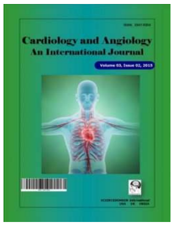

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Mean Arterial Pressure Classification: A Better Tool for Statistical Interpretation of Blood Pressure Related Risk Covariates

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Authors' contributions

This work was carried out in collaboration between all authors. Author RNK collected the data, prepared the checker board for mean arterial pressure and wrote the first draft of the manuscript. Author SB designed the study and contributed in writing the draft. Author MD designed the study, analyzed the data and wrote the final draft. All authors read and approved the final manuscript.

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ABSTRACT

Purpose: Both Systolic blood pressure (SBP) and diastolic blood pressure (DBP) are equally important to analyze the associations between blood pressure and its associated risk covariates. Quantitative analyses however, sometime provide separate results for SBP and DBP. It is more evident in people with systolic or diastolic hypertension. It sometime becomes difficult to interpret while performing statistical analyses. Mean arterial pressure (MAP) which is a time-weighted average of the arterial pressure over the whole cardiac cycle is a very useful tool for biological and medical science. But, till date to the best of our knowledge, no classifications available like blood pressures. So, in this paper a classification of MAP was formulated following the blood pressure classification as recommended by World Health Organization (WHO) and European Society of Hypertension and European Society of Cardiology (ESH/ESC). The resultant value of MAP was then classified into several categories like, optimal, normal, high normal and so on. The present

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article is therefore, an attempt to postulate the MAP classification as innovative method for better statistical analyses, screening and analyses in association studies related to blood pressures.

Materials and Methods: SBP & DBP were measured on right arm in sitting posture by means of aneroid sphygmomanometer and stethoscope. Pulse pressure and MAP was computed as per the standard formula. Necessary statistical analyses were performed using SPSS (version 14.0).

Results: It was found that MAP was a better predictor of blood pressure associated with risk covariates like Body Mass Index (BMI) and Waist Circumference (WC) as compare to SBP and DBP separately. Both correlation and stepwise regression analyses shows that the MAP is no less significant than SBP and DBP by considering blood pressure as dependent and BMI & WC as independent variables.

Conclusion: A researcher can therefore use this MAP classification for data analysis as it will yield only one statistical result instead of two separate results (i.e. SBP and DBP) as to observe the relation of blood pressure (MAP) with different risk covariates. The vascular complications associated with hypertension including stroke, cardiovascular disease, chronic renal failure etc. require regular screening to avoid serious organ damage. Classification of MAP would therefore be more effective than blood pressure classifications not only in clinical practice but in public health as well. MAP classification would immensely help in translating large epidemiological data in to meaningful statistical interpretations.

Keywords: Mean arterial pressure; systolic blood pressure; diastolic blood pressure; mean arterial pressure classification; cardiometabolic risk.

1. INTRODUCTION

Hypertension (HT) is a major health problem throughout the world due to its high prevalence and strong association with increased risk of cardiovascular disease (CVD). The World Health Organization (WHO) has estimated that high blood pressure cause one in every eight deaths, making HT the third killer in the world [1]. Primary prevention is the most cost-effective approach to restrict the emerging HT epidemic. Good management of HT is central to any strategy formulated to control HT at the community level. There are different types of health problem arising primarily due to unawareness or lack of consciousness [2]. Nowadays it is an important subject matter of bio-medical science in developing countries, because most of the people not only have little or no consciousness towards high blood pressure risks, they do not even check their blood pressure in regular interval [3]. As a result, instead of prevention it is increasing abruptly in recent years. In India the average age of patients with heart disease is 52 years, much higher compare to America where it is 70 years, as reported by American College of Cardiology [4]. It has been argued that a comprehensive surveillance system is important for the management of non-communicable disease like HT [5]. There are numerous variables which can be taken from the individuals of a population to clarify physical health of that particular population of which, one important variable is blood pressure [6].

In this study authors have collected data of blood pressure (as dependent variables) and some anthropometric measures (as independent variables), from Bengali speaking population living in and around Kolkata, West Bengal, India. Each individual have their specific blood pressure (SBP & DBP) which cannot follow together by any standard classification. It has been found very often that an individual have normal systolic pressure (for example 120 mmHg) but high diastolic pressure (for example 86 mmHg) or vice-versa. It then becomes quite difficult to classify those individuals, since available blood pressure classification includes both SBP and DBP. However, both SBP and DBP are equally important to analyze the associations between blood pressure and other risk factors [7].

