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Performance of Sitting Time as A Screening Tool for Prehypertension Among Selected Workers in Kano State Nigeria; A Comparison with Obesity Measures

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ABSTRACT
The relationship between obesity and sedentary behavior on the one hand and cardiometabolic diseases on the other hand had been well established. To be used as screening tools for cardiometabolic disease, such risk factors must demonstrate sufficient discriminatory capacity as measured by area under the curve (AUC) of receiver operating characteristics curve (ROC). The aim of this study is to compare the performance of sitting time and obesity measures as screening tools for prehypertension among selected workers in Kano State Nigeria. This is a cross sectional analytical study conducted among workers enrolled in a part-time degree program at Bayero University Kano, Kano State, Nigeria. Body weight was measured using a digital weighing scale, height using a portable stadiometer, circumferences (waist and hip) using an inelastic tape and blood pressure using a mercury sphygmomanometer. Sitting time was reported using a standard questionnaire. The ROC analysis showed the cut off points of body mass index, waist circumference and sitting time were respectively 24kg/m2 for males and 26kg/m2 for females, 84cm for both sexes and 8 hours for males and 9 hours for females. The respective AUCs were respectively 59%, 61% and 58%. In conclusion, sitting time has performance comparable to that of body mass index in predicting prehypertension among the study subjects.

Keywords: Prehypertension, Body Mass Index, Waist Circumference, Sitting Time, Obesity, AUROC

INTRODUCTION

Prehypertension (PHTN) is a borderline high-risk blood pressure status defined as systolic Blood Pressure (BP) of 120-139mmHg and/or diastolic BP of 80-89mmHg (National High Blood Pressure Education Program, 2004). There are estimated 41.1 million adult Nigerians with prehypertension according to a recent meta-analysis (Bashir et al., 2021). Prehypertension is more than just a transition state to overt hypertension. The worldwide increased risk of hypertension, coronary heart disease, stroke, chronic kidney disease and all-cause mortality due to prehypertension are respectively 16 times (Lindblad et al., 2021), 62% (Han et al., 2019; Huang et al., 2015), 48%, 28% (Li et al., 2016) and 3% (Huang et al., 2014).

Sedentary behavior is any waking behavior characterized by an energy expenditure ≤ 1.5 metabolic equivalent of task (MET = energy expenditure at rest which is about 3.5ml of O2/Kg/minute) (Sedentary Behaviour Research Network, 2012). There is a consistent evidence from observational studies that sedentary behavior is associated with cardiometabolic disease incidence and mortality (Bell et al., 2023; Guo et al., 2020; Lee & Wong, 2015).

Obesity has been defined as excessive accumulation of fat in the body to the extent that leads to impairment of health (WHO, 2000). A simple correlate of total body fat is the body mass index (BMI), defined as weight in Kg divided by square of height in meters (Kg/m2). There are 4 (four) categories of abnormal BMI; the preobesity and classes I-III of obesity. The ranges of the categories are, respectively, 25-29.99Kg/m2, 30-34.99Kg/m2, 35-39.99Kg/m2 and values of 40Kg/m2 or greater (WHO, 2000). The World Health Organization defined sex-specific central obesity as waist-hip ratio > 0.9 in males and > 0.85 in females (World Health Organization, 2008). The body also recommended ethnic-specific cut off of waist circumference for defining central obesity such as the value of ≥ 102cm and ≥ 88cm for Caucasian males and females respectively. (World Health Organization, 2008).

Early detection of prehypertension risk using simple, readily available and inexpensive tools will enable targeted and cost-effective public health measures and programs to prevent progression to hypertension and thus reduce the burden of cardiovascular diseases in the country. The aim of this study is to evaluate the performance of obesity and sedentary behavior in predicting prehypertension among selected workers in Kano State Nigeria.

MATERIALS AND METHODS

Study Area

The study was conducted in Bayero University Kano (BUK), a university located in the North-West Region of Kano State in Nigeria, a lower middle income (World Bank, 2021) Western African nation. Kano State shares boundary with Katsina in the northwest, Jigawa State in the northeast, Bauchi State in the southeast and Kaduna in the southwest. It has total land area of 21,276.9 Km2 and a projected population of 12,150,811 by 2017 (Figure 1) (Abdulkadir et al., 2018).

