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# Sex differences in ambulatory blood pressure among patients referred for 24-hour monitoring

## A retrospective cross-sectional study

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**Abstract**

Few studies have addressed the differences between hypertensive women and men regarding the diagnosis and control of blood pressure (BP). Accordingly, we aimed to assess the possible discrepancies in BP values between women and men who underwent 24-hour ambulatory blood pressure monitoring. The study population comprised all patients who underwent 24-hour ambulatory blood pressure monitoring, which was retrospectively screened and recorded. Demographic and clinical characteristics of 1204 patients were included in the analysis. Sex-specific analyses of all patients, including those with and without a former diagnosis of hypertension (HT), were performed. Two-thirds of the patients were women. In the general population, both systolic and diastolic BP levels in women were significantly lower than those in men. BP in women was also significantly lower than that in men, both in patients with and without a former diagnosis of HT. Our study demonstrated that women exhibited significantly lower systolic and diastolic BP values than men in this referral cohort, irrespective of a prior diagnosis of HT. While the exact mechanisms remain to be elucidated, this difference highlights the necessity for further research into sex-specific hemodynamic profiles. Consequently, further research is necessary to establish diagnostic thresholds and BP targets to achieve effective and targeted management of BP abnormalities in women.

**Abbreviations:** ABPM = ambulatory blood pressure monitoring, BP = blood pressure, DBP = diastolic blood pressure, DM = diabetes mellitus, HT = hypertension, SBP = systolic blood pressure.

**Keywords:** blood pressure, hypertension, men, sex, women

## 1. Introduction

Hypertension (HT) is one of the most devastating diseases, along with its cardiovascular risk factors, namely, diabetes mellitus (DM), hyperlipidemia, smoking, age, and sex.[1] Due to its profound effect on cardiovascular morbidity and mortality through the atherosclerotic process and HT-mediated organ damage, blood pressure (BP) control is of paramount importance in the field of cardiology. Therefore, every aspect of HT, including diagnosis and treatment in association with comorbid conditions of DM, chronic kidney disease, heart failure, and coronary artery disease, has been well defined in a comprehensive approach focusing on every detail by the guidelines of major societies.[2,3] However, these recommendations have been made irrespective of sex. Recently, a limited number of studies have begun to address the presence of differences between women and men hypertensive patients regarding the diagnosis and control of BP.[4–8] Accordingly, we aimed to assess the possible discrepancies in BP values between women and men who underwent 24-hour ambulatory blood pressure monitoring (ABPM).

## 2. Materials and methods

### 2.1. Study population and patient selection protocol

The study population comprised all patients who underwent 24-hour ABPM at Türkiye Hospital between February 2021 and August 2023. All patients' clinical and demographic data

*The authors have no funding and conflicts of interest to declare.*

*The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.*

*The study protocol was reviewed and approved by the Institutional Ethics Committee of Alanya Alaaddin Keykubat University (approval number: 2025-42). This retrospective study was conducted in strict adherence to the ethical principles set forth in the Declaration of Helsinki. Given the retrospective design and anonymous handling of clinical data, the requirement for written informed consent was waived by the ethics committee.*

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and 24-hour ABPM results were screened and recorded retrospectively. A flowchart of the study is presented in Figure 1. Patients with insufficient measurements (<70% of planned), atrial fibrillation, hypertrophic cardiomyopathy, systolic heart failure (ejection fraction < 50%), severe valvular heart diseases, chronic kidney disease, hepatic failure, anemia, and malignancies were excluded from the study. The study protocol was reviewed and approved by the Institutional Ethics Committee of Alanya Alaaddin Keykubat University (approval number: 2025-42), and it was conducted in strict adherence to the ethical principles of the Declaration of Helsinki.

### 2.2. ABPM monitoring instrumentation and data processing

Twenty-four-hour ABPM recordings were performed using validated automatic oscillometric devices (Contec PM50, Contec Medical Systems and Tonoport V, GE Healthcare). Both devices had been recently calibrated in accordance with the manufacturers' specifications, and the data were analyzed using their respective proprietary software. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) measurements were also averaged for the day and night spans according to the patients' reported time of waking up and going to bed. The participants were instructed to continue their daily life and keep their arm at heart level when measuring BP. Readings were obtained at 30-minute intervals during the day (typically 7 AM–11 PM) and 60-minute intervals at night (according to the patients' reported time of waking up and going to bed).

