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**Original Research Article**

# Ultrasonographic Evaluation of the Association between the Prostate Volume and Anthropometric Measurements in a Subset of Adult Nigerian Men with Benign Prostatic Hypertrophy

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**Abstract:** ***Background*:** Benign prostatic hypertrophy (BPH), a major cause of men`s morbidity, is positively related to obesity, which is assessed using anthropometric measurements. Despite the scarcity of local literature on this relationship, varying associations between prostate volume (PV), age, and anthropometric parameters have been reported. ***Objectives*:** To ascertain the average BPH volume, the predominant age at risk for BPH, and any correlations between PV and anthropometric measurements in our community. ***Methods*:** A prospective cross-sectional study conducted on 125 men aged 40–80years, with normal prostatic-specific antigen (PSA) levels, at the Radiology department, Benue State University Teaching Hospital, Makurdi, from May 2023 to May, 2024. PV was calculated by transabdominal ultrasonography. Anthropometric measurements were made using set procedures, from which the body mass index (BMI), waist-to-hip ratio (WHR), and waist-to-height ratio (WHTR) were computed. The data was analyzed using SPSS and Microsoft Excel with *P* value < 0.05. ***Results*:** The mean age and PV of participants was 61.6±9.5years and 74.2±52.5ml, respectively with majority, 41 (32.8%) of men in their seventh decade of life. Age and PV did not statistically significantly correlate (*P* = 0.159); however, BMI, HC, WC and WHTR did (*P* = 0.000, 0.002, 0.006, and 0.014). ***Conclusion*:** The mean sonographic PV was 74.2±52.5ml, with men in their seventh decade being the most at risk for BPH. PV exhibited a statistically significant correlation with some anthropometric parameters but not with respondents' age. The equations and models generated from this study will benefit future research on prostatic growth and early detection of BPH.

**Keywords:** Adult men, Anthropometric measurements, Association, Benign prostatic hypertrophy, Evaluation, Nigerian, Prostate volume, Ultrasonographic.



## INTRODUCTION

Prostatic hypertrophy (BPH), prostatic carcinoma, and prostatitis are the three main afflictions of the prostate gland, a pyramidal-shaped fibromuscular organ situated around the male urethra from the bladder base to the least distensible membranous region of the posterior urethra. However, BPH is the most prevalent of these conditions, with periurethral zonal involvement along with glandular and stromal hyperplasia [1].

Even though BPH does not always result in death, it can cause bothersome lower urinary tract symptoms (LUTS) that can lower men's quality of life and have negative social and economic consequences. The etiopathogenesis of BPH is not clearly known, however previous research links it with genetic predisposition and hormonal levels of sex-steroids. Diet, lifestyle, exercise and metabolic disturbances have recently received attention as potential risk factors for BPH, in addition to well-established factors such as testosterone levels and age [2].

Whilst there seems to be some consensus that men's PV increases starting around age 40, there are conflicting reports regarding the relationship between PV and age [3]. In a study involving two hundred and twenty-eight (228) men between the ages of 40 and 60 years, Yang *et al.*, [4], found a correlation between PV and age. This report, however, contradicted findings from a Taiwanese study, that showed no appreciable correlation between PV and age [5]. However, various other studies on healthy adults show that the PV does not

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only vary with ageing and androgen levels [6] but also with ethnicity as well as anthropometric parameters, such as body mass index (BMI) and waist-hip circumference (WHC) [6, 7].

Obesity, which is known to positively correlate with PV, is frequently evaluated using anthropometric parameters such as BMI, waist circumference (WC), hip circumference (HC) and waist-to hip ratio (WHR). Whereas BMI is a measure of generalized or overall obesity, WC, WHR, WHTR (waist to height ratio) evaluate central or abdominal obesity [8, 9], with the former being a less hazardous risk factor for BPH than the latter, central or abdominal obesity. Although there is paucity of knowledge on the role of obesity as a risk factor for BPH, several complex hypotheses have been propounded why this is so. For example, central or abdominal obesity is said to produce hormonal (higher estrogen but lower testosterone levels) and systemic modifications leading to prostatic inflammation, ischemia and oxidative stress which favors BPH in such men [9, 10].

The remarkable improvements in image resolution, consistency, and quality, along with the relative affordability, portability, lack of radiation, and absence of risks associated with iodinated contrast media, have firmly established ultrasound (US) technology as a diagnostic tool in prostatic imaging. Furthermore, reduced examination time, better appreciation of blood flow, and improved image quality is currently been enjoyed courtesy of dynamic scanners, color flow and real time US imaging. Many approaches such as transabdominal, transurethral, trans-perineal and transrectal ultrasonography have been used to image the prostate. Transabdominal and transrectal ultrasound, however, are the two most common methods for assessing the prostatic shape, volume, intravesical extent and associated periprostatic anatomy [11]. In this study, we employed transabdominal ultrasonography (TAUS) of the prostate, which makes use of the urine-filled bladder as an acoustic window.

Prior to our study, foreign predetermined correlation values between PV and age as well as preset links between PV and anthropometric parameters were been used as our guidelines. The results of this study will help in the early detection of BPH by estimating the mean PV in a subset of adult Nigerian males with BPH. We shall also identify obesity, based on the prospective finding of unusually elevated values of anthropometric measurements. The prevalent age at risk for BPH will be determined and we shall seek to ascertain whether anthropometric measurements might predict the onset of BPH in our environment. We anticipate that this research will also result in the establishment of a favourable relationship between PV and anthropometric measurements, which will be extremely useful in the development of a normogram for quick and indirect determination of PV. Thus, forming a basis for comparison with studies elsewhere nationally and internationally, when the need arises by physicians in our community.