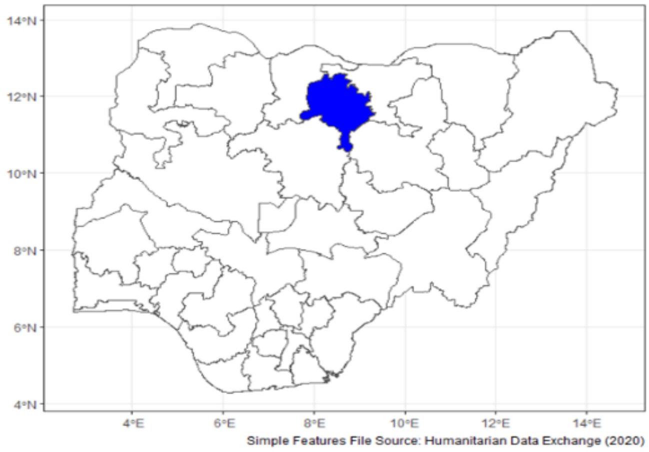

Figure 1: Map of Kano State in Nigeria

Study Design
The study design was cross-sectional analytical study

Study Population
The study population consists of the students of the School of Continuing Education (SCE) of Bayero University Kano. The university is a leading tertiary institution in Nigeria founded in 1976 and about fifty thousand (50,000) students currently enrolled (MacArthur Foundation, 2024). SCE is a part-time program school meant mostly for workers with classes taking place mostly on weekends. There are 25 programs across five (5) departments and currently enrolls more than four thousand (4, 000) students (Bayero University kano, 2024).

Sample Size Calculation
Sample size was calculated through a simulation work flow recommended by Kruschke (Kruschke, 2014) and detailed by Kurz (Kurz, 2019) as follows:

i. Determination of the primary data type which was binary (prehypertensive vs normotensive).
ii. Determination of the regression model (which was logistic) and parameter of interest [odds ratio of 2.52 for prehypertension (Deng et al., 2013)].
iii. Normal prior with mean of 0 and standard deviation of 2 on the logistic scale was picked for the regression parameter as recommended by Gelman et al (2008). This is because odds ratio is a parameter derived from probabilities whose values are in the range of 0 to 1. The priors of mean 0 and standard deviation of 2 on logistic scale mean a range of probabilities from 0.01 to 0.99 which is almost the entire parameter space for probabilities by Gelman (Gelman et al., 2008).
iv. An arbitrary sample size starting point of 50 was chosen for the iteration.
v. An initial model was fitted and saved.
vi. Large number of data sets (1000) were simulated based on reported odds of prehypertension and prediabetes associated with central obesity. 1000 models were fitted representing each simulated data set.
vii. Proportion of parameters (odds ratio) which did not include null value (1 in case of odds ratios) in their 95% credible interval was reported as the power of detecting that odds ratio at that sample size.
viii. After repeated iterations of increasing sample size, sample sizes of 400 (200 each for prehypertensives and normotensives was found to have power of 99% (Figure 2).

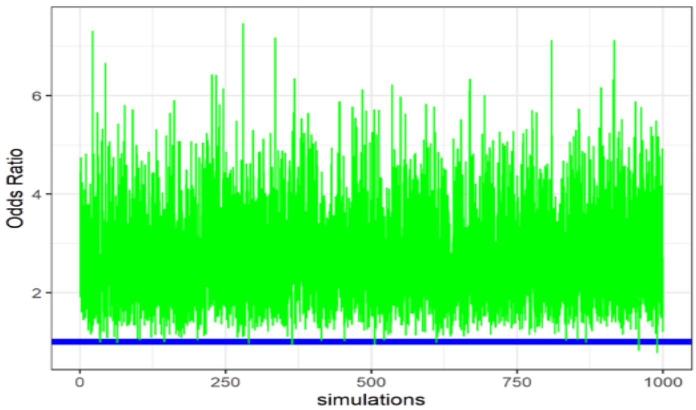

Figure 2: Sample Size Calculation Simulations

Sampling Methods
Sampling was a multi-stage sampling method. The 25 programs in the school were assigned numbers 1 to 25 and then two numbers representing two (2) programs were randomly selected using random number generator function in R (R Core Team, 2021). Next, each of the four (4) levels of the selected programs were assigned numbers and two (2) levels were randomly selected from each of the selected programs using the same random number generator function in R (R Core Team, 2021). The four selected levels had the sample size equally divided and systemic sampling (every

other student in a serialized list) was employed to recruit the desired sample size.

Eligibility Criteria

Inclusion Criteria

Eligible participants was an SCE student of BUK, who:

i. is a worker

ii. gave informed consent

iii. is not hypertensive or diabetic

iv. Does not have a cardiovascular endpoint event such as coronary heart disease or stroke.

