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Effect of Age and Heart Rate on the Blood Pressure Parameters of 5343 Africans South of the Sahara

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Abstract: Regarding the burden of hypertension in sub-Saharan Africa, we wanted to know if age and heart rate would influence blood pressure parameters differently in black African subjects. Our research hypothesis was that there is no difference between the white race and the black race regarding the evolution of blood pressure parameters according to age and heart rate. This was a descriptive study for analytical purposes from secondary analysis of the WHO STEPwise survey in Senegal in 2015. The study included 5343 individuals. As results, isolated systolic hypertension predominated in those over 50 years of age, while isolated diastolic hypertension predominated in subjects under 50 years of age. There is a statistically significant relationship between heart rate and diastolic blood pressure (p-Value<0.001, cor=0.149). Mean diastolic blood pressure evolved in the shape of an "inverted U" with age. Mean systolic blood pressure evolved in the form of a "stair step" with age. The frequency of subjects with pathological pulse pressure was highest in the age groups [50-54 years], [55-59 years], [60-64 years] and [65-70 years]. To conclude, all these findings are also found in studies carried out on white subjects. This is explained by the physiopathology that is common to us such as the cardiac cycle, arterial rigidity, and arterial pulse wave. The measurement of the arterial pulse wave must be made systematic. It should be an integral part of blood pressure measurement because it provides additional diagnostic, prognostic and therapeutic interest in the management of arterial hypertension.

Keywords: Heart Rate, Age, Blood Pressure, Arterial Pulse Wave, Cardiac Physiology, Black, African

1. Introduction

Blood pressure (BP) is that force that allows blood flow through all the blood vessels of the body allowing proper perfusion of the tissues and organs of the body [1–5]. Arterial pressure (BP) is the product of cardiac output (Co) and peripheral resistance (R): BP= Co x R. Cardiac output is the product of systolic ejection volume (SEV) and heart rate (HR): Co = SEV x HR. The peripheral resistances (R) depend on the radius of the vessel (r), its length (L), blood viscosity (μ): $R = 8\mu L/3.14r^4$. It is in the light of all this that Poiseuille defined BP according to the following law:

$$BP = SEV \times HR \times 8\mu L/3.14r^4$$ [1–5].

Several factors work together to determine BP. These are the nervous factors (higher nerve centers, central ischemic reflex, baro-reflexes, chemo-reflexes, sinocarotid tensio-reflex, sympathetic and parasympathetic autonomic nervous system) [1–5]. Hormonal factors (renin angiotensin aldosterone system, antidiuretic hormone (ADH), atrial natriuretic factor (ANF), catecholamines, thyroid hormones), genetic and environmental factors (stress, behaviors, diet, metabolism, physical effort) [1–5]. The state of key organs (glomerular filtration rate (kidney), valvular system, inotropism, cardiac bathmotropy (heart), endothelium compliance and vascular distensibility of large blood vessels, sleep-wake cycle and age [1–5].

BP is therefore a variable hemodynamic parameter dependent on a complex, time-stratified and highly adaptive control system. A distinction is made between instantaneous regulation (beat by beat), short-term regulation both by nervous means and medium and long-term regulation by hormonal means [1–5]. It oscillates between two extremes: the maximum of the BP corresponds to the systolic blood pressure (SBP) and the minimum to the diastolic blood pressure (DBP) [1–4]. Amplitude represents pulse pressure, i.e. the difference between SBP and DBP [1–4].

There are several methods of measuring blood pressure [1–4]. Intra-arterial or direct invasive measurement is done by arterial catheterization with a pressure probe [13, 29–31]. This is the reference method for determining BP [1–4]. The non-invasive or indirect measurement uses the Riva-Rocci occlusive cuff principle (to ensure a counter-BP) and a technique to detect the signal corresponding to the BP (palpation of the radial pulse, auscultation of the Korotkoff sounds at the level of the humeral artery, oscillation detected by an electronic tensiometer, Doppler recorded by an ultrasound sensor, plethysmography, etc) [1–4].

Our research hypothesis was that there is no difference between the white race and the black race regarding the evolution of blood pressure parameters according to age and heart rate.

The general objective of this study was to analyze the evolution of blood pressure parameters according to age and heart rate in a black population from Sub-Saharan Africa. Specifically, the relationship between SBP and DBP, SBP and heart rate, DBP and heart rate, isolated systolic hypertension and age, isolated diastolic hypertension and age, elevated pulse pressure and age.

2. Methodology

This was a secondary analysis of the STEPwise WHO Senegal 2015 survey. Our study was descriptive quantitative epidemiology for analytical purposes. Data collection was done from August 1 to December 15, 2015.

The target population is the entire population living on the territory of Senegal on the date of 2015. The source population was all individuals meeting the eligibility criteria.

The inclusion criteria for the study were to be between the ages of 18 and 70 during the year of the survey and to reside on the territory of Senegal, at least more than 6 months before the start of the survey.

The criteria for non-inclusion in the study were: Being pregnant, Having a mental and/or physical disability and/or being sick in bed, Being an absent member of the household whose return was not expected within two and a half days presence of the team in the DR and finally not having given their consent to participate in the study.

The calculation of the size of the representative sample to be drawn from the source population was done according to the STEP methodology with the following formula:

$$N = Z^2 * \frac{p*(1-p)}{e^2} * d * t * s * a$$

Z = level of confidence=1.96; p = initial level of indicators; e = is the margin of error= 5%; d = effect of sampling plan =2; t = non-response rate (20%) = 1.2; s=stratum by sex = 2; a=stratum by age= 6. The size of the representative sample was calculated at 6306 individuals.

The sampling technique was done by stratification in three stages of sampling. The first stage consisted of a systematic selection with probability proportional to the size of the census districts (CD) based on RGPHAE 2013. The second stage of sampling involved a systematic selection with equal probability of households in the selected CDs. The third and last stage of sampling concerned individuals with a draw by Kish method of individuals in each selected household. All members aged 65-70 from sampled households were included. The sampling unit was therefore initially the CD, then the household and finally the individual. The statistical unit of the study was the individual aged 18 to 70 on Senegalese territory in 2015 and having been chosen by the survey.

The data collection tool was the WHO BASIC AND EXPANDED MODULES STEPwise survey form. It included a questionnaire section dedicated to STEP 1 and a form section to collect data relating to STEP 2 and STEP 3. The collection tool was electronically supported. The final version of the survey form had been implemented in PDAs (Personal Digital Assistant) configured with the appropriate STEP application. But note that paper media were also available. In this study we took into account the environment, sex, age, history of h The mode of data collection was done during a face-to-face interview with each individual in terms of environment, sex, age and history of hypertension, blood pressure, heart rate.

The mode of data collection was done during a face-to-face interview with each individual in terms of environment, sex, age and history of hypertension.

