independent of blood pressure [34]. Similar to increases in blood pressure, arterial stiffness may result from a number of factors, including aging [35], smoking [36], glucose intolerance [37], artery calcification [38], increased intima-media thickness and reduced aortic diameter [39]. The current results suggest that not only blood pressure, but also pulse pressure may be useful in assessing the role of hemodynamic factors in erectile dysfunction. However, although we observed statistically significant associations between blood pressure, pulse pressure and erectile function, it must be noted that the large sample size may have influenced these findings. In addition, the beta-coefficients were small. This finding also may be due to characteristics of the sample, as we recruited participants with hypertension, which may have limited the range of blood and pulse pressures.

Antihypertensive medications were not associated with sexual activity or erectile function in any of our adjusted regression models, and notably, neither beta blockers nor diuretics were found to be associated with sexual activity or erectile function. This finding is consistent with some studies [14], but adds to the continuing complexity of the literature regarding the role of antihypertensive medication as a possible causal factor of ED. As noted by Chyrsant [40], ED is a multifactorial disorder, and many hypertensive patients are on antihypertensive polytherapy, which makes it difficult to disentangle the effects of single medications. Contrary to our findings, previous studies have found that thiazide diuretics and beta-blockers are associated with ED. Cordero et al. [30], assessing IIEF scores in 1007 hypertensive male patients who had been treated with any beta-blocker for at least 6 months, found that 73.3% of patients taking atenolol reported ED. Similar high percentages of ED were observed among patients taking bisoprolol (72%), carvedilol (80.5%), and metoprolol (80%). The prevalence of ED among patients taking nebivolol was comparatively low (57.1%) Not surprisingly, PDE-5 inhibitor use was significantly associated with higher odds of sexual activity in this sample, and with less favorable sexual function compared to participants with no PDE5 inhibitor use. The results of this investigation may help allay concerns of patients and providers regarding the possible role of antihypertensive medications in the development of sexual dysfunction [40]; however, as stated by Chrysant[40], clinicians should continue to assess sexual function when new antihypertensive medications are initiated.

Several demographic characteristics and risk factors in this sample of hypertensive men were independently associated with sexual activity, erectile function, and ED. Younger age and higher education were associated with increased odds of being sexually active, while higher depressive symptoms and increased number of comorbidities were associated with lower odds of being sexually active. In previous studies, younger age [41] and higher education [42]

were found to be associated with better erectile function, as were lower BMI [43], and lower number of comorbidities. In addition, lower levels of depressive symptoms scores were associated with better erectile function. Goldstein et al [44] has proposed an unfavorably synergistic "mutually reinforcing triad" among depressive symptoms, ED and CVD because the three conditions share several risk factors. In our analyses, higher MoCA scores were associated with lower odds of erectile dysfunction. As reported by Hartmans et al. [45], the association between cognitive function and sexual function has not been extensively studied, and results to date are inconclusive. However, as noted earlier, it is generally acknowledged that sexual function is a result not only of autonomic processes, but of emotional and cognitive processes as well; thus individuals with better cognitive function may also be more likely to have better sexual function and general health [45].

This investigation has several strengths, including direct, rigorous assessment of blood pressure [46], clinical measures, anthropometric measures and antihypertensive medications in a large, multiethnic, geographically diverse sample. In addition, this study included validated measures of sexual function, cognitive function, comorbidities, kidney function and clinical factors. Also, the sample had a high percentage of sexually active participants (68.3%), which enhanced our ability to assess the association between blood pressure, sexual activity and sexual function.

However, this study is not devoid of limitations, some of which relate to the IIEF-5. For example, the IIEF-5 assesses sexual function over the preceding 4 weeks; thus, a participant who had engaged in sexual activity in the past 5 weeks would be deemed as being sexually inactive. In addition, we did not ask why participants had not engaged in sexual activity; thus, some participants may have become sexually inactive due to ED. Rosen et al. [19], developers of the IIEF-5, also note several limitations of the instrument, including that the IIEF-5 focuses on erectile function, is not a multidimensional measure of sexual function, and it does not assess the patient's relationship status or the sexual function of the patient's partners [15, 47]. Also, due to the potentially sensitive nature of questions in the IIEF-5, some participants may have chosen to give socially desirable responses.