Mean arterial pressure (MAP) is one of the important tools by which researcher can solved this particular problem because MAP is a time-weighted average of the arterial pressure over the whole cardiac cycle, which is calculated as the diastolic pressure plus one-third of the pulse pressure [8]. It gives a measure of the average perfusion pressure of the systematic circulation. However, no standard classification of MAP is available so far. The authors therefore, intended to formulate a ready-to-use classification of MAP by incorporating the MAP formula over the internationally accepted blood pressure classification.

2. MATERIALS AND METHODS

The present study has been conducted in four steps. First two steps are fundamental tools and next two steps are for formulating the classification.

I. Selection of a blood pressure classification
II. Selection of a formula of mean arterial pressure.
III. Calculation of mean arterial pressure.
IV. Data collection and statistical analyses.

2.1 Selection of a Blood Pressure Classification

Classification of blood pressures as guided by the European Society of Hypertension and the European Society of Cardiology has taken in to consideration as it is an elaborate and standardize classification globally well accepted [9].

Table 1 shows classification of all the categories except isolated systolic HT were included as it has no particular cut off point. It was observed that if isolated systolic HT included in the analysis then, blood pressure values fluctuate abruptly at the time of calculation of checker-board. Hence, we did not include isolated systolic HT in the checker-board. From the different category of blood pressure only maximum cut off values were included in the checker board. For SBP values of 120, 129, 139, 159, 179 and 180, and for DBP values of 80, 84, 89, 99, 109 and 110 were included for Optimal, Normal, High normal, Grade 1, Grade 2 and Grade 3 hypertension, respectively. Another widely used classification of blood pressures was also studied as recommended by WHO [7].

2.2 Selection of a Formula of Mean Arterial Pressure (MAP)

MAP is not a simple arithmetic average of the diastolic and systolic blood pressures because the arterial blood spends relatively longer near the diastolic pressure than the systolic blood pressure. The MAP is directly proportional to cardiac output. For the most working purpose, an approximation to MAP can be obtained by applying the following simple equation [8]:

$$\text{Mean Arterial Pressure} = \text{Diastolic Pressure} + \left(\frac{1}{3} \times \text{Pulse Pressure}\right)$$

Pulse Pressure (mmHg) is the difference between systolic and diastolic blood pressures, formula of the pulse pressure is written as:

$$\text{Pulse Pressure} = (\text{Systolic Blood Pressure} - \text{Diastolic Blood Pressure})$$

2.3 Calculation of Mean Arterial Pressure

Mean arterial pressure was calculated against each categories of blood pressure classification as given in Table 2.

Table 1. Classification of blood pressure

Category	Systolic pressure	Diastolic pressure
Optimal	<120	<80
Normal	120-129	80-84
High normal	130-139	85-89
Grade 1 Hypertension (Mild)	140-159	90-99
Grade 2 Hypertension (Moderate)	160-179	100-109
Grade 3 Hypertension (Severe)	≥180	≥110
Isolated systolic hypertension	≥140	<90

Values are measured in mmHg

Table 2. Mean arterial pressure against each category of blood pressure classification

Blood pressure category	Blood pressure value		Pulse pressure	MAP value
	SBP	DBP		
Optimal	120	80	40	93.33
Normal	129	84	45	99.00
High normal	139	89	50	105.67
Grade 1 Hypertension	159	99	60	119.00
Grade 2 Hypertension	179	109	70	132.33
Grade 3 Hypertension	180	110	70	133.33

Values are measured in mmHg

The above mentioned values were then incorporated in a checker-board called 'MAP checker-board'. This terminology has been used for the ongoing analysis of MAP classification. The MAP checker-board created in the following ways. At first, the maximum value of SBP was entered serial-wise in the left side vertically; then, the maximum value of DBP was entered serial-wise in the top side horizontally. MAP was then calculated as per the standard equation and entered into the appropriate cells. For example, if the systolic blood pressure is 120 mmHg and the diastolic blood pressure is 80 mmHg, then MAP = [80 + {1/3 × (120-80)}] or 93.33 mmHg as given in Table 3.

It is very easy to calculate the MAP value from any standard blood pressure classification by the help of mean arterial pressure formula.