Blood pressure and heart rate required direct contact with the participant. They were taken in a secluded location to ensure privacy. Blood pressure was measured non-invasively or indirectly using the Riva-Rocci occlusive cuff principle (to ensure counter-BP) [1–4] (Figure 1). The oscillometric method was used (Figure 1). It uses an inflatable cuff automatically connected to an automatic electronic tensiometer which determines the mean arterial pressure (MAP), oscillation of greater amplitude, deduces the SBP and the DBP and displays them on a screen. The participant was asked to sit quietly and rest for at least 15 minutes, without crossing their legs. The procedure to be followed was explained to him. The participant was reassured before taking blood pressure. Registration of the device identifier in the PDA was carried out.

The equipment used was an approved OMRON electronic tensiometer. The measurement procedure was standardized with the following steps: The left arm free of any clothing was chosen to take the blood pressure, failing which it was the right arm (Figure 1). The armband was well placed on the participant's left arm, palm facing up and well secured with the "Velcro" (Figure 1). The ART (artery position) mark was aligned with the participant's brachial artery (where the pulsation was felt just above the bend of the elbow on the inside of the arm) (Figure 1). The lower base of the cuff was located between 1.2 and 2.5 cm above the bend of the elbow (inner side of the arm) (Figure 1). The cuff was held at the same level as the heart during the measurement. The next step was to set the MODE function of the device to AVG and the P-Set function to Auto. With these settings, the device gave two consecutive blood pressure measurements. Then it was a matter of pressing START to begin taking blood pressure. The first reading was displayed, then the investigator proceeded to the second measurement and then to the third measurement each at 3 minute intervals. The values of the three measurements were checked by pressing the DEFLATION key. This is how SBP and DBP in mmHg and heart rate in beats per minute were obtained.

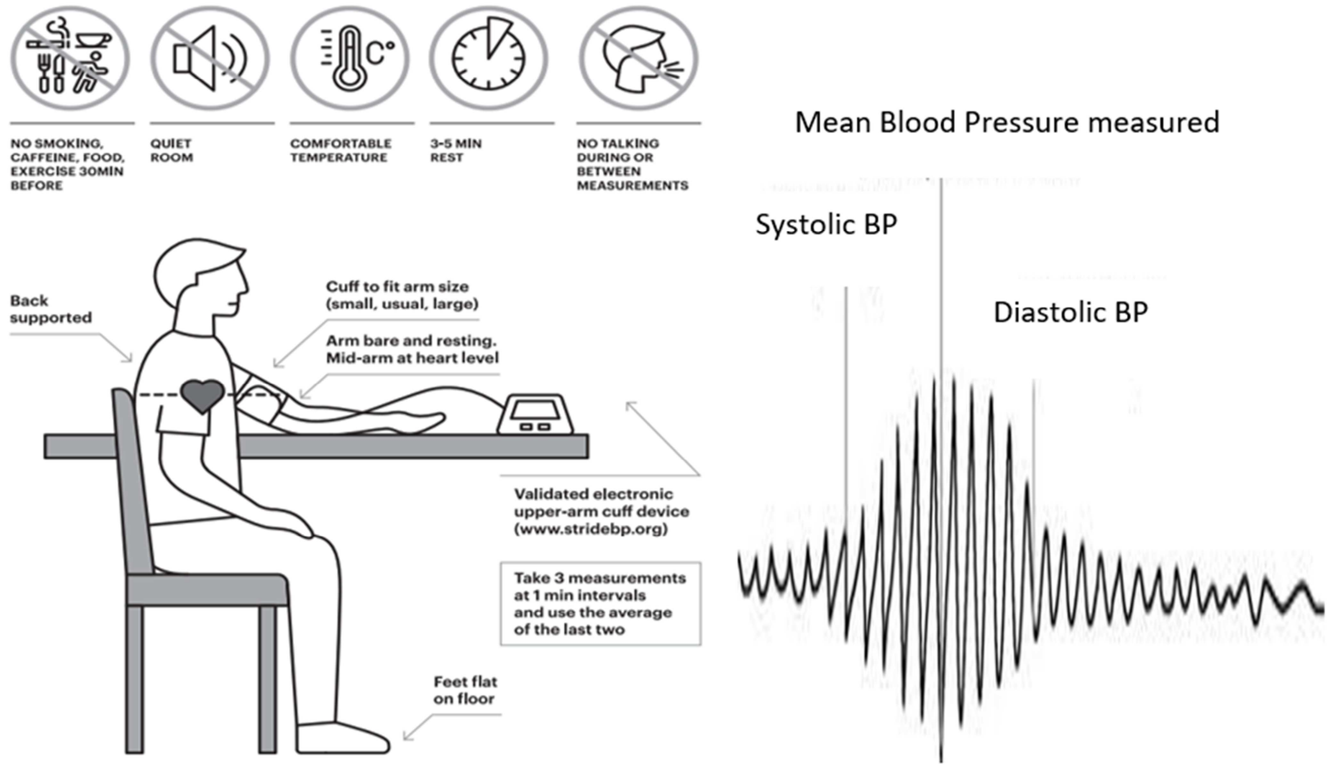


Figure 1. *Blood pressure measurement by the oscillometric principle.*

With regard to the operational definition of the variables: for the known history of arterial hypertension, it was knowledge of a hypertensive state diagnosed by a health professional, the data were obtained from the participant's declarations or from the treatment specific for high blood pressure. Isolated systolic hypertension is defined by an average of 3 systolic blood pressure (SBP) values ≥ 140 mmHg and an average of 3 diastolic blood pressure (DBP) values < 90 mmHg. Isolated diastolic hypertension is defined by an average of 3 systolic blood pressure (SBP) values <140 mmHg and an average of 3 diastolic blood pressure (DBP) values ≥ 90 mmHg. Systolic and/or diastolic arterial hypertension is defined by an average of 3 systolic blood pressure (SBP) values ≥ 140 mmHg and/or an average of 3 diastolic blood pressure (DBP) values ≥ 90 mmHg. New systolic and/or diastolic hypertension is defined by an average of 3 systolic blood pressure (SBP) values ≥ 140 mmHg and/or an average of 3 diastolic blood pressure (DBP) values ≥ 90 mmHg in a subject without a history of arterial hypertension. The prevalence of arterial hypertension in Senegal was obtained by adding the known history of hypertension and the new systolic and/or diastolic hypertension diagnosed. High pulse pressure is defined for a SBP-DBP difference ≥ 60 mmHg.

Data entry was done directly in the field with the PDAs that were used collection support. In the event of a PDA failure, the paper questionnaires were used to be entered immediately after repairing the device.

The statistical analysis of the data was done with the statistical analysis software Rstudio version 4.0.2.

It initially consisted in expressing the modalities of the qualitative variables in the form of absolute and relative frequency. The descriptive analysis of the quantitative variables was made with the position parameters (mean, median) and the dispersion parameters (standard deviation, extremes). To take into account fluctuations due to sampling, all proportions and means have been given with their 95% confidence interval (95% CI).