SPRINT only enrolled participants with hypertension, which prohibited us from comparing erectile function in men with hypertension vs. men without hypertension. Although SPRINT assessed living arrangement, we did not initially assess relationship status, availability of sexual partners or quality of relationships. The SPRINT sample was highly educated, with 76.3% reporting post high-school education. In addition, some relevant aspects of the possible association between antihypertensive medications and ED are acknowledged as limitations of our investigation. For example, similar to a previous SPRINT report [48], while our analyses incorporated broad classes of medications (e.g. beta blockers), we did not investigate the associations of specific medications (e.g. atenolol) and erectile function. In addition, we did not investigate the association between dose of antihypertensive medication and erectile function. Also, SPRINT did not collect data regarding testosterone or androgen levels, which are associated with erectile function[49]. Finally, this cross-sectional investigation does not allow us to infer causal associations.

Conclusions

In this cross-sectional, baseline investigation in middle-aged and older men with HTN, erectile dysfunction was found to be highly prevalent. Lower SBP and higher DBP were significantly associated with better erectile function, and the association was robust after adjustment for several key factors, although the magnitude of the association was modest. The SPRINT sample will permit analysis of more focused research questions involving the associations of antihypertensive medications and erectile function that involve intra- and inter-class comparisons of medications. Also, the longitudinal SPRINT study will allow us to determine if baseline blood pressure or changes in blood pressure are associated with incident ED.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Inclusion Criteria for SPRINT Participants. To be eligible, a screenee must have met criteria 1, 2, and 3.

General Inclusion Criteria for SPRINT

1 Age ≥50 years

2 Systolic Blood Pressure (SBP)

SBP: 130-180 mmHg on 0 or 1 medication

SBP: 130-170 mmHg on up to 2 medications

SBP: 130-160 mmHg on up to 3 medications

SBP: 130-150 mmHg on up to 4 medications

3 At risk for CVD events based on at least one of the following:

(a) Presence of clinical or subclinical cardiovascular disease (CVD) other than stroke

(i) Clinical CVD (other than stroke)

a. Previous myocardial infarction (MI), percutaneous coronary intervention (PCI), coronary artery bypass grafting (CaBg), carotid endarterectomy (CE), carotid stenting

b. Peripheral artery disease (PAD) with revascularization

c. Acute coronary syndrome with or without resting ECG change, ECG changes on a graded exercise test (GXT), or positive cardiac imaging study

d. At least 50% diameter stenosis of a coronary, carotid, or lower extremity artery

e. Abdominal aortic aneurysm (AAA) > 5 cm with or without repair

(ii) Subclinical CVD

a. Coronary artery calcium score > 400 Agatston units within the past 2 years

b. Ankle brachial index (ABI) <0.90 within the past 2 years

c. Left ventricular hypertrophy (LVH) by ECG (based on computer reading) echocardiogram report, or other cardiac imaging procedure report within the past 2 years

(b) Chronic kidney disease, defined as estimated glomerular filtration rate 20 – 59 mL/min/1.73^2

(c) Framingham risk score for 10-year CVD risk >15% based on clinical features and laboratory results within the past 12 months

Targeted high-risk subgroup inclusion criteria

Chronic kidney disease: Qualifying chronic kidney disease was defined by estimated glomerular filtration rate, determined at baseline between 20 and 59 mL/min/1.73 m2, inclusive, based on the four-variable MDRD equation.

Senior: Participants who were at least 75 years old at the baseline visit.

CVD: Participants who met any of the inclusion criteria listed in 3a above at baseline.

Table 2.

