The Relation Between Ambulatory Blood Pressure, Age and Gender

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KEYWORDS
Ambulatory blood pressure; systolic blood pressure, diastolic blood pressure; heart rate variability; circadian rhythm; age; gender; hypertension.

ABSTRACT

Introduction: Ambulatory blood pressure (ABP) monitoring offers an extensive evaluation of blood pressure (BP) fluctuations over a 24-hour period, facilitating a more profound comprehension of the impact of demographic variables such as age and gender. This study seeks to examine the correlation among age, gender, and arterial blood pressure (ABP), specifically emphasizing systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR) variability. Comprehending these relationships is essential for formulating individualized methods for hypertension therapy.

Methodology: The methodology employed was cross-sectional observational research conducted at NAWAT ALMUSTAKBAL .AZAWEA LIBYA from 2022 to 2024. Continuous 24-hour blood pressure and heart rate data were obtained by ambulatory cardiovascular monitoring (ABPM) technology at Nawat Almostaqbal Clinic. Participants engaged in a standardized preparatory phase, which included a 5-minute acclimatization period, succeeded by three baseline measures of blood pressure and heart rate. Participants were then equipped with ABPM devices to continually monitor blood pressure during their routine daily activities and sleep.

Results: The findings indicate that age significantly influences systolic blood pressure, with elevated readings observed in older individuals. Nevertheless, age appeared to exert minimal influence on diastolic blood pressure. Conversely, gender significantly influenced diastolic blood pressure, with males demonstrating elevated levels of lean BP during wakefulness, but no notable variations in systolic blood pressure were observed between the genders. The research indicated that wake/sleep status significantly affected SBP due to circadian rhythms, but did not notably alter DBP variability or HR variability. Age, gender, and circadian state did not significantly influence heart rate variability or the fluctuation of diastolic blood pressure.

Conclusion: The findings from the research indicate that although age significantly influences SBP, gender exerts a far greater impact on DBP levels. The diurnal cycle significantly affects the variation of SBP, indicating that physicians should take the time of day into account while managing a patient with hypertension. The conclusion is evident regarding the necessity for physicians to employ distinctive treatment options for patients.

1. Introduction

Ambulatory blood pressure monitoring (ABPM) offers essential insights into blood pressure (BP) variations over a 24-hour duration, uncovering subtleties frequently overlooked in standard clinical assessments. Age and gender are critical determinants affecting ambulatory blood pressure, with diverse consequences for cardiovascular health. (1)

As people grow older, their systolic blood pressure tends to increase, but diastolic blood pressure does not follow a simple pattern. For many individuals, mean diastolic pressure stays about the same even as they age, while the systolic number reaches a peak around age 75 (before either stabilizing or dropping due to decreased arterial pliability in the oldest-old). Of course, not everyone follows this pattern, but changes in the vascular system associated with aging, such as the stiffening of main arteries and a loss of compliance in the rest of the vascular system, do seem to account for the not-so-desirable rise in systolic pressure that is often observed in older adults. (2)

Systolic hypertension affects a large segment of the older population, with nearly 75% of people over the age of 75 afflicted by this condition. Isolated systolic hypertension ISH happens when systolic pressure is too high, yet diastolic pressure is normal or even lower, which in turn means that the pulse pressure must be elevated as well. ISH is a critical risk factor for cardiovascular incidents, including stroke and heart failure, highlighting the necessity of proficient blood pressure management in the elderly. (3)

Aging influences both average blood pressure levels and blood pressure variability. Older persons exhibit greater variability in both systolic and diastolic blood pressure, correlating with an elevated risk of end-organ damage

and cardiovascular incidents. (4)

Blood pressure variability holds distinct implications for older individuals compared to younger ones. Blood pressure typically increases with age, though not at a constant rate. While certain fluctuations in systolic pressure are considered normal, excessive dips or peaks—despite remaining within acceptable limits—indicate a need for careful monitoring, as they may signal an impending issue with the body's overall health, with blood pressure serving as a primary indicator. (5)

Blood pressure is strongly influenced not just by an individual's chronological age but also by their biological age. Research indicates that blood pressure levels deemed normal may be detrimental to individuals who are biologically older, despite being younger in chronological age. They are associated with an elevated risk of mortality. Conversely, blood pressure values are associated with a reduced risk of mortality by middle age; such levels would be classified as prehypertensive or hypertensive according to contemporary norms for a middle-aged individual. (6)

Men often have elevated blood pressure levels compared to women until the latter attain menopause. The primary cause of this discrepancy is hormones. Estrogen safeguards the cardiovascular systems of premenopausal women. Upon reaching menopause, individuals forfeit the protective advantage, resulting in an increase in blood pressure, particularly with systolic readings presumably elevated due to a significant decline in estrogen levels. (7)

Research indicates that both blood pressure levels and circadian patterns differ between men and women. For instance, the average readings for a cohort indicate that middle-aged women reach their peak in the late afternoon, but men peak in the morning. (8)

This variance indicates that daily stressors may differentially affect genders, influencing blood pressure responses. Moreover, women have been noted to have a more pronounced "white-coat effect," wherein clinic blood pressure levels surpass ambulatory measurements. This phenomenon may result in an overestimation of hypertension in women when just clinic measurements are taken into account. (9)

Research demonstrates that women display unique hemodynamic characteristics in contrast to men. For example, women, particularly younger individuals, generally have reduced systemic vascular resistance alongside an elevated cardiac index. Conversely, older women exhibit greater vascular resistance compared to men within the same age cohort. (10)

This indicates that gender-specific mechanisms, including hormonal impacts and variations in heart function, are key factors in blood pressure regulation. Gender disparities also affect the therapy of hypertension. The regulation of blood pressure and response to antihypertensive therapy may vary between genders, partially attributable to differences in hormonal influences, the renin-angiotensin system, and vascular reactivity. (11)

Nonetheless, demonstrating the advantages of antihypertensive treatments for women, particularly post-menopausal individuals, has been challenging. This demographic has an elevated risk for cardiovascular disease (CVD), and various causes elucidate this greater susceptibility. Hypertension, our longstanding acquaintance, impacts over 30 percent of the post-menopausal demographic. The intensity of both systolic and diastolic blood pressure is associated with a heightened incidence of cardiovascular morbidity and mortality. Nonetheless, this correlation did not apply to the general variability in blood pressure—specifically, the fluctuations in blood pressure levels over time within the same individual—indicating possible new avenues for exploring female hypertension and cardiovascular disease. (12)

This study aims to examine the correlation between ambulatory blood pressure and other demographic characteristics. It examines the ABP age equation in further detail and seeks to derive significance from it. The research employs both fundamental and advanced statistical methods to assess blood pressure data. Fundamental statistics indicate that as soldiers age, their systolic and diastolic blood pressures increase. The subsequent phase of the experiment was to ascertain whether there are significant variations in ABP throughout the age spectrum.

