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Arterial Blood Flow and its Association with BMI in Hypertensive Adult Male Subjects under Resting State

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AAA and OMO carried out the bench work and statistical analysis. Author REU managed the literature searches. Author IOI wrote the first draft of the manuscript and author CPA designed and supervised the study. All authors read and approved the final manuscript.

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ABSTRACT

The goal of this study was to determine the association between arterial blood flow in normal and high BMI of hypertensive adult male subjects under resting state. To achieve this, 400 humans were ethically recruited from Irrua Specialist Teaching hospital, Irrua, Edo State of Nigeria.

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Subjects were sorted by age and grouped based on values from blood pressure readings as; 120 normotensive normal BMI (120-NNBMI), 120 normotensive high BMI (120-NHBMI), 80 hypertensive normal BMI (80-HNBMI), and 80 hypertensive high BMI (80-HHBMI). For the arterial blood flow at day time before noon of non-fasting subjects, left brachial arteries were measured in cm/s. At interval of five minutes, procedure was repeated three times with average taken. Subjects were then grouped as normotensive or hypertensive based on the average systolic and diastolic blood pressure values (120/80 mmHg or 140/90 mmHg, respectively). Body mass index was determined by weight-to-height ratio (kg/m^2). Mean values of weight, height, BMI, blood pressure (BP) and arterial blood flow were determined and expressed as mean ± standard error of mean (SEM). Obtained data was then analysed using ANOVA. P values less than 0.05 was the basis for significance. Pearson Product Moment Correlation Coefficient was used for statistical measurements of association. In the end, there was a significant negative correlation between arterial blood flow and BMI in hypertensive subjects. Whereas, normotensive subjects show insignificant correlation.

Keywords: Normotensives; hypertensives; blood pressure; body mass index; arterial blood flow.

1. INTRODUCTION

The coexistence of hypertension and high BMI has been on the rise especially in the rural and urban settlements of world's emerging economies. The majority of patients with high blood pressure have high BMI [1]. High BMI produces an increment in total blood volume and cardiac output that is caused in part by the increased metabolic demand induced by excess body weight [2-4]. High BMI is reported to be strongly associated with higher-than-optimal blood pressure [4]. This results in increased blood pressure which are related to changes in cardiac output and peripheral vascular resistance, because BP=CO×SVR, where BP is blood pressure, CO is cardiac output, and SVR is systemic vascular resistance. According to WHO, (2008), mechanisms linking high BMI and hypertension includes an increase in peripheral vascular resistance: endothelial dysfunction, insulin resistance, sympathetic nervous system, substances released from adipocytes and sleep apnea are factors that puts direct effects of high BMI on cardiovascular hemodynamics [5,6]. Thus, at any given level of activity the cardiac workload is greater for high BMI subjects [7-9].

A high BMI subjects have higher cardiac output and a lower total peripheral resistance than do lean individuals. The increased cardiac output is attributable mostly to increased stroke volume because heart rate increases little if at all[10]. More so, increased blood flow rates in skeletal muscle are well established in hyperthyroidism [11,12]. The effects of blood flow on muscle glucose uptake has also been examined in a recent study using the arteriovenous difference technique across the forearm muscles after the consumption of a mixed meal [13]. In their study, muscle blood flow (measured with strain-gauge plethysmography) was found to be increased. In agreement with the *in vitro* [14] and *in vivo* studies [15], in the postprandial period (*i.e*., in the presence of physiological levels of insulin), net glucose uptake by skeletal muscle (which depends on blood flow) was normal. In contrast, fractional glucose extraction (which is independent of blood flow) was actually decreased [13] which suggests that in hyperthyroidism or high BMI, in addition to the liver, skeletal muscle is also resistant to insulin that may result in decreased arterial blood flow.

High BMI is involved with endothelial function abnormalities [16]. Usually a reduced function of the endothelium results in decrease in nitric oxide. Reduced nitric oxide in obesity may be associated to a rise in systemic by-product of normal metabolism of oxygen [16]. Dwindling activity of nitric oxide would lead to vasoconstriction and promote vascular resistance which will ultimately prompt cardiovascular disease risk feature like hypertension. Such increase in peripheral vascular resistance will eventually result in diminished arterial blood flow. Documented evidence also show that high BMI or obesity partakes in diastolic dysfunction, reduced maximal myocardial blood flow, weakened myocardial metabolism and increased danger of heart physiological health [17,18]. Among men, the prevalence of high blood pressure increased progressively with increasing BMI, from 15% at a BMI of <25 kg/m^2 to 42% at a BMI of ≥30 kg/m^2 [19]. Positive association of BMI and blood pressure has also been reported among Asian populations. India in a process of rapid economic development and modernization with changing life style factors has an increasing trend of hypertension especially among urban population [20].