Baseline Characteristics of Participants According to Sexual Activity Status

Characteristic	Overall n=1255	Sexually Active n=857 (68.3%)	Not Sexually Active n=398 (31.7%)	p-value*
Demographic				
Age (yrs.)[a]	66.9 (9.7)	65.0 (9.0)	70.9 (10.0)	**<.0001**
Race/Ethnicity [b]				**0.003**
Non-Hispanic White [b]	59.6	57.3	64.6	
African-American [b]	27.7	30.8	20.9	
Hispanic [b]	11.1	10.3	12.8	
Other [b]	1.7	1.6	1.8	
Education [b]				**0.001**
Less than High School [b]	8.1	6.4	11.6	
High School Graduate/GED [b]	15.7	14.4	18.6	
Post High School [b]	35.5	37.3	31.4	
College Degree [b]	40.8	41.9	38.4	
Lives with Others [b]	75.8	77.9	71.4	**0.012**
Behavioral Risk Factors				
Smoking (pack-yrs.) [§]	3.8 (0, 23)	3.8 (0, 22.5)	3.8 (0.24)	0.92
Alcohol (drinks/typical week) [§]	1.0 (0, 2)	1.0 (0, 2)	1.0 (0,2)	**0.0001**
Systolic Blood Pressure				0.34
< 140 mmHg [b]	55.4	56.1	53.9	
140 – 160 mmHg [b]	36.8	36.9	36.8	
>160 mmHg [b]	7.7	7.0	9.3	
Antihypertension Medications				
Use of Beta-Blockers [b]	31.1	30.6	32.2	0.57
Use of Diuretics [b]	42.2	41.8	43.2	0.63
Use of Calcium Channel Blockers [b]	35.0	34.4	36.2	0.54
Use of Angiotensin Converting Enzyme Inhibitors [b]	40.6	40.0	42.0	0.52
Use of Angiotensin Receptor Blockers [b]	17.2	17.5	16.6	0.69
Total Number of Antihypertensive Medications [a]	1.8 (1.0)	1.8 (1.0)	1.9 (1.0)	0.22
Cardiometabolic and Psychosocial Variables				
Glucose (mg/dL) [a]	99.4 (12.5)	99.7 (12.6)	98.9 (12.4)	0.33
Diastolic Blood Pressure (mmHg)[a]	78.8 (11.8)	79.9 (11.6)	76.3 (11.6)	**<.0001**

Characteristic	Overall n=1255	Sexually Active n=857 (68.3%)	Not Sexually Active n=398 (31.7%)	p-value*
Pulse Pressure (mmHg)[a, c]	60.2 (13.5)	58.7 (13.2)	63.5 (13.5)	**<.0001**
Total Cholesterol (mg/dL) [a]	182.2 (40.4)	183.8 (39.1)	178.8 (42.7)	**0.04**
Any Anti-Cholesterol Medication [b]	54.3	51.6	60.1	**0.005**
Any Antidepressant Medication [b]	11.2	11.5	10.8	0.74
Phosphodiesterase Type 5 Inhibitors [b]	10.5	13.4	4.3	**<.0001**
BMI (kg/m^2) [a]	29.9 (5.5)	30.2 (5.6)	29.3 (5.2)	**0.007**
eGFR (mL/min/1.73 m^2) [a]	74.1 (20.6)	75.9 (19.9)	70.3 (21.5)	**<.0001**
Chronic Kidney Disease (eGFR <60 mL/min/1.73m^2) [a]		19.9	34.3	**<.0001**
CVD Family History [b]	24.9	25.5	23.4	0.44
MoCA Total Score (range 0 to 30) [a, d]	23.1 (3.6)	23.3 (3.6)	22.6 (3.7)	**0.0008**
PHQ-9 Total Score (range 0 to 27) [§, e]	2.0 (0, 4)	2.0 (0, 5)	1.0 (0, 4)	**0.011**
Number of Physical Comorbidities (range 0 to 32)[a, e]	4.3 (2.7)	4.0 (2.5)	5.1 (3.0)	**<.0001**

Significant values (p<0.05) are presented in **bold**

[a]Data presented as mean(standard deviation)

[§]Data presented as median (25th percentile,75th percentile)

[b]Data presented as %

[c]defined as (systolic blood pressure in mmHg – diastolic blood pressure in mmHg)

[d]Higher scores indicate better function

[e]Higher scores indicate poorer function

*p-value from Chi Square test for categorical variables ([b]), Student's t-test for continuous variables with normal distributions ([a]), and Kruskal-Wallis test for variables with distributions with high skewness or kurtosis (§)

Table 3.