Exclusion Criteria

Excluded from the study was any student who

i. is not a worker

ii. is pregnant

iii. refused participation in the study

iv. is hypertensive or diabetic

v. has a cardiovascular endpoint event such as coronary heart disease or stroke.

Ethical Considerations

Ethical clearance was sought from Bayero University Health Research Ethical Committee (BUK-HREC) and the Kano State Ministry of Health ethical committee (NHREC/17/03/2018).

Participants' Consent

Informed written consents was sought from the study participants

Body Weight Measurement

Body weight was measured using an electronic weighing scale (Seca, Germany) with maximum reading of 150Kg and accuracy of 0.1Kg. With the scale reading zero, the subject stood on the centre of the scale without support and with the weight distributed evenly on both feet (Centers for Disease Control and Prevention, 2014).

Height Measurement

Height was measured using a portable stadiometer (Seca, Germany) with maximum of 200cm and accuracy of 0.1cm. With the subject standing with the feet together and the heels, buttocks and upper part of the back touching a wall and the head placed in the Frankfort plane (a position of the head whereby the lower edge of the eye socket is in the same horizontal plane as the notch superior to the tragus of the ear). When aligned, the Vertex was the highest point on the skull (Centers for Disease Control and Prevention, 2014).

Body Mass Index

The Body Mass Index (BMI) was calculated as weight (in kilograms) divided by the square of height (in meters). Normal BMI was defined as the range 18.50-24.99 Kg/m2. Values at 25.0SKg/m2 and above were defined as abnormal (WHO, 2000). There are 4 (four) categories of abnormal BMI; the preobesity and classes I-III of obesity. The ranges of the categories are, respectively, 25-29.99Kg/m2, 30-34.99Kg/m2, 35-39.99Kg/m2 and values of 40Kg/m2 or greater (WHO, 2000).

Waist Circumference

Waist circumference was measured using an inelastic measuring tape (MEDLINE, 1-800-Medline, USA). With the subject assuming a relaxed standing position with the arms folded across the thorax, measurement was taken at the mid-point between the lower costal (10th rib) border and the iliac crest at the end of expiration. Central obesity was defined as values ≥ 94cm in males and ≥ 80cm females (WHO, 2000).

Hip Circumference and Waist-Hip Ratio

Hip circumference was measured using an inelastic measuring tape (MEDLINE, 1-800-Medline, USA). With the subject assuming a relaxed standing position with the arms folded across the thorax, the circumference was taken at the level of the greatest posterior protuberance of the buttocks which usually corresponds anteriorly to about the level of the symphysis pubis (Centers for Disease Control and Prevention, 2014). Central Obesity was defined as waist-to-hip ratio > 0.9 in males and > 0.85 in females (World Health Organization, 2008).

Determination of Blood Pressure Status

Blood pressure (BP) was measured using a portable mercury sphygmomanometer (Accoson, England) calibrated in millimeters of mercury (mmHg) with minimum recording of 0mmHg and maximum of 320mmHg. The accuracy of the instrument is 2mmHg. Littman's stethoscope (Master Classic IITM, United States) was used to auscultate the Korotkoff sounds.

The subjects were allowed to relax, sitting in a chair (feet on floor, back supported) for >5 minutes. The subjects were advised to avoid caffeine, exercise and smoking for at least 30 min before measurement. Neither the subject nor the observer was allowed to talk during the measurement. All clothing covering the location of cuff placement were removed. Subject's arm was placed resting on a desk. The middle of the cuff was positioned on the patient's upper arm at the level of the right atrium (the midpoint of the sternum). Correct cuff size, such that the bladder encircles 80% of the arm, was used. Either the stethoscope diaphragm or bell was used for auscultatory readings. A palpated estimate of radial pulse obliteration pressure was used to estimate SBP. The cuff was inflated 20–30 mm Hg above this level for an auscultatory determination of the BP level. For auscultatory readings, the cuff pressure was deflated at the rate of 2 mm Hg per second and Korotkoff sounds listened for. Systolic BP and diastolic BP was recorded as onset of the first Korotkoff sound and disappearance of all Korotkoff sounds, respectively, using the nearest even number (Whelton et al., 2018). An average of two readings was taken as the subject's blood pressure. Prehypertension was defined as systolic BP of 120-139mmHg and/or diastolic BP of 80-89mmHg (National High Blood Pressure Education Program, 2004).

