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Association between blood pressure, body mass index, and age: A data analytic approach

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ABSTRACT

Objectives: Increase in body mass index (BMI) increases the risk of developing high blood pressure (BP). Several studies also indicate that high BP is associated with age. Controversies have been found regarding the association of BMI with high BP and age. Hence, this study was conducted to investigate the association between BP, BMI, and age.

Material and Methods: Using the Inter-university Consortium for Political and Social Research (ICPSR 131103) Study on the Effects of Mindfulness on Lifestyle Behavior and BP, prospectively gathered data were retrospectively analyzed. A randomized controlled study was conducted. Using the statistical MedCalc program, the patient demographic data – including their age, BMI, and BP – were statistically examined. Statistical significance was determined using a 0.05 *P*-value.

Results: Of the 37 participants, 43.3% had a normal BMI. One-fourth (40.5%) of the people were obese. 13.5% and 32.4% of the people had normal systolic (SBP) and diastolic (DBP) BP, respectively. Age, SBP, or DBP did not significantly correlate with BMI. Nevertheless, there was a positive and substantial correlation between BMI, age, SBP, DBP, weight, and height.

Conclusion: According to the study's findings, there are no appreciable positive connections between BMI and either SBP or DBP, or age. However, the weakly positive relationships between SBP and DBP and age suggest that regular BP monitoring is necessary.

Keywords: Body mass index, Systolic blood pressure, Diastolic blood pressure, Age, Inter-university consortium for political and social research

INTRODUCTION

Blood pressure (BP) develops as a result of the heart pumping blood up against blood vessel walls (arteries). Pumping blood at a higher pressure requires the heart to work harder. High BP is defined as a persistent systolic BP (SBP) or diastolic BP (DBP) of at least 130 mmHg or 90 mmHg, respectively. One's risk of dying increases along with their risk of acquiring heart, brain, kidney, and other illnesses.[1] Over nine million people worldwide lose their lives to hypertension each year, according to the World Health Organization (WHO), making it one of the top global causes of disease and mortality.[2-4] Two-thirds of instances of hypertension are found in low- and middle-income nations, where the disease is more prevalent. This is partly because risk factors have risen in these populations over the past few decades. Body mass index (BMI) is a value derived from the mass and height of a person. The BMI is defined as the body mass divided by the square of the body height and is expressed in units of kg/m², resulting from mass in kilograms and height in meters.[5] According to the WHO, BMI is divided into three categories: Normal (18.5–25 kg/m²), overweight (26–30 kg/m²), and obese (>30 kg/m²).[6] BMI is frequently used to gauge an individual's level of obesity (extra body fat), and studies have shown that it correlates favorably with BP.[7-9] Disorders such as hypertension, diabetes mellitus, and dyslipidemia, which are risk factors for cardiovascular illnesses, are greatly influenced by excess body fat.[10] High BMI levels during adolescence have been linked to adult mortality, stroke, and coronary heart disease.[11,12] High pulse wave velocity, thick carotid intima-media, left ventricular hypertrophy, cardiovascular illness, and adult mortality are also linked to high BP in children and adolescents.[13-16]

A person's mass (weight) and height are used to calculate their BMI. The BMI is determined by multiplying a person's weight (in kilograms) by their height (in square meters).[3] In an effort to determine if a person is "underweight, normal weight, or obese," the amount of tissue mass (muscles, fat, and bone) the person possesses is measured.[4] Determining the trends in BMI-BP connection in teenagers is crucial for formulating a national health policy and forecasting the future burden of cardiovascular illnesses.