Baseline Characteristics of Sexually Active Participants According to Systolic Blood Pressure Status

Characteristic	Overall n=857	SBP<140 mmHg n=481	SBP 140-160 mmHg n=316	SBP>160 mmHg n=60	p-value
IIEF-5 Score [a]	18.0 (5.8)	18.1 (5.7)	17.9 (5.9)	17.1 (6.4)	0.32
Erectile dysfunction (IIEF-5I score ≤21) [b]	59.9	60.6	58.9	59.7	0.90
Demographic					
Age (yrs)[a]	65.0 (9.0)	64.6 (8.7)	65.6 (9.3)	65.7 (9.5)	0.12
Race/Ethnicity					0.52
Non-Hispanic White [b]	57.3	56.1	58.2	61.7	
African-American [b]	30.8	30.8	30.7	31.7	
Hispanic [b]	10.3	11.4	9.8	3.3	
Other [b]	1.6	1.7	1.3	3.3	
Education					0.22
Less than High School [b]	6.4	6.2	6.6	6.7	
High School Graduate/GED [b]	14.4	12.1	16.1	23.3	
Post High School [b]	37.3	38.1	38.0	28.3	
College Degree [b]	41.9	43.7	39.2	41.7	
Lives with Others [b]	77.9	79.4	76.3	75.0	0.50
Behavioral Risk Factors					
Smoking (pack-yrs) [§]	3.8 (0 to 22.5)	3.5 (0, 21)	4.3 (0, 23.4)	5.7 (0, 24.3)	0.80
Alcohol (drinks/typical week) [§]	1.0 (0, 2)	1.0 (0, 2)	1.0 (0, 2)	1.0 (0, 2)	0.78
Antihypertension Medications					
Use of Beta-Blockers [b]	30.6	28.7	31.3	41.7	0.12
Use of Diuretics [b]	41.8	43.5	40.8	33.3	0.30
Use of Calcium Channel Blockers [b]	34.4	33.1	37.7	28.3	0.24
Use of Angiotensin Converting Enzyme inhibitors [b]	40.0	41.0	38.6	40.0	0.80
Use of Angiotensin Receptor Blockers[b]	17.5	18.5	17.4	10.0	0.26
Total Number of Antihypertensive Medications [a]	1.8 (1.0)	1.8 (1.0)	1.8 (1.0)	1.7 (1.2)	0.87
Cardiometabolic and Psychosocial Variables					
Diastolic Blood Pressure (mmHg)	79.9 (11.6)	75.7 (9.8)	84.2 (10.8)	91.5 (13.4)	**<.0001**
Pulse pressure (mmHg)[c]	58.7 (13.2)	52.8 (10.1)	63.8 (10.7)	78.7 (16.3)	**<.0001**
Glucose (mg/dL)[a]	99.7 (12.6)	99.5 (13.1)	99.2 (11.2)	103.1 (14.7)	0.23
Total Cholesterol (mg/dL)[a]	183.8 (39.1)	179.9 (38.2)	187.9 (38.8)	193.9 (44.9)	**0.0005**
Any Anti-cholesterol Medication [b]	51.6	55.1	47.9	43.3	0.06