The main indications for ABPM were to assess the presence of white coat HT, masked HT, and symptoms suggestive of BP abnormalities and uncontrolled BP.

### 2.3. Clinical definitions and risk factor stratification

Among the cardiovascular risk factors, DM was defined as a fasting blood glucose level ≥126 mg/dL or antidiabetic treatment, hyperlipidemia as a plasma concentration of low-density lipoprotein cholesterol ≥130 mg/dL, and current smokers as those who smoked at least 7 cigarettes per week for at least 6 months.[9–11] HT was defined as BP values >129/79 mm Hg documented by ABPM or antihypertensive treatment.[1]

### 2.4. Statistical analysis

All statistical analyses were performed using SPSS version 16.0 software (SPSS, Inc.). Continuous variables are expressed as mean ± standard deviation, and categorical variables are expressed as counts and percentages. Continuous variables were compared using paired and unpaired *t* tests, and categorical variables were compared using the chi-squared test. Statistical significance was considered as a *P* value < .05. Data visualization and graphical representations were generated using Python programming language and the Matplotlib library.

## 3. Results

### 3.1. Screening outcomes and clinical cohort stratification

Between February 2021 and August 2023, 2004 patients underwent diagnostic evaluation of ABPM in a cardiology outpatient clinic. After excluding 800 patients, 1204 patients who met the inclusion criteria comprised the study population. Of these 1204 patients, 654 had already been diagnosed with HT and were receiving antihypertensive medications; these patients were classified as group I. Patients who did not have a previous diagnosis of HT were classified as group II.

### 3.2. Demographic profiles and baseline risk characteristics

Men comprised 31% (374) of all patients, and 830 patients (69%) were women (Table 1 and Fig. 2). There were no statistically significant differences between women and men regarding DM, hyperlipidemia, HT, and smoking status (Table 2). Women were slightly younger than their men counterparts (58 ± 15 years vs 59 ± 15 years, respectively, *P* = .04). The ABPM measurements of women and men are presented in Table 2. The

