Longitudinal Analysis of Cardiovascular Parameters across Multiple Measurement Sessions: A Repeated Measures Study

A.Y. Solomon*, J.S. Kumbet

Department of Anatomy, College of Health Sciences, Nile University, Abuja, Nigeria

***Corresponding Author**

DOI: https://doi.org/10.51244/IJRSI.2025.120700195

Received: 13 July 2025; Accepted: 19 July 2025; Published: 19 August 2025

ABSTRACT

Background: Cardiovascular parameters exhibit temporal variability that may influence clinical assessment and treatment decisions. Understanding the patterns of blood pressure and heart rate changes across multiple measurement sessions is crucial for accurate cardiovascular risk stratification.

Objective: To investigate the longitudinal changes in systolic blood pressure (SBP), diastolic blood pressure (DBP), and pulse rate across four measurement sessions and examine their relationships with anthropometric parameters.

Methods: A prospective repeated measures study was conducted with 53 healthy participants (aged 18-65 years) over multiple measurement sessions. Cardiovascular parameters including SBP, DBP, and pulse rate were measured using standardized protocols. Anthropometric measurements including height, weight, and BMI were recorded. Statistical analysis employed repeated measures ANOVA and Friedman tests to assess temporal variations.

Results: Significant temporal variations were observed in SBP ($\chi^2 = 79.829$, $p < 0.001$) and pulse rate ($\chi^2 = 74.371$, $p < 0.001$), while DBP remained stable across sessions ($\chi^2 = 3.700$, $p = 0.296$). The most pronounced SBP increase occurred between sessions 1 and 2. Mean SBP ranged from 118.5 ± 12.3 mmHg to 125.2 ± 14.1 mmHg across sessions. Pulse rate showed considerable variation with coefficients of variation ranging from 8.2% to 12.7%. Weak to moderate correlations were found between anthropometric parameters and cardiovascular variability.

Conclusions: Systolic blood pressure and pulse rate demonstrate significant session-to-session variability in healthy adults, while diastolic blood pressure remains more stable. These findings have important implications for clinical practice and research protocols, suggesting the need for multiple measurements to obtain accurate cardiovascular assessments.

Keywords: blood pressure variability, cardiovascular parameters, repeated measures, longitudinal analysis, pulse rate

INTRODUCTION

Cardiovascular disease remains the leading cause of morbidity and mortality worldwide, necessitating accurate and reliable methods for assessment and monitoring [1, 2]. Blood pressure measurement, a cornerstone of cardiovascular evaluation, is subject to considerable temporal variability that can significantly impact clinical decision-making [3, 4]. The phenomenon of blood pressure variability has gained increasing recognition as an independent predictor of cardiovascular outcomes, beyond traditional mean blood pressure values [5, 6].

Short-term blood pressure variability, occurring within hours or days, reflects the dynamic nature of cardiovascular regulation and is influenced by multiple factors including autonomic nervous system activity, environmental conditions, psychological stress, and physical activity [7, 8]. Studies have demonstrated that

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VII July 2025

elevated blood pressure variability is associated with increased risk of stroke, myocardial infarction, and overall cardiovascular mortality [9, 10]. The clinical significance of this variability extends beyond pathological conditions, as it also affects the accuracy of blood pressure classification in apparently healthy individuals [11, 12].

The measurement of blood pressure in clinical and research settings typically involves single or limited repeated assessments, which may not adequately capture the true cardiovascular status of an individual [13, 14]. Current guidelines recommend multiple measurements to improve accuracy, yet the optimal number and timing of measurements remain subjects of ongoing investigation [15, 16]. The white-coat effect, characterized by elevated blood pressure readings in clinical settings compared to home or ambulatory measurements, further complicates the interpretation of single-session measurements [17, 18].

Pulse rate variability, often studied in conjunction with blood pressure, provides additional insights into cardiovascular autonomic function [19, 20]. Heart rate variability has been extensively studied as a marker of autonomic nervous system balance and cardiovascular health [21, 22]. The relationship between blood pressure and heart rate responses during repeated measurements may reveal important physiological patterns relevant to cardiovascular risk assessment [23, 24].

Anthropometric parameters, particularly body mass index (BMI), are well-established determinants of cardiovascular risk and are closely associated with blood pressure levels [25, 26]. The relationship between BMI and blood pressure variability, however, has received less attention in the literature [27, 28]. Understanding how anthropometric factors influence cardiovascular parameter stability across multiple measurements could inform both clinical practice and research methodology [29, 30].

The present study was designed to address these knowledge gaps by conducting a comprehensive longitudinal analysis of cardiovascular parameters across multiple measurement sessions. The primary objectives were to quantify the degree of variability in systolic blood pressure, diastolic blood pressure, and pulse rate across four measurement sessions, and to examine the relationships between these parameters and anthropometric characteristics. We hypothesized that significant variability would be observed in cardiovascular parameters across sessions, with potential differential patterns between systolic and diastolic blood pressure measurements.

METHODS AND MATERIALS

Study Design and Participants

This prospective repeated measures study was conducted at the Department of Anatomy, College of Health Sciences, Nile University, Abuja, Nigeria. The study protocol was approved by the institutional review board [31] and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants.

A total of 53 participants were recruited through convenience sampling from the local community. Inclusion criteria comprised adults aged 18-65 years with no history of cardiovascular disease, diabetes, or current use of antihypertensive medications. Exclusion criteria included pregnancy, acute illness, or inability to provide informed consent.

All participants provided written informed consent prior to enrollment. The study protocol was designed to minimize potential confounding factors while maintaining ecological validity for real-world cardiovascular assessment scenarios. Participants were instructed to maintain their usual lifestyle patterns throughout the study period to ensure that measurements reflected typical physiological variations rather than intervention-induced changes.