Sitting Time Measurement

Sitting time was measured using English version of Hausa IPAQ-SF, a Nigerian version of the International Physical Activity Questionnaire Short Form. The test–retest reliability (ICC = 0.33–0.73) and concurrent validity (rho = 0.78–0.92) of the questionnaire were found to be good (Oyeyemi et al., 2011). Sitting time was reported as minutes per weekday.

Statistical Analyses

The statistical analysis was carried out based on Bayesian hierarchical modelling paradigm whereby all model parameters (cut-off values, specificity, sensitivity and area under the curves) were assigned probability distributions. Distributions, rather than merely point estimates, were reported. Distributional estimates of diagnostic performance of obesity and sitting time (sensitivity, specificity and AUCs) were determined using ROCnreg R package (Rodriguez-Alvarez & Inacio, 2021).

All analyses were done in R statistical environment (R Core Team, 2021).

RESULTS AND DISCUSSION

Characteristics of the Study Subjects

A total of 400 subjects were recruited into the prehypertension arm of the study with 200 prehypertension cases and 200 age-matched controls. The prehypertension cases consisted of 125 males (mean age = 38 years, 7.8) and 75 females (mean age = 35 years, ±8.6). The prehypertension control consisted of 118 males (mean age = 39 years, ± 7.0) and 82 females (mean age = 32 years, ±8.6).

Cut off Values for Predicting Prehypertension

The respective cut-off values for males and females were 24cm and 26cm for body mass index, 84cm in both sexes for waist circumference, 0.90 and 0.83 for waist-to-hip ratio and 0.5 for waist-to-height ratio in both sexes. For sitting time per weekday, the cut off values were 9 hours 8 for males and females respectively (Table 1).

Table 1: Sex-Specific Threshold Values of Body Mass Index, Waist Circumference, Waist-Hip Ratio, Waist-Height Ratio and Sitting Time for Predicting Prehypertension

Parameter	SEX	BMI	WC	WHR	WHtR	Sitting hours
AUC (%)		59 (50-67)	61 (52-69)	61 (52-69)	60 (52-68)	58 (49-67)
Cut-off Value	Females	26kg/m2 (23-33)	84cm (76-96)	0.83 (0.79-0.88)	0.52 (0.47-0.60)	9 (6.4-15.4)
	Males	24k g/m2 (21-30)	84cm (76-94)	0.9 (0.84-0.95)	0.49 (0.45-0.56)	8.2 (6.7-14.0)
False Positive Fraction	Females	0.51 (0.22-0.78)	0.48 (0.22-0.77)	0.43 (0.24-0.73)	0.51 (0.24-0.78)	0.55 (0.21-0.79)
	Males	0.53 (0.24-0.78)	0.48 (0.24-0.74)	0.46 (0.23-0.75)	0.52 (0.26-0.76)	0.57 (0.25-0.77)
True Positive Fraction	Females	0.65 (0.17-0.84)	0.63 (0.20-0.83)	0.63 (0.32-0.80)	0.66 (0.18-0.84)	0.62 (0.13-0.87)
	Males	0.66 (0.20-0.84)	0.64 (0.30-0.84)	0.61 (0.25-0.80)	0.67 (0.23-0.84)	0.74 (0.17-0.86)

Values in Brackets are 95% Credible Intervals. AUC = Area Under the Curve. WC = Waist-Circumference, BMI = Body Mass Index, WHR = Waist-to-Hip Ratio, WHtR = Waist-to-Height Ratio

Area Under the Curves of Sitting Time and Obesity Measures for Predicting Prehypertension

The corresponding AUCs of body mass index, sitting time, waist circumference, waist-to-hip ratio and waist-to-height ratio and sitting time for predicting prehypertension were, respectively, 59% (Figure 3A), 58% (Figure 3B), 61% (Figure 3C), 61% (Figure 3D) and 60% (Figure 3E).