These cardiovascular disorders are supposedly attributed to sedentary life style occasioned by improved socio-economic status of individuals. This therefore suggests the need for scientific data in relationship to objectively guide clinicians and other extension health workers in terms of management of their patients. It follows therefore that the association between arterial blood flow in normal and high BMI of hypertensive subjects in man under resting state is yet to be clearly understood.

1.1 Aim of Study

This study aimed at finding the association between arterial blood flow and BMI in hypertensive adult male subjects under resting state.

2. METHODOLOGY

2.1 Resources and Sources

2.1.1 Ethical permission

Ethical Permission for the study was sourced from the Ethical Committee of the Irrua Specialist Teaching Hospital, Irrua, informed consent from the subjects of study was obtained as well.

2.1.2 Humans

Using the random sampling technique, a total of four hundred (400) male subjects between ages 20 and 68years were ethically recruited from Irrua Specialist Teaching hospital, Irrua, in Esan Central and Cinos fitness center in Esan West Local Government Areas of Edo State. The reason for choosing male subjects was because, hypertension has been reported to be more prevalent amongst men than women in a cross sectional study carried in the middle belt of Nigeria [21].

2.1.3 Sample size determination

In sample size determination, Slovin's formula was used to find the sample size, which is written as: $n = N / (1 + Ne^2)$ where n = Number of samples, N = Total population i.e. National population census of Esan West and Esan Central Local Government Area of Edo State, Nigeria, 2006 is 230,000 NPC, (2006) and e = Error tolerance (0.05). That is $n=230000/1+230000(0.05)^2 = 399.3$ to the nearest whole number or more is equal to 400 subjects. It has an area of 502 km² and a population of 125,842 at the 2006 census.

2.1.4 The sample size

The sample size for the study was 400 male subjects which comprised of 120 normotensive groups with normal BMI; 120, normotensives with high BMI; 80, hypertensives with normal BMI; and 80, hypertensives with high BMI groups. All 400 male participants were then categorised into 160 hypertensive and 240 normotensives as found. These were further subdivided into three age categories as: 20-30 years age group, 31-40 years age bracket and 41-68 years age group for normotensive and hypertensive groups respectively.

2.1.5 Blood flow measurement

For the blood flow measurement at day time before noon, left brachial arteries of a non-fasting subject was measured with a bidirectional Doppler ultrasonography (Doppler-SmartDop30EX) at interval of five minutes and repeated three times in a sitting position at room temperature of 25℃ and averaged.

2.1.6 Selection criteria

Those who were considered suitable based on inclusion and exclusion criteria described below were selected with their consents.

2.1.7 Inclusion criteria

- Age = 20-50+years
- Gender = Male
- Drugs (i.e., those that are not on vasodilators or any adrenergic stimulants)

2.1.8 Exclusion criteria

Those who had disease such as: Diabetes Mellitus (DM), Peripheral vascular disease (PVD), Hyperlipidemia, or on vasodilators or any adrenergic stimulants, were not allowed for the study.

Table 1. Normotensive and hypertensive male subjects

S/no	Groups	Age category	Normotensives	Hypertensives
1	Normotensive Normal BMI (NNBMI)	20-30YRS	40	
2	Normotensive Normal BMI (NNBMI)	31-40 YRS	40	
3	Normotensive Normal BMI (NNBMI)	41-68 YRS	40	
4	Normotensive High BMI (NHBMI)	20-30YRS	40	
5	Normotensive High BMI (NHBMI)	31-40 YRS	40	
6	Normotensive High BMI (NHBMI)	41-68 YRS	40	
7	Hypertensive Normal BMI (HNBMI)	31-40 YRS		40
8	Hypertensive Normal BMI (HNBMI)	41-68 YRS		40
9	Hypertensive High BMI (HHBMI)	31-40 YRS		40
10	Hypertensive High BMI (HHBMI)	41-68 YRS		40
Sub-total	(Hypertensives)			160
Sub-total	(Normotensives)		240	
Total	(Volunteers)			

International Classification of adult BMI as Normal or High
BMI →Kg/m2: Normal Range; 18.50 - 24.99; Overweight ≥ 25.00- 29.99; Obese ≥ 30.00
Sources: adapted from WHO, 2004.

2.1.9 Procedure

The procedure was as follows:

i. History, Clinical examination and laboratory investigation were carried out to ascertain the health status of the subjects.
ii. Cardiovascular measurements such as systolic and diastolic blood pressure at rest were ascertained.
iii. Blood flow measurements in three successive readings at rest were repeated with mean values recorded after five minutes.
iv. Doppler Instrument (Smart Dop30 EX) was used for the blood flow measurements.