2. Methodology:

Study Design:

This research employed a cross-sectional observational strategy to assess the correlation between age, gender, and ambulatory blood pressure (ABP). A dependable methodology facilitated precise data acquisition over a

continuous 24-hour duration utilizing the ambulatory cardiovascular monitoring (ABPM) technology. The duration of this study is from 2022 to 2024 at NAWAT ALMUSTAKBAL .AZAWEA LIBYA.

Participant Preparation:

Participants were first allowed to settle into the room; then, after 5 minutes, BP and HR were measured three times. Following these standard, well-calibrated techniques allowed for secure baseline data prior to the main event—fitting the participants with the laboratory-obtained, ambulatory blood pressure monitoring device.

Exclusion Criteria:

This research did not apply any exclusion criteria, resulting in a sample that is both comprehensive and inclusive—ideal for evaluating the kinds of normal changes that occur with age and gender in blood pressure.

Fitting of the Ambulatory Blood Pressure Monitor:

Upon concluding the preliminary measures, each participant was equipped with a Welch Allyn ABPM 6100 device for 24-hour ambulatory blood pressure and heart rate monitoring. The cuff was positioned on the non-dominant arm to minimize disruption to everyday activities. To guarantee precise calibration, three manual blood pressure measurements were obtained from the contralateral arm utilizing a mercury sphygmomanometer. These manual measurements were recorded concurrently with the monitor's inflations. The calibration technique was deemed appropriate only if the manual readings were within 5 mm Hg of the ambulatory monitor readings.

Monitoring Procedure:

Procedure for Monitoring: Participants were given unambiguous directions to ensure that the ABP readings were accurate. They were instructed to keep their arms still during each inflation of the monitor. This step was important because we wanted to minimize any movement artifacts that could have interfered with the reading. Even though the monitor itself is capable of correcting for a certain amount of motion, the best signal-to-noise ratio is obtained when the participant is as still as possible. This is the same principle used in obtaining a good electrocardiogram (ECG) tracing. Also, we did not want movement to elevate the blood pressure just before taking a reading. Aside from that, we instructed participants not to take any baths or showers while they were wearing the monitor. Moisture could have interfered with the readings and possibly damaged the monitor's electronics.

Throughout the daytime, the monitor was worn and set to take readings at an almost constant interval of 20 minutes. For the sleep period, as reported by the participants, the monitor was set to take readings every hour. This schedule was chosen to keep the number of measurements taken during sleep to the barest minimum while still providing the researchers with an adequate amount of data to get a clear picture of blood pressure changes over time.

Data Collection:

To enhance the automated blood pressure monitoring, participants were supplied with a journal to document relevant information throughout the 24-hour monitoring duration. The diary entries documented the precise times of monitor activation throughout wakefulness, along with notable behaviors or events that may have impacted blood pressure readings, like physical activity, mental stress, or alterations in posture.

Upon completion of the 24-hour monitoring period, participants returned to the laboratory for the removal of the ambulatory monitor. The diaries were assessed for clarity and comprehensiveness to guarantee the dependability of the obtained data. Post-monitoring interviews were performed to elucidate any inconsistencies in the diaries, enabling researchers to validate the self-reported wake and sleep durations. These data were essential for classifying each recorded blood pressure measurement as either 'Wake' or 'Sleep.' Only the nocturnal values, obtained from participants' reported sleep lengths, were employed in the analysis of sleep-related blood pressure data, so ensuring an accurate evaluation of the disparities between diurnal and nocturnal blood pressure patterns.

Reliability and Validity of the Monitoring Device:

The Welch Allyn ABPM 6100 was selected for its outstanding reliability and validity, having been rigorously assessed against intra-arterial measures and established clinical standards. Prior research has established its precision, rendering it an optimal instrument for continuous ambulatory blood pressure monitoring.

Statistical analysis

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). The Kolmogorov- Smirnov was used to verify the normality of distribution of variables, Paired t-test was used to compare two periods for normally distributed quantitative variables while ANOVA with repeated measures was used for comparing the different studied periods for normally distributed quantitative variables and followed by Post Hoc test (Bonferroni adjusted) for pairwise comparison. Pearson coefficient to correlate between two normally distributed quantitative variables. Significance of the obtained results was judged at the 5% level

Table 1: Relation between Gender and ambulatory BP

	Male	Female	P value	Statistically significant
	N=93	N=102		
Overall Blood Pressure				
SBP (mm Hg)	137.87±20.33	133.23±21.51	0.1025	N. S
DBP(mm Hg)	77.53±11.48	74.95±15.92	0.0367	Sig.
Awake Blood Pressure				
SBP (mm Hg)	139.95±22.25	135.14±22.12	0.11633	N. S
DBP(mm Hg)	78.67±12.36	76.02±15.63	0.0279	Sig.
Sleep Blood Pressure				
SBP (mm Hg)	130.91±21.55	128.57±24.6	0.1697	N. S
DBP(mm Hg)	72.54±13.19	69.13±14.79	0.0733	N. S
Morning Blood Pressure				
SBP (mm Hg)	134.01±23.55	129.7±23.86	0.1534	N. S
DBP(mm Hg)	74.58±17.29	73.11±17.97	0.6665	N. S
Heart Rate	73.76±10.84	72.26±13.78	0.4704	N. S
Overall Blood Pressure variability				
SBP (mm Hg)	15.78±5.39	15.18±5.43	0.4453	N. S
DBP(mm Hg)	12.57±3.14	12.48±5.96	0.1073	N. S
Awake Blood Pressure variability				
SBP (mm Hg)	14.66±5.18	15.1±6.02	0.8605	N. S
DBP(mm Hg)	11.63±3.46	12.57±8.15	0.1547	N. S
Sleep Blood Pressure variability				
SBP (mm Hg)	13.82±5.61	12.51±5.86	0.0882	N. S
DBP(mm Hg)	10.17±3.76	9.58±4.83	0.1217	N. S
Heart Rate variability	13.97±17.38	12.56±13.75	0.2397	N. S
Statistical test used: Tow sample T-test				
p-value≤0.05 considered statistically significant (95% confidence interval).				