## MATERIALS AND METHODS

This was a prospective observational study carried out on 125 adult male patients who met the inclusion criteria and presented from May 2023 to May 2024 at the ultrasound unit of the radiology department of Benue State University Teaching Hospital (BSUTH), Makurdi. Easily accessible by air, land, and sea Benue State's capital, Makurdi, lies between latitudes 7.3 and 8.32 degrees. Its estimated 2016 population was 365,000 [12]. The goal of the study was to identify the average BPH volume, the most common age at risk for BPH, and any associations between BPH volume and anthropometric measurements in a subset of our indigenous population**.** This was explained to the patients and informed voluntary consent was obtained. The Benue State University Teaching Hospital's ethics committee evaluated and approved every component of the study before it commenced.

Inclusion criteria were adult men aged 40years and above, with BPH-related lower urinary tract symptoms (LUTS), who willingly consented to be included in the research and had normal laboratory values of their prostatic specific antigen (PSA) of less than 4 ng/ml.

Patients were excluded from the study if they had any form of prostate surgery, acute prostatitis, recurrent urinary tract infection, bladder stones or were on medications affecting prostatic growth such as 5-alpha reductase inhibitors and antiandrogens. In a similar vein, those with sonographic or histologic evidence of prostate cancer or elevated PSA levels greater than 4 ng/mL were excluded.

A Siemens Sonoline G-50 ultrasound machine fixed with a curvilinear 2.0–5.0 MHZ transducer was used to conduct the sonographic examination, and a suitable mode for transabdominal ultrasonography (TAUS) was selected. Transabdominal ultrasound scan began with the patient positioned supine with a full bladder or after drinking roughly one litre of water, just enough to have a full, yet pleasantly distended urinary bladder. After covering a suitably exposed pelvic region with a toilet paper sheet, coupling gel was applied to bridge the acoustic impedance between the probe surface and skin. Using the ultrasound machine's default computer algorithm based on the ellipsoid formula, PV (ml) = length(L) × width(W) × height(H) × 0.524($\pi$/6) [13], where the highest craniocaudal, transverse, and anteroposterior diameters were represented by the length, width, and height, respectively, as seen in figure 1. These measurements were used for the estimation of the prostate volume (in ml). However, when the "report" knob on the US machine was pressed, the computed bladder volume was automatically displayed.

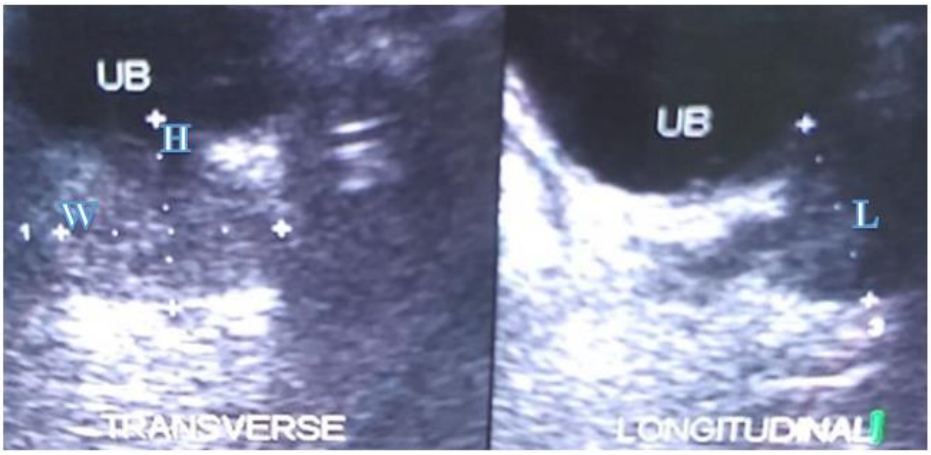


**Figure 1: The prostate gland's width (W), height (H), and length (L) are displayed as PV measurements on a transverse and longitudinal (sagittal) transabdominal ultrasound scan**

All measurements of the participants` body size and weight were done while they were barefooted and dressed in hospital gowns, according to established protocols, and the results entered into the structured questionnaire. The weight (W) and height (H) of the participants were measured using a 2007 German-made 200 kg capacity SECA electronic weighing scale, model 769, which was additionally equipped with a 200 cm height range stadiometer. Each respondent was individually asked to climb onto the weighing scale placed on a firm floor with both feet at the center of the scale inorder to obtain their weight (kg) measurements, after removing heavy shoes, clothing, or hair decorations. For height (m) estimation, the patient stands erect on the machine, feet flat, straight legs, arms by their side, and with leveled shoulders against the stadiometer.

Using a calibrated inelastic, 150 cm long, made in China, measuring tape, waist circumference (WC) was measured around the umbilicus, roughly between the lower rib margin and the iliac crest, while the landmark chosen to measure the hip circumference (HC) was the widest circumference across the buttocks. Every measurement was taken by the same skilled staff. The first two circumference measurements were repeated if there was a difference greater than one centimeter. Using internationally recognized standards for anthropometric measurement, the participants' body mass index (BMI), waist-hip ratio (WHR), and waist-height ratio (WHTR) were calculated [1, 14, 15].

All pertinent information, including biodata, anthropometry and ultrasonographic findings, were recorded on the structured questionnaire and then entered into a spreadsheet for analysis. The statistical analysis was done with statistical package for social science (SPSS) version 23 software (IBM Inc., Chicago, Illinois, USA 2015) and Microsoft Excel 2007. Descriptive statistics of the respondents` PV, age, weight, height, BMI, WC, HC, WHR and WHTR were calculated with their mean and standard deviation. The linear relationship between the study variables was examined using Pearson's correlation coefficient (r).

Additionally, we utilized simple linear regression analysis to determine the linear association between age, BMI, WC, HC, and PV. Appropriate tables, figures and percentages were used to present the general distribution of data with a *P*-value set at $< 0.05$.