In bivariate analysis, before each crossing, we had made two hypotheses: H0: hypothesis of absence of statistical link between the crossed elements (hypothesis of equality or null); H1: alternative hypothesis or presence of statistical link between the crossed elements. The type I risk α had been set at 5% (the risk of wrongly asserting that there is a link).

On the one hand, we made comparisons of unpaired proportions: The objective was to find the existence of a statistically significant link between the two variables. This link was retained as statistically significant for a p-value < 0.05. This link was sought with the appropriate statistical test according to its conditions of applicability, so we used: Pearson's Chi 2 parametric test, if all the theoretical values were ≥ 5; Yates' corrected Chi 2 parametric test, if at least one of the theoretical values was between 3 and 5; Fischer's non-parametric test, if at least one of the theoretical values was < 3.

On the other hand we were comparing more than two unpaired means. The objective was to find the existence of a statistically significant link between the two variables. This link was retained as statistically significant for a p-value ≤ 0.05. This link was sought with the appropriate statistical test according to its conditions of applicability, so we used the ANOVA test, if normal distribution of the quantitative variable in the strata of the qualitative variable and if the variances are homogeneous, if only one condition was missing so we used the Kruskal Wallis test. NB: The normality test of the distributions was done graphically using histograms. The test on the homogeneity of the variances was done with the Barlett test. A p-Value ≤ 0.05 on the Barlett test shows that the variances are not homogeneous.

We were also doing a simple linear correlation of two unpaired quantitative variables. The objective was to find the slope of the correlation. This slope was sought with the appropriate statistical test according to its conditions of applicability. We used the Pearson correlation coefficient test (expressed in cor) if the two distributions are normal. If this condition was missing then Spearman's correlation coefficient test (expressed in Rau) or Kendall's correlation coefficient test (expressed in tau) was used.

NB: The normality test of the distributions was done quantitatively using the Shapiro test associated with the qqnorm test. If p-Value ≤ 0.05 then abnormal distributions.

With regard to the ethical framework, the STEP survey complied with Law No. 2009-17 of March 9th, 2009 on the Code of Ethics for Health Research in Senegal [6, 7]. The STEP survey had obtained the favorable scientific opinion of the National Ethics Committee for Health Research (CNERS) and an administrative authorization issued by the Health Authority. Notices of passage for the STEP survey were distributed beforehand to the households selected in the DRs. In each household, the interviewer provided the respondent with the information form on the study and offered to go through it with him, highlighting the various elements mentioned. All this with a view to its free and informed participation. This form clearly explained the objectives of the study, what each step involved the benefits of the study and the rights of the participant. If the respondent was illiterate or unable to read on their own, the information form was read and explained to them. In cases where the interviewee was dissuaded, or coerced, from participating in the survey by a third party, such as their spouse, relative or other member of the local population, the interviewer clearly indicated that it was their the interviewee and it is up to them alone to decide whether they wish to be interviewed or not. The interviewer checked that the interviewee had read and understood the information form, only after that the consent had to be written. The interviewee was asked to sign two informed consent forms before proceeding with the interview. One of the two was given to the participant after acceptance and signature and the investigator kept the other. All physical measurements were taken in an isolated location. Intimacy was ensured for waist circumference and hip circumference measurements in accordance with the degree of privacy desired by the participant. In the event of an anomaly or not during the medical tests during the collection of information, the participant was informed with a sheet bearing the results of his measurements. If necessary, the respondent was referred to the nearest health center. A respondent’s identification number thanks to a coding associating the census district, the interviewer, the date and time of the interview, ensured anonymity.

3. Results

3.1. Descriptive Analysis Results

Sociodemographic characteristics: The rural environment was the predominant origin with 58.1% (3103/5343). Women were in the majority with 63.4% with a sex ratio (M/F) of 0.57. The 18-23 age group was the most represented with 18.9% (Table 1).

Known history of high blood pressure: 24.5% (787/3208) were known hypertensive, diagnosed by a healthcare professional. The duration of this known state of hypertension was greater than 12 months in 62.3% (490/787) (Table 1).

Table 1. *Distribution according to socio-demographic characteristics and known history of arterial hypertension, national WHO STEPwise survey, Senegal 2015.*

	N	**%**	**$^{95\%}$CI**	**N**
Socio-demographic characteristics				
Environment				5343
Rural	3103	*58.1*	[56.73; 59.40]	
Urban	2240	*41.9*	[40.59; 43.26]	
Sex				5343
Men	1958	*36.6*	[35.35; 37.95]	
Women	3385	*63.4*	[62.04; 64.64]	
Age				5343

	N	%	95%CI	N
18-23 years old	1009	*18.9*	[17.84; 19.96]	
24-29 years old	806	*15.1*	[14.14; 16.07]	
30-34 years old	700	*13.1*	[12.21; 14.04]	
35-39 years old	627	*11.7*	[10.89; 12.63]	
40-44 years old	603	*11.3*	[10.45; 12.17]	
45-49 years old	454	*8.5*	[7.76; 9.28]	
50-54 years old	380	*7.1*	[6.44; 7.84]	
55-59 years old	329	*6.2*	[5.53; 6.84]	
60-64 years old	244	*4.6*	[4.03; 5.16]	
65-70 years old	191	*3.6*	[3.10; 4.11]	
Known history of high blood pressure				
Known history of high blood pressure				3208
No	2421	*75.5*	[73.93; 76.94]	
Yes	787	*24.5*	[23.05; 26.06]	
The seniority of this state of hypertension greater than 12 months				787
No	297	*37.7*	[34.35; 41.24]	
Yes	490	*62.3*	[58.75; 65.64]	

Heart rate: The average of the individual averages of the 3 resting heart rates was 80.5 beats per minute with a standard deviation of 13.1 beats per minute. The median was 80.2 beats per minute with extremes ranging from 30 to 145 beats per minute (Table 2).

Blood pressure: The mean of the individual means of the 3 SBPs was 127mmHg ±19.8 mmHg with a median of 123 mmHg and extremes of 73 to 243 mmHg. The mean of the individual means of the 3 DBPs was 83.1mmHg ±12.4 mmHg with a median of 81.7 mmHg and extremes of 47.3 to 145 mmHg. According to the average of the individual averages of the 3 SBP and 3 DBP taken, the systolic and/or diastolic hypertension was 28.9% (1506/5207). Just over one in five people had newly diagnosed systolic/diastolic hypertension 23.8% (563/2361). Thus, in 2015, the prevalence of hypertension in Senegal (old and new) was 23.5% (1254/5343) (Table 2).