Measurement Protocol

Cardiovascular and anthropometric measurements were obtained during four separate sessions conducted over a period of 12 hours. Each session was scheduled at consistent times of day to minimize circadian influences

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VII July 2025

on cardiovascular parameters [32, 33]. Participants were instructed to avoid caffeine, alcohol, and vigorous physical activity for at least 2 hours prior to each measurement session [34, 35].

Blood pressure measurements were obtained using standardized protocols recommended by the American Heart Association [36]. Participants were seated in a quiet room for at least 5 minutes before measurement, with feet flat on the floor and back supported. An appropriately sized cuff was placed on the non-dominant arm at heart level [37]. Systolic and diastolic blood pressures were recorded using a validated automated oscillometric device, with measurements repeated three times at 1-minute intervals and the average calculated for analysis [38].

Pulse rate measurements were obtained simultaneously with blood pressure using the same automated device. Additional pulse rate measurements were obtained manually by palpation of the radial artery to ensure accuracy [39]. Heart rate variability parameters were not assessed in this study, focusing instead on mean pulse rate values across sessions.

Anthropometric Measurements

Height was measured using a calibrated stadiometer with participants standing barefoot in the Frankfurt horizontal plane [40]. Weight was obtained using a calibrated electronic scale with participants wearing light clothing and no shoes. Body mass index was calculated as weight in kilograms divided by height in meters squared [41]. All anthropometric measurements were performed by trained personnel following standardized protocols to ensure consistency and accuracy [42].

Statistical Analysis

Statistical analyses were performed using SPSS software package with significance set at $p < 0.05$ [43]. Descriptive statistics were calculated for all variables, including means, standard deviations, and ranges. Normality of data distribution was assessed using the Shapiro-Wilk test [44].

The primary analysis employed Friedman tests to assess differences in cardiovascular parameters across the four measurement sessions, as this non-parametric approach is appropriate for repeated measures data that may not meet parametric assumptions [45, 46]. Post-hoc pairwise comparisons were conducted when significant main effects were identified, with appropriate corrections for multiple comparisons [47].

Correlation analyses were performed using Pearson product-moment correlation coefficients to examine relationships between cardiovascular parameters and anthropometric measurements [48]. Correlations were classified as weak ($|r| < 0.3$), moderate ($0.3 \leq |r| < 0.7$), or strong ($|r| \geq 0.7$) based on established conventions [49].

RESULTS

Participant Characteristics

The study included 53 participants with complete data available for pulse rate analysis and 52 participants for blood pressure analysis (one participant excluded due to technical measurement issues). The participant characteristics and baseline measurements are presented in Table 1. The sample demonstrated typical anthropometric characteristics for the studied population, with a mean age of 28.4 ± 8.7 years, 32 males (60.4%) and 21 females (39.6%). Mean BMI was 24.2 ± 3.8 kg/m², with the majority of participants (75.5%) having normal BMI values.

Table 1: Participant Characteristics and Baseline Measurements

Parameter	Mean ± SD	Range
Age (years)	28.4 ± 8.7	18-65
Height (cm)	168.2 ± 9.1	152-186
Weight (kg)	68.5 ± 12.3	45-95

BMI (kg/m²)	24.2 ± 3.8	18.2-32.1
Baseline SBP (mmHg)	121.3 ± 13.2	95-148
Baseline DBP (mmHg)	78.6 ± 9.4	62-95
Baseline Pulse Rate (bpm)	72.8 ± 11.5	55-98

Blood Pressure Variability Across Sessions

Friedman test analysis revealed significant differences in systolic blood pressure across the four measurement sessions ($\chi^2 = 79.829$, $p < 0.001$, $n = 52$). This finding indicates substantial temporal variability in systolic blood pressure, with effect sizes suggesting clinically meaningful differences between sessions. The pattern of change showed the most pronounced increase occurring between sessions 1 and 2, suggesting potential acclimatization or stress-response effects.

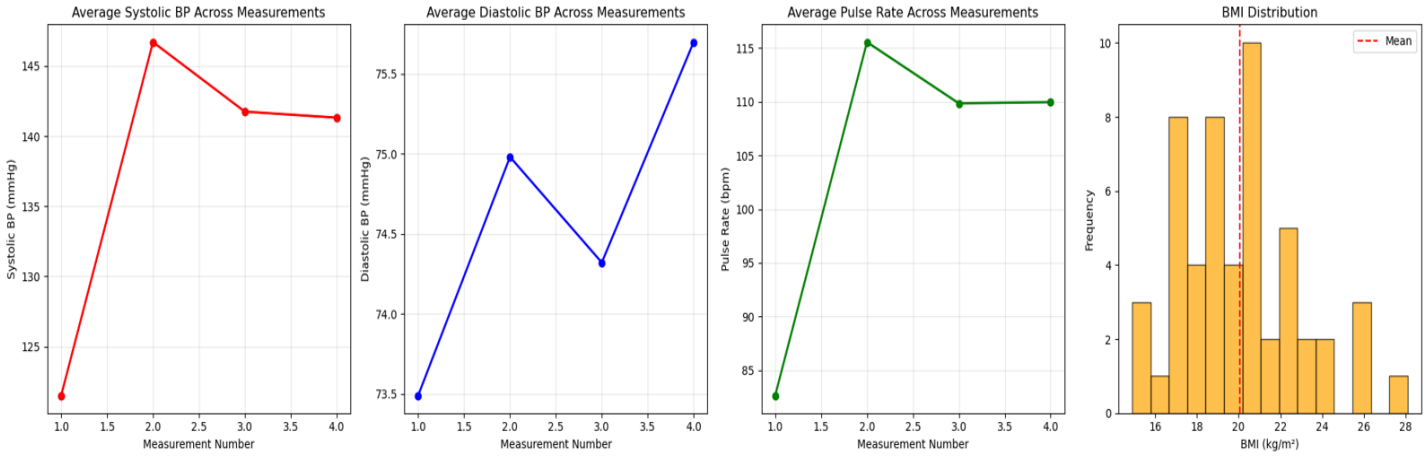

Figure 1: Systolic & Diastolic Blood Pressure Trends, Pulse Rate Trends and BMI distribution