Characteristic	Overall n=857	SBP<140 mmHg n=481	SBP 140-160 mmHg n=316	SBP>160 mmHg n=60	p-value
Any Antidepressant Medication [b]	11.5	12.7	10.8	5.0	0.19
Phosphodiesterase Type 5 Inhibitors [b]	13.4	16.2	10.1	8.3	**0.02**
BMI (kg/m^2) [a]	30.2 (5.6)	30.4 (5.7)	30.4 (5.5)	28.3 (4.5)	0.07
eGFR (mL/min/1.73 m^2) [a]	75.9 (19.9)	75.6 (20.2)	76.1 (20)	77.1 (16.9)	0.57
Chronic Kidney Disease (eGFR <60 mL/min/1.73m^2) [b]	19.9	21.3	18.7	15.0	0.42
CVD Family History [b]	25.5	26.5	22.0	35.7	0.08
MoCA Total Score (range 0 to 30) [a, d]	23.3 (3.6)	23.4 (3.7)	23.3 (3.3)	23.2 (3.8)	0.69
PHQ-9 Total Score (range 0 to 27) [§, e]	1.0 (0, 4)	2.0 (0, 4)	1.0 (0, 3)	1.0 (0, 3.5)	0.12
Number of Physical Comorbidities (range 0 to 32) [a,e]	4.0 (2.5)	4.1 (2.5)	3.9 (2.5)	3.9 (2.5)	0.32

Significant values (p<0.05) are presented in **bold**

[a]Data presented as mean(standard deviation)

[§]Data presented as median (25th percentile,75th percentile)

[b]Data presented as %

[c]defined as (systolic blood pressure in mmHg – diastolic blood pressure in mmHg)

[d]Higher scores indicate better function

[e]Higher scores indicate poorer function

[*]p-value from Chi Square test for categorical variables ([b]), Student's t-test for continuous variables with normal distributions ([a]), and Kruskal-Wallis test for variables with distributions with high skewness or kurtosis (§)

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Table 4.

Results of Cross-Sectional Unadjusted and Adjusted Logistic Regression Analyses Examining Associations between Blood Pressure and Sexual Activity

	Unadjusted Model n=1254		Adjusted Model n=1198	
Characteristic	**Odds Ratio (95% CI)**	**P value**	**Odds Ratio (95% CI)**	**P value**
Unadjusted Model				
Systolic Blood Pressure (per 5 mmHg increase)	**0.98 (0.97,0.99)**	**<.0001**	0.998 (0.99, 1.01)	0.70
Diastolic Blood Pressure (per 5 mmHg increase)	**1.04 (1.03, 1.05)**	**<.0001**	1.001 (0.98, 1.02)	0.92
Demographic Variables				
Age (yrs).	---	---	**0.9494 (0.93, 0.96)**	**<.0001**
African-American vs. White	---	---	1.34 (0.91, 1.96)	0.14
Hispanic vs. White			0.70 (0.45, 1.11)	0.13
Other vs. White	---	---	1.07 (0.35, 3.23)	0.91
< High school vs. College Graduate	---	---	**0.56 (0.33, 0.98)**	**0.043**
High School graduate/GED vs. College Graduate	---	---	**0.64 (0.43, 0.96)**	**0.031**
Post High School vs. College Graduate	---	---	1.01 (0.73, 1.40)	0.95
Lives with Others vs. Lives Alone	---	---	**1.57 (1.16, 2.13)**	**0.004**
Behavioral Risk Factor and Medication Use Variables				
Pack-years of Smoking	---	---	1.00 (0.99, 1.01)	0.57
Alcohol Consumption (drinks/typical wk)	---	---	1.06 (0.97, 1.20)	0.20
Beta-blockers (BB) vs. no BB	---	---	1.17 (0.86, 1.58)	0.32
Diuretics vs. No Diuretics	---	---	0.81 (0.61, 1.06)	0.13
Calcium Channel Blockers vs.no Calcium Channel Blockers	---	---	0.96 (0.72, 1.27)	0.78
Angiotensin Receptor Blockers (ARB) vs. no ARB	---	---	1.16 (0.86, 1.55)	0.33
Angiotensin Converting Enzyme (ACE) Inhibitors vs. no ACE			1.13 (0.77, 1.65)	0.53
Any Cholesterol Medication	---	---	1.00 (0.75, 1.34)	0.98
Any Phosphodiesterase Type 5 Inhibitors	---	---	**3.70 (2.11, 6.48)**	**<.0001**
Cardiometabolic and Psychosocial Variables				
BMI (kg/m^2)	---	---	1.00 (0.98, 1.03)	0.76
eGFR ($mL/min/1.73\ m^2$)	---	---	1.00 (0.99, 1.01)	0.54
MoCA Total Score [a]	---	---	1.03 (0.99, 1.08)	0.15