Table 2. *Distribution by heart rate and blood pressure in the national WHO STEPwise survey, Senegal 2015.*

	n	%	95%CI	N
Heart Rate				
Individual average of the 3 heart rate measurements				5208
Mean (Standard Deviation)	80.5 (13.1)	-	[80.16; 80.87]	
Median [Min, Max]	80.2 [30, 145]	-	-	
Blood pressure				
Individual average of the 3 SBP				5207
Mean (Standard Deviation)	127 (19.8)	-	[126.14; 127.22]	
Median [Min, Max]	123 [73.0, 243]	-	-	
Individual average of the 3 DBPs				5208
Mean (Standard Deviation)	83.1 (12.4)	-	[82.77; 83.44]	
Median [Min, Max]	81.7 [47.3, 145]	-	-	
Isolated systolic hypertension				5207
No	4225	*81.1*	[80.04; 82.18]	
Yes	982	*18.9*	[17.81; 19.95]	
Isolated diastolic hypertension				5208
No	3946	*75.8*	[74.57; 76.92]	
Yes	1262	*24.2*	[23.07; 25.42]	
Systolic and/or diastolic hypertension				5207
No	3701	*71.1*	[69.82; 72.30]	
Yes	1506	*28.9*	[27.69; 30.17]	
Newly diagnosed systolic and/or diastolic hypertension				2361
No	1798	*76.2*	[74.37; 77.85]	
Yes	563	*23.8*	[22.14; 25.62]	
High blood pressure prevalence Senegal				5343
No	4089	*76.5*	[75.36; 77.65]	
Yes	1254	*23.5*	[22.34; 24.63]	

3.2. Univariate Analysis Results

Comparison of systolic blood pressure with diastolic blood pressure: There is a statistically significant relationship between DBP and SBP (p-Value<0.001, tau=0.557). Every one unit increase in DBP (1mmHg) increases SBP by 0.55 units (0.55 mmHg) (Figure 2).

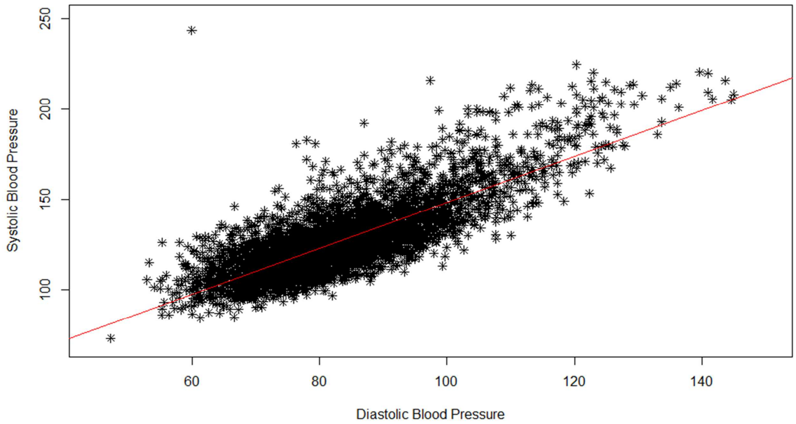


Figure 2. *Distribution of 5207 Senegalese according to the average of the 3 systolic blood pressures and that of the 3 diastolic blood pressures, national WHO STEPwise survey, Senegal 2015.*

Comparison of systolic and diastolic blood pressure according to heart rate: There is no statistically significant relationship between HR and SBP (p-Value=0.9032) (Figure 3). However, there is a statistically significant relationship between HR and DBP (p-Value<0.001, cor=0.149). Every one unit increase in HR (1 bpm) increases DBP by 0.149 units (0.149 mmHg) (Figure 4).

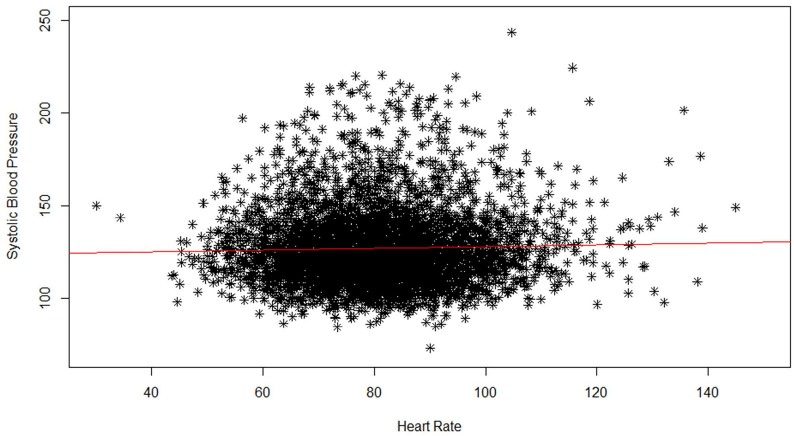


Figure 3. *Distribution of the averages of the 3 systolic blood pressures according to the averages of the 3 heart rates, the national WHO STEPwise survey, Senegal 2015.*

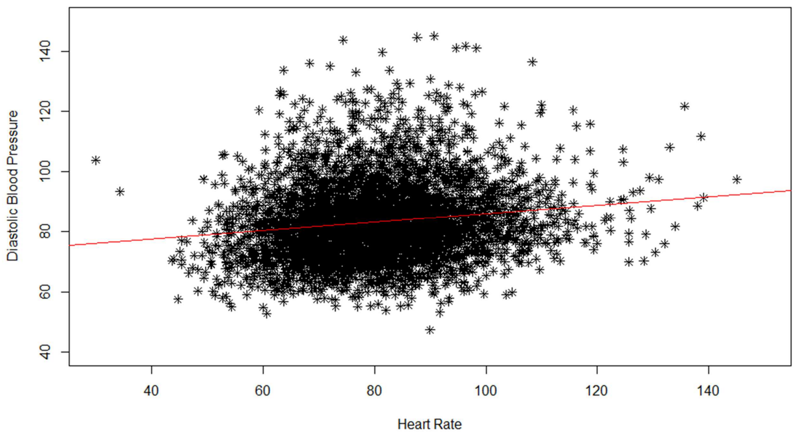


Figure 4. *Distribution of the averages of the 3 diastolic blood pressures according to the averages of the 3 heart rates, the national WHO STEPwise survey, Senegal 2015.*

Comparison of systolic and diastolic blood pressure according to age groups: The average DBP evolved in the shape of an "inverted U" with age (Figure 5). It increased from 18 to 45 years old, reaching a plateau maximum between 45 and 60 years old before decreasing after 60 years old (Figure 5). The average SBP evolved in the form of a “stair step” with age (Figure 6). It increased from 18 to 70 years, reaching a plateau maximum after 60 years (Figure 6). There is a statistically significant relationship between age group and SBP or DBP (p-Value <0.001). At least one average SBP of one age group was different from the others. Similarly, at least one average DBP of one age group was different from the others.