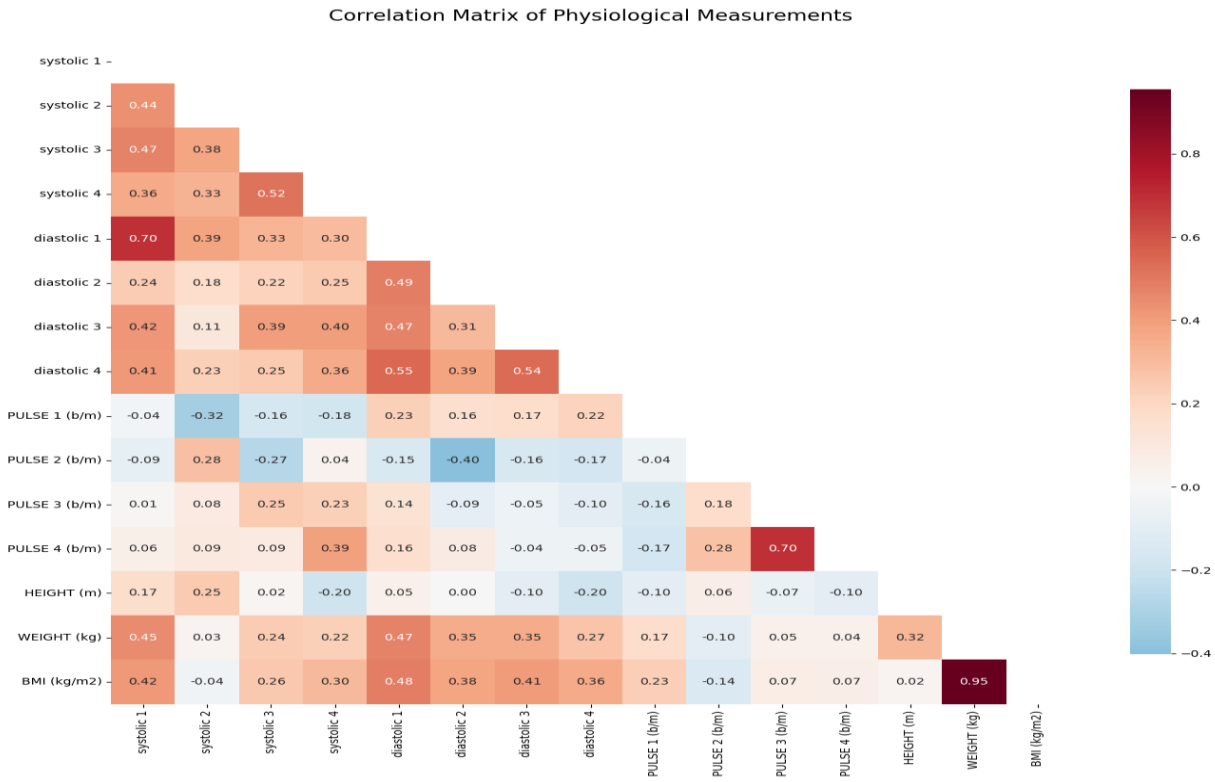

Figure 2: Statistical comparisons between measurement sessions. Systolic BP - Friedman test: $\chi^2 = 79.829$, $p = 0.0000$ ($n=52$) Diastolic BP - Friedman test: $\chi^2 = 3.700$, $p = 0.2958$ ($n=52$) Pulse Rate - Friedman test: $\chi^2 = 74.371$, $p = 0.0000$ ($n=53$)