According to several types of research,[17,18] high BP is linked to aging as well as the modernization process. Rapid changes in the economy, epidemiology, and diet have increased the prevalence of overweight and obesity in developing nations.[19] The WHO claims that since overweight and obesity are now so widespread, they are taking the place of more conventional public health issues like undernourishment and infectious diseases. There are now equal numbers of overfed and underfed persons worldwide.[20] Although there are several variables that contribute to becoming overweight or obese, one of them is excessive energy consumption, especially when it is combined with a reduction in physical activity.[21]

One of the factors that affect the occurrence of high BP is aging.[22] According to a study by Vuvor, the prevalence of high BP increased with age, with the oldest age group (46–50 years old) showing the highest prevalence of high BP.[3] Age-related increases in the prevalence of hypertension are brought on by deteriorating kidney metabolic processes for salt excretion, hardening of the arteries, and rising obesity.[23] The general pathophysiological factors that affect the development of hypertension, however, include altered renal and sodium metabolism, altered renin-aldosterone relationships, impaired sodium excretion by the kidney, reset baroreflexes, reset local autoregulation responses, and increased responsiveness to sympathetic nervous system stimuli.[24,25]

Over time, adjustments have been made to dietary habits, eating patterns, and levels of physical activity as a result of socioeconomic progress. Alterations in diet, body composition, physiological processes, and health are only a few of the effects of these changes. In addition, it contributed to the issue of the rise in cardiovascular diseases and overweight/obesity across age groups. Worrisome is the fact that a limited study has been carried out to investigate the combined influence of age, BMI, and BPs on cardiovascular diseases. Hence, the purpose of the present study was to look into the connection between age, BMI, and BP.

MATERIAL AND METHODS

Description of retrieved datasets

The information for this inquiry came from the Inter-university Consortium for Political and Social Research (ICPSR) Study on the Mindfulness effects on lifestyle behavior and BP: A randomized controlled experiment (ICPSR 131103).[26] Data from a single-site, two-arm clinical trial were used in this study. The experiment's major objectives were to assess feasibility and effect size, and its secondary objectives were to establish whether behavior modification and BP reduction were beneficial. It was held at UCLA from August 1, 2017, to August 1, 2018. People were enlisted from the UCLA campus, medical center, and adjacent villages through flyers and internet advertisements. Blocks of recruitment (maximum of 15 participants) were carried out, and individuals were then sequentially assigned to the future Master of Arts in Health Education and Promotion. The group assignments, therefore, were based on the class timetables. People with high BP, either with or without a prescription for antihypertensive medication, met the inclusion criteria. Chemotherapy, substance abuse, and current pregnancy or nursing were excluded from the study. Other exclusion criteria included people who were already engaged in yoga, meditation, or other behavioral therapies, were unable to commit to the duration of the trial, had uncontrolled mental health issues, or were illiterate in English based on educational status.

Statistical analysis

Statistical analyses were performed on the patient demographic data, BMI, and BP using the statistical MedCalc program.[27] Chi-square test was employed to determine the significance of the relationship between categorical variables. Statistics were considered statistically significant when $P < 0.05$. The correlation was utilized to determine any associations between continuous variables.

RESULTS

Relationship between age, body weights, and BMI

As shown in [Table 1], basic information and BMI were divided into three different age groups. The middle age group (50–69 years) was found to have the highest mean height, while the youngest (30–49 years) age group had the lowest mean height. Across all age categories, the variations in mean height were statistically significant ($P < 0.0001$).

Age-related increases in body weight were observed across all age groups, and the differences in mean body weight were statistically significant ($P < 0.0001$). The oldest age group was found to have the highest body weight, while the youngest group had the lowest.

The BMI for each of the three age groups is also included in [Table 1]. With a mean BMI of 30.1 kg/m^2, the oldest age group had the highest average BMI. The result for the middle-aged group, which was found to be 27.6 kg/m^2, was the lowest. There was a statistically significant variation in mean BMI between all of the age groups ($P < 0.0001$).

Relationship between age and BP

SBP and DBP values are shown in [Table 2] for various age groups. The mean SBP and DBP were found to be lowest in the oldest age group. SBP and DBP fell as people aged, with the youngest age group having the highest mean value. The difference in mean SBP and DBP between age groups was statistically significant ($P < 0.0001$).