**Contextual terminologies used: body mass index (BMI), generalized (overall), central (abdominal), and normal-weight central obesity.**

Weight in kilograms divided by height in meters squared ($kg/m^2$) yields the body mass index (BMI), which is a measure of generalized or overall obesity. BMI (generalized or overall obesity) is categorized in accordance with World health organization (WHO) [8, 14, 16] criteria as underweight (<18.5 $kg/m^2$), normal-weight (18.5-24.9 $kg/m^2$), overweight (25.0-29.9 $kg/m^2$) and obesity (>30.0 $kg/m^2$). Central or abdominal obesity in men is defined according to WHO criteria [8, 16] as WC ≥ 94.0cm or waist-to-hip ratio (WHR) ≥ 0.90 and a WHTR of >0.50. Normal-weight central obesity in such individuals is regarded as central obesity (CO) with a normal weight by BMI [8].

## RESULTS

A total of 125 adult Nigerians men with BPH, aged 40-80 years, were recruited for the study, with a mean age of 61.6±9.5years. The predominant age range was 60-69years, representing 41(32.8%) of the total population. More than a third 48(38.4%) of the respondents had a PV of between 41-80ml.The minimum and maximum PV was 30.0 and 265.9ml, respectively with an overall mean PV of 74.2±52.5ml. A good number 53(42.4%) of respondence weighed between 57-76kg with an overall mean weight of 70.2±14.0kg. Sixty-one (48.8%) of the respondents were in the 1.60 to 1.69-meter height category with an overall mean height of 1.7±0.1 meters. The overall mean BMI was 25.5±4.5$kg/m^2$, with nearly half 62(49.6%) of the respondents having a normal BMI of between 18.5-

24.9kg/m$^2$. However, 21(16.8%) of the participants were obese. Majority 91(72.8%) of cases had low risk WC<94.0cm for obesity, whereas 34(27.2%) others had high-risk WC(>94.0cm). The minimum and maximum WC was 57.5 and 120.6cm, respectively, with an overall mean WC of 85.2±12.7cm. With an overall mean HC of 94.3±11.4 cm, 118 (94.4%) of the respondents had a HC of <108.0 cm. The WHR which gives a rough idea about visceral fat or abdominal obesity was in the good range of <0.90 in more than half 72(57.6%) of the respondents, with an overall mean value of 0.90±0.1. The minimum and maximum WHTR was 0.34 and 51.0, respectively with an overall mean value of 0.92±4.5. The above data is as presented in tables 1 and 2.

**Table 1: Distribution of respondents' parameters (n=125)**

| Variable | Frequency | Percentage (%) |
|---|---|---|
| **Age Group (years)** | | |
| 40-49 | 18 | 14.4 |
| 50-59 | 32 | 25.6 |
| 60-69 | 41 | 32.8 |
| 70-79 | 32 | 25.6 |
| ≥8o | 2 | 1.6 |
| Total | 125 | 100.0 |
| **Prostate volume (ml)** | | |
| 30-40 | 39 | 31.2 |
| 41-80 | 48 | 38.4 |
| 81-100 | 8 | 6.4 |
| >100 | 30 | 24.0 |
| Total | 125 | 100.0 |
| **Weight (Kg)** | | |
| ≤56 | 23 | 18.4 |
| 57-76 | 53 | 42.4 |
| 77-91 | 28 | 22.4 |
| ≥92 | 21 | 16.8 |
| Total | 125 | 100 |
| **Height(m)** | | |
| 1.50-1.59 | 28 | 22.4 |
| 1.60-1.69 | 61 | 48.8 |
| 1.70-1.79 | 34 | 27.2 |
| ≥1.80 | 2 | 1.6 |
| Total | 125 | 100.0 |
| **BMI (Kg/m$^2$)** | | |
| <18.5 | 4 | 3.2 |
| 18.5-24.9 | 62 | 49.6 |
| 25.0-29.9 | 38 | 30.4 |
| >30 | 21 | 16.8 |
| Total | 125 | 100.0 |
| **WC (cm)** | | |
| <94.0 | 91 | 72.8 |
| >94.0 | 34 | 27.2 |
| Total | 125 | 100.0 |
| **HC (cm)** | | |
| <108 | 118 | 94.4 |
| >108 | 7 | 5.6 |
| Total | 125 | 100.0 |
| **WHR** | | |
| <0.90 | 72 | 57.6 |
| >0.90 | 53 | 42.4 |
| Total | 125 | 100.0 |
| **WHTR** | | |
| <0.50 | 59 | 47.2 |
| >0.50 | 66 | 52.8 |
| Total | 125 | 100.0 |

**Table 2: Distribution of descriptive statistics of the respondents' parameters**

| Parameter | N | Minimum | Maximum | Mean | Median | Mode | Std.dev |
|---|---|---|---|---|---|---|---|
| Age(years) | 125 | 40.0 | 80.0 | 61.6 | 61.0 | 60.0 | 9.5 |
| Prostate volume (ml) | 125 | 30.0 | 265.9 | 74.2 | 53.4 | 35.9 | 52.5 |
| Weight (Kg) | 125 | 48.0 | 100.0 | 70.2 | 68.1 | 90.0 | 14.0 |
| Height (m) | 125 | 1.5 | 1.9 | 1.7 | 1.7 | 1.7 | 0.1 |
| BMI | 125 | 16.8 | 36.6 | 25.5 | 24.2 | 24.0 | 4.5 |
| WC (cm) | 125 | 57.5 | 120.6 | 85.2 | 82.2 | 82.2 | 12.7 |
| HC (cm) | 125 | 69.0 | 123.1 | 94.3 | 96.5 | 91.0 | 11.4 |
| WHR | 125 | 0.78 | 1.0 | 0.90 | 0.90 | 0.89 | 0.1 |
| WHTR | 125 | 0.34 | 51 | 0.92 | 0.51 | 0.49 | 4.5 |

Together with some anthropometric indices, the distribution of PV by age groups is as shown in Table 3. The peak PV of 95.3±82.4ml, was found at the 5th decade of life, while the lowest PV,62.2±56.1ml was noted at the 6th decade. Thereafter, there was a reduction of the PV till the 8th decade. The highest PV among the BMI groups was 92.2±73.6ml which was seen in the obese participants. For the WC groups, 70.2±38.6 and 86.3±78.7ml was recorded for the low risk(<94.0cm) and the high risk(>94.0cm) obesity WC groups respectively. The PV was however, paradoxically higher in patients with lower risk <108.0cm HC than in the high risk >108.0cm HC group!