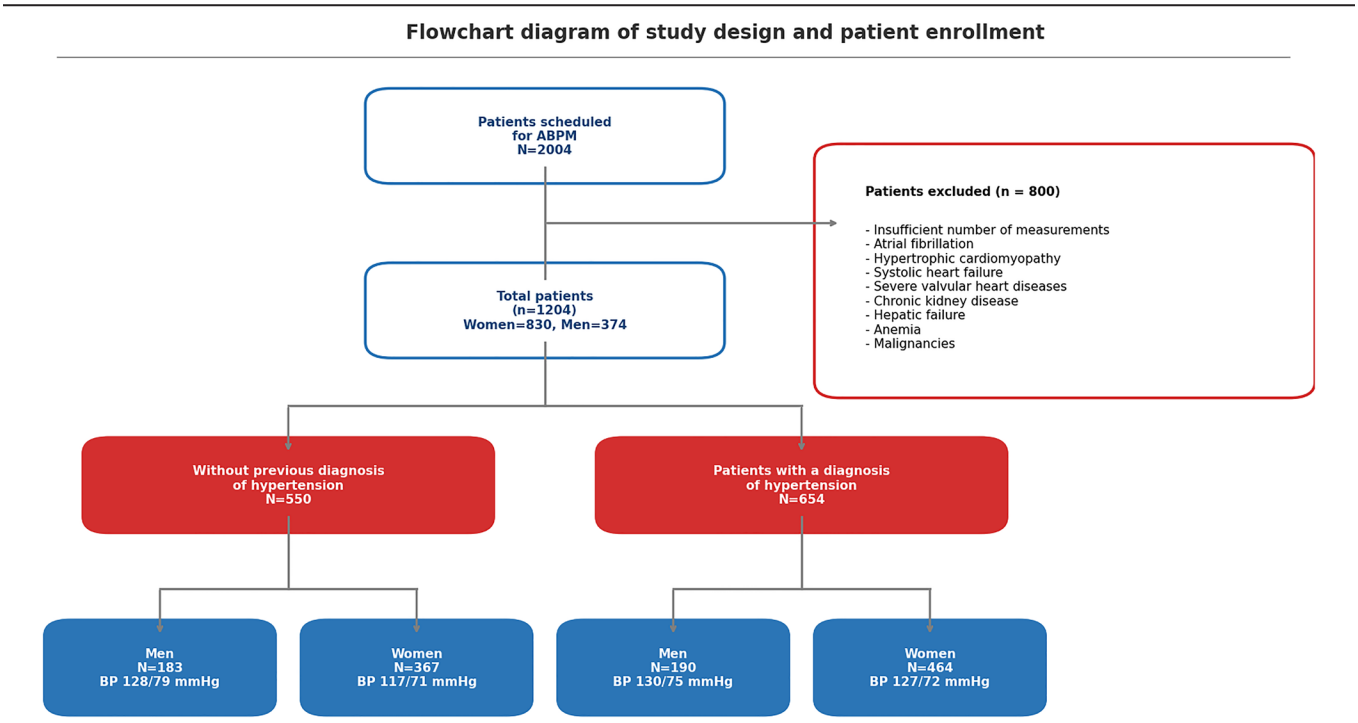


**Figure 1.** Flowchart diagram of study design and patient enrollment. ABPM = ambulatory blood pressure monitoring, BP = blood pressure.

**Table 1**

**Clinic and demographic characteristics of women and men.**

| | | Women | Men | |
|---|---|---|---|---|
| | n = 1204 | n = 830 (69%) | n = 374 (31%) | *P* value |
| Age (yr) | 58 ± 15 | 58 ± 15 | 59 ± 15 | .04 |
| Former diagnosis of hypertension | 654/1204 | 464 (56%) | 190 (51%) | .35 |
| New diagnosis of hypertension | 321/550 | 211 (26%) | 110 (29%) | .16 |
| Diabetes mellitus | 416 | 300 (36%) | 116 (31%) | .06 |
| Hyperlipidemia | 137 | 100 (12%) | 37 (10%) | .37 |
| Smoking | 284 | 188 (22%) | 96 (26%) | .27 |