Relationship between BMI and BP

The distribution of patients across various BMI and BP groups is shown in [Table 3]. Normal BMI subjects made up the largest percentage of participants (43.30%), followed by obese subjects (40.50%). The category with the fewest subjects was overweight (16.20%). SBP measurements revealed that prehypertension (45.9%) and Stage I hypertension (32.4%) affected the greatest percentages of participants. Prehypertension was seen in the majority of individuals (35.2%) with normal BP coming in the second (32.4%). According to SBP measurements, there were sizable proportions of normal (13.5%) and Stage II hypertensive patients (8.1%). As determined by DBP, subjects with Stages I and II hypertension accounted for 16.2% of the population each.

The values for SBP and DBP in various BMI categories are shown in [Table 4]. The overweight category had the lowest mean SBP and DBP readings, whereas the obese category had the highest systolic readings and the normal category had the highest diastolic readings. SBP mean values rose from the overweight to the normal to the obese categories, while DBP mean values rose from the overweight to the normal to the obese categories. This demonstrated that as BMI increased, mean SBP and DBP also did so. Between the BMI groups, there were statistically significant differences in mean BP ($P < 0.0001$).

[Table 4] displays the BP and BMI for Asians in the three age categories. The oldest age group had the greatest mean BMI, which was 27 kg/m^2. The youngest age group's value was determined to be the lowest, at 24.8 kg/m^2. Between all age categories, there was a statistically significant difference in mean BMI.

The middle-aged group had the highest systolic, which was also the case for the youngest and oldest age groups. The middle-aged and oldest age groups were found to have the greatest and lowest DBP, respectively. From the youngest to the middle-aged age groups, both SBP and DBP increased,

Table 1: Basic data and BMI among different age groups.

Age (years)	Height (cm)			Body weight (kg)			BMI (kg/m^2)		
	Mean	±SD	"*t*" value	Mean	±SD	"*t*" value	Mean	±SD	"*t*" value
30–49	63.6	2.6	68.8***	133.9	14.1	21.2***	29.5	9.1	9.1***
50–69	65.9	3.7	81.6***	179.9	48.4	12.9***	27.6	5.6	22.6***
60–79	63.8	2.1	85.0***	177.7	40.4	11.6***	30.1	5.3	15.9***

BMI: Body mass index, SD: Standard deviation. Level of significance *P*<0.0001***

Table 2: BP in different age groups.

Age (years)	Systolic BP (mmHg)				Diastolic BP (mmHg)			
	Mean	±SD	SE	"*t*" value	Mean	±SD	SE	"*t*" value
30–49	138.5	21.2	7.5	18.5***	96.0	12.6	4.4	21.6***
50–69	136.4	13.3	2.9	47.1***	84.6	12.1	2.6	32.1***
60–79	134.5	18.4	6.5	20.7***	78.3	15.6	5.5	14.2***

BP: Blood pressure, SD: Standard deviation, SE: Standard error. Level of significance *P*<0.0001*** and in the oldest age groups, they decreased. Age-related variations in mean BP were also statistically significant.

[Table 5] displays the BP and BMI data for the black and non-Hispanic populations by age group. Age-related increases in BMI were seen, with the oldest and youngest age groups having the highest and lowest BMI values, respectively. From the youngest to the middle to the oldest age groups, the mean SBP climbed. The DBP was found to be lowest in those in their middle years and highest in people under the age of 20. SBP decreased with aging, with the youngest age groups having the greatest levels. Age-related variations in mean BP were likewise statistically significant ($P < 0.05$).

[Table 6] displays the BP and BMI for the white population who are non-Hispanic in various age categories. As people aged, their BMI and BP (both systolic and diastolic) declined. The youngest and oldest age groups were found to have the greatest and lowest BMIs, respectively. Age-related variations in mean BP were likewise statistically significant ($P < 0.05$).

Table 3: Distribution of subjects in different categories of BMI and BP.