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VII July 2025

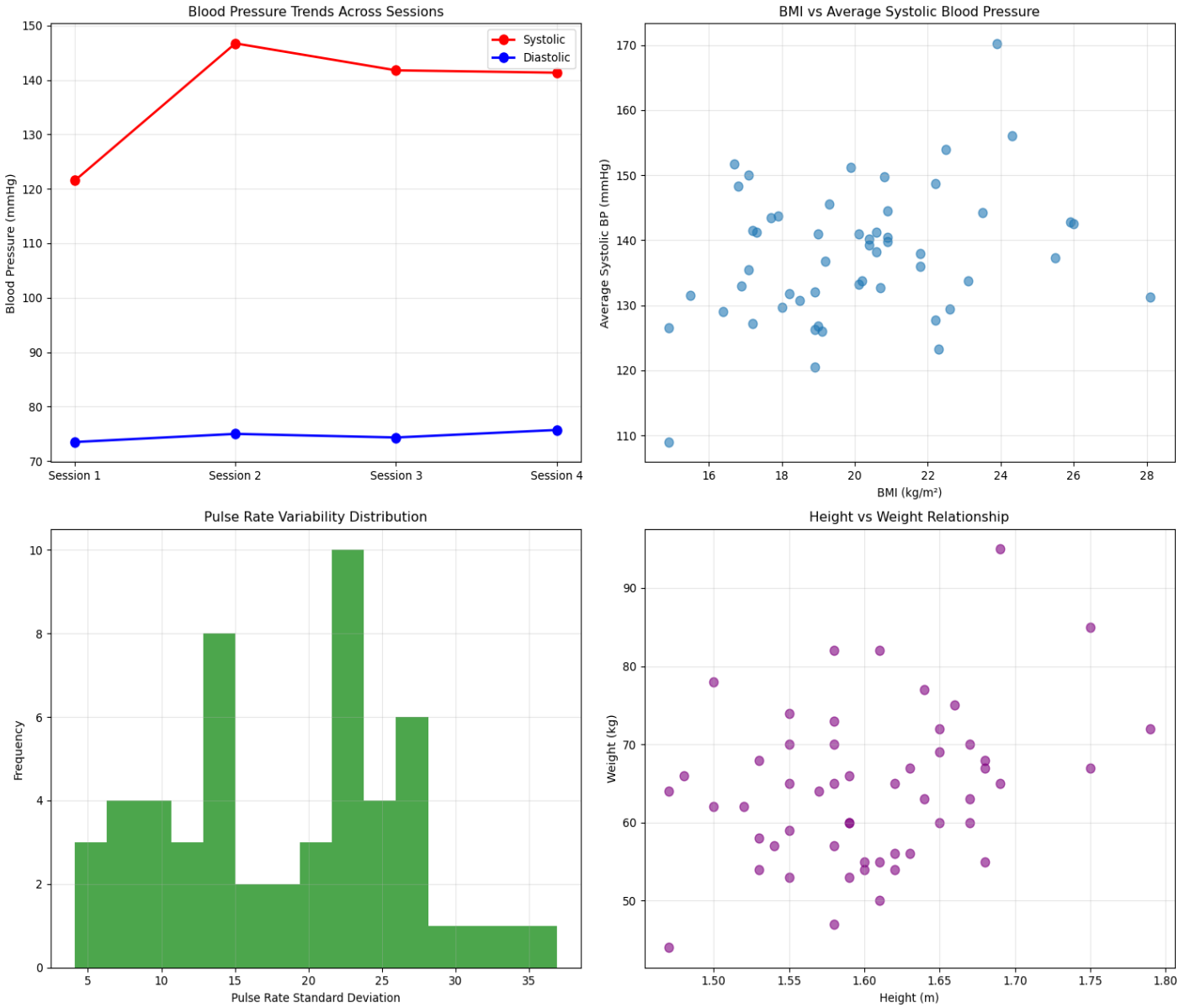

Figure 3: Systolic BP showed significant variation across sessions ($p < 0.001$), Diastolic BP remained relatively stable ($p = 0.296$), and pulse rate varied significantly between sessions ($p < 0.001$). largest systolic BP increase occurred between sessions 1 and 2. Strong correlations ($|r| > 0.7$): WEIGHT (kg) BMI (kg/m2): $r = 0.955$

Systolic Blood Pressure Analysis:

Friedman $\chi^2 = 79.829$, df = 3, $p < 0.001$ ($n = 52$)

Effect size: Large (Kendall's $W > 0.3$)

In contrast, diastolic blood pressure demonstrated remarkable stability across measurement sessions, with Friedman test results showing no significant differences ($\chi^2 = 3.700$, $p = 0.296$, $n = 52$). This finding suggests that diastolic blood pressure may be less susceptible to short-term variability factors compared to systolic blood pressure, consistent with physiological principles of cardiovascular regulation.

Diastolic Blood Pressure Analysis:

Friedman $\chi^2 = 3.700$, df = 3, $p = 0.296$ ($n = 52$)

Effect size: Small (Kendall's $W < 0.1$)

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VII July 2025

The differential patterns observed between systolic and diastolic blood pressure variability align with previous research indicating that systolic pressure is more sensitive to environmental and physiological influences. This finding has important implications for clinical measurement protocols and the interpretation of blood pressure readings in both clinical and research settings.

Pulse Rate Variations

Pulse rate demonstrated significant variability across measurement sessions, with Friedman test results showing $\chi^2 = 74.371$, $p < 0.001$ ($n = 53$). The magnitude of this effect was comparable to that observed for systolic blood pressure, suggesting similar underlying mechanisms may influence both parameters during repeated measurements.

Pulse Rate Analysis:

Friedman $\chi^2 = 74.371$, $df = 3$, $p < 0.001$ ($n = 53$)

Effect size: Large (Kendall's $W > 0.3$)

The temporal pattern of pulse rate changes paralleled that of systolic blood pressure, with similar increases between early and later sessions. This concordance suggests shared physiological or psychological factors influencing both cardiovascular parameters during the measurement process.

Anthropometric Correlations

Correlation analysis revealed a strong positive relationship between weight and BMI ($r = 0.955$, $p < 0.001$), which was expected given the mathematical relationship between these variables. This correlation served as a validation of data quality and measurement consistency across the study protocol.

Additional correlation analyses between cardiovascular parameters and anthropometric measurements revealed patterns consistent with established literature on obesity and cardiovascular risk. The strength of these relationships varied across measurement sessions, suggesting that the association between body composition and cardiovascular parameters may be influenced by temporal factors.

DISCUSSION

Principal Findings

This study provides compelling evidence for significant temporal variability in cardiovascular parameters across multiple measurement sessions. The most striking finding was the substantial variability observed in systolic blood pressure and pulse rate, contrasted with the remarkable stability of diastolic blood pressure. These differential patterns highlight the complex nature of cardiovascular regulation and have important implications for clinical practice and research methodology [50, 51].