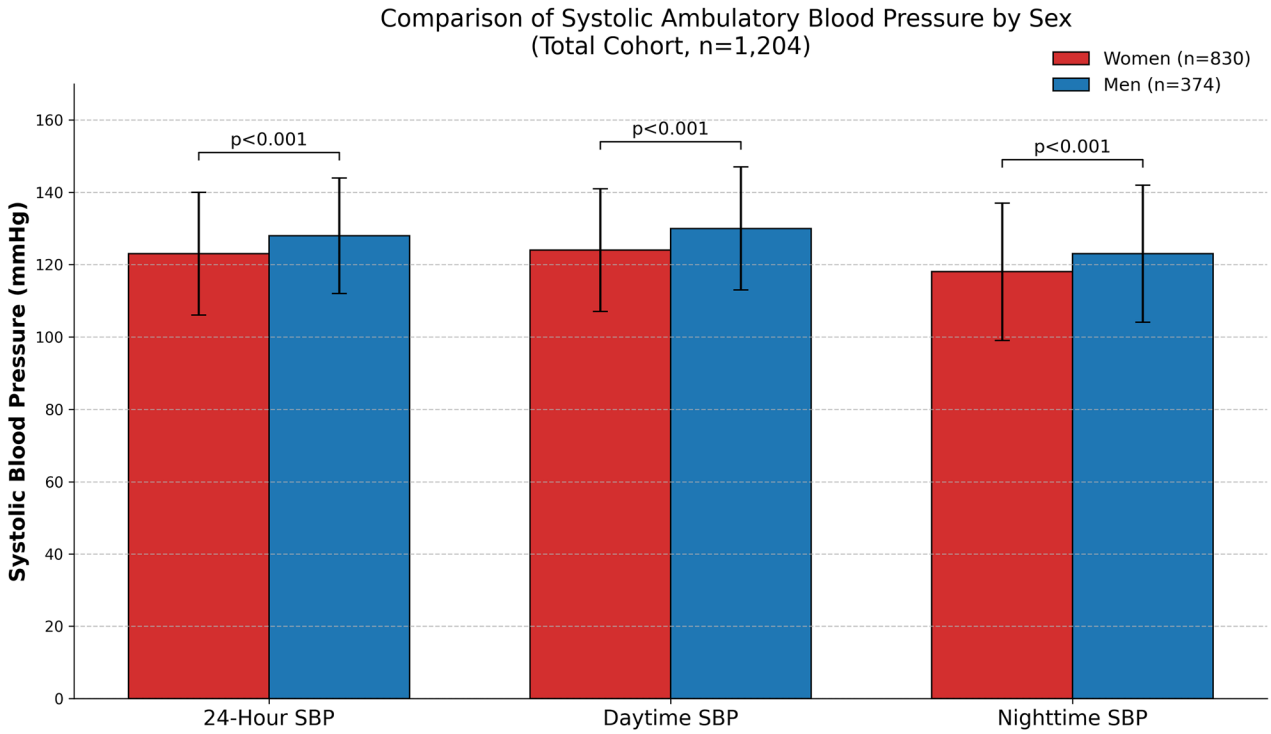


**Figure 2.** Comparison of systolic ambulatory blood pressure by sex (total cohort, n = 1204). SBP = systolic blood pressure.

**Table 2**

**Blood pressure measurement comparison of women and men.**

| | | Women* | Men | |
|---|---|---|---|---|
| | n = 1204 | n = 830 (69%) | n = 374 (31%) | *P* value |
| SBP 24 h (mm Hg) | 124 ± 17 | 123 ± 17 | 128 ± 16 | <.001 |
| DBP 24 h (mm Hg) | 73 ± 11 | 72 ± 10 | 77 ± 13 | <.001 |
| Heart rate 24 h (bpm) | 76 ± 15 | 76 ± 10 | 76 ± 24 | .88 |
| Pulse pressure 24 h (mm Hg) | 51 ± 12 | 51 ± 12 | 52 ± 12 | .03 |
| SBP daytime (mm Hg) | 126 ± 17 | 124 ± 17 | 130 ± 17 | <.001 |
| DBP daytime (mm Hg) | 75 ± 11 | 74 ± 10 | 79 ± 13 | <.001 |
| Heart rate daytime (bpm) | 78 ± 7 | 79 ± 10 | 77 ± 10 | .02 |
| Pulse pressure daytime (mm Hg) | 51 ± 12 | 51 ± 12 | 52 ± 12 | .04 |
| SBP nighttime (mm Hg) | 119 ± 19 | 118 ± 19 | 123 ± 19 | <.001 |
| DBP nighttime (mm Hg) | 68 ± 12 | 67 ± 11 | 72 ± 13 | <.001 |
| Heart rate nighttime (bpm) | 69 ± 9 | 69 ± 9 | 67 ± 9 | .001 |
| Pulse pressure nighttime (mm Hg) | 51 ± 13 | 50 ± 13 | 52 ± 13 | .13 |

DBP = diastolic blood pressure, SBP = systolic blood pressure.

*Versus men.

sex ratio remained almost the same when the entire study population was divided into groups I and II with respect to the former diagnosis of HT (group I: 464 women [71%] and 190 men [29%]) or not (group II: 367 women [67%] and 183 men [33%]).