Table 1 indicates gender disparities in ambulatory blood pressure (BP), especially in diastolic blood pressure (DBP). In terms of overall blood pressure, males exhibit marginally elevated systolic blood pressure (SBP) compared to females (137.87 mm Hg vs. 133.23 mm Hg), however this discrepancy is not statistically significant (p-value = 0.1025). The diastolic blood pressure is notably elevated in males (77.53 mm Hg) relative to females (74.95 mm Hg), with a p-value of 0.0367, signifying statistical significance.

The pattern persists when examining blood pressure during wakefulness. Men generally exhibit elevated systolic blood pressure (SBP) levels (139.95 mm Hg) relative to women (135.14 mm Hg), although this disparity lacks statistical significance (p-value = 0.11633). Conversely, the diastolic blood pressure (DBP) during the waking time is markedly elevated in males (78.67 mm Hg) compared to females (76.02 mm Hg), with a p-value of 0.0279, substantiating the observation that males typically exhibit greater diastolic pressure while awake.

The disparities in blood pressure between males and females during sleep are not statistically significant. The systolic blood pressure for males (130.91 mm Hg) and females (128.57 mm Hg) exhibits no significant difference (p-value = 0.1697). Likewise, males have a marginally elevated DBP (72.54 mm Hg) relative to females (69.13 mm Hg), however this disparity is not statistically significant (p-value = 0.0733).

In the morning, both SBP and DBP exhibited no significant variations between genders, with p-values of 0.1534 and 0.6665, respectively. Heart rate exhibited no significant gender differences, with males averaging 73.76 bpm and females 72.26 bpm, resulting in a p-value of 0.4704, which indicates a lack of statistical significance.

The variability of both systolic and diastolic blood pressure between males and females was not statistically different. The p-value for systolic blood pressure fluctuation was 0.4453, whereas for diastolic blood pressure variability, it was 0.1073. Throughout wakefulness, the variability of SBP and DBP exhibited no significant differences, with p-values of 0.8605 for SBP and 0.1547 for DBP. Likewise, during sleep, the p-value for SBP variability was marginally lower at 0.0882, however it remained non-significant. Heart rate variability exhibited

no significant differences between genders (p-value = 0.2397).