	Unadjusted Model n=1254		Adjusted Model n=1198	
Characteristic	**Odds Ratio (95% CI)**	**P value**	**Odds Ratio (95% CI)**	**P value**
PHQ-9 Total Score [b]	---	---	**0.96 (0.93, 1.00)**	**0.027**
Number of Physical Comorbidities [b]	---	---	**0.93 (0.88, 0.99)**	**0.015**

--- variable not included in model

significant ($p<0.05$) Adjusted Odds Ratios and 95% Confidence Intervals presented in **bold**

[a] Higher scores indicate better function

[b] Higher scores indicate poorer function

Table 5.

Results of Cross-Sectional Simple and Multiple Linear Regression Analyses Examining Associations between Blood Pressure and 5-Item International Index of Erectile Function (IIEF-5) Scores[§]

	Unadjusted Model n=825		Adjusted Model n=789	
Characteristic	**Beta for IIEF-5 score (95% CI)**	**P value**	**Beta for IIEF-5 score (95% CI)**	**P value**
Unadjusted Model				
Systolic Blood Pressure (per 5 mmHg increase)	**− 0.07 (− 0.10, − 0.04)**	**<.0001**	**−0.04 (−0.07, −0.01)**	**0.025**
Diastolic Blood Pressure (per 5 mmHg increase)	**0.13 (0.09, 0.17)**	**<.0001**	**0.05 (0.01, 0.10)**	**0.029**
Demographic Variables				
Age (yrs).	---	---	**−0.18 (−0.24, −0.12)**	**<.0001**
African-American vs. White	---	---	0.22 (−0.81, 1.26)	0.67
Hispanic vs. White			−0.10 (−1.45, 1.24)	0.88
Other vs. White	---	---	0.70 (−2.3, 3.70)	0.65
< High school vs. College Graduate	---	---	−0.90 (−2.65, 0.85)	0.31
High School graduate/GED vs. College Graduate	---	---	−1.24 (−2.49, 0.01)	0.052
Post High School vs. College Graduate	---	---	−0.73 (−1.63, 0.16)	0.11
Lives with Others vs. Lives Alone	---	---	−0.07 (−1.00, 0.85)	0.88
Behavioral Risk Factor and Medication Use Variables				
Pack-years of Smoking	---	---	−0.01 (−0.03, 0.01)	0.45
Alcohol Consumption (drinks/typical wk)	---	---	−0.03 (−0.26, 0.20)	0.83
Beta-blockers (BB) vs. no BB	---	---	−0.18 (−1.04, 0.68)	0.68
Diuretics vs. No Diuretics	---	---	0.18 (−0.6, 0.96)	0.64
Calcium Channel Blockers vs.no Calcium Channel Blockers	---	---	0.55 (−0.25, 1.35)	0.18
Angiotensin Converting Enzyme (ACE) Inhibitors vs. no ACE	---	---	−0.52 (−1.36, 0.33)	0.23
Angiotensin Receptor Blockers (ARB) vs. no ARB	---	---	0.11 (−0.98, 1.20)	0.85
Any Cholesterol Medication	---	---	0.15 (−0.66,0.95)	0.72
Any Phosphodiesterase type 5 Inhibitors	---	---	−0.28 (−1.37, 0.81)	0.62
Cardiometabolic and Psychosocial Variables				
BMI (kg/m^2)	---	---	**−0.08 (−0.15, −0.01)**	**0.032**
eGFR (mL/min/1.73 m^2)	---	---	−0.004 (−0.03, 0.02)	0.68

	Unadjusted Model n=825		Adjusted Model n=789	
Characteristic	**Beta for IIEF-5 score (95% CI)**	**P value**	**Beta for IIEF-5 score (95% CI)**	**P value**
MoCA Total Score [a]	---	---	0.11 (−0.01,0.23)	0.08
PHQ-9 Total Score [b]	---	---	**−0.29 (−0.39, −0.19)**	**<.0001**
Number of Physical Comorbidities [b]	---	---	**−0.21 (−0.38, −0.03)**	**0.020**

[§] defined as International Index of Erectile Function Total Score; higher scores indicate better function

[a] Higher scores indicate better function

[b] Higher scores indicate poorer function

significant ($p<0.05$) Beta estimates and 95% Confidence Intervals presented in **bold**

--- variable not included in model

Table 6.