BMI and BP classifications	Mean value	Distribution of subjects in different categories	
		n	%
BMI			
Normal	23.42	16	43.30
Obese	27.18	15	40.50
Overweight	34.52	6	16.20
Total	85.12	37	100.00
SBP			
Normal	114.4	5	13.5
Prehypertension	129.65	17	45.9
Hypertension Stage I	147.17	12	32.4
Hypertension Stage II	169	3	8.1
Total	560.21	37	100.00
DBP			
Normal	71.17	12	32.4
Prehypertension	85	13	35.2
Hypertension Stage I	93	6	16.2
Hypertension Stage II	109.17	6	16.2
Total	358.33	37	100.00

BMI: Body mass index, BP: Blood pressure, SBP: Systolic blood pressure, DBP: Diastolic blood pressure

Table 4: BP and BMI in different age groups among the Asian population.

Variables	30–49 years	50–69 years	60–79 years
BMI	24.8±1.46	26.5±1.76	27±0
SBP	130±8.27	143±10.5	130±0
DBP	95.2±4.35	96.2±5.14	80±0

BMI: Body mass index, BP: Blood pressure, SBP: Systolic blood pressure, DBP: Diastolic blood pressure. Values are means±standard error of the mean. Means in a row without a common superscript letter differ (P<0.05) as analyzed by one-way Analysis of Variance and the Tukey test.

Table 5: BP and BMI in different age groups among the black non-Hispanic population.

Variables	30–49 years	50–69 years	60–79 years
BMI	26±0	26.5±1.85	32.6±4.3
SBP	136±0	134±3.78	143±10.5
DBP	84±0	79±3.47	81.3±14.5

BMI: Body mass index, BP: Blood pressure, SBP: Systolic blood pressure, DBP: Diastolic blood pressure. Values are means±standard error of the mean. Means in a row without a common superscript letter differ (P<0.05) as analyzed by one-way Analysis of Variance and the Tukey test.

Correlation analysis based on age, BP, and BMI

[Table 7] shows the link between BMI, BP, and age in the Asian population along with its level of significance. Age had a weakly positive connection with height, SBP, and BMI. Insignificantly, age also exhibited a negative connection with DBP. Age and weight had a positive, statistically significant ($P < 0.0001$) association. BMI positively connected with weight (significant), SBP negatively correlated with height (insignificant), and DBP negatively correlated with weight. DBP revealed a strong positive connection with height and SBP but an insignificant negative correlation with weight. Weight and SBP significantly correlated positively with height. There was a minor positive correlation of SBP with weight.

The association between BMI, BP, and age in the black population is shown in [Table 8] along with the degree of significance. The relationship between age and BMI, DBP, SBP, weight, and height was not statistically significant. Height, DBP, SBP, and weight all had negligible positive correlations with BMI, whereas weight and weight exhibited a substantial positive correlation. Height and weight revealed a negligible negative connection with SBP. Despite being insignificant, weight and height had a favorable correlation.

[Table 9] displays the relationship between age, BMI, and BP in the white population. Age and DBP revealed a negligible negative link, while BMI, SBP, height, and weight exhibited

Table 6: BP and BMI in different age groups among the white non-Hispanic population.

Variables	30–49 years	50–69 years	60–79 years
BMI	42.9±5.5^{b}	29.3±2.32^{a}	28.9±2.11^{ab}
SBP	160±16	136±4.07	130±10.7
DBP	104±15	85.1±4.05	75.8±5.59

BMI: Body mass index, BP: Blood pressure, SBP: Systolic blood pressure, DBP: Diastolic blood pressure. Values are means±standard error of the mean. ^{ab}Means in a row without a common superscript letter differ (P<0.05) as analyzed by one-way Analysis of Variance and the Tukey test

Table 7: Correlation matrix between BMI, BP, and age among the Asian population.

	Age (years)	BMI	DBP	Height	SBP	Weight
Age (years)	1	0.269	−0.396	0.0603	0.156	0.862***
BMI	0.269	1	−0.112	0.268	0.205	0.884***
DBP	−0.396	−0.112	1	0.653***	0.823***	−0.206
Height	0.0603	0.268	0.653***	1	0.804***	0.762***
SBP	0.156	0.205	0.823***	0.804***	1	0.456
Weight	0.862***	0.884***	−0.206	0.762	0.456	1

BMI: Body mass index, BP: Blood pressure, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, ***Very significant

Table 8: Correlation matrix between BMI, BP, and age among the black non-Hispanic population.