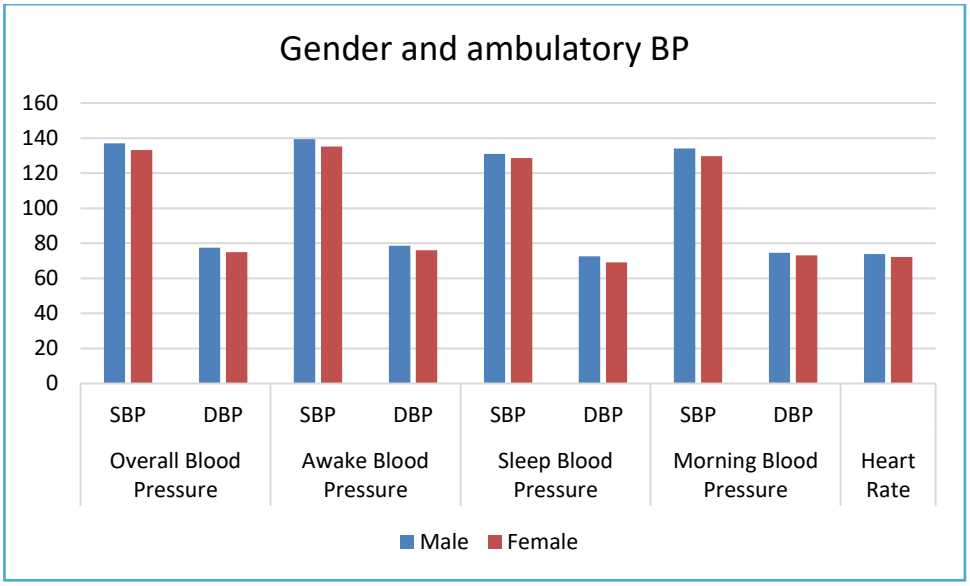

Figure 1: Gender and ambulatory BP

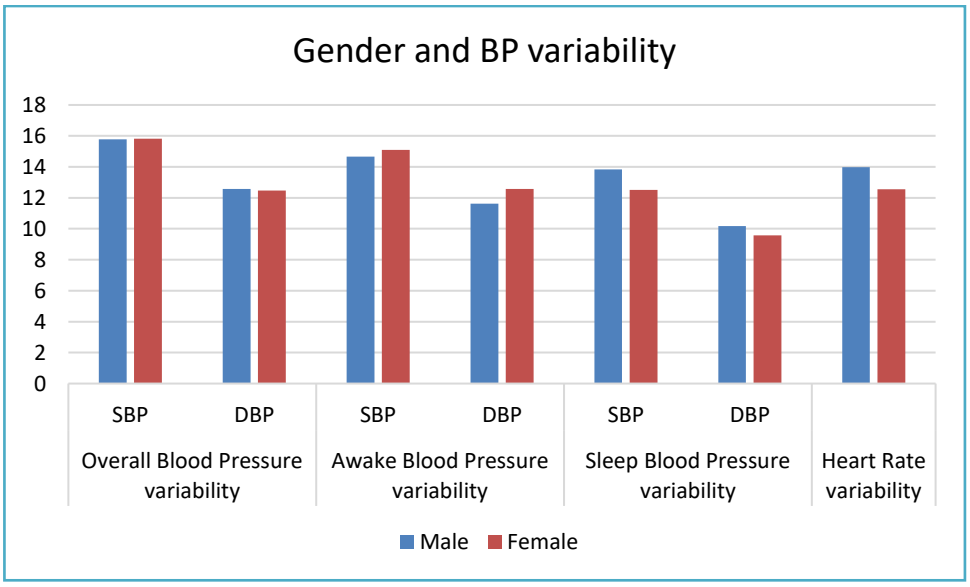

Figure 2: Gender and BP variability

Table 2: Relation between Age and BP variability

	Young N=58	Elderly N=137	P value	Statistically significant
Overall Blood Pressure				
SBP (mm Hg)	135.05±22.12	135.84±20.84	0.3926	N. S
DBP(mm Hg)	76.93±17.5	75.96±12.31	0.6364	N. S
Awake Blood Pressure				
SBP (mm Hg)	137.89±23.53	137.59±21.93	0.7517	N. S
DBP(mm Hg)	78.44±16.48	76.99±13.09	0.9445	N. S
Sleep Blood Pressure				
SBP (mm Hg)	130.27±22.18	129.15±23.33	0.4362	N. S
DBP(mm Hg)	71.61±13.69	70.26±14.16	0.6948	N. S
Morning Blood Pressure				
SBP (mm Hg)	135.05±28.03	130.28±21.28	0.7153	N. S
DBP(mm Hg)	73.77±19.13	73.57±16.82	0.6303	N. S
Heart Rate	73.23±13.51	72.99±11.84	0.3994	N. S
Overall Blood Pressure variability				
SBP (mm Hg)	15.21±4.15	15.57±5.8	0.5358	N. S
DBP(mm Hg)	12.73±4.49	12.35±4.92	0.7483	N. S
Awake Blood Pressure variability				

SBP (mm Hg)	14.83±4.94	14.9±5.82	0.8627	N. S
DBP(mm Hg)	11.37±5.03	11.76±5.36	0.8328	N. S
Sleep Blood Pressure variability				
SBP (mm Hg)	14.11±5.32	12.9±5.86	0.4798	N. S
DBP(mm Hg)	11.22±4.71	9.3±4.03	0.0662	N. S
Heart Rate variability	12.74±14.91	13.2±15.49	0.0367	Sig.
Statistical test used: Tow sample T-test				
p-value≤0.05 considered statistically significant (95% confidence interval).				

Table 2 examines the correlation between age and ambulatory blood pressure (BP), contrasting younger and older persons. A important observation from the table is that, overall, there are no statistically significant variations in blood pressure readings between the young and elderly cohorts over several measurements. The following is a comprehensive analysis of the outcomes.

The systolic blood pressure (SBP) of the younger group (135.05 ± 22.12 mm Hg) is comparable to that of the senior group (135.84 ± 20.84 mm Hg), with a p-value of 0.3926, signifying no significant difference. The diastolic blood pressure (DBP) of the young (76.93 ± 17.5 mm Hg) and the old (75.96 ± 12.31 mm Hg) is not substantially different (p-value = 0.6364).

Awake Blood Pressure show The systolic (137.89 ± 23.53 mm Hg in the young vs. 137.59 ± 21.93 mm Hg in the elderly) and diastolic (78.44 ± 16.48 mm Hg in the young vs. 76.99 ± 13.09 mm Hg in the elderly) values do not exhibit significant differences between the two cohorts. The p-values of 0.7517 and 0.9445 indicate that the differences lack statistical significance.

There are no significant variations in SBP and DBP during sleep between the two groups. The younger cohort exhibits a systolic blood pressure (SBP) of 130.27 ± 22.18 mm Hg and a diastolic blood pressure (DBP) of 71.61 ± 13.69 mm Hg, whereas the older cohort has an SBP of 129.15 ± 23.33 mm Hg and a DBP of 70.26 ± 14.16 mm Hg. The p-values for SBP (0.4362) and DBP (0.6948) demonstrate that the differences lack statistical significance.

The morning blood pressure exhibits no substantial changes between the young and the elderly. The systolic blood pressure (SBP) is 135.05 ± 28.03 mm Hg in the young and 130.28 ± 21.28 mm Hg in the old, with a p-value of 0.7153. DBP exhibits no significant difference between the two groups (73.77 ± 19.13 mm Hg in the young versus 73.57 ± 16.82 mm Hg in the elderly), with a p-value of 0.6303.

The heart rate of young adults (73.23 ± 13.51 bpm) and senior individuals (72.99 ± 11.84 bpm) exhibits no significant difference, as evidenced by a p-value of 0.3994, suggesting that age does not substantially influence heart rate in this demographic.

Blood Pressure Variability show There is no statistically significant difference in overall blood pressure variability between the young and elderly populations for both systolic blood pressure (SBP) (p-value = 0.5358) and diastolic blood pressure (DBP) (p-value = 0.7483). Likewise, awake blood pressure variability demonstrates no significant differences for both systolic blood pressure (SBP) (p-value = 0.8627) and diastolic blood pressure (DBP) (p-value = 0.8328). While the variability in systolic blood pressure (SBP) during sleep exhibits no significant difference (p-value = 0.4798), the variability in diastolic blood pressure (DBP) approaches statistical significance (p-value = 0.0662), suggesting a potential trend towards increased DBP variability in younger persons.

The sole statistically significant finding pertains to heart rate variability. Young adults have marginally reduced heart rate variability (12.74 ± 14.91) relative to the elderly (13.2 ± 15.49), with a p-value of 0.0367, rendering this the sole significant difference in the table.