2.4 Data Collection and Statistical Analyses

The present study was conducted on 500 adult ($\geq$ 30 yrs) Bengali speaking population living in and around Kolkata, India which include 257 males and 243 females. Anthropometric measures like height, weight, waist circumference, hip circumference were measured as per standard techniques [10]. Body mass Index was computed as weight (kg) divided by height (m) squared. Blood pressures (both systolic and diastolic) were measured twice by means of aneroid sphygmomanometer and stethoscope twice in sitting posture over right arm and the average was considered for analyses. A third measurement was taken if the difference between two measurements were $\geq$ 5mm/Hg. MAP was calculated as discussed earlier. The Institutional Ethics Committee of the West Bengal State University, Barasat, India had approved the study. Written consent was obtained from each participants prior to actual commencement of the study.

All statistical analyses were performed on SPSS (Version14.0). A statistical significance was set at $p<0.05$ (two-tailed).

3. RESULTS AND DISCUSSION

From the MAP checker-board the cut-off range of MAP against each category was done in the following ways:

- Optimal MAP value is <93.33; since for blood pressure to be optimal the SBP value should be < 120 mmHg and DBP < 80 mmHg, so optimal MAP value becomes < 93.33.
- Normal MAP values are 93.33 to 99.00; as normal blood pressure means SBP in between 120 to 129 mmHg and DBP in between 80 to 84 mmHg, therefore normal MAP falls between 93.33 and 99.00.
- High Normal MAP values are 99.01 to 105.67; as the high normal blood pressure value started just after the value of highest value of normal blood pressure, i.e., SBP 130-139 mmHg and DBP 85-89mmHg, therefore high normal MAP falls between 99.01 and 105.67.
- Grade 1 Hypertension (Mild) MAP values are 105.68 to 119.00; same as high normal blood pressure the lowest value begins after the highest value of high normal value up to the highest value of grade 1 hypertension, so the MAP value for Grade 1 Hypertension (Mild) falls between 105.68 and 119.00.
- Grade 2 Hypertension (Moderate) MAP values are 119.01 to 132.33; as the lowest value begins after the highest value of grade 1 hypertension value up to the highest value of grade 2 hypertension hence, the MAP value for Grade 2 Hypertension (Moderate) falls between 119.01 and 132.33.
- Grade 3 Hypertension (Severe) MAP values are above 132.33; it has no doubt that the value grade 3 hypertension included the higher value than the maximum value of grade 2 hypertension, hence the value of grade 3 hypertension becomes ≥132.34.

MAP classification was finally formulated as given in Table 4.

This classification was then tested with the data collected for analyses and interpretation in order to fulfill the purpose of the present study. Correlation coefficient analyses, as given in Table 5a, showed that MAP was a better predictor of blood pressure (significantly correlated) with BMI and WC as compare to SBP and DBP separately. The Table 5b shows the multiple regression (stepwise) analyses with blood pressure (SBP, DBP and MAP) as dependent variable and BMI & WC as independent variables. It was found that MAP was equally significant predictor, like SBP, and more than DBP, for the amount of variance accounted for by the independent variables as indicated by R^2change. Fig. 1 illustrates the classification of MAP in comparison with SBP and DBP.

It therefore seems that MAP is a better indicator for analytical interpretation as compare to SBP and DBP separately, as it yields different results. MAP is significantly correlated with adiposity measures as compare to SBP and DBP. Moreover, the stepwise regression analyses shows that the MAP is no less significant that SBP and DBP. The R^2change for SBP and MAP are same but not DBP thereby indicating that MAP could be used as the representative variable for blood pressure in place of SBP and DBP separately.

Table 3. Checker board for mean arterial pressure

Category			Diastolic pressure (mmHg)					
			Optimal	**Normal**	**High normal**	**Grade 1**	**Grade 2**	**Grade 3**
			80	**84**	**89**	**99**	**109**	**110**
Systolic pressure (mmHg)	Optimal	120	93.33	96	99.33	106	112.67	113.33
	Normal	129	96.33	99	102.33	109	115.67	116.33
	High normal	139	99.67	102.33	105.67	112.33	119	119.67
	Grade 1	159	106.33	109	112.33	119	125.67	126.33
	Grade 2	179	113	115.67	119	125.67	132.33	133
	Grade 3	180	113.33	116	119.33	126	132.67	133.33