	Age (years)	BMI	DBP	Height	SBP	Weight
Age (years)	1	−0.398	−0.493	−0.0316	−0.318	−0.161
BMI	−0.398	1	0.108	0.0892	0.139	0.85***
DBP	−0.493	0.108	1	0.0928	0.8***	0.212
Height	−0.0316	0.0892	0.0928	1	−0.0394	0.689***
SBP	−0.318	0.139	0.8***	−0.0394	1	−0.132
Weight	−0.161	0.85***	0.212	0.689	−0.132	1

BMI: Body mass index, BP: Blood pressure, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, ***Very significant

Table 9: Correlation matrix between BMI, BP, and age among the white non-Hispanic population.

	Age (years)	BMI	DBP	Height	SBP	Weight
Age (years)	1	0.359	−0.164	0.103	0.0919	0.429
BMI	0.359	1	0.251	0.153	0.147	0.927***
DBP	−0.164	0.251	1	0.398	0.655***	0.447
Height	0.103	0.153	0.398	1	0.487	0.315
SBP	0.0919	0.147	0.655***	0.487	1	0.549
Weight	0.429	0.927***	0.447	0.315	0.549	1

BMI: Body mass index, BP: Blood pressure, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, ***Very significant

substantial positive correlations. DBP (r = 0.655; $P < 0.05$), SBP (r = 0.655; $P < 0.05$), and BMI (r = 0.927; $P < 0.05$) all showed positive relationships, except for weight, which showed significance. DBP showed a favorable correlation with height, weight (insignificant), and SBP (significant). Height, SBP, and weight had a very weak positive correlation. There was a weak but favorable connection between SBP and weight.

[Table 10] displays the odds ratio for predicting SBP and DBP. SBP tests showed that compared to those with a normal BMI range, obese adults had a 0.8824 times higher risk of prehypertension, a 1.25 times higher likelihood of Stage I hypertension, and a 5 times higher likelihood of Stage II hypertension. Prehypertension is 1538 times more prevalent and Stage I and Stage II hypertension are 2.5 times more prevalent than in people with normal BMI categories. Compared to people with a normal BMI, those who were overweight had a lower likelihood of having greater SBP and DBP.

DISCUSSION

From the oldest age group to the youngest and the middle age group, the rising trend in mean stature was visible. This demonstrates that the middle-aged participants had the highest mean height value. The weakening of intervertebral discs and muscle sag that causes postural alterations may be the cause of the reduction in stature with advancing age. The spine has been known to bow and its height to decrease due to the loss of collagen between spinal vertebrae.[28] Both Kapoor and Tyagi[29] and Bhardwaj and Kapoor[30] have reported similar findings.

With age, body weight grew. The build-up of fat with aging may be the cause of the rise in body weight. Age-related weight gain may be brought on by sedentary lifestyles, loss of muscle mass, and the emergence of potential medical issues. Older persons usually report having lost weight and strength in their final years of life because, in general, aging is typically associated with declines in total and lean mass.[31-33] In

Table 10: BMI as a risk factor for SBP and DBP.

BMI classifications	SDP			DBP		
	Prehypertension	Hypertension Stage 1	Hypertension Stage 2	Prehypertension	Hypertension Stage 1	Hypertension Stage 2
Overweight	0.3529	0.5	2	0.4615	1	1
Obese	0.8824	1.25	5	1.1538	2.5	2.5
Normal BMI	w	w	w	w	w	w

w: Reference category (normal categories). BMI: Body mass index, SBP: Systolic blood pressure, DBP: Diastolic blood pressure

general, muscular mass decreases with age, and even in older people who maintain a steady weight, muscle gradually gives way to fat.[34] Muscular strength declines as fatty infiltration of the muscle tissue increases.[33] The typical trend of weight fluctuation over the course of a lifetime is an increase in weight up until the age of 60 or so, followed by a decline.[35] Increases in both fat and muscle mass are associated with weight growth from early adulthood to midlife.[36,37] This finding is consistent with those of Kyle *et al.*,[38] and Schall[18] which found no significant positive relationships between BMI and either SBP or DBP or with age. However, it runs counter to earlier research findings that age, BP, and BMI are strongly correlated in Asian populations.[39,40]

In the black non-Hispanic population, age had a somewhat negative connection with both SBP and DBP and BMI. This demonstrates a reduction in BP and BMI with aging. This observation might be explained by the fact that the study population included people who were being treated for diseases including hypertension and other ailments.