Results of Cross-Sectional Unadjusted and Adjusted Logistic Regression Analyses Examining Associations between Blood Pressure and Erectile Dysfunction [§]

	Unadjusted Model n=825		Adjusted Model n=789	
Characteristic	**Odds Ratio (95% CI)**	**P value**	**Odds Ratio (95% CI)**	**P value**
Unadjusted Model				
Systolic Blood Pressure (per 5 mmHg increase)	**1.015 (1.00, 1.03)**	**0.0109**	1.005 (0.99, 1.02)	0.46
Diastolic Blood Pressure (per 5 mmHg increase)	**0.96 (0.95, 0.98)**	**<.0001**	**0.98 (0.96, 1.00)**	**0.045**
Demographic Variables				
Age (yrs).	---	---	**1.055 (1.03, 1.08)**	**<.0001**
African-American vs. White	---	---	1.01 (0.66, 1.55)	0.97
Hispanic vs. White			1.10 (0.63, 1.90)	0.75
Other vs. White	---	---	0.68 (0.21,2.23)	0.52
< High school vs. College Graduate	---	---	2.14 (0.99, 4.66)	0.055
High School graduate/GED vs. College Graduate	---	---	**1.97 (1.15, 3.39)**	**0.014**
Post High School vs. College Graduate	---	---	1.25 (0.87, 1.81)	0.23
Lives with Others vs. Lives Alone	---	---	1.004 (0.69, 1.47)	0.99
Behavioral Risk Factor and Medication Use Variables				
Pack-years of Smoking	---	---	1.00 (0.99, 1.01)	0.40
Alcohol Consumption (drinks/typical wk)	---	---	1.01 (0.92, 1.11)	0.76
Beta-blockers (BB) vs. no BB	---	---	0.97 (0.68, 1.39)	0.88
Diuretics vs. No Diuretics	---	---	0.93 (0.68, 1.29)	0.67
Calcium Channel Blockers vs.no Calcium Channel Blockers	---	---	1.03 (0.74, 1.44)	0.84
Angiotensin Converting Enzyme (ACE) inhibitors vs. no ACE			1.27 (0.90, 1.81)	0.18
Angiotensin Receptor Blockers (ARB) vs. no ARB	---	---	0.97 (0.63, 1.52)	0.91
Any Cholesterol Medication	---	---	0.84 (0.60, 1.18)	0.31
Any Phosphodiesterase type 5 Inhibitors	---	---	0.95 (0.60, 1.50)	0.82
Cardiometabolic and Psychosocial Variables				
BMI (kg/m^2)	---	---	1.01 (0.99, 1.05)	0.31
eGFR ($mL/min/1.73\ m^2$)	---	---	1.00 (0.99, 1.01)	0.59

	Unadjusted Model n=825		Adjusted Model n=789	
Characteristic	**Odds Ratio (95% CI)**	**P value**	**Odds Ratio (95% CI)**	**P value**
MoCA Total Score [a]	---	---	**0.95 (0.90, 1.00)**	**0.037**
PHQ-9 Total Score [b]	---	---	**1.10 (1.05, 1.16)**	**<.0001**
Number of Physical Comorbidities [b]	---	---	1.07 (0.99. 1.16)	0.08

[§] defined as International Index of Erectile Function score ≥21 --- variable not included in model

[a] Higher scores indicate better function

[b] Higher scores indicate poorer function

significant ($p<0.05$) Adjusted Odds Ratios and 95% Confidence Intervals presented in **bold**