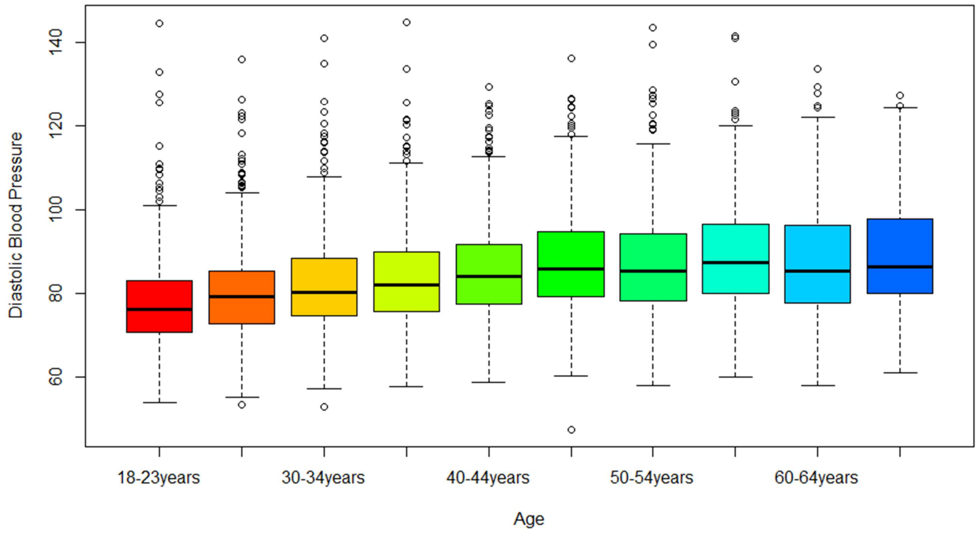


Figure 5. *Distribution of average diastolic blood pressure by age group, National WHO STEPwise survey, Senegal 2015.*

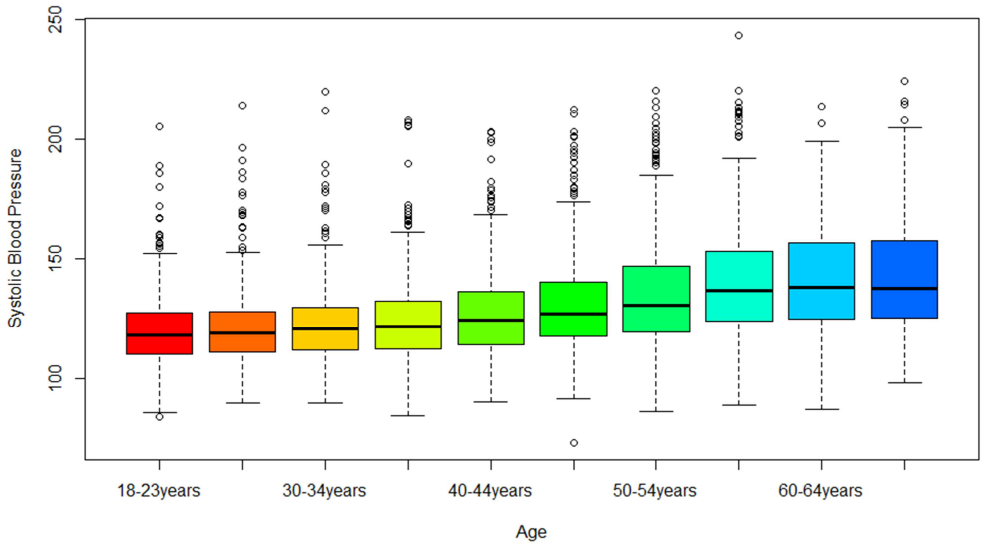


Figure 6. *Distribution of average systolic blood pressure by age group, national WHO STEPwise survey, Senegal 2015.*

Comparison of isolated systolic, isolated diastolic arterial hypertension according to age groups: The age groups containing the most isolated systolic hypertension were [50-54 years], [55-59 years] and [60-64 years] (Figure 7). The age groups containing the most isolated diastolic hypertension were [24-29 years], [30-34 years], [35-39 years] and [40-44 years] and [45-49 years] (Figure 8). There is a statistically significant relationship between the age group and the absolute frequency of isolated systolic hypertension (p-Value <0.001) as well as the absolute frequency of isolated diastolic hypertension (p-Value <0.001). At least one absolute frequency of diastolic hypertension isolated from one age group was different from the others. Similarly, at least one absolute frequency of systolic hypertension isolated from one age group was different from the others.

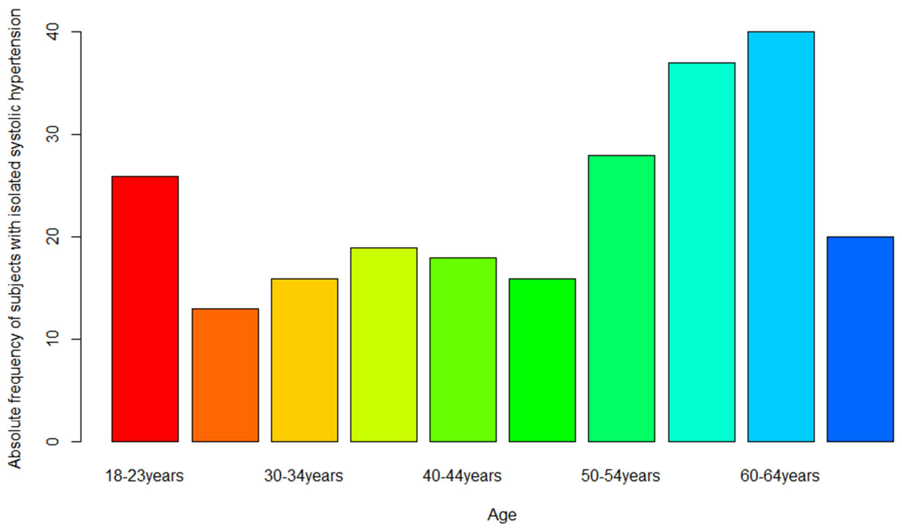


Figure 7. *Distribution of isolated systolic hypertensive according to age, national WHO STEPwise survey, Senegal 2015.*