**Table 3: Distribution of prostate volume by age groups and some anthropometric measurements (n=125)**

| Age/Anthropometric measurement | | Prostate volume (mls) |
|---|---|---|
| **Age groups (years)** | **Frequency (%)** | |
| 40-49 | 18(14.4) | 95.3±82.4 |
| 50-59 | 32(25.6) | 62.2±56.1 |
| 60-69 | 41(32.8) | 71.1±46.7 |
| 70-79 | 32(25.6) | 75.3±33.0 |
| ≥80 | 2(1.6) | 74.8±0.0 |
| Total | 125(100.0) | 74.2±52.5 |
| **BMI groups** | | |
| Underweight | 4(3.2) | 42.8±2.8 |
| Normal weight | 62(49.6) | 56.0±18.9 |
| Overweight | 38(30.4) | 71.7±43.4 |
| Obesity | 21(16.8) | 92.2±73.6 |
| Total | 125(100.0) | 74.2±52.5 |
| **WC groups** | | |
| <94.0cm | 91(72.8) | 70.2±38.6 |
| >94.0cm | 34(27.2) | 86.3±78.7 |
| Total | 125(100.0) | 74.2±52.5 |
| **HC groups** | | |
| <108.0cm | 116(92.8) | 76.6±53.7 |
| >108.0cm | 9(7.2) | 41.9±10.0 |
| Total | 125(100.0) | 74.2±52.5 |

Table 4 shows a weak (r=0.127.), statistically non-significant correlation (*P*=0.159) between PV and age. The correlation between PV versus BMI, HC, WC and WHTR, on the other hand was stronger and statistically significant, with *P*=0.000,0.002, 0.006 and 0.014, in that order.

**Table 4: The distribution of Pearson's correlation (r) with PV and selected anthropometric parameters (n=125)**

| Variable | Pearson's correlation (r) | P-value |
|---|---|---|
| Prostate volume (PV) vs Age | 0.127 | 0.159 |
| PV vs Weight | 0.159 | 0.077 |
| PV vs Height | -0.105 | 0.246 |
| PV vs BMI | 0.313 | 0.000 |
| PV vs HC | 0.268 | 0.002 |
| PV vs WC | 0.245 | 0.006 |
| PV vs WHR | 0.164 | 0.067 |
| PV vs WHTR | 0.220 | 0.014 |

Figures 2-5 show scatter diagrams of linear regression analysis performed to predict PV(y) from age, BMI, WC, and HC, in that sequence. The degree to which a linear regression model fits the data is indicated

by its coefficient of determination or R-squared ($R^2$), which is also depicted on the scatter diagrams.