2.1.10 Measurement of blood pressure

The subjects were grouped as normotensives or hypertensives if the average systolic blood pressure and diastolic blood pressure values were 120/80 mm Hg or 140 / 90 mm Hg, respectively. The blood pressure reading day time before noon of the individual was established by having three successive blood pressure measurements after a 5 minute rest in a sitting position at room temperature of 25℃.

2.1.11 Competency in measuring BP

i. For accurate measurements of blood pressure, qualified nurse or medical doctor were used. Precautionary measures were taken in order to achieve acceptable records [22,23] as follows:
ii. The bladder encircled and covers two-third of the extent of the upper arm.
iii. The individual was seated on a chair and both feet were placed on flat floor for a period of five minutes preceding the reading.
iv. The individual was not on any adrenergic stimulants.
v. By means of a stethoscope, deflation was made at a pace of 2 to 3 mmHg per second. Systolic pressure reading was taken.
vi. Diastolic pressure was recorded as the sound disappears or abruptly muffled.
vii. Three measurements were taken at 5 minutes apart and the readings were averaged.

2.1.12 Measuring the BMI

For the assessment of BMI at day time before noon of a non- fasting subject, height, and weight measurements were taken using standard protocols given by Weiner and Lourie (1981). Body weight was measured (to the nearest 0.5 kg) with the subject standing motionless on the bathroom weighing scale in light clothing and without shoes. Each weighing scale was standardized every day with a weight of 50 kg. Height was measured (to the nearest 0.5 cm) with the subject standing in an erect position against a vertical scale of portable stadiometer and with the head positioned so that the top of the external auditory meatus was in level with the inferior margin of the bony orbit. BMI was calculated as weight in kilograms divided by squared height in meter. Conventional BMI cut-off points were applied to classify the study populations into underweight (BMI<18.5 kg/m^2), normal BMI (18.5≥BMI<25 kg/m^2) and overweight (BMI≥25 kg/m^2).

2.2 Statistical Analysis

Values were expressed as mean ± standard error of the mean (SEM). The data was analysed using Students T-test. P values less than 0.05 was the basis for significance. Pearson Product Moment Correlation Coefficient was used for statistical measurements of association. SPSS (version 17) software was used in the evaluation of collected data for statistical significance.

3. RESULTS

While there was no significant difference between the mean arterial blood flow of the two categories of subjects, mean arterial blood flow of group with normal BMI was 23.60 ±0.45 cm/s, which for subjects with high BMI was 23.39 ± 0.47 cm/s.

As shown in Figure. 2, mean arterial blood flow of hypertensives with normal BMI was significantly ($p<0.05$) greater than those of hypertensives with high BMI. While mean arterial blood flow of group with normal BMI was 25.64± 0.46 cm/s, that for group with high BMI was 23.16 ± 0.50 cm/s.

Figure 3 shows that mean arterial blood flow between group with normal and high BMI had no significant difference, irrespective of age bracket. Besides, the mean arterial blood flow of the subjects within 41-68 years of age (irrespective of BMI status) were significantly ($p<0.05$) and respectively greater than the mean arterial blood flow of subjects with normal or high BMI within each of the 20-30 years and 31-40 years age brackets.

Figure 4 shows a mean arterial blood flow of resting hypertensive subjects within 31-40 years age bracket with normal BMI significantly ($p<0.05$) less compared to the mean arterial blood flow of other group of subjects. The arterial blood flow of subjects with normal and high BMI within 41-68 years age group were not significantly different, and they were similar to the mean value of subjects with normal BMI within 31-40 years age group.

Table 2 shows the mean BMI and arterial blood flow of different sub-groups in resting normotensives and hypertensives with normal and high BMI, based on age groups at rest. Except for the pairs of normotensives with normal BMI (NNBMI 20-30 yrs) all other sub-group pairs of BMI and arterial blood flow, show significant ($p < 0.05$) difference, whereas all sub-groups were insignificantly correlated.

3.1 Correlation between Arterial Blood Flow and BMI

The results of the investigation on the relationship between Arterial Blood Flow and BMI are presented in Table 3.

There was a significant negative correlation between arterial blood flow and BMI in hypertension under resting state. While the correlation coefficient of arterial blood flow and BMI of normotensives was 0.048, that for hypertensives was -0.19.

As shown, mean arterial blood flow of resting hypertensive subjects within 31-68 age group compared with their BMI was significantly ($p<0.05$) less, when compared with the mean arterial blood flow and BMI of 20—68 years age groups of normotensive subjects. For the hypertensive group, the study could not be extended to subjects below 20-30 years age group during data collection because hypertensives were not found.