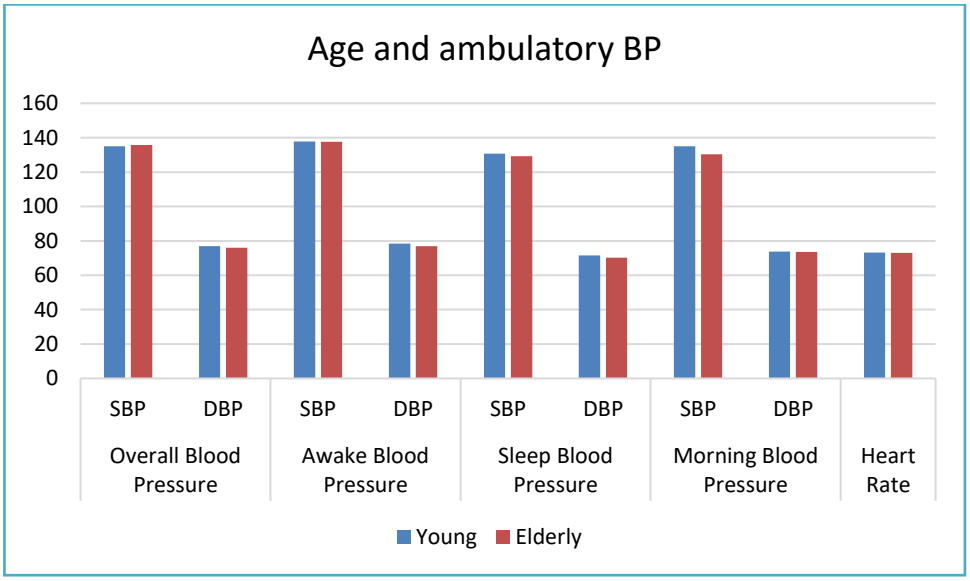

Figure 3: Age and ambulatory BP

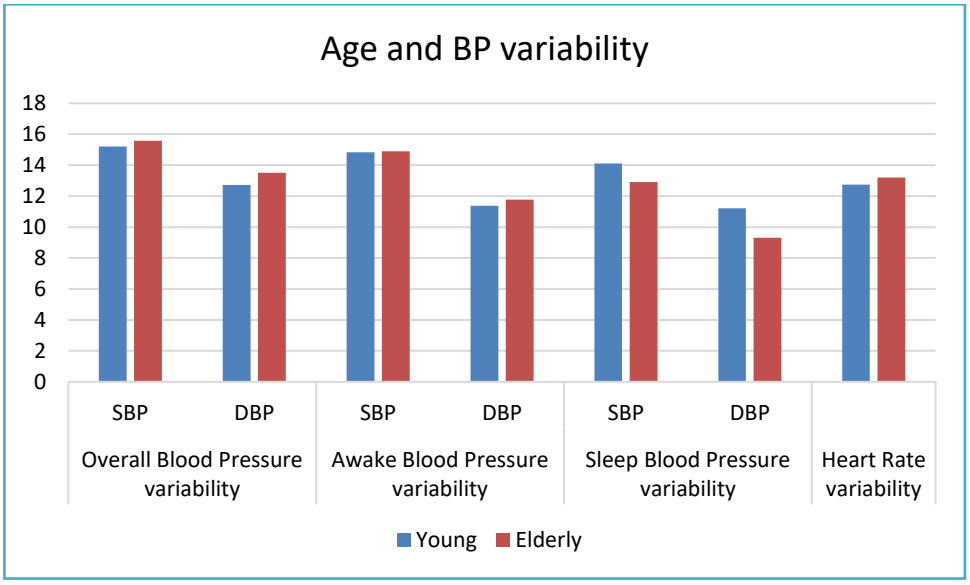

Figure 4: Age and BP variability

Table 3: Relation between Dipper and BP variability

	Not Dipper N=171	Dipper N=56	P value	Statistically significant
Overall Blood Pressure				
SBP (mm Hg)	135.87±21.12	133.96±23.07	0.6428	N. S
DBP(mm Hg)	76.24±14.22	75.82±13.74	0.3689	N. S
Awake Blood Pressure				
SBP (mm Hg)	137.62±22.33	137.59±23.99	0.6748	N. S
DBP(mm Hg)	76.99±14.26	79.26±14.23	0.5254	N. S
Sleep Blood Pressure				
SBP (mm Hg)	131.71±23.18	115.52±18.39	0.0005	Sig.
DBP(mm Hg)	71.73±14.05	63.68±13.15	0.0057	Sig.
Morning Blood Pressure				
SBP (mm Hg)	135.05±28.03	124.9±32.52	0.4036	N. S
DBP(mm Hg)	72.93±17.87	72.4±17.45	0.941	N. S
Heart Rate	74.01±11.5	66.72±15.93	0.0073	Sig.
Overall Blood Pressure variability				
SBP (mm Hg)	16.54±15.85	17.32±5.24	0.0316	Sig.
DBP(mm Hg)	13.05±7.41	19.25±22.46	0.0219	Sig.
Awake Blood Pressure variability				
SBP (mm Hg)	15.85±13	20.14±21.92	0.0573	Sig.
DBP(mm Hg)	13.41±10.64	12.96±10.51	0.9906	N. S

Sleep Blood Pressure variability				
SBP (mm Hg)	14.63±13.49	15.62±21.19	0.3964	N. S
DBP(mm Hg)	11.43±11.1	10.63±11.08	0.2513	N. S
Heart Rate variability	13.14±16.27	12.9±12.56	0.9517	N. S
Statistical test used: Tow sample T-test				
p-value≤0.05 considered statistically significant (95% confidence interval).				

Table 3 explored the association between BP variability and dipping status for overall, awake, sleep, and morning periods. There were no differences in the overall systolic and diastolic BP levels between Dippers and Non-Dippers, which is indicative of similar mean BP values throughout the day.

In sleeping conditions, though, both systolic and diastolic BP were significantly lower for Dippers than for Non-Dippers. This is quite expected from the nature of the Dippers, since their BP falls more deeply during sleep or rest periods. The values, in absolute terms, were: for Dippers, systolic. Thus, there is a more marked drop in BP at night among Dippers.

No significant differences between the two groups were obtained either for systolic or diastolic BP in the morning. Notably, heart rate was significantly lower in Dippers than in Non-Dippers, with values of 66.72 bpm versus 74.01 bpm, respectively; this fact means that lower heart rate is significantly associated with the dipping status.

Overall systolic and diastolic measures, however, showed greater BP variability for Dippers, reflecting increased oscillations throughout the day. This increased variability also extended to awake systolic BP but not diastolic BP, nor during sleep. Heart rate variability did not differ significantly between groups.