### *3.3. Sex-specific variances in ambulatory hemodynamic parameters*

Twenty-four-hour ABPM revealed that both SBP and DBP in women were significantly lower than those in men in terms of the mean 24-hour measurements and both nighttime and daytime spans (Table 2). A comparison of the demographic and clinical characteristics of women and men in groups I and II is presented in Table 3. There were statistically significant differences between women and men with respect to ABPM measures in group I (already diagnosed with HT) and group II (without a previous diagnosis of HT; Table 4). The SBP and DBP of women were significantly lower than those of their men counterparts in group II patients who had no previous diagnosis of HT (ABPM 24-hour SBP: 117 ± 17 mm Hg vs 128 ± 17 mm Hg, $P < .001$; 24-hour DBP: 71 ± 10 mm Hg vs 79 ± 12 mm Hg, $P < .001$, respectively; represented in Fig. 3 and Table 4). Similar significant differences were also observed between women and men in daytime and nighttime ABPM measurements (daytime SBP: 119 ± 15 mm Hg vs 129 ± 19 mm Hg, $P < .01$; daytime DBP: 73 ± 10 mm Hg vs 81 ± 13 mm Hg, $P < .01$; Table 4 and Fig. 3). Similar significant differences were also observed between women and men in daytime and nighttime ABPM measurements (nighttime SBP: 112 ± 18 mm Hg vs 121 ± 18 mm Hg, $P < .001$; nighttime DBP: 67 ± 12 mm Hg vs 73 ± 13 mm Hg, $P < .01$, represented in Table 4 and Fig. 3). Significant but less profound differences were documented in group I patients who had already been diagnosed with HT (ABPM 24-hour SBP: 127 ± 17 mm Hg vs 130 ± 15 mm Hg, $P = .01$; 24-hour DBP: 72 ± 10 mm Hg vs 75 ± 12 mm Hg, $P = .03$, respectively, as shown in Table 4 and Fig. 4).

## 4. Discussion

There are several main observations that can be derived from our study population who underwent ABPM assessment. First, two-thirds of the study population were women. This ratio was preserved in patients with and without a previous diagnosis of HT. This predominance of women among patients referred for ABPM has also been reported by Banegas et al in primary care settings.[4] Another key finding of our study population was that women had significantly lower SBP and DBP values in both the general population and those with a previous diagnosis of HT. However, these differences were more prominent in patients without a previous diagnosis of HT.

These findings indicate that women referred for ABPM present with lower BP levels than men. While the exact mechanisms remain to be elucidated, this difference highlights the necessity for further research into sex-specific hemodynamic profiles. This is not the first publication reporting such a difference. Indeed, it has been previously reported that women have lower BP levels than men in adulthood and in a healthy state,[5] while the definition of "healthy state" needs to be reappraised. SBP at the age of 18 in men has been reported to be 10 mm Hg higher than in women.[6] The issue is whether a lower range of BP might be considered normal for women versus men regarding the diagnosis of HT. Sex-specific evidence regarding cardiovascular risk assessment has been sparsely reported in the literature. Likewise, it has been reported that BP in adult women is lower than that in men in a healthy state.[7] In addition, cardiovascular risk increases at early threshold levels of BP in women compared to that in men. Interestingly, in the multivariate adjusted model, an SBP of 100 to 109 mm Hg was associated with incident cardiovascular diseases in women, in contrast to men, in whom such an association was seen with SBP of 130 to 139 mm

**Table 3**

**Comparison of women and men demographic and clinic parameters in group I and group II patients.**

| | Group I (n = 654) | | | Group II (n = 550) | | |
|---|---|---|---|---|---|---|
| | Women (n = 464, 71%) | Men (n = 190, 29%) | *P* value | Women (n = 367, 67%) | Men (n = 183, 33%) | *P* value |
| Age (yr) | 65 ± 12 | 64 ± 12 | .14 | 49 ± 13 | 49 ± 13 | .51 |
| Diabetes mellitus | 233 (52%) | 86 (52%) | .94 | 59 (16%) | 14 (8%) | .01 |
| Hyperlipidemia | 75 (16%) | 34 (18%) | .62 | 23 (6.3%) | 4 (2.2%) | .037 |
| Smoking | 72 (15%) | 41 (21%) | .07 | 116 (32%) | 55 (30%) | .66 |