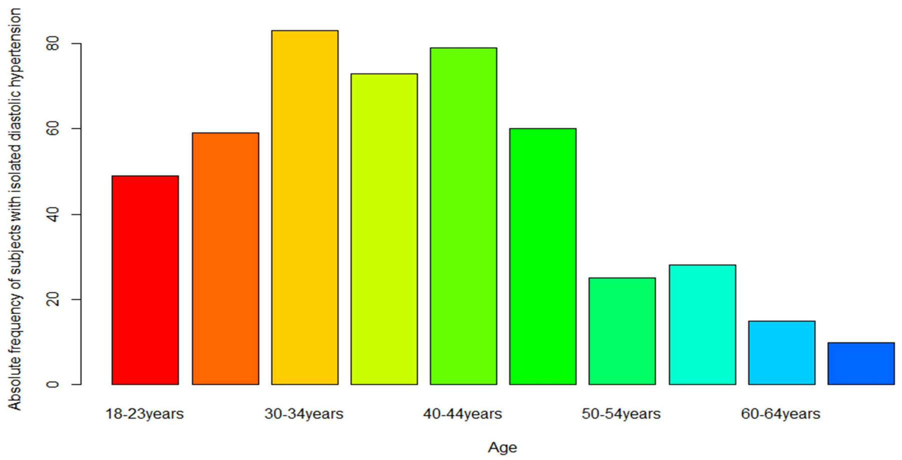


Figure 8. *Distribution of isolated diastolic hypertensive according to age, national WHO STEPwise survey, Senegal 2015.*

Comparison of high pulse pressure according to age groups: The frequency of subjects with pathological pulse pressure (>60 mmHg) was highest in the age groups [50-54 years], [55-59 years], [60-64 years old] and [65-70 years old] (Figure 9). There is a statistically significant relationship between the age group and the absolute frequency of pathological pulse pressure (p-Value <0.001). At least one pathological pulse pressure absolute frequency of one age group was different from the others.

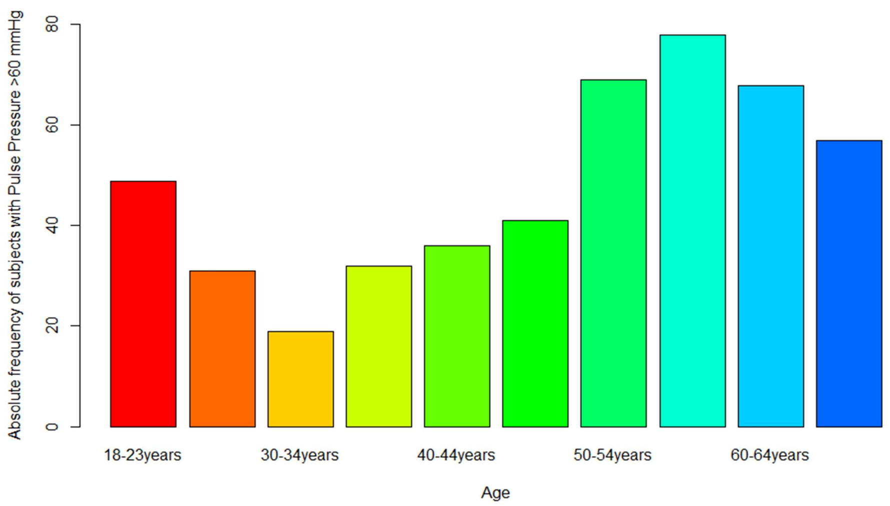


Figure 9. *Distribution of subjects with pulse pressures ≥ 60mmHg by age, national WHO STEPwise survey, Senegal 2015.*

4. Discussion

Relationship between isolated systolic hypertension, isolated diastolic hypertension and age: isolated systolic hypertension predominated in those over 50 years of age, while isolated diastolic hypertension predominated in subjects under 50 years of age. Berney et al. had already reported these observations [8].

Relationship between SBP, DBP and heart rate: There is no statistically significant relationship between HR and SBP (p-Value=0.9032). But there are some between HR and DBP (p-Value<0.001, cor=0.149). Every one unit increase in HR (1 bpm) increases DBP by 0.149 units (0.149 mmHg). Indeed, the link between heart rate and DBP can be explained physiologically. Any increase in heart rate is at the expense of diastolic time. However, it is during diastole that we observe the drop in pressure in the aorta, which makes DBP. Thus, any shortening of diastole will limit the pressure drop in the aorta, resulting in a higher DBP.

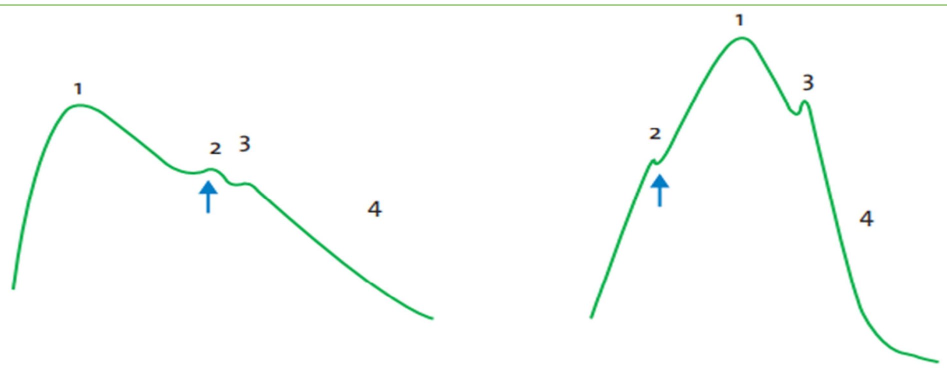
Relationship between SBP, DBP and age: The average DBP evolved in the shape of an "inverted U" with age. It increased from 18 to 45 years old, reaching a plateau maximum between 45 and 60 years old before decreasing after 60 years old. The mean SBP meanwhile evolved in the form of a "stair step" with age. It increased from 18 to 70 years, reaching a plateau maximum after 60 years. This is reflected on the pulsating pressure.

Relationship between high pulse pressure and age: The frequency of subjects with pathological pulse pressure (>60 mmHg) was highest in the age groups [50-54 years], [55-59 years], [60-64 years] and [65-70 years old]. These findings had been reported in the large study by Framingham [9]. The high pulsed pressure is the witness of a rigidity of the large arterial trunks which leads to a reduction in their compliance and their distensibility [9–12]. This rigidity is the prerogative of the elderly subject [9–12]. This is pathophysiological explained by the pulse wave.

Arterial pulse wave: it is the wave of deformation of the vessels transmitted along the arterial tree at each systole when the blood ejected by the left ventricle hits the aorta [12, 13]. This pulse wave will propagate along the aorta (incident wave) with a speed of 6-10 m/sec, which is faster than the speed of red blood cells in the aorta [12, 13]. This pulse wave will encounter “walls”, represented by systemic vascular resistance (SVR) [12, 13]. It will therefore be reflected at these levels and leave in the opposite direction (reflected wave) [12, 13]. The reflected wave depends on the level of peripheral resistances, the distance from the site of reflection and arterial compliance [12, 13].

Physiologically, when the large arteries are "elastic", this reflected wave returns to protodiastole, which increases diastolic blood pressure [12, 13]. This wave is called the dicrotic wave (Figure 10).

In the elderly subject, due to arterial stiffness and the reduction in arterial compliance, the reflection of the pulse wave will be earlier [12, 13]. The pulse wave returns to systole too soon and will therefore increase systolic blood pressure and thus pulse pressure [12, 13] (Figure 10).