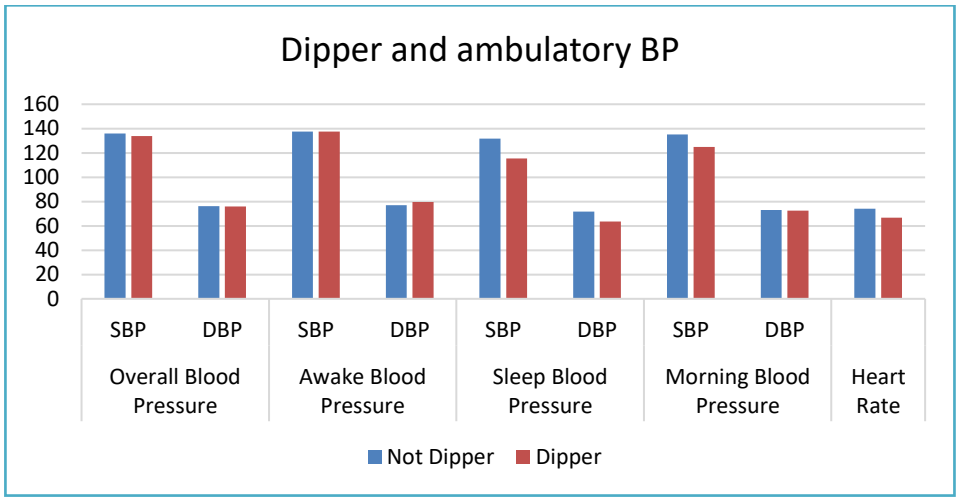

Figure 5: Age and ambulatory BP

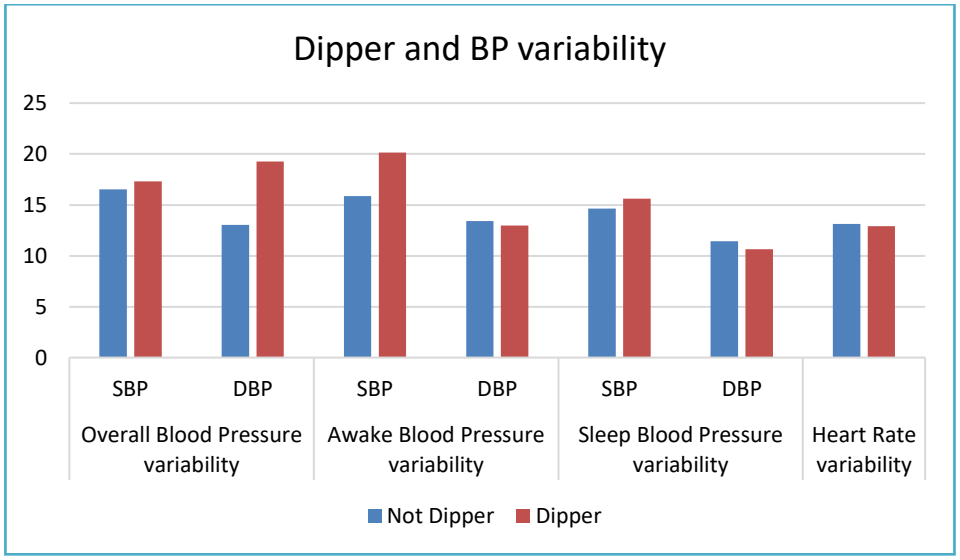

Figure 6: Age and BP variability

Table 4: Significant effects of analyses of covariance (Age, Gender, Wake/Sleep, Dipper)

Variable	Effect	F value	P value
SBP level	Age	1.491	0.049
	Gender	0.682	0.411
	Age × Gender	1.723	0.3
	Wake/Sleep	50.63	<0.0001
	Dipper	0.389	0.534
DBP level	Age	1.458	0.059
	Gender	8.298	0.005
	Age × Gender	0.946	0.541
	Wake/Sleep	38.1	<0.0001
	Dipper	1.009	0.314
HR level	Age	0.867	0.695
	Gender	0.037	0.848
	Age × Gender	0.9	0.601
	Dipper	0.125	0.725
SBP Variability	Age	0.747	0.86
	Gender	0.158	0.691
	Age × Gender	0.418	0.992
	Wake/Sleep	0.271	0.604
	Dipper	0.980	0.323
DBP Variability	Age	0.721	0.887
	Gender	0.128	0.721
	Age × Gender	1.198	0.257
	Wake/Sleep	1.303	0.256
	Dipper	0.027	0.869
HR Variability	Age	0.906	0.615
	Gender	0.373	0.544
	Age × Gender	0.743	0.722
	Dipper	0.023	0.880

The ANCOVA results in Table 3 assess the impact of age, gender, wake/sleep and Dipper status on many cardiovascular variables, including systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), and their associated variabilities.

Age significantly influences systolic blood pressure values, evidenced by a p-value of 0.049. This demonstrates that SBP varies with age, although the effect magnitude, evidenced by the F-value of 1.491, suggests that the variation is very minor. Conversely, gender does not have a significant impact on SBP levels (p-value = 0.411, F = 0.682). The interaction between age and gender or Dipper is not statistically significant (p-value = 0.3, F = 1.723), indicating that the combination of these variables does not result in meaningful changes in SBP. The most significant impact on SBP is attributed to wake/sleep status, evidenced by a p-value of less than 0.0001 and an F-value of 50.63. This indicates that SBP varies considerably between alertness and sleep, presumably aligning with the body's inherent circadian rhythm.

Age does not exert a statistically significant influence on diastolic blood pressure, evidenced by a p-value of 0.059, which is near the significance threshold. This indicates a potential trend in DBP variation with age, albeit it lacks sufficient strength for a definitive conclusion. Gender significantly influences DBP, evidenced by a p-value of 0.005 and an F-value of 8.298, demonstrating disparities in DBP levels between males and females. The interaction between age and gender or Dipper is statistically insignificant (p-value = 0.541, F = 0.946), suggesting that the joint effect of these variables does not significantly impact DBP. Similar to SBP, DBP demonstrates a substantial difference contingent upon wake/sleep status, evidenced by a p-value of less than 0.0001 and an F-value of 38.1, indicating that DBP levels fluctuate between awake and sleep states.