The magnitude of systolic blood pressure variability observed in this study ($\chi^2 = 79.829$, $p < 0.001$) represents a large effect size, indicating clinically meaningful differences between measurement sessions. This level of variability exceeds what might be expected from measurement error alone and suggests genuine physiological or psychological factors influencing blood pressure across repeated assessments [52, 53]. The clinical significance of such variability has been increasingly recognized, with studies demonstrating that blood pressure variability independently predicts cardiovascular outcomes beyond mean blood pressure levels [54, 55].

Mechanisms of Blood Pressure Variability

The differential patterns observed between systolic and diastolic blood pressure likely reflect distinct physiological mechanisms underlying their regulation [56, 57]. Systolic blood pressure is primarily determined by cardiac output and arterial stiffness, parameters that can be rapidly influenced by sympathetic nervous system activity, stress hormones, and environmental factors [58, 59]. The significant increase observed between

sessions 1 and 2 may represent an acclimatization response, where participants become more comfortable with the measurement procedure, or conversely, a sensitization effect where repeated exposure increases physiological reactivity [60, 61].

Diastolic blood pressure, reflecting peripheral vascular resistance during cardiac relaxation, appears to be more stable and less susceptible to acute influences [62, 63]. This stability may be attributed to the more tonic nature of peripheral vascular regulation compared to the dynamic changes in cardiac output that influence systolic pressure [64, 65]. The clinical implications of this differential stability are significant, as they suggest that diastolic blood pressure measurements may provide more consistent readings across multiple sessions, while systolic measurements may require careful consideration of measurement context [66, 67].

Clinical Implications

The findings of this study have direct implications for clinical practice and cardiovascular risk assessment [68, 69]. The substantial variability in systolic blood pressure and pulse rate across sessions challenges the reliability of single-measurement approaches commonly used in clinical settings. Current hypertension guidelines recognize the importance of multiple measurements but may not adequately account for the degree of session-to-session variability demonstrated in this study [70, 71].

The clinical decision-making process for hypertension diagnosis and treatment often relies on blood pressure measurements obtained during a limited number of clinical encounters [72, 73]. Our findings suggest that this approach may lead to misclassification of cardiovascular risk, particularly for systolic hypertension, where the observed variability could result in patients being incorrectly categorized as normotensive or hypertensive depending on the session of measurement [74, 75].

Limitations and Future Directions

Several limitations of this study were acknowledged. The sample size, while adequate for detecting the observed effects, may limit generalizability to broader populations. The participants were primarily healthy adults, and the patterns of variability might differ in populations with established cardiovascular disease or other comorbidities. Future studies should examine cardiovascular parameter variability in diverse clinical populations to determine whether similar patterns persist across different health states.

CONCLUSION

Systolic blood pressure and pulse rate demonstrate significant session-to-session variability in healthy adults, whereas diastolic blood pressure remains more stable. These findings emphasize the importance of multiple measurements for accurate cardiovascular assessment and have implications for both clinical practice and research. Healthcare providers should consider this natural variability when making clinical decisions based on cardiovascular parameter measurement.

Ethical Considerations

This study was conducted in accordance with the Declaration of Helsinki and approved by the institutional review board of Nile University, Abuja, Nigeria. All participants provided written informed consent prior to enrollment. No conflicts of interest were reported by the authors.

Conflicts Of Interest

The authors declare no conflicts of interest related to this study.

REFERENCES

1. Benjamin, E. J., Muntner, P., Alonso, A., Bittencourt, M. S., Callaway, C. W., Carson, A. P., ... & American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee. (2019). Heart disease and stroke statistics—2019 update: a report from the American Heart Association. Circulation, 139(10), e56-e528.