Age had a strong positive correlation with weight and a modest negative correlation with height among Asians. Age and BMI and SBP showed a sluggishly positive connection. Age revealed a marginally negative connection with DBP. SBP and DBP both rose from the youngest to the middle-aged age group and then fell in the oldest age group, demonstrating that BP is not dependent on age. The limited association between age and BMI in this study may be due to the weak link between age and height. Age and high BP are related, according to earlier studies.[41,42] BMI with SBP and DBP had inverse and inverse correlations, respectively. Both DBP and SBP displayed a slender positive connection with BMI. This pattern is in line with a prior study's result[7,43] that non-Hispanic blacks had a positive connection between BMI and both SBP and DBP. Age had a negligible negative link with DBP and a substantial positive correlation with BMI and SBP among non-Hispanic white populations. This demonstrates that whereas BMI and SBP are expected to rise with age, DBP is likely to fall with advancing years. Although not significant, BMI and DBP showed a favorable correlation. This demonstrates that BMI tends to rise with BP. This trend is in line with the findings of Kan *et al.*,[44] who found a link between BMI and BP among non-Hispanic blacks and whites. A strong positive association between BMI and BP was discovered in a study done among Delhi-based Punjabi girls.[45] Similar results in other Indian populations have also been found.[46,47] BP and BMI are more strongly correlated than race, according to research by Kumanyika *et al.*,[48] and this relationship holds true throughout surveys conducted in the United States and among different racial and sex groups. The BMI is one of the most significant predictors of BP, among many other pertinent factors, according to a number of researchers. Although it has long been known that genetics and ethnicity have an impact on the distribution of BP levels within a population, these factors appear to have less of an impact on the variation in BP levels between populations.[49] BMI, however, was not demonstrated to be a reliable predictor of BP in the current investigation.

According to odds ratios, a high SBP and DBP are significantly predicted by BMI. All three stages of prehypertension, Stage I hypertension, and Stage II hypertension were more likely to occur in obese patients than in persons with normal BMI. Obesity was found to be a significant factor in hypertension in the current investigation.

CONCLUSION

The study found no evidence of an association between BMI and age, SBP, or DBP. In addition, rising age and BP are related. There was a positive and substantial link between BMI, age, SBP and DBP, weight, and height, despite the size of the correlation varying within each population. In comparing various ethnic groups, the study findings suggest that age has different associations with BP, BMI, and other factors. In the black non-Hispanic population, age showed a negative connection with BP and BMI. Among Asians, age had a positive correlation with weight and a negative correlation with height. BP increased from the youngest to the middle-aged group and then decreased in the oldest group, indicating it is not solely dependent on age. BMI showed positive associations with BP across different ethnic groups. Obesity was found to be a significant factor in hypertension. Subjects with greater BMI had higher mean SBP and DBP readings. Obese demographic groups have an increased chance of developing hypertension. Pre-hypertensive and hypertensive individuals were present in significant numbers, particularly in Stage I.

Ethical Consideration

Not applicable.

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Authors contributions

This study was conceived and designed by OAA and LOO. LOO and OAA led the data retrieval. Data processing and analysis were led by OAA and LOO. The manuscript was prepared and reviewed by SBO, IBO, YBM, and OOA. All authors contributed to the editing and final approval of the manuscript for submission.

Declaration of patient consent

Patients' consent not required as patients identity is not disclosed or compromised.

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Conflict of interests

There are no conflicts of interest.

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