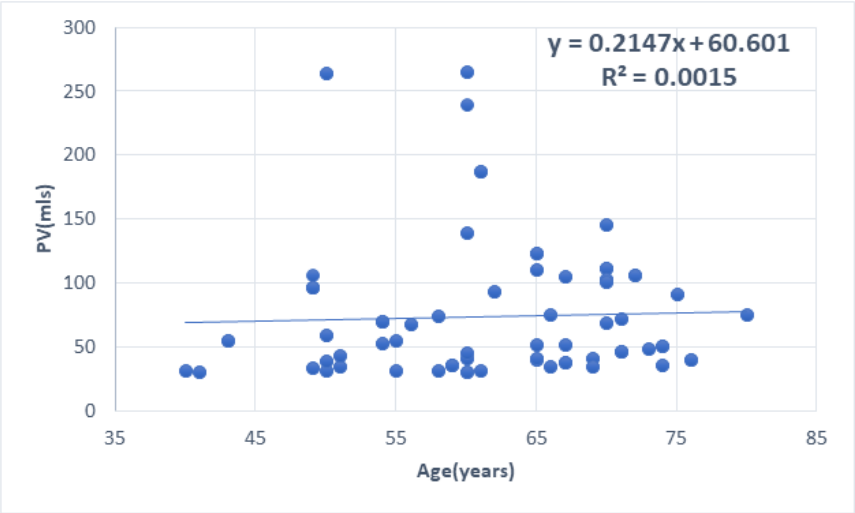


**Figure 2: A scatter plot of the correlation between age and PV**

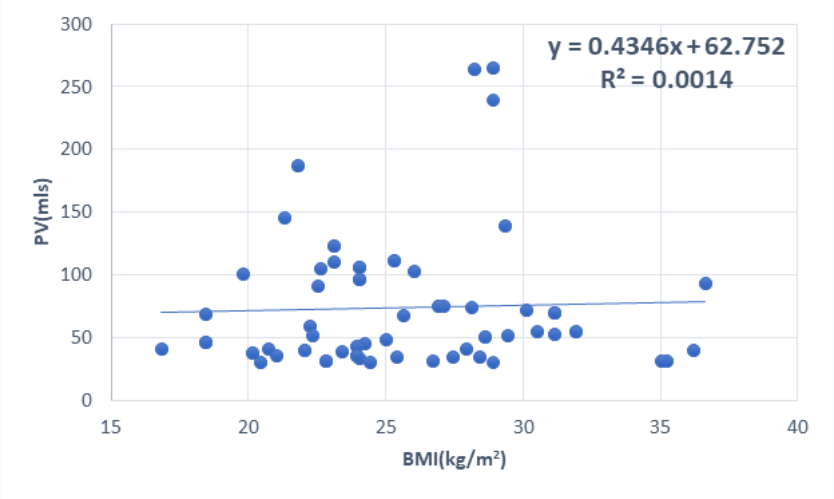


**Figure 3: A scatter plot of the correlation between BMI and PV**

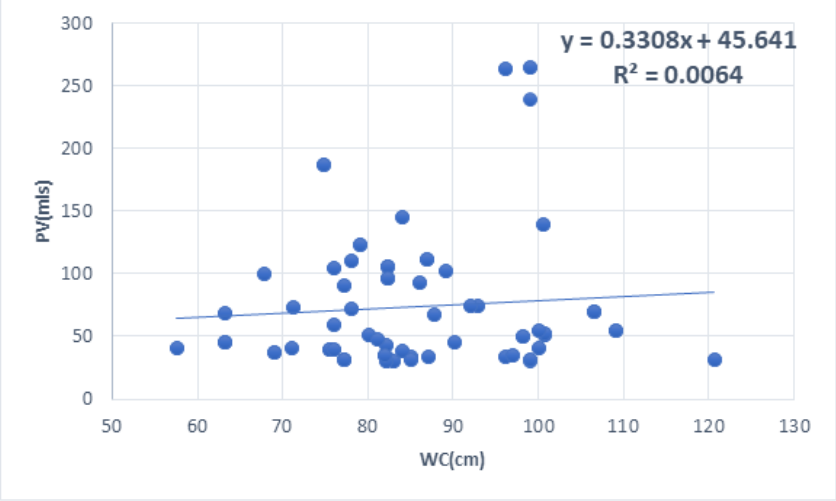


**Figure 4: A scatter plot of the correlation between WC and PV**

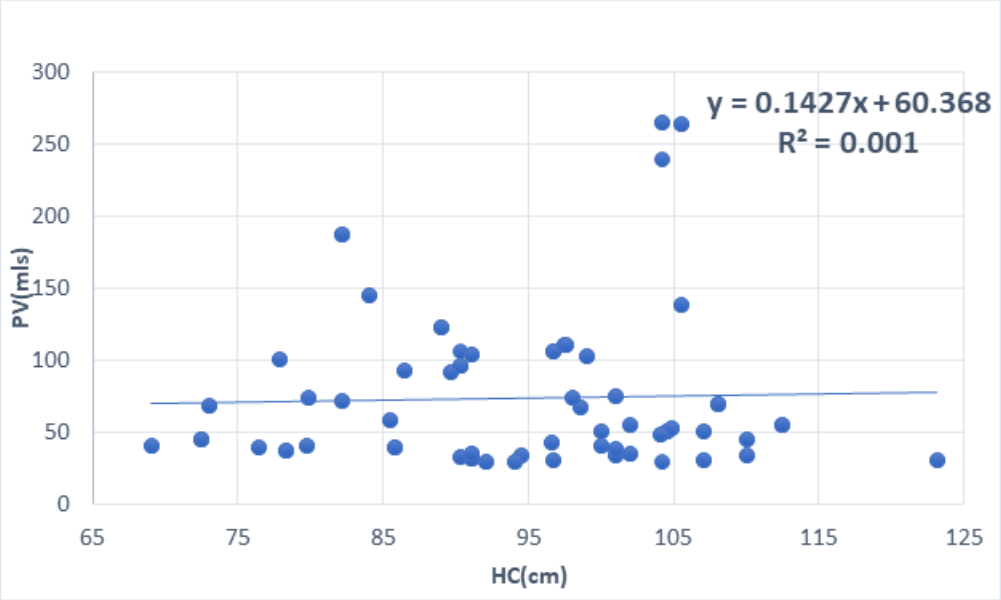


**Figure 5: A scatter plot of the correlation between HC and PV**

Figure 6 shows the distribution of types of obesity, including generalized (overall), central (abdominal) and normal weight-central obesity. Underweight, normal, overweight, and obesity had a prevalence of 4 (3.2%), 62 (49.6%), 38 (30.4%), and 21 (16.8%), respectively. We reported the corresponding prevalence rates of central obesity by WC, WHR, and WHTR to be 34 (27.2%), 53 (42.4%), and 66 (52.8%). Normal weight-central obesity, which is referred to as central obesity in those with normal weight (by BMI), was 2(3.2%), 14(22.6%), and 17(27.4%) for WC, WHR, and WHTR, respectively.