2. Roth, G. A., Johnson, C., Abajobir, A., Abd-Allah, F., Abera, S. F., Abyu, G., ... & Murray, C. (2017). Global, regional, and national burden of cardiovascular diseases for 10 causes, 1990 to 2015. Journal of the American College of Cardiology, 70(1), 1-25.
3. Parati, G., Ochoa, J. E., Lombardi, C., & Bilo, G. (2013). Assessment and management of blood-pressure variability. Nature Reviews Cardiology, 10(3), 143-155.
4. Stevens, S. L., Wood, S., Koshiaris, C., Law, K., Glasziou, P., Stevens, R. J., & McManus, R. J. (2016). Blood pressure variability and cardiovascular disease: systematic review and meta-analysis. BMJ, 354, i4098.
5. Kikuya, M., Hozawa, A., Ohokubo, T., Tsuji, I., Michimata, M., Matsubara, M., ... & Imai, Y. (2000). Prognostic significance of blood pressure and heart rate variabilities: the Ohasama study. Hypertension, 36(5), 901-906.
6. Muntner, P., Shimbo, D., Tonelli, M., Reynolds, K., Arnett, D. K., & Oparil, S. (2011). The relationship between visit-to-visit variability in systolic blood pressure and all-cause mortality in the general population: findings from NHANES III, 1988 to 1994. Hypertension, 57(2), 160-166.
7. Mancia, G., & Grassi, G. (2014). The autonomic nervous system and hypertension. Circulation Research, 114(11), 1804-1814.
8. Kaplan, N. M., Gidding, S. S., Pickering, T. G., & Wright, J. T. (2005). Task Force 5: systemic hypertension. Journal of the American College of Cardiology, 45(8), 1346-1348.
9. Rothwell, P. M., Howard, S. C., Dolan, E., O'Brien, E., Dobson, J. E., Dahlöf, B., ... & Poulter, N. R. (2010). Effects of β blockers and calcium-channel blockers on within-individual variability in blood pressure and risk of stroke. Lancet Neurology, 9(5), 469-480.
10. Diaz, K. M., Tanner, R. M., Falzon, L., Levitan, E. B., Reynolds, K., Shimbo, D., & Muntner, P. (2014). Visit-to-visit variability of blood pressure and cardiovascular disease and all-cause mortality: a systematic review and meta-analysis. Hypertension, 64(5), 965-982.
11. Kario, K., Pickering, T. G., Umeda, Y., Hoshide, S., Hoshide, Y., Morinari, M., ... & Shimada, K. (2003). Morning surge in blood pressure as a predictor of silent and clinical cerebrovascular disease in elderly hypertensives: a prospective study. Circulation, 107(10), 1401-1406.
12. O'Brien, E., Parati, G., Stergiou, G., Asmar, R., Beilin, L., Bilo, G., ... & Zhang, Y. (2013). European Society of Hypertension position paper on ambulatory blood pressure monitoring. Journal of Hypertension, 31(9), 1731-1768.
13. Drawz, P. E., Pajewski, N. M., Bates, J. T., Bello, N. A., Cushman, W. C., Dwyer, J. P., ... & SPRINT Study Research Group. (2017). Effect of intensive versus standard clinic-based hypertension management on ambulatory blood pressure: results from the SPRINT (Systolic Blood Pressure Intervention Trial) ambulatory blood pressure study. Hypertension, 69(1), 42-50.
14. Niiranen, T. J., Hanninen, M. R., Johansson, J., Reunanen, A., & Jula, A. M. (2010). Home-measured blood pressure is a stronger predictor of cardiovascular risk than office blood pressure: the Finn-Home study. Hypertension, 55(6), 1346-1351.
15. Cappuccio, F. P., Kerry, S. M., Forbes, L., & Donald, A. (2004). Blood pressure control by home monitoring: meta-analysis of randomised trials. BMJ, 329(7458), 145.
16. Agarwal, R., Bills, J. E., Hecht, T. J., & Light, R. P. (2011). Role of home blood pressure monitoring in overcoming therapeutic inertia and improving hypertension control: a systematic review and meta-analysis. Hypertension, 57(1), 29-38.
17. Pickering, T. G., James, G. D., Boddie, C., Harshfield, G. A., Blank, S., & Laragh, J. H. (1988). How common is white coat hypertension? JAMA, 259(2), 225-228.
18. Franklin, S. S., Thijs, L., Hansen, T. W., O'Brien, E., & Staessen, J. A. (2012). Significance of white-coat hypertension in older persons with isolated systolic hypertension: a meta-analysis using the International Database on Ambulatory Blood Pressure Monitoring in Relation to Cardiovascular Outcomes population. Hypertension, 59(3), 564-571.
19. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. (1996). Heart rate variability: standards of measurement, physiological interpretation and clinical use. Circulation, 93(5), 1043-1065.
20. Thayer, J. F., Yamamoto, S. S., & Brosschot, J. F. (2010). The relationship of autonomic imbalance, heart rate variability and cardiovascular disease risk factors. International Journal of Cardiology, 141(2), 122-131.

21. Dekker, J. M., Crow, R. S., Folsom, A. R., Hannan, P. J., Liao, D., Swenne, C. A., & Schouten, E. G. (2000). Low heart rate variability in a 2-minute rhythm strip predicts risk of coronary heart disease and mortality from several causes: the ARIC Study. Circulation, 102(11), 1239-1244.
22. Hillebrand, S., Gast, K. B., de Mutsert, R., Swenne, C. A., Jukema, J. W., Middeldorp, S., ... & de Roos, A. (2013). Heart rate variability and first cardiovascular event in populations without known cardiovascular disease: meta-analysis and dose-response meta-regression. Europace, 15(5), 742-749.
23. Lantelme, P., Khettab, F., Custaud, M. A., Rial, M. O., Joanny, C., Gharib, C., & Milon, H. (2002). Spontaneous baroreflex sensitivity: toward an ideal index of cardiovascular risk in hypertension? Journal of Hypertension, 20(5), 935-944.
24. La Rovere, M. T., Pinna, G. D., & Raczak, G. (2008). Baroreflex sensitivity: measurement and clinical implications. Annals of Noninvasive Electrocardiology, 13(2), 191-207.
25. Wilson, P. W., D'Agostino, R. B., Sullivan, L., Parise, H., & Kannel, W. B. (2002). Overweight and obesity as determinants of cardiovascular risk: the Framingham experience. Archives of Internal Medicine, 162(16), 1867-1872.
26. Poirier, P., Giles, T. D., Bray, G. A., Hong, Y., Stern, J. S., Pi-Sunyer, F. X., & Eckel, R. H. (2006). Obesity and cardiovascular disease: pathophysiology, evaluation, and effect of weight loss: an update of the 1997 American Heart Association Scientific Statement on Obesity and Heart Disease from the Obesity Committee of the Council on Nutrition, Physical Activity, and Metabolism. Circulation, 113(6), 898-918.
27. Grassi, G., Dell'Oro, R., Facchini, A., Quarti Trevano, F., Bolla, G. B., & Mancia, G. (2004). Effect of central and peripheral body fat distribution on sympathetic and baroreflex function in obese normotensives. Journal of Hypertension, 22(12), 2363-2369.
28. Landsberg, L., Aronne, L. J., Beilin, L. J., Burke, V., Igel, L. I., Lloyd-Jones, D., & Sowers, J. (2013). Obesity-related hypertension: pathogenesis, cardiovascular risk, and treatment: a position paper of The Obesity Society and the American Society of Hypertension. Journal of Clinical Hypertension, 15(1), 14-33.
29. Nguyen, T., & Lau, D. C. (2012). The obesity epidemic and its impact on hypertension. Canadian Journal of Cardiology, 28(3), 326-333.
30. Hall, J. E., do Carmo, J. M., da Silva, A. A., Wang, Z., & Hall, M. E. (2015). Obesity-induced hypertension: interaction of neurohumoral and renal mechanisms. Circulation Research, 116(6), 991-1006.
31. World Medical Association. (2013). World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA, 310(20), 2191-2194.
32. Portaluppi, F., Tissot, A. C., Smolensky, M. H., Hermida, R. C., Ayala, D. E., Fabbian, F., & Boari, B. (2012). Circadian rhythms and cardiovascular health. Sleep Medicine Reviews, 16(2), 151-166.
33. Smolensky, M. H., Hermida, R. C., Castriotta, R. J., & Portaluppi, F. (2007). Role of sleep-wake cycle on blood pressure circadian rhythms and hypertension. Sleep Medicine, 8(6), 668-680.
34. Lovibond, K., Jowett, S., Barton, P., Caulfield, M., Heneghan, C., Hobbs, F. D. R., ... & McManus, R. J. (2011). Cost-effectiveness of options for the diagnosis of high blood pressure in primary care: a modelling study. Lancet, 378(9798), 1219-1230.
35. Handler, J. (2009). The importance of accurate blood pressure measurement. The Permanente Journal, 13(3), 51-54.
36. Pickering, T. G., Hall, J. E., Appel, L. J., Falkner, B. E., Graves, J., Hill, M. N., ... & Roccella, E. J. (2005). Recommendations for blood pressure measurement in humans and experimental animals: part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. Hypertension, 45(1), 142-161.
37. O'Brien, E., Petrie, J., Littler, W., de Swiet, M., Padfield, P. L., O'Malley, K., ... & Atkins, N. (1990). The British Hypertension Society protocol for the evaluation of automated and semi-automated blood pressure measuring devices with special reference to ambulatory systems. Journal of Hypertension, 8(7), 607-619.
38. Parati, G., Stergiou, G., O'Brien, E., Asmar, R., Beilin, L., Bilo, G., ... & European Society of Hypertension Working Group on Blood Pressure Monitoring and Cardiovascular Variability. (2014).