**Table 4**

**Comparison of ABPM parameters between women and men in group I and group II patients.**

| | Group I (n = 654) | | | Group II (n = 550) | | |
|---|---|---|---|---|---|---|
| | Women (n = 464, 71%) | Men (n = 190, 29%) | *P* value | Women (n = 367, 67%) | Men (n = 183, 33%) | *P* value |
| SBP 24 h (mm Hg) | 127 ± 17 | 130 ± 15 | .01 | 117 ± 17 | 128 ± 17 | <.001 |
| DBP 24 h (mm Hg) | 72 ± 10 | 75 ± 12 | .03 | 71 ± 10 | 79 ± 12 | <.001 |
| Heart rate 24 h (bpm) | 76 ± 10 | 76 ± 32 | .94 | 77 ± 9 | 76 ± 9 | .51 |
| Pulse pressure 24 h (mm Hg) | 54 ± 13 | 56 ± 12 | .16 | 46 ± 9 | 49 ± 10 | .05 |
| SBP day (mm Hg) | 129 ± 17 | 132 ± 15 | .03 | 119 ± 15 | 129 ± 19 | <.01 |
| DBP day (mm Hg) | 74 ± 10 | 76 ± 13 | .08 | 73 ± 10 | 81 ± 13 | <.01 |
| Heart rate day (bpm) | 78 ± 10 | 75 ± 9 | .004 | 80 ± 9 | 79 ± 10 | .55 |
| Pulse pressure day (mm Hg) | 54 ± 13 | 56 ± 12 | .15 | 46 ± 9 | 48 ± 10 | .01 |
| SBP night (mm Hg) | 122 ± 19 | 125 ± 20 | .09 | 112 ± 18 | 121 ± 18 | <.001 |
| DBP night (mm Hg) | 68 ± 11 | 70 ± 12 | .007 | 67 ± 12 | 73 ± 13 | <.01 |
| Heart rate night (bpm) | 69 ± 10 | 67 ± 9 | .006 | 69 ± 9 | 68 ± 9 | .07 |
| Pulse pressure night (mm Hg) | 54 ± 15 | 56 ± 15 | .12 | 46 ± 10 | 47 ± 10 | .2 |

ABPM = ambulatory blood pressure monitoring, DBP = diastolic blood pressure, SBP = systolic blood pressure.