Values are measured in mmHg

Table 4. Classification of mean arterial pressure (MAP)

Category	**MAP (mmHg)**
Optimal	<93.33
Normal	93.33 - 99.00
High normal	99.01 - 105.67
Grade 1 Hypertension (Mild)	105.68 - 119.00
Grade 2 Hypertension (Moderate)	119.01 - 132.33
Grade 3 Hypertension (Sever)	≥132.34

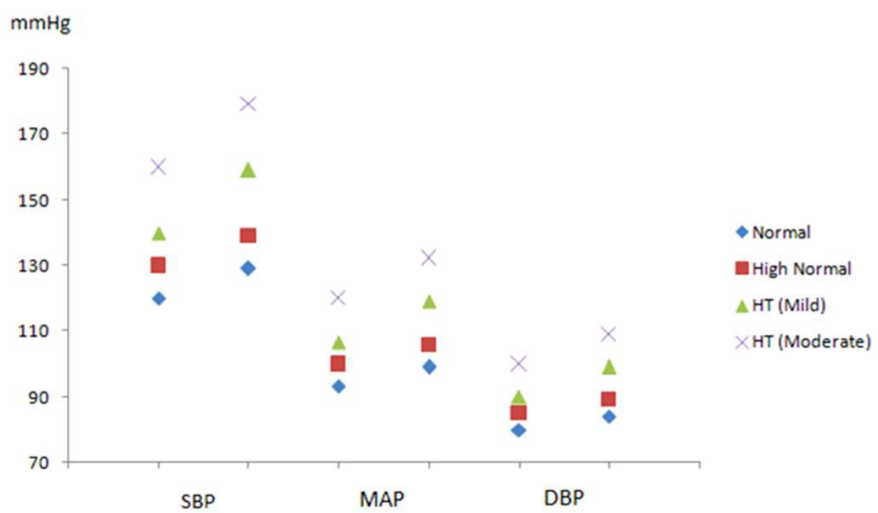

Fig. 1. Classification of MAP in association with SBP and DBP
SBP-systolic blood pressure; DBP- diastolic blood pressure; MAP-mean arterial pressure; mmHg-millimeter of mercury; HT-hypertension

Table 5a. Correlation coefficient between blood pressure and adiposity measures

Correlation	WC (p value)	BMI (p value)
MAP	0.427 (0.0001)	0.404 (0.0001)
SBP	0.426 (0.0001)	0.399 (0.0001)
DBP	0.349 (0.0001)	0.332 (0.0001)

Table 5b. Multiple regression (stepwise) with blood pressure measures as dependent and adiposity measures as independent variables

Regression	B	R^2 change	t value	p value
MAP	0.427	0.182	7.153	0.0001
SBP	0.576	0.182	7.147	0.0001
DBP	0.349	0.122	5.644	0.0001

SBP-systolic blood pressure; DBP- diastolic blood pressure; MAP-mean arterial pressure; WC- waist circumference; BMI-body mass index; B-regression coefficient; R^2change-change in amount of variance of the dependent variable accounted for by the independent variables; t- value of t-test; p-statistically significant value

4. CONCLUSION

In fact, MAP is intermediate to SBP and DBP and is considered to be the perfusion pressure of the body. So arguably, this classification would be very useful for researchers to perform different quantitative analysis particularly for inferential statistics. MAP could be used as the representative variable for blood pressure instead of SBP and DBP separately. In various studies it has been found that a person might have systolic pressure normal but diastolic pressure higher or vice versa. In such cases, MAP classification could be very useful particularly, when working on large epidemiological data, for better inferential statistics and meaningful interpretation. Few studies in recent past have also found that MAP and pulse pressure to be better associated with coronary heart disease among elderly in a Framingham Heart Study [11]; CVD among elderly population [12]; septic shock with chronic arterial HT [13]; and patients with haemodialysis [14,15] than SBP and DBP separately.

It is however reasonable to mention, that both SBP and DBP are important in case of clinical purpose or medical treatment rather than just MAP. Researcher could not be able to apply this classification to study about isolated systolic HT as it has no particular cut-off value. Otherwise, MAP seems to be very useful for analytical purpose in both clinical as well as large scale epidemiological studies focusing on blood pressures and its associated risk covariates like CVD, coronary heart disease, type 2 diabetes etc. for better interpretation and preventive purposes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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