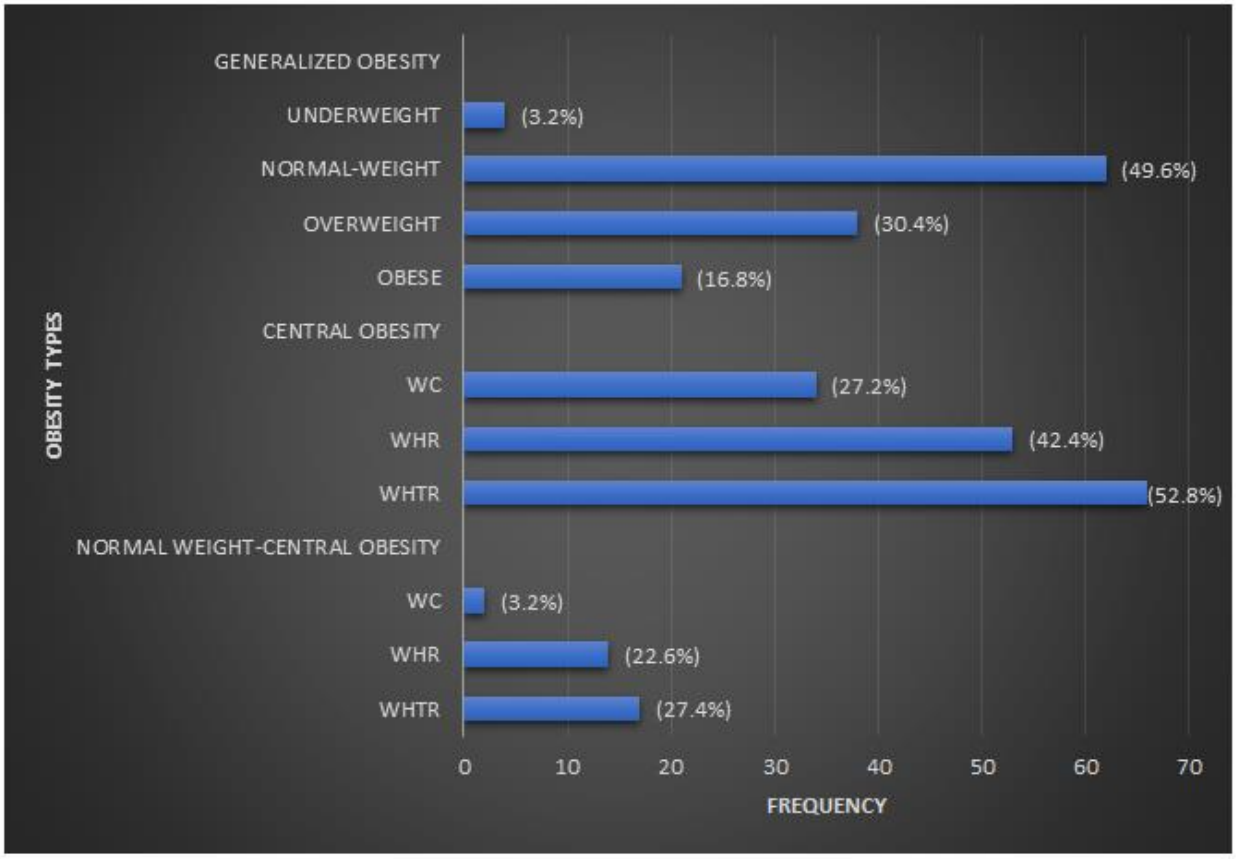


**Figure 6: Distribution of types of obesity-generalized (overall), central(abdominal) and normal weight-central obesity**

Figure 7 illustrate the distribution of WC-health risk groups using BMI-WC index in which, 62(49.6) respondents with normal (healthy) weight, by BMI had either a low-risk, 60(48.0%) or high-risk, 2(1.6%) WC. Twenty-one (16.8%) of the overweigh respondents had a low-risk WC while 9(7.2%) from the obese-group had very high-risk WC.

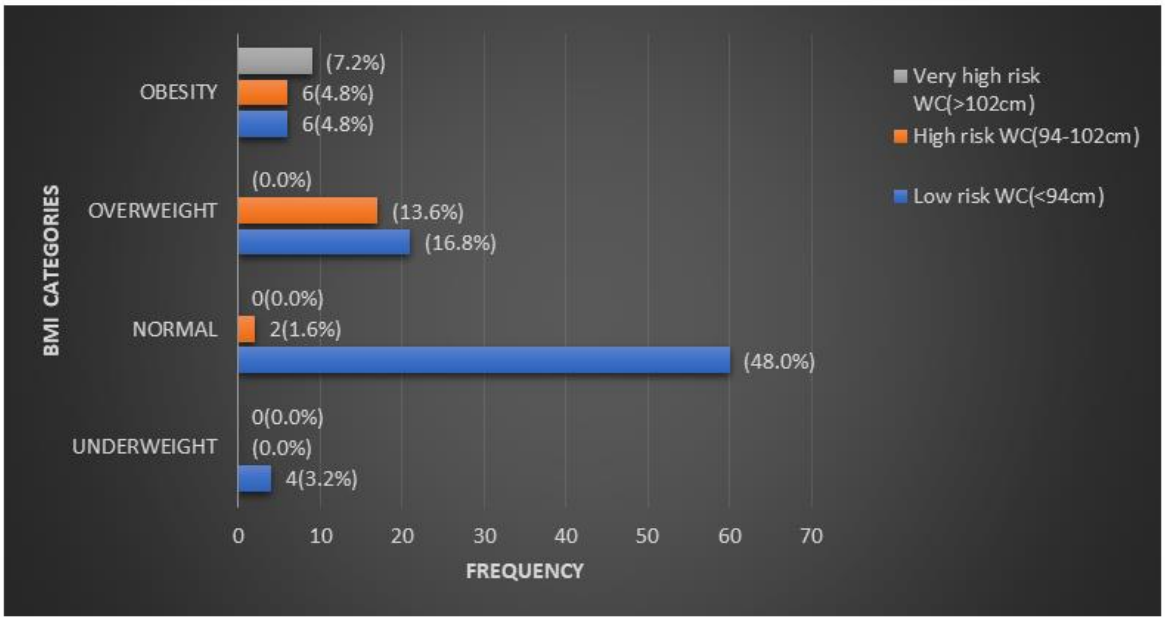


**Figure 7: Distribution of WC-Health risk groups using BMI-WC index**

## DISCUSSION

The age range of respondents with BPH in our index study was 40–80 years old, while their mean age was 61.6±9.5 years. The majority of patients, 41 (32.8%), were in their seventh decade of life (Table 1). The above findings are comparable to the mean ages of 62.5±13.7 and 64.0±14.5years that were reported locally by Mohammed *et al*., [17] in Zaria and Udeh *et al*., [18] in Enugu, respectively, as well as the 64.1±0.0 years that were published by Deori *et al*., [19] in India, where the majority of patients—208 (34.5%), 72 (46.0%), and 17 (42.5%), were both in their seventh decade of life. This is consistent with the widely held belief that BPH is a disease of ageing men [1, 4, 19].