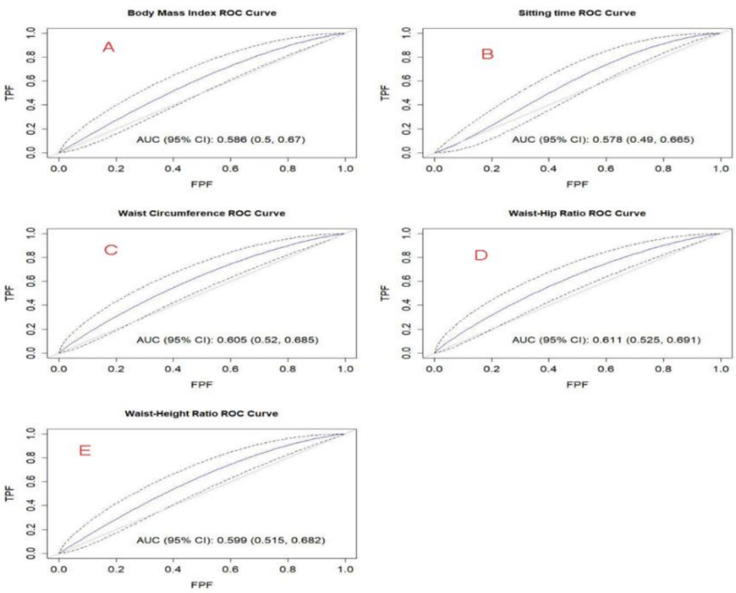

Figure 3: Area under the Curves (AUCs) for Predicting Prehypertension Using Body Mass Index (A), Sitting Time (B), Waist Circumference (C), Waist-to-Hip Ratio (D) and Waist-to-Height Ratio (E). TPF = True Positive fraction, FPF = False Positive Fraction

Discussion

Cut-off Values for Predicting Prehypertension

The BMI cut-off value for males found in this study (26kg/m2)is higher than the World Health Organization (WHO) recommended value, whereas the female cut-off value found (26kg/m2) is lower than the value recommended by the WHO (2004). This distinct pattern between the sexes is consistent with what was found in assessing the performance of BMI in predicting 10-year atherosclerotic cardiovascular disease (ASCVD) among National Health and Nutrition Examination Survey (NHANES) database participants (Tang & Zeng, 2024). The males' BMI cut-off value is, however, comparable to what was found among a Portuguese population (Raposo et al., 2018), Kurdish adults (Pasdar et al., 2020), and Indians (Midha, 2014), but remains lower than what was found among Malaysians (Mohd Zaher et al., 2009).

The waist circumference cut-off value for predicting prehypertension estimated by this study (84 cm) is similar in both sexes. This value is lower than the WHO recommended cut-off value for males (> 94 cm) but higher than the recommended female value (> 80 cm) (World Health Organization, 2008). This specific cut-off value is lower than the 101 cm for males and 92 cm for females found among NHANES database participants (Tang & Zeng, 2024), the 89 cm found among Portuguese cohorts (Raposo et al., 2018), the 99.5 cm found among Kurdish adults (Pasdar et al., 2020), and the 86 cm found among Malaysians (Mohd Zaher et al., 2009). It is, however, highly comparable to the 83 cm threshold identified among Indian males (Midha, 2014).

Furthermore, the waist-to-hip ratio (0.90 for males and 0.83 for females) and waist-to-height cut-off values (0.5 for both sexes) estimated by this study closely reflect the standard baseline cut-off values set by the World Health Organization (2008). Crucially, the cut-off values of sitting time found in this study—9 hours for females and 8.2 hours for males—are highly similar to The Canadian Society for Exercise Physiology recommendations of limiting total sedentary time to 8 hours or less per day (Ross et al., 2020).

Area Under the Curves (AUC) of Sitting Time and Obesity Measures

The BMI AUC found in this study (59%) is higher than the 55% found in NHANES database participants (Tang & Zeng, 2024) and the 57% found in Kurdish adults (Pasdar et al., 2020). It is, however, lower than the 71% found among Portuguese populations (Raposo et al., 2018), the 67% found among Malaysians (Mohd Zaher et al., 2009), the 78%–82% found among Indians (Midha, 2014), and the thresholds exceeding 65% reported in two large global meta-analyses (Ashwell et al., 2012; Darbandi et al., 2020).

The 60%–61% AUC for central obesity measures found in this study is consistent with the 58%–60% found in the south-eastern part of Nigeria (Okafor et al., 2011) and the 63% found in NHANES database participants (Tang & Zeng, 2024). Conversely, it is lower than the 68%–74% found among Portuguese populations (Raposo et al., 2018), the 67%–74% found among Kurdish adults (Pasdar et al., 2020), the 69% found among Malaysians (Mohd Zaher et al., 2009), and the findings exceeding 69% reported in two separate large-scale meta-analyses (Ashwell et al., 2012; Darbandi et al., 2020).