Heart rate is not substantially influenced by age, evidenced by a p-value of 0.695 and an F-value of 0.867, indicating that heart rate remains generally constant across various age demographics. Likewise, gender has no statistically significant impact on heart rate (p-value = 0.848, F = 0.037), and the interaction between age and gender or Dipper similarly demonstrates no significant effect on heart rate (p-value = 0.601, F = 0.9). This indicates that neither age nor gender, nor their interaction, significantly affects heart rate values.

No factors, including age, gender, or their combination, significantly influence SBP variability. The p-values for age, gender, and the interaction of age and gender, Dipper are 0.86, 0.691, and 0.992, 0.323 respectively, suggesting that SBP variability is mostly unaffected by these factors. Furthermore, waking/sleep status does not markedly affect SBP variability, evidenced by a p-value of 0.604 and an F-value of 0.271, indicating that SBP variability remains consistent across varying wake and sleep states.

Diastolic blood pressure variability exhibits no significant differences for age (p-value = 0.887), gender (p-value = 0.721), or the combination of age and gender (p-value = 0.257), or Dipper (p-value = 0.869),. This indicates that DBP variability remains comparatively stable irrespective of these circumstances. Furthermore, wake/sleep status does not markedly affect DBP variability (p-value = 0.256, F = 1.303).

Heart rate variability is not substantially influenced by age (p-value = 0.615), gender (p-value = 0.544), or the interaction of age and gender (p-value = 0.722), Dipper (p-value = 0.880). This suggests that variations in heart rate remain rather consistent throughout age, gender, or their combination.

3. Discussion

The present investigation revealed that males exhibited elevated diastolic blood pressure (DBP) during wakefulness. This aligns with prior research, including Caraballo et al., which indicated that, generally, males exhibit greater diastolic blood pressure, with this disparity being particularly significant during intensive tasks. While not the primary focus of our investigation, Caraballo et al. observed that men exhibit a greater diastolic blood pressure (DBP), but women may demonstrate a propensity for elevated systolic blood pressure (SBP) readings. This insight is pertinent to our study's findings, as it may elucidate the occurrence of low DBP and high SBP. (13)

Our analysis revealed no significant gender differences in blood pressure variability. Omboni and colleagues have demonstrated that whereas males typically have higher average ambulatory blood pressure (BP) values, females may exhibit greater fluctuation, particularly in diastolic blood pressure (DBP). (14)

Nonetheless, this nocturnal observation did not correlate with morning blood pressure values, which exhibited comparable systolic blood pressure, diastolic blood pressure, and heart rate variability between genders. This nocturnal equivalence in both sexes aligns with a prior discovery by Silveri and colleagues regarding non-significant gender disparities in the morning. Moreover, while Silveri's group identified gender differences in the previously indicated pressures, these differences were characterized as nuanced and devoid of persistent statistical significance. (15)

The results of our study indicate that there are no substantial gender disparities in sleep or wake durations. This discovery corresponds with the recent focus in scholarly literature on the influence of hormones in the regulation of blood pressure (BP). Drury and colleagues contend that the substantial effects of gender on blood pressure can primarily be elucidated by the variations in the quantities and types of hormones produced by men and women . (16)

The overall pattern of results suggests that although some gender differences in BP exist, particularly in DBP during wakefulness, these differences may not be substantial enough to require different management strategies based solely on gender. However, recent work by Ullah et al. has highlighted that while men and women may respond similarly to antihypertensive treatments, subtle differences in BP patterns suggest that personalized approaches could be beneficial for optimizing outcomes, especially in managing DBP variability. (17)

Our research revealed that systolic blood pressure (SBP) is strongly affected by age, but not by gender. This study aligns with the research of Wu et al., who demonstrated that systolic blood pressure (SBP) often rises with age in both genders, to levels in older individuals that are often misclassified as hypertensive, even in the absence of warning signs or symptoms. (18)

Research indicates that systolic blood pressure (SBP) attains its lowest point at 14 years of age, then increasing without a definitive limit, particularly in individuals over 60 years old. This aligns with Omboni et al.'s findings that the most significant changes in SBP among age groups arise when categorizing subjects as either asleep or awake. (14)

Our analysis revealed that diastolic blood pressure (DBP) is not influenced by age, whereas gender does have an effect on it. This outcome aligns with the study performed by Caraballo et al. The male population has a higher diastolic blood pressure (DBP) than the female population. Their investigation demonstrates that the disparities in DBP measurements are more significant when both sexes are awake. Caraballo et al. proposed several conjectures regarding the potential reasons for this phenomenon. They asserted that to get at a conclusion, one may likely attribute it to the male's autonomic nervous system and its regulation of blood pressure in those conditions. (13)

Our study’s findings indicate that heart rate and heart rate variability (HRV) are not significantly influenced by

age, gender, or their interaction. This is consistent with research by Silveri et al., who found that while HRV may be affected by factors like stress and lifestyle, demographic variables such as age and gender do not consistently impact HRV in controlled ambulatory settings. Additionally, Kim & Kim found no significant gender differences in heart rate outcomes after hypertension interventions, suggesting that HRV may be more influenced by behavioral factors than demographic characteristics. (15, 19)

Recent research by Chen et al. corroborates the college's finding that diastolic blood pressure variability is not significantly affected by age, gender, or wake/sleep status. They discovered that variables often influencing other blood pressure metrics, such as stress and circadian rhythms, exert no impact on diastolic blood pressure variability, which they claim remains consistent across nearly all demographic categories—age, gender, etc. This indicates that although systolic blood pressure may be somewhat variable, responding to many external and likely internal stimuli, diastolic blood pressure is more stable than previously believed and possibly more steady than any other readily available human biomarker. (20)

Our study conclusion that dipper status does not significantly affect heart rate variability or DBP variability aligns with findings from Hill et al., who noted that the dipping pattern primarily influences systolic BP and has limited impact on heart rate or DBP variability. This suggests that while dipper/non-dipper status is an important predictor of cardiovascular risk, its influence on other parameters such as HRV may not be as pronounced. (21)

4. Conclusion

This study demonstrates that age considerably affects systolic blood pressure (SBP), although gender does not exert a considerable influence on SBP levels. The predominant influence on SBP is the wake/sleep status, underscoring the significant significance of circadian rhythms in blood pressure regulation. Conversely, diastolic blood pressure (DBP) is more influenced by gender than by age, with males typically demonstrating elevated DBP while awake. Nonetheless, age, gender, and circadian status exhibit minimal impact on diastolic blood pressure variability, heart rate, and heart rate variability. The findings indicate that although demographic parameters such as age and gender influence certain elements of blood pressure dynamics, the circadian rhythm predominantly regulates systolic blood pressure levels. The study emphasizes the necessity for individualized blood pressure management strategies that take into account demographic features, daily activity patterns, and sleep cycles to achieve optimal hypertension control.