Our mean transabdominal PV of 74.2±52.5ml is higher than the 43.7±0.4ml and 42.9±12.6ml respectively reported in Caucasians [20] and Asians [21], even though our values compared favorably with data from other parts of Nigeria [3, 18]. The higher PV seen in blacks has been variously attributed to racial predisposition, late presentation of patients to the clinic and increased sexual activity from polygamy [3-5]. The observed variations may also, in general, be possibly attributed to ultrasonography technique (TRUS vs TAUS), sample size differences and the ultrasound operator expertise [17].

The mean weight of our respondents was 70.2±14.0kg, which is quite close to the reported 72.0±0.0kg average weight of a Nigerian male [22]. We also reported an overall mean height of 1.7±0.1m, which fits within the height category that is widely considered to be an average height for an adult African man [23]. However, a single body parameter, might not be responsible for the association between anthropometric measurements and PV [7]. Therefore, it is not surprising that our research did not find any significant correlation between PV and weight or height, individually (Table 4). Nevertheless, our result was at variance with the research findings of Fowke *et al*., [7], which reported that height was significantly associated with a larger prostate volume in high-grade cases.

The mean BMI of 25.5 kg/m$^2$ that we found in our study is comparable to the BMIs of 24.0, 24.6, and 24.7 kg/m$^2$ that other researchers had reported [1, 3, 24]. Our obesity rate, 21(16.8%), while being much higher than the 6(7.5%) reported by Aigbe *et al*., [3], compares favorably, in terms of percentage value with the 14(14.8%) reported by Ukoli *et al*., [24] among the urban Nigerian population. Numerous literature reports have shown that obesity is linked to an increased risk of prostatic enlargement. [2, 25, 26]. This is consistent with the findings of our index study, in which among the BMI-groups, individuals who were obese had the highest PV of 92.2±73.6ml (Table 3). Numerous theories exist regarding how obesity worsens BPH, including the fact that obesity increases intra-abdominal pressure, which raises intravesical pressure, initiating or exacerbating BPH symptoms such as nocturia, weak stream, and hesitancy. Two other suggested pathways by which obesity causes BPH are obesity-related prostatic-inflammatory activity and oxidative stress [27, 28]. Additionally, studies have found links between elevated

levels of insulin, insulin-like growth factor-1, and serum estrogen—all of which are associated with obesity and also prostatic enlargement. However, growth stimulation is inhibited in obese men by lower serum testosterone levels, a crucial prostate growth factor. Therefore, for these reasons, males with a BMI of 30 to 34.9 kg/m$^2$ may have a larger PV than those with a BMI of ≥35 kg/m$^2$, despite the fact that in general, increased BMI would cause PV to grow [25].

While Body Mass Index (BMI) has been the standard indicator for assessing generalized (overall) obesity and diagnosing underweight and overweight, alternative measures that reflect central (abdominal) obesity, such as WC, WHR and WHTR, have been suggested as being superior to BMI in additionally, predicting cardiovascular disease (CVD) risk [29-31]. The overall prevalence of central obesity in our study was between 34(27.2%) to 66(52.8%) depending on the criteria that was used (Figure 6). It was highest with WHTR 66(52.8%), followed by WHR 53(42.4%) and lowest with WC 34(27.2%). Our percentage values were, nevertheless, lower than the overall prevalence of central obesity in a previous rural Nigerian community [32], which was between 236(56.8%) to 273(65.5%), with the highest being with WHR 273(65.5%), followed by WHTR 258(62.1%), and lowest with WC 236(56.8%). Adediran OS *et al*., [33], however reported a lower percentage value 46(20.1%) than that from our index study. This emerging new trend in the prevalence of obesity may be linked with the rapid westernization of Nigerians' lifestyle and dietary habits, as well as the possible interplay of hereditary and environmental factors [30].

The reported prevalence of normal weight-central obesity, defined as central obesity (CO) in patients with normal weight (by BMI) in our index study ranged from 2(3.2%) to 17(27.4%), with the findings being 2(3.2%), 14(22.6%) and 17(27.4%) by WC, WHR, and WHTR respectively (Figure 6). Although, comparable in a way by percentage value to the 499(15.4%) reported among Thai health-workers [34], our values by percentage were largely lower than the 269(26.9%) to 368(36.9%) among south-African adults [8]. Studies have indicated that the risk of cardiovascular death is increased in people with normal weight-central obesity compared to people with a similar BMI but no central obesity [35]. This is indicative of the need to include other anthropometric measurements in the clinical assessment of excessive body weight, rather than employing BMI alone, as BMI solely is no longer sufficient [8, 36].

More than a quarter of our participants 34(27.2%) (Figure 6 & 7) had either high or very high health risk WC based on the National institute for health and care excellence (NICE) BMI-WC composite index [37] which was comparable by percentage to the 268(26.9%) participants who had either high-risk or very high-risk WC as reported by Owolabi *et al*., [8]. Our value was, however slightly lower by percentage to 167(38.6%) of the participants who had either high or very high-risk WC as published by Cherono [36]. Obtaining anthropometric data, such as WC, alongside BMI can provide doctors with vital information for providing care and attention to their patients based on their health risk WC classification. Furthermore, those at-risk population could be promptly identified and given appropriate timely care, thus reducing the chances of mis-classification of such individuals [8]. In our opinion, these kinds of initiatives could assist in prioritizing cardio-metabolic health screening, thus mitigating the effects of central obesity, even with limited resources.

A weak (r = 0.127), statistically non-significant (P = 0.159) correlation between PV and age was found (Table 4), This was in keeping with earlier research [3, 5], which found no meaningful association between PV and age. However, our results contradicted the findings of other researchers [4, 6, 38] who found that PV increased with aging in men with BPH.

Our index study reported the strongest positive correlation (r = 0.313) between PV and BMI, which was statistically significant (*P* = 0.000). This was consistent with earlier studies [26, 39] which also found association between PV and BMI. Other researchers did not, however find any statistically significant correlation between PV and BMI [1, 3, 28]. Whereas larger sample sizes have been reported to show a positive association between these two variables, a smaller sample size more often does not [3]. Thus, it follows from our findings that losing weight might cause PV to decrease.