Pulse wave of the young subject

The systolic peak is early **(1)** its amplitude is low, the reflection waves are responsible for a rebound **(Arrow) (2)** before the notch **(3)**, the return wave continues after the notch in diastole **(4),** and is responsible for the undulations of the curve and its weaker decrease

Pulse wave in the elderly

The systolic peak is later and more important **(1)**, the return waves occur more precociously (because of the decrease in compliance), their beginning is responsible for a shoulder on the ascending part of the curve **(2) (arrow).** The diastolic decrease is more marked **(4)** because there is no longer any influence of the return waves after the notch **(3)**

Figure 10. *Blood pressure curves in young subjects vs elderly subjects [13].*

Arterial pulse wave: friend or foe? When the large arteries are “elastic”, the pulse wave is beneficial, because its reflected component returns in diastole, increasing the DBP, which optimizes the coronary perfusion pressure [12, 13]. But when it returns to systole, in subjects with poorly compliant rigid arteries, it increases systolic blood pressure. At this time, it becomes problematic, because in addition to not favoring coronary perfusion pressure, it will even worsen it by increasing myocardial work, because the heart pump will have to fight against a higher afterload [12, 13]. Pulse wave velocity has demonstrated its importance in studies of cardiovascular morbidity and mortality [1, 2, 12–19]. Indeed, pulse wave velocity is inversely proportional to compliance and arterial stiffness [1, 2, 12–19]. This is why a carotid-femoral pulse wave velocity ≥ 10 m/s or a high pulse pressure (≥60mmHg) is considered a risk factor for a cardiovascular event, especially in a 50-year-old subject and more [1, 2, 12–19].

Clinical implication: Make systematic the measurement of the arterial pulse wave at the examination of each patient. In a subject in supine position at rest for at least 10 minutes, a tonometer probe or a vascular ultrasound probe is applied to the right common carotid artery and to the ipsilateral femoral artery. The signals are recorded simultaneously or successively for 10 seconds and are synchronized with the ECG. The distance separating the two application sites of the tonometer, (direct femoral carotid distance) is entered in the software. It calculates the carotid-femoral arterial pulse wave velocity considering the 80% of the carotid-femoral direct distance [12, 20, 21]. This so-called "direct" method is the most recommended compared to the so-called subtraction method [12, 20, 21] (Figure 11).

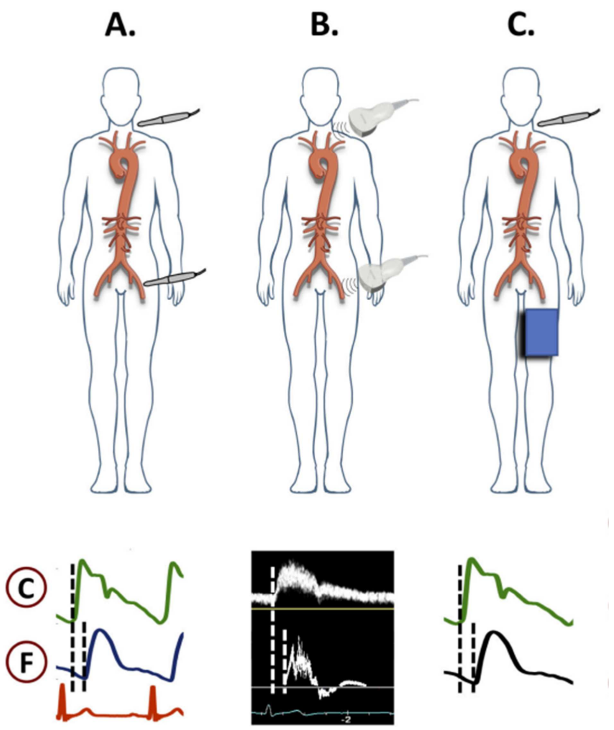


Figure 11. *Carotid-femoral arterial pulse wave measurement methods [12].*

A.: Measurement with two tonometer probes;
B.: Measurement with two vascular ultrasound probes;
C.: Measurement with a tonometer probe and an automatic cuff;
(C) Hemodynamic signal at the level of the carotid artery
(F) Hemodynamic signal at the level of the femoral artery

Therapeutic implications: the subject with so-called rigid arterial hypertension (50 years and over, high SBP, normal or low DBP, high pulse pressure, carotid-femoral pulse wave velocity ≥10m/s) should benefit from dual antihypertensive therapy combining a calcium channel blocker and an enzyme-converting enzyme inhibitor or an angiotensin 2 receptor antagonist [22–26].

5. Limits

First, scientific rigor dictates that the parameter measured by indirect techniques be called "arterial back pressure" and not "arterial pressure" [1–4]. Indeed, it is the counter-pressure exerted by the inflatable pocket of the cuff that the device measures [1–4]. Arterial back pressure only approaches intra-arterial pressure when the area over which backpressure is applied by the inflatable cuff pocket is matched to the circumference of the limb where the arterial backpressure is being measured [1–4]. Indeed, a cuff that is too small overestimates the arterial pressure and a cuff that is too large underestimates it [1–4]. Choosing an appropriate cuff size for your upper arm circumference is crucial for accurate blood pressure measurement. The length of the bladder contained in the cuff should be 75–100% of the mid-arm circumference and its width should be between 37–50% of the mid-arm circumference [1–4]. For some automated electronic devices, the cuff size must be selected according to the device's instructions [1–4]. People with large arms (mid-arm circumference >42 cm) should prefer a conical cuff rather than a rectangular one [1–4].

Then, given that MAP= (SBP+2DBP)/3 and that the oscillometric method deduces the SBP and the DBP from the detected MAP, it comes that this method estimates the SBP better than the DBP. It is therefore necessary to always have approved electronic blood pressure monitors to minimize measurement errors. Learned societies in arterial hypertension make approved devices available on their website [27–30].

Finally, it should be remembered that apart from the emergency, the diagnosis of arterial hypertension also requires self-measurement or ambulatory measurement of blood pressure [1, 2, 14]. These methods provide complementary information for diagnostic and therapeutic decisions [1, 2, 14].

6. Conclusion

The results of this study in the black subjects are also found in the studies carried out in the white subject. They find their explanations in common pathophysiological facts such as the cardiac cycle, arterial stiffness, and arterial pulse wave.

The measurement of the arterial pulse wave must be made systematic. It should be an integral part of blood pressure measurement because it provides additional diagnostic, prognostic and therapeutic interest in the management of arterial hypertension.

7. What Is Known, What This Study Adds

What is known about topic

Variations in blood pressure parameters according to age and heart rate have already been demonstrated in several studies carried out in white populations in developed countries.