References

[1] Aung K, Htay T. Relationship between outpatient clinic and ambulatory blood pressure measurements and mortality. Current cardiology reports. 2019;21:1-8.

[2] Banegas JR, Ruilope LM, de la Sierra A, Vinyoles E, Gorostidi M, de la Cruz JJ, et al. Relationship between clinic and ambulatory blood-pressure measurements and mortality. New England Journal of Medicine. 2018;378(16):1509-20.

[3] Beatty Moody DL, Waldstein SR, Tobin JN, Cassells A, Schwartz JC, Brondolo E. Lifetime racial/ethnic discrimination and ambulatory blood pressure: The moderating effect of age. Health Psychology. 2016;35(4):333.

[4] Huang Q-F, Yang W-Y, Asayama K, Zhang Z-Y, Thijs L, Li Y, et al. Ambulatory blood pressure monitoring to diagnose and manage hypertension. Hypertension. 2021;77(2):254-64.

[5] Kario K, Shin J, Chen CH, Buranakitjaroen P, Chia YC, Divinagracia R, et al. Expert panel consensus recommendations for ambulatory blood pressure monitoring in Asia: the HOPE Asia Network. The Journal of Clinical Hypertension. 2019;21(9):1250-83.

[6] Macumber IR, Weiss NS, Halbach SM, Hanevold CD, Flynn JT. The association of pediatric obesity with nocturnal non-dipping on 24-hour ambulatory blood pressure monitoring. American journal of hypertension. 2016;29(5):647-52.

[7] Rakow A, Laestadius Å, Liliemark U, Backheden M, Legnevall L, Kaiser S, et al. Kidney volume, kidney function, and ambulatory blood pressure in children born extremely preterm with and without nephrocalcinosis. Pediatric Nephrology. 2019;34:1765-76.

[8] Ruschitzka F, Borer JS, Krum H, Flammer AJ, Yeomans ND, Libby P, et al. Differential blood pressure effects of ibuprofen, naproxen, and celecoxib in patients with arthritis: the PRECISION-ABPM (Prospective Randomized Evaluation of Celecoxib Integrated Safety Versus Ibuprofen or Naproxen Ambulatory Blood Pressure Measurement) Trial. European heart journal. 2017;38(44):3282-92.

[9] Schwartz JE, Burg MM, Shimbo D, Broderick JE, Stone AA, Ishikawa J, et al. Clinic blood pressure underestimates ambulatory blood pressure in an untreated employer-based US population: results from the masked hypertension study. Circulation. 2016;134(23):1794-807.

[10] Sherwood A, Hill LK, Blumenthal JA, Hinderliter AL. The effects of ambulatory blood pressure monitoring on sleep quality in men and women with hypertension: dipper vs. nondipper and race differences. American journal of hypertension. 2019;32(1):54-60.

[11] Yegül-Gülnar G, Kasap-Demir B, Alparslan C, Çatli G, Mutlubaş F, Yavaşcan Ö, et al. Ambulatory blood pressure monitoring parameters in obese children and adolescents with masked hypertension. Blood Pressure Monitoring. 2019;24(6):277-83.

[12] Staplin N, de la Sierra A, Ruilope LM, Emberson JR, Vinyoles E, Gorostidi M, et al. Relationship between clinic and ambulatory blood pressure and mortality: an observational cohort study in 59 124 patients. The Lancet. 2023;401(10393):2041-50.

[13] Caraballo C, Mahajan S, Gu J, Lu Y, Spatz ES, Dreyer RP, et al. Hemodynamic differences between women and men with elevated blood pressure in China: A non-invasive assessment of 45,082 adults using impedance cardiography. PLOS ONE. 2022;17(6):e0269777.

[14] Omboni S, Khan NA, Kunadian V, Olszanecka A, Schutte AE, Mihailidou AS. Sex Differences in Ambulatory Blood Pressure Levels and Subtypes in a Large Italian Community Cohort. Hypertension. 2023;80(7):1417-26.

[15] Silveri G, Pascazio L, Ajčević M, Miladinović A, Accardo A, editors. Influence of the Gender on the Relationship Between Heart Rate and Blood Pressure2021; Cham: Springer International Publishing.

[16] Drury ER, Wu J, Gigliotti JC, Le TH. Sex differences in blood pressure regulation and hypertension: renal, hemodynamic, and hormonal mechanisms. Physiological Reviews. 2024;104(1):199-251.

[17] Ullah S, Khan S, Bazargan-Hejazi S, Ramirez E, Teklehaimanot S, Diab S, et al. Use and outcomes of antihypertensive medication treatment in the US hypertensive population: A gender comparison. Health Promot Perspect. 2023;13(2):140-6.

[18] Wu J, Jiao B, Zhao J. Gender Disparities in Blood Pressure and the Role of Body Mass Index: A Birth Cohort Analysis in China. Journal of Epidemiology and Global Health. 2023;13(3):485-94.

[19] Kim H-S, Kim H-J. Sex differences in effect of patients-centered intervention on blood pressure in patients with hypertension. Scientific Reports. 2023;13(1):13952.

[20] Chen X, Xu S-k, Li Y, Hu Z, Wang H-y, Yu W, et al. Within-Visit Blood Pressure Variability in an Unselected Adult Population. American Journal of Hypertension. 2021;34(10):1125-6.

[21] Hill LK, Thayer JF, Williams DP, Halbert JD, Hao G, Robinson V, et al. Ethnic and sex differences in the longitudinal association between heart rate variability and blood pressure. Blood Pressure. 2021;30(3):165-71.