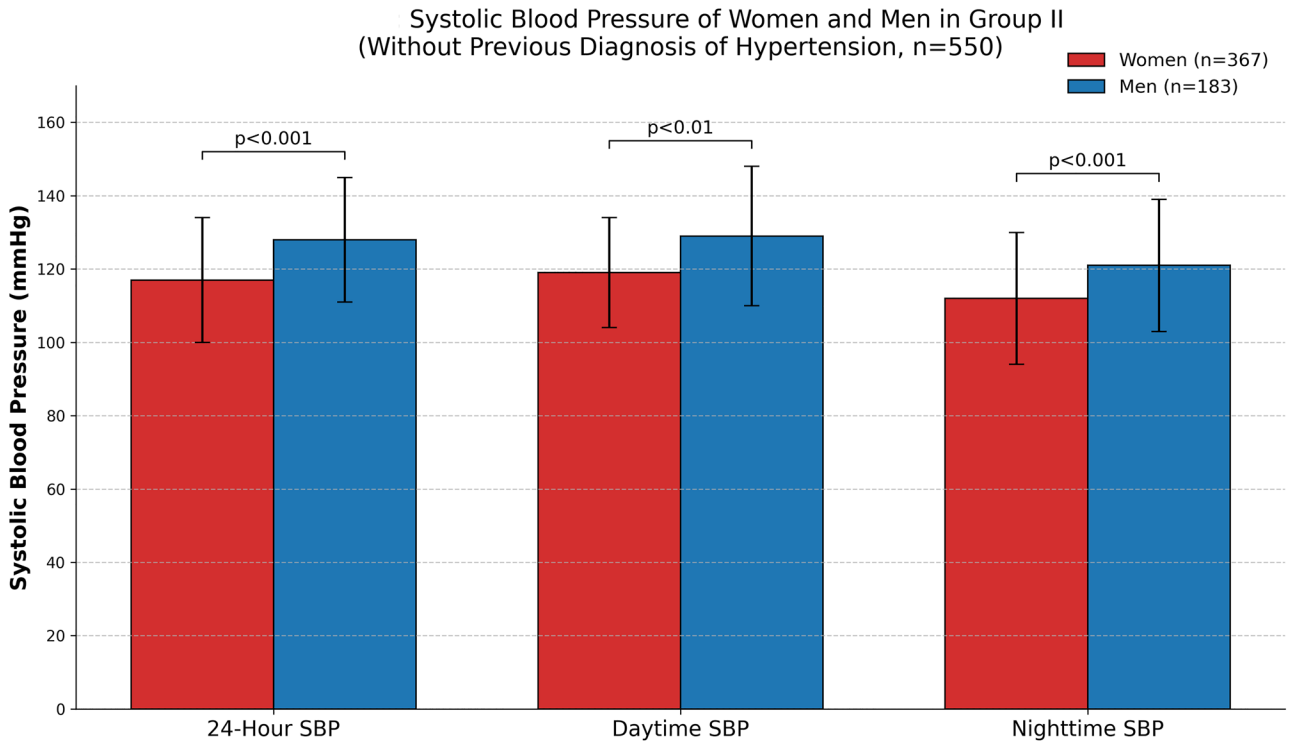


**Figure 3.** Systolic blood pressure of women and men in group II (without previous diagnosis of hypertension, n = 550). SBP = systolic blood pressure.

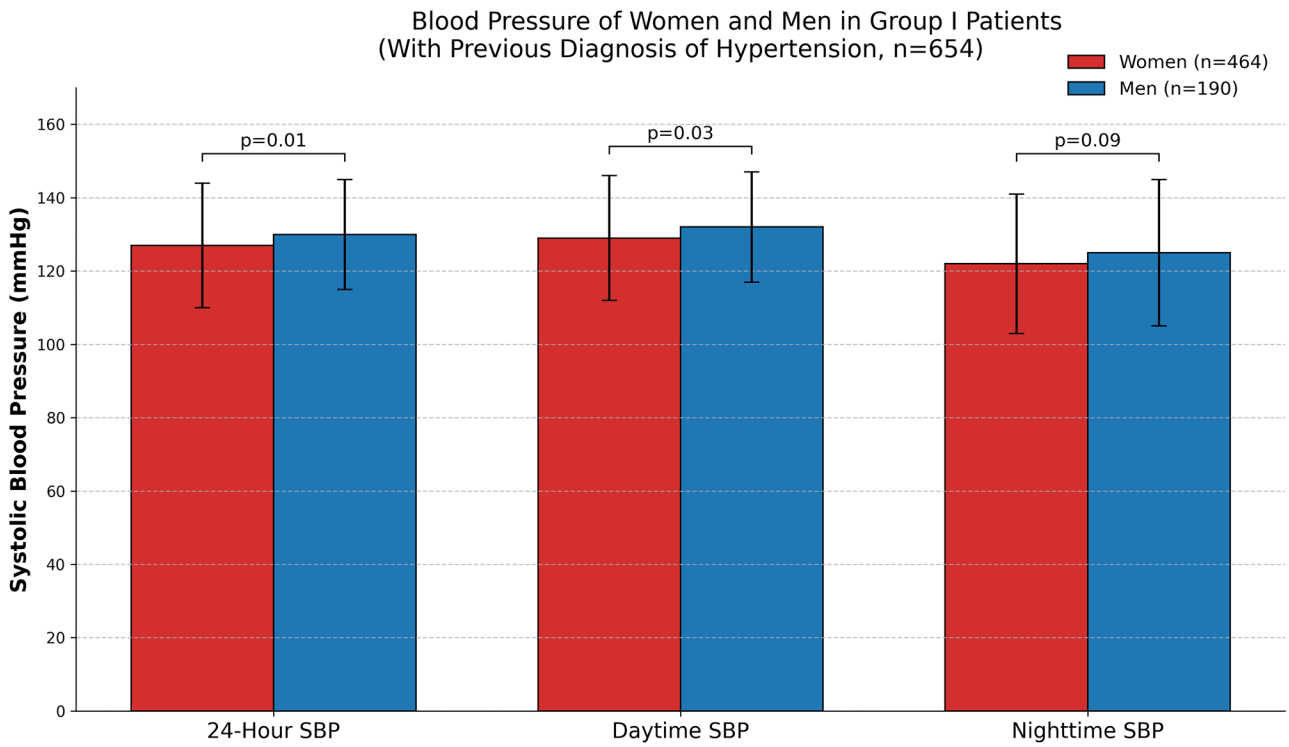


**Figure 4.** Blood pressure of women and men in group I patients (with previous diagnosis of hypertension, n = 654). SBP = systolic blood pressure.