What this study adds

1) Our study is the first of its kind carried out in a black African population (about 5343 subjects).
2) The results provide proof that the evolution of blood pressure parameters according to age and heart rate does not depend on race or level of development. The discussion makes it possible to understand that only human cardiovascular physiology explains these similarities.

Data Availability Statement

The datasets generated during and/or analysed during the current study are not publicly available but are available from the corresponding author on reasonable request.

Author Contributions

Pengd-Wende Habib BousseTRAORE posed the research question. Adama FAYE made it possible to answer it with the national database of the STEP survey. Jean Augustin Diegane TINE and Pengd-Wende Habib BousseTRAORE carried out the statistical analysis. Pengd-Wende Habib Boussewrote the manuscript TRAORE. Abdoul KANE accompanied the interpretation of the results.

Competing Interests

The authors declare no competing interests.

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References

[1] KANE A. Arterial hypertension in adults: From diagnosis to therapeutic management. First edition. Dakar University Press; 2015.

[2] KANE A. Arterial hypertension in adults: From diagnosis to therapeutic management. Second edition. Dakar University Press; 2021. 126 p.

[3] Asmar R. Blood pressure. Regulation and epidemiology. Normal measurements and values. Therapeutic Nephrology. 2007; 3 (4): 163–84.

[4] Stergiou GS, Palatini P, Parati G, O'Brien E, Januszewicz A, Lurbe E, et al. 2021 European Society of Hypertension practice guidelines for office and out-of-office blood pressure measurement. J Hypertens. 2021; 39 (7): 1293–302.

[5] Shahoud JS, Sanvictores T, Aeddula NR. Physiology, Arterial Pressure Regulation [Internet]. StatPearls [Internet]. StatPearls Publishing; 2022 [cited 2022 Nov 4]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK538509/

[6] Law on the Code of Ethics for Health Research. Law no. 2009-17 p. 10.

[7] Official journal of the republic of Senegal [Internet]. [cited 2021 Apr 4]. Available from: http://www.jo.gouv.sn/spip.php?article7557

[8] Berney M, Burnier M, Wuerzner G. Isolated diastolic hypertension: should we still be concerned? Swiss Medical Rev. 2018; 14 (618): 1607–10.

[9] Franklin SS, Gustin W, Wong ND, Larson MG, Weber MA, Kannel WB, et al. Hemodynamic Patterns of Age-Related Changes in Blood Pressure. Circulation. 1997; 96 (1): 308–15.

[10] O'Rourke MF, Hashimoto J. Mechanical Factors in Arterial Aging. J Am Coll Cardiol. 2007; 50 (1): 1–13.

[11] Mitchell GF. Arterial Stiffness and Hypertension: Chicken or Egg? Hypertension. 2014; 64 (2): 210–4.

[12] Chirinos JA, Segers P, Hughes T, Townsend R. Large-Artery Stiffness in Health and Disease: JACC State-of-the-Art Review. J Am Coll Cardiol. 2019; 74 (9): 1237–63.

[13] ABASSADE P. The pulse wave: form, propagation, variations and clinical applications. cardiological realities. 2010; 6.

[14] Unger T, Borghi C, Charchar F, Khan NA, Poulter NR, Prabhakaran D, et al. 2020 International Society of Hypertension Global Hypertension Practice Guidelines.: 24.

[15] Palombo C, Kozakova M. Arterial stiffness, atherosclerosis and cardiovascular risk: Pathophysiologic mechanisms and emerging clinical indications. Vascul Pharmacol. 2016; 77: 1–7.

[16] Franklin SS, Lopez VA, Wong ND, Mitchell GF, Larson MG, Vasan RS, et al. Single versus combined blood pressure components and risk for cardiovascular disease: the Framingham Heart Study. Circulation. 2009; 119 (2): 243–50.

[17] Briet M, Boutouyrie P, Laurent S, London GM. Arterial stiffness and pulse pressure in CKD and ESRD. Kidney Int. 2012; 82 (4): 388–400.

[18] Hashimoto J, Ito S. Central pulse pressure and aortic stiffness determine renal hemodynamics: pathophysiological implication for microalbuminuria in hypertension. Hypertens Dallas Tex 1979. 201; 58 (5): 839–46.

[19] Valencia-Hernández CA, Lindbohm JV, Shipley MJ, Wilkinson IB, McEniery CM, Ahmadi-Abhari S, et al. Aortic Pulse Wave Velocity as Adjunct Risk Marker for Assessing Cardiovascular Disease Risk: Prospective Study. Hypertension. 2022; 79 (4): 836–43.

[20] Pulse wave measurement – Technique and interpretation [Internet]. Practical Cardiology. 2013 [cited 2022 Nov 5]. Available from: https://www.cardiologie-pratique.com/axistv/video/la-mesure-de-londe-de-pouls-technique-et-interpretation

[21] CardieX Limited. PWV Demonstration [Internet]. 2016 [cited 2022 Nov 6]. Available from: https://www.youtube.com/watch?v=XeeQmbVpt8M

[22] Kario K. Proposal of RAS-diuretic vs. RAS-calcium antagonist strategies in high-risk hypertension: insight from the 24-hour ambulatory blood pressure profile and central pressure. J Am Soc Hypertens JASH. 2010; 4 (5): 215–8.

[23] Ghiadoni L. The effects of antihypertensive drugs on arterial stiffness☆. Artery Res. 2016; 14 (C): 1.

[24] The CAFE Investigators, CAFE Steering Committee and Writing Committee, Williams B, Lacy PS, Thom SM, Cruickshank K, et al. Differential Impact of Blood Pressure–Lowering Drugs on Central Aortic Pressure and Clinical Outcomes: Principal Results of the Conduit Artery Function Evaluation (CAFE) Study. Circulation. 2006; 113 (9): 1213–25.

[25] Jatic Z, Skopljak A, Hebibovic S, Sukalo A, Rustempasic E, Valjevac A. Effects of Different Antihypertensive Drug Combinations on Blood Pressure and Arterial Stiffness. Med Arch. 2019; 73 (3): 157–62.

[26] Flack JM, Sica DA, Bakris G, Brown AL, Ferdinand KC, Grimm RH, et al. Management of high blood pressure in Blacks: an update of the International Society on Hypertension in Blacks consensus statement. Hypertens Dallas Tex 1979. 2010; 56 (5): 780–800.

[27] BP monitors [Internet]. British and Irish Hypertension Society | Registered UK Charity No. 287635. [cited 2022 Nov 4]. Available from: https://bihsoc.org/bp-monitors/

[28] BP Monitors [Internet]. [cited 2022 Nov 4]. Available from: https://www.stridebp.org/bp-monitors

[29] Validate BP [Internet]. [cited 2022 Nov 4]. Available from: https://www.validatebp.org/

[30] admin. Blood Pressure Devices [Internet]. Hypertension Canada | For Healthcare Professionals. [cited 2022 Nov 4]. Available from: https://hypertension.ca/bpdevices