Additionally, we found statistically significant correlations between PV and central obesity anthropometric measurements of WC and WHTR (*P* = 0.006, 0.014), respectively. The reasons why central obesity or adiposity contributes to BPH are unknown, however, an elevated testosterone to oestrogen ratio in BPH patients may provide a clue [1]. No statistically significant correlation (*P*=0.067) was found between PV and WHR.

For the model employed in our research, the R-squared ($R^2$) or coefficient of determination (Figures 2-5), a statistical metric that determines the degree to which a linear regression model fits the data, was low (between 0.1 and 1.0%). However, comparable low values of between 1.0 to 1.1% were obtained in a previous study by Aigbe *et al*., [3]. Normally, $R^2$ values fall between 0.0% and 100.0%. When they are at 0.0%, it means that the model does not explain any of the variability, and when at 100.0%, it means the model fits the data. In principle, a higher $R^2$ value should suggest a better fit between the model and the data, but this is not always true. Low $R^2$ values, such as reported in our model study, can be justified by two basic reasons. Firstly, unlike forecasting physical processes, human research can be

very complex to predict, thereby leading to low $R^2$ values, typically less than 50.0%. Additionally, substantial conclusions about the relationship between changes in predictor values and changes in response values can still be drawn from predictors with low $R^2$ values that are statistically significant. Regardless of $R^2$, significant coefficients continue to indicate the average change in the response when one predictor is altered while the other stay fixed. Clearly, this kind of information is incredibly important to our clinicians [40].

Model equations were derived from the linear regression analysis we performed to predict PV from age, BMI, WC, and HC in that sequence (figures 2-5). The model's equation for age is y = 0.22x + 60.6, where y is PV (mls) and x is age (years). For every unit in age variation, PV changes by 0.22. Age accounts for only 0.15% of the variation in PV as demonstrated in figure 2. For BMI, the equation is y=0.44x + 62.8, where y=PV((mls) and x=BMI (kg/m$^2$). For every unit of BMI variation, PV changes by 0.44. BMI explains only 0.14% of the variation in PV (Figure 3). The same explanation applies to model equations in figures 4 and 5 for WC and HC, respectively. Similar equations and models were generated in a study by Aigbe *et al.*, [3]. This kind of regression analysis will be most beneficial in devising a nomogram for swift and indirect estimation of PV in men with BPH in our environment.

**Limitations of study**

We faced limitations since we could not possibly compare the PV estimated by transabdominal ultrasound (TAUS) with that obtained by transrectal ultrasound (TRUS). In addition to the operator-dependent nature of ultrasound and its poor reproducibility, our study's limited sample size has the potential to jeopardize its validity.

The absence of a histopathologic diagnosis was another significant drawback. Although a combination of clinical features and PSA levels greatly increases specificity, the limited positive predictive value and non-specificity of TAUS findings for prostate cancer, mean that a histopathologic diagnosis would have remained the most reliable choice.

Furthermore, the study's cross-sectional design limited the evaluation of our men with BPH to only a single point in time rather than tracking them over a period of time through a longitudinal survey, which would have increased the statistical power and broadened the estimation of conditional probability.

Again, although the study provided a general overview of the burden of BPH and anthropometric measurements in our immediate environment, the data were largely hospital-based and did not sufficiently reflect what happens in the larger society; thus, extrapolations to other climates must be done with caution.

# CONCLUSION

Our research revealed that men in their seventh decade of life were most frequently at risk of developing BPH. Furthermore, despite the fact that we were unable to find a statistically significant correlation between PV and age, there was an association between PV and some anthropometric indices. This finding is very significant because obesity, which is known to be positively linked to PV, is frequently evaluated using anthropometric measurements. Whereas BMI is a measure of generalized or overall obesity; WC, WHR and WHTR evaluate central or abdominal obesity, with the latter being a more dangerous risk factor for BPH. Thus, we deduce that routine prevention of obesity with diligent management or loss of weight might be an effective therapy for minimizing the prevalence of BPH in our environment.

One in every six respondents in our study was obese, and with a mean BMI of 25.5 kg/m$^2$, our participants were marginally overweight. The results also indicated that the overall prevalence of central obesity in our study was highest with WHTR, therefore, WHTR-specific reference values may be useful in our environment to evaluate central obesity. Nonetheless, obesity may be on the increase, and so are the risks of developing BPH in our environment. This is made worse by the ease with which our indigenous people have adapted to western lifestyles and nutritional changes, as well as the shift from agricultural to wage labour, which has reduced people's physical activity.

Our respondents BMI-WC composite index showed that over a quarter of them had a high or extremely high WC-health risk. If anthropometric measurements like WC were frequently recorded alongside BMI, medical personnel would have easy access to this vital information at health facilities and be able to treat patients based on their WC-health risk rating. Our findings highlight the necessity to incorporate additional anthropometric measurements, such as WC, into the evaluation of excessive body weight, as BMI measurement alone is no longer sufficient.

We performed linear regressions analysis to predict PV from age, BMI, WC and HC respectively. The equations and models developed as a result of our research are extremely useful in developing a nomogram for quick and indirect assessment of PV in men with BPH in our environment, thus supporting further research on BPH and enhancing its early diagnosis.

# RECOMMENDATIONS

In order to prevent an increase in the prevalence of BPH, we recommend that health education about healthy lifestyles and other obesity prevention measures be incorporated into the primary health care (PHC) system to effectively serve our indigenous people, with the media also playing a significant role in this initiative.

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**Ethical approval**

The study was reviewed and approved by the Benue State University Teaching Hospital (BSUTH) Institutional health research ethics committee (HREC) number BSUTH/MKD/HREC/2023/019.

**Conflict of interest:** None was reported by the authors

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