Hg.[8] Within this context, it is reasonable to expect that women might have lower BP threshold values to initiate antihypertensive treatment compared with men. It has been suggested that this gray zone of HT can be overcome by individualized and symptom-oriented approaches in selected populations.[12] Notably, we have recently reported a case in which the reduction of BP from 106/63 to 98/56 mm Hg by antihypertensive medication resulted in prominent symptomatic recovery.[13] There has been no sex-specific approach for the diagnosis or treatment of HT. Current guidelines' recommendations are similar for both men and women regarding diagnostic and treatment modalities.[1,2,14] In conclusion, our findings demonstrate that among patients referred for ABPM, women exhibit lower ambulatory BP values than men. Therefore, future outcome-based

investigations are warranted to determine whether sex-specific diagnostic thresholds and BP targets would improve cardiovascular risk stratification and management.

Beyond the immediate clinical evaluation, establishing accurate BP thresholds – particularly for women – is crucial for preventing long-term target organ damage. Tight BP control serves as a fundamental pillar in halting structural cardiac remodeling, given that even borderline elevations exert a cumulative, adverse effect on the left ventricular mass index. Prolonged exposure to such hemodynamic burden frequently leads to pathological hypertrophy, a process characterized by detrimental shifts in both cardiac architecture and prognostic biomarkers like pro-B-type natriuretic peptide.[15] To effectively mitigate these risks, contemporary cardiovascular management is increasingly relying on digital health interventions. Integrating remote monitoring technologies not only facilitates continuous data preservation but also significantly enhances patient adherence and clinical guidance.[16] Moreover, the importance of continuous activity tracking and lifestyle optimization has become undeniable in reducing atherosclerotic burden. Recent evidence clearly demonstrates that sustained physical activity, objectively measured via daily step counts, favorably alters cardiovascular disease risk scores.[17] In a similar vein, the deployment of smart devices and mobile health applications has proven highly effective in improving functional capacity and peak oxygen uptake.[18] Ultimately, combining personalized, sex-specific diagnostic approaches with these multifaceted digital monitoring strategies could offer a highly effective framework for reducing left ventricular mass index and overall cardiovascular risk in clinical practice.

## 5. Limitations

Certain limitations of the present study warrant acknowledgment. Primarily, the retrospective and single-center nature of the design may restrict the generalizability of our findings to broader populations. Due to the real-world clinical nature of this cohort, highly granular data concerning body mass index, menopausal status, specific antihypertensive drug classes, treatment duration, and medication adherence were inconsistently documented. Consequently, a rigorous multivariable regression analysis adjusting for these critical confounders could not be performed without risking substantial selection bias. The reliance on unadjusted comparative analyses represents a major limitation. In addition, this study relies on a cross-sectional evaluation of ABPM parameters without longitudinal follow-up. Consequently, the current data cannot establish how the observed sex-based discrepancies in BP levels translate to long-term cardiovascular clinical endpoints. Therefore, our findings should be strictly interpreted as hypothesis-generating observations. Prospective, multicenter studies incorporating long-term prognostic data and comprehensive confounder adjustments are required to confirm these observations and justify the potential implementation of sex-specific diagnostic guidelines.

## 6. Conclusion

The present study demonstrates that women exhibit significantly lower ambulatory SBP and DBP levels compared to their men counterparts. This distinct physiological variance persists across the entire 24-hour monitoring period, as well as during specific daytime and nighttime intervals, regardless of a previous diagnosis of HT or the administration of antihypertensive medical therapies. Notably, the observed hemodynamic separation between the sexes is most pronounced among treatment-naive individuals within the evaluated cohort. Given that contemporary clinical guidelines utilize uniform, non-sex-specific criteria for the diagnosis and management of HT, these findings indicate that standard thresholds may fail to account for the baseline differences between women and men. Consequently, further clinical research is warranted to determine whether the introduction of sex-specific diagnostic cutoffs and tailored therapeutic targets would optimize risk stratification and BP management in clinical practice.

## Author contributions

**Conceptualization:** Hasan Atmaca.
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**Writing – review & editing:** Hasan Atmaca, Doğaç Çağlar Gürbüz, Mustafa Kemal Erol, Ertan Yetkin.

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