Pathophysiological Mechanisms of Sedentary Behavior on Blood Pressure

The findings establish sitting time as a screening parameter with predictive capability comparable to traditional anthropometric measures. This aligns with recent clinical evidence demonstrating that prolonged sitting drives immediate vascular dysfunction (Tamiya et al., 2024). Acute experimental and cross-sectional studies reveal that increased uninterrupted sitting duration is positively and linearly associated with increases in both systolic and diastolic blood pressure (Rosenberg et al., 2024; Silva et al., 2026)

From a physiological perspective, staying in a seated posture forces a major anatomical bending of the main blood vessels within the lower limbs. This bending generates highly turbulent blood flow profiles and leads to severe blood pooling in the lower extremities. Recent hemodynamics trials have shown that this pooling triggers an immediate rise in peripheral vascular resistance and elevates sympathetic nerve activity within just one hour of continuous sitting (Tamiya et al., 2024; Silva et al., 2026).

Furthermore, extensive periods of uninterrupted sedentary behavior significantly suppress skeletal muscle lipoprotein lipase (LPL) activity (Sedentary Behaviour Research Network, 2012). This suppression blocks lipid clearance, lowers high-density lipoprotein (HDL) cholesterol levels, and increases local inflammation. Concurrently, the reduction in regular leg muscle contractions heavily decreases local vascular shear stress. This drop in shear stress dampens endothelial nitric oxide synthase (eNOS) activity, which severely limits nitric oxide production, impairs essential vasodilation, and directly accelerates arterial stiffening and baseline blood pressure levels (Silva et al., 2026).

Regional and Occupational Context in Sub-Saharan Africa

The results must also be interpreted within the rapidly evolving landscape of non-communicable diseases (NCDs) in Sub-Saharan Africa. Historically considered a region dominated by infectious diseases, Sub-Saharan Africa now faces a steep rise in cardiovascular risks due to shifts toward urban lifestyles. Recent regional epidemiological surveys and community meta-analyses consistently rank physical inactivity and abdominal obesity as primary drivers of the growing regional hypertension epidemic (Twinamasiko et al., 2018; Akpa et al., 2021).

Crucially, occupational transitions in semi-urban and urban African settings have created unique risk clusters. Studies examining high-sitting professions in East and West Africa show that individuals in sedentary work settings are significantly more likely to display elevated blood pressure parameters compared to those in active occupations. This context perfectly explains the vulnerability observed in our cohort of part-time students who double as working professionals. This specific group experiences an intersection of workplace sitting and extended classroom sitting, placing them past the 8-to-9-hour danger threshold identified in our ROC model (Akpa et al., 2021).

Limitations and Future Directions

While these outcomes provide crucial baseline data, certain study limitations must be addressed:

Subjective Assessment

Using the Hausa version of the IPAQ-SF questionnaire to gather weekday sitting data introduces potential recall or social desirability bias. Future tracking protocols would gain precision by utilizing objective wearable physical accelerometers.

Study Design

The cross-sectional analytical study framework prevents making explicit causal statements regarding the chronological progression from sedentary blocks to prehypertension.

Homogeneous Cohort

The study population is drawn exclusively from working students at Bayero University Kano. Because this group balances professional duties with weekend lectures, they likely exhibit higher occupational sitting patterns than the general population, which may limit the generalizability of these findings.

Public Health Implications

Prehypertension currently impacts an estimated 41.1 million adult Nigerians (Bashir et al., 2021). Left unmanaged, it significantly escalates an individual's long-term risk of developing chronic kidney disease, stroke, and all-cause mortality (Huang et al., 2014; Li et al., 2016). Within lower-middle-income regional frameworks where clinical anthropometric evaluations face practical equipment boundaries, monitoring sitting time serves as an immediate, cost-effective screening alternative. Sitting time should also incorporated into risk assessment tools such as machine learning models designed to predict hypertension risk (Egwa et al., 2026).

Clinical trials have shown that reducing daily sedentary duration by as little as 30 minutes, or regularly introducing brief standing or light walking breaks every 30 to 60 minutes, yields blood pressure reductions comparable to weight loss or structured aerobic exercise programs. Public health initiatives should look past weight management alone and explicitly target sedentary habits. Simple, workplace-driven adjustments—such as the integration of standing desks, mandating hourly movement breaks, and limiting recreational screen time—should be widely promoted in corporate and educational environments across Nigeria.

CONCLUSIONS

When it comes to predicting prehypertension among the studies subjects, measures of central obesity were found to maintain their greater role with AUC of 61% compared to body mass index AUC of 59%. Sedentary behaviour, as defined by sitting time in a weekday, was found to have similar predictive power as body mass index in the diagnosis of prehypertension (AUC of 58%). Recommendations about reducing sitting time, including screen time, should be integrated within programs aimed at reducing obesity in the country.

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