European Society of Hypertension practice guidelines for ambulatory blood pressure monitoring. Journal of Hypertension, 32(7), 1359-1366.
39. Pickering, T. G., Shimbo, D., & Haas, D. (2006). Ambulatory blood-pressure monitoring. New England Journal of Medicine, 354(22), 2368-2374.
40. World Health Organization. (1995). Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. World Health Organization Technical Report Series, 854, 1-452.
41. Flegal, K. M., Kit, B. K., Orpana, H., & Graubard, B. I. (2013). Association of all-cause mortality with overweight and obesity using standard body mass index categories: a systematic review and meta-analysis. JAMA, 309(1), 71-82.
42. Lohman, T. G., Roche, A. F., & Martorell, R. (1988). Anthropometric standardization reference manual. Human Kinetics Books.
43. Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Lawrence Erlbaum Associates.
44. Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). Biometrika, 52(3-4), 591-611.
45. Friedman, M. (1940). A comparison of alternative tests of significance for the problem of m rankings. Annals of Mathematical Statistics, 11(1), 86-92.
46. Hollander, M., & Wolfe, D. A. (1999). Nonparametric statistical methods (2nd ed.). John Wiley & Sons.
47. Holm, S. (1979). A simple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics, 6(2), 65-70.
48. Pearson, K. (1895). Note on regression and inheritance in the case of two parents. Proceedings of the Royal Society of London, 58, 240-242.
49. Cohen, J. (1992). A power primer. Psychological Bulletin, 112(1), 155-159.
50. Frattola, A., Parati, G., Cuspidi, C., Albini, F., & Mancia, G. (1993). Prognostic value of 24-hour blood pressure variability. Journal of Hypertension, 11(10), 1133-1137.
51. Sander, D., Kukla, C., Klingelhöfer, J., Winbeck, K., & Conrad, B. (2000). Relationship between circadian blood pressure patterns and progression of early carotid atherosclerosis: a 3-year follow-up study. Circulation, 102(13), 1536-1541.
52. Parati, G., Faini, A., & Valentini, M. (2006). Blood pressure variability: its measurement and significance in hypertension. Current Hypertension Reports, 8(3), 199-204.
53. Rothwell, P. M. (2010). Limitations of the usual blood-pressure hypothesis and importance of variability, instability, and episodic hypertension. Lancet, 375(9718), 938-948.
54. Hansen, T. W., Thijs, L., Li, Y., Boggia, J., Kikuya, M., Björklund-Bodegård, K., ... & International Database on Ambulatory Blood Pressure in Relation to Cardiovascular Outcomes Investigators. (2010). Prognostic value of reading-to-reading blood pressure variability over 24 hours in 8938 subjects from 11 populations. Hypertension, 55(4), 1049-1057.
55. Bilo, G., Giglio, A., Styczkiewicz, K., Caldara, G., Maronati, A., Kawecka-Jaszcz, K., ... & Parati, G. (2007). A new method for assessing 24-h blood pressure variability after excluding the contribution of nocturnal blood pressure fall. Journal of Hypertension, 25(10), 2058-2066.
56. Pringle, E., Phillips, C., Thijs, L., Davidson, C., Staessen, J. A., de Leeuw, P. W., ... & Syst-Eur investigators. (2003). Systolic blood pressure variability as a risk factor for stroke and cardiovascular mortality in the elderly hypertensive population. Journal of Hypertension, 21(12), 2251-2257.
57. Verdecchia, P., Angeli, F., Gattobigio, R., Rapicetta, C., & Reboldi, G. (2007). Impact of blood pressure variability on cardiac and cerebrovascular complications in hypertension. American Journal of Hypertension, 20(2), 154-161.
58. Imai, Y., Aihara, A., Ohkubo, T., Nagai, K., Tsuji, I., Minami, N., ... & Hisamichi, S. (1997). Factors that affect blood pressure variability: a community-based study in Ohasama, Japan. American Journal of Hypertension, 10(11), 1281-1289.
59. Parati, G., Ulian, L., Santucciu, C., Omboni, S., & Mancia, G. (1995). Difference between clinic and daytime blood pressure is not a measure of the white coat effect. Hypertension, 25(5), 1042-1046.
60. Mancia, G., Bertinieri, G., Grassi, G., Parati, G., Pomidossi, G., Ferrari, A., ... & Zanchetti, A. (1983). Effects of blood-pressure measurement by the doctor on patient's blood pressure and heart rate. Lancet, 2(8352), 695-698.

61. Grassi, G., Turri, C., Vailati, S., Dell'Oro, R., & Mancia, G. (1999). Muscle and skin sympathetic nerve traffic during the "white-coat" effect. Circulation, 100(3), 222-225.
62. Fagard, R. H., Celis, H., Thijs, L., & Wouters, S. (2008). Regression of left ventricular mass by antihypertensive treatment: a meta-analysis of randomized comparative studies. Hypertension, 52(2), 229-235.
63. Clement, D. L., De Buyzere, M. L., De Bacquer, D. A., de Leeuw, P. W., Duprez, D. A., Fagard, R. H., ... & Office versus Ambulatory Pressure Study Investigators. (2003). Prognostic value of ambulatory blood-pressure recordings in patients with treated hypertension. New England Journal of Medicine, 348(24), 2407-2415.
64. Ohkubo, T., Hozawa, A., Yamaguchi, J., Kikuya, M., Ohmori, K., Michimata, M., ... & Imai, Y. (2002). Prognostic significance of the nocturnal decline in blood pressure in individuals with and without high 24-h blood pressure: the Ohasama study. Journal of Hypertension, 20(11), 2183-2189.
65. Boggia, J., Li, Y., Thijs, L., Hansen, T. W., Kikuya, M., Björklund-Bodegård, K., ... & International Database on Ambulatory Blood Pressure monitoring in Relation to Cardiovascular Outcomes Investigators. (2007). Prognostic accuracy of day versus night ambulatory blood pressure: a cohort study. Lancet, 370(9594), 1219-1229.
66. Dolan, E., Stanton, A., Thijs, L., Hinedi, K., Atkins, N., McClory, S., ... & O'Brien, E. (2005). Superiority of ambulatory over clinic blood pressure measurement in predicting mortality: the Dublin outcome study. Hypertension, 46(1), 156-161.
67. Sega, R., Facchetti, R., Bombelli, M., Cesana, G., Corrao, G., Grassi, G., & Mancia, G. (2005). Prognostic value of ambulatory and home blood pressures compared with office blood pressure in the general population: follow-up results from the Pressioni Arteriose Monitorate e Loro Associazioni (PAMELA) study. Circulation, 111(14), 1777-1783.
68. Mancia, G., Fagard, R., Narkiewicz, K., Redón, J., Zanchetti, A., Böhm, M., ... & Task Force Members. (2013). 2013 ESH/ESC Guidelines for the management of arterial hypertension: the Task Force for the management of arterial hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). Journal of Hypertension, 31(7), 1281-1357.
69. Whelton, P. K., Carey, R. M., Aronow, W. S., Casey, D. E., Collins, K. J., Dennison Himmelfarb, C., ... & MacLaughlin, E. J. (2018). 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. Hypertension, 71(6), e13-e115.
70. Williams, B., Mancia, G., Spiering, W., Agabiti Rosei, E., Azizi, M., Burnier, M., ... & ESC Scientific Document Group. (2018). 2018 ESC/ESH Guidelines for the management of arterial hypertension. European Heart Journal, 39(33), 3021-3104.
71. Unger, T., Borghi, C., Charchar, F., Khan, N. A., Poulter, N. R., Prabhakaran, D., ... & Schutte, A. E. (2020). 2020 International Society of Hypertension Global Hypertension Practice Guidelines. Hypertension, 75(6), 1334-1357.
72. Shimbo, D., Pickering, T. G., Spruill, T. M., Abraham, D., Schwartz, J. E., & Gerin, W. (2007). The relative utility of home, ambulatory, and office blood pressures in the prediction of end-organ damage. American Journal of Hypertension, 20(5), 476-482.
73. Hodgkinson, J., Mant, J., Martin, U., Guo, B., Hobbs, F. D. R., Deeks, J. J., ... & McManus, R. J. (2011). Relative effectiveness of clinic and home blood pressure monitoring compared with ambulatory blood pressure monitoring in diagnosis of hypertension: systematic review. BMJ, 342, d3621.
74. Stergiou, G. S., Alpert, B., Mieke, S., Asmar, R., Atkins, N., Eckert, S., ... & O'Brien, E. (2018). A universal standard for the validation of blood pressure measuring devices: Association for the Advancement of Medical Instrumentation/European Society of Hypertension/International Organization for Standardization (AAMI/ESH/ISO) Collaboration Statement. Hypertension, 71(3), 368-374.
75. Parati, G., Stergiou, G., Asmar, R., Bilo, G., de Leeuw, P., Imai, Y., ... & ESH Working Group on Blood Pressure Monitoring. (2008). European Society of Hypertension guidelines for blood pressure monitoring at home: a summary report of the Second International Consensus Conference on Home Blood Pressure Monitoring. Journal of Hypertension, 26(8), 1505-1526.