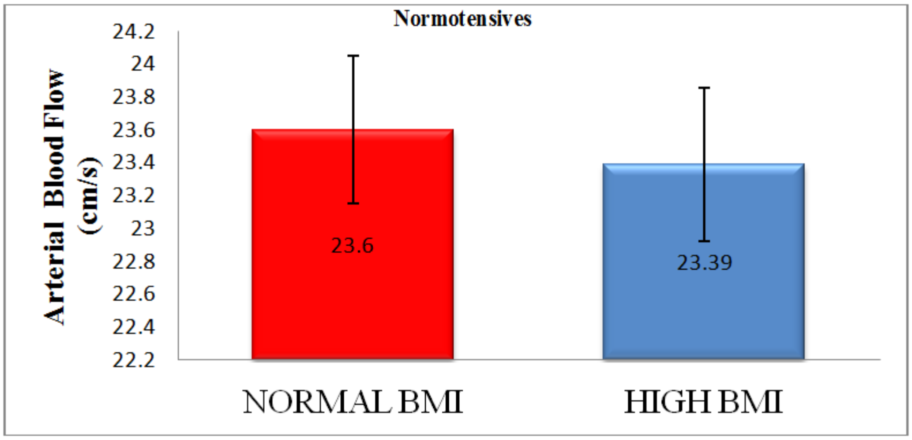

Figure 1. Comparison of arterial blood flow in normotensive subjects at rest

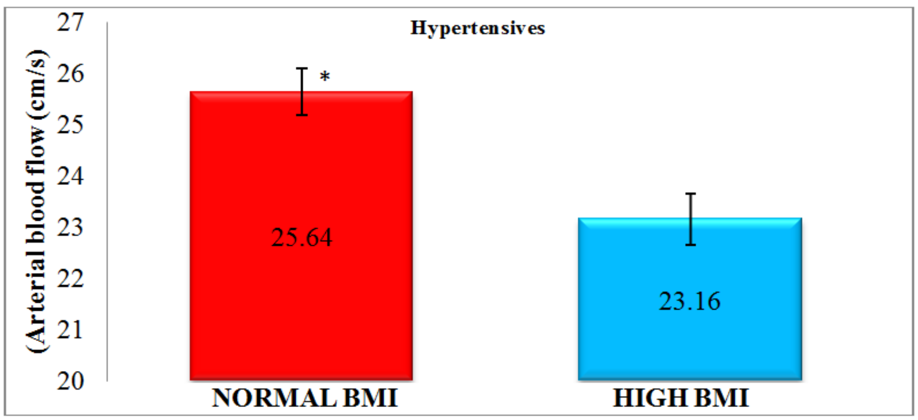

Figure 2. Comparison of arterial blood flow in hypertensive groups at rest
**p<0.05, compared with value for hypertensives with high BMI, n=80*

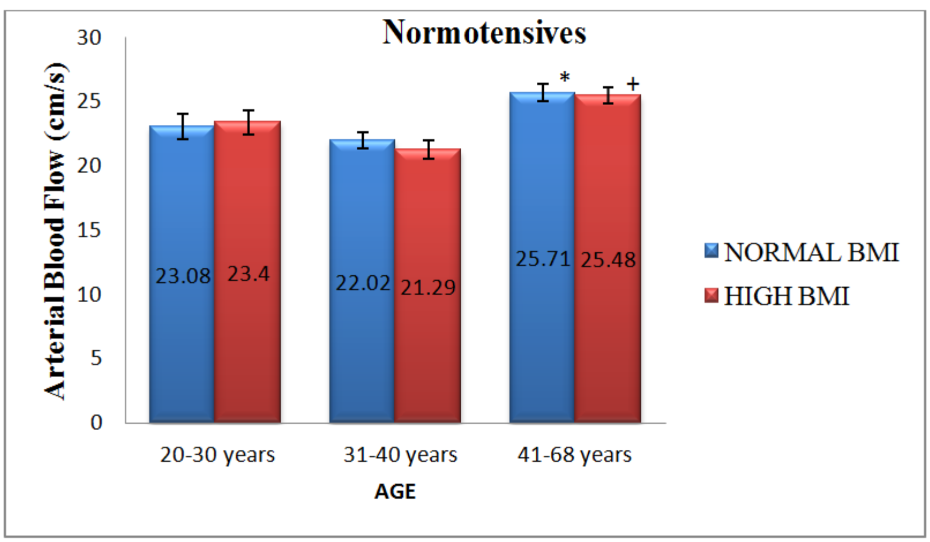

Figure 3. Mean arterial blood flow in normotensives based on age at rest
** P< 0.05, compared with 20-30 years and 31-40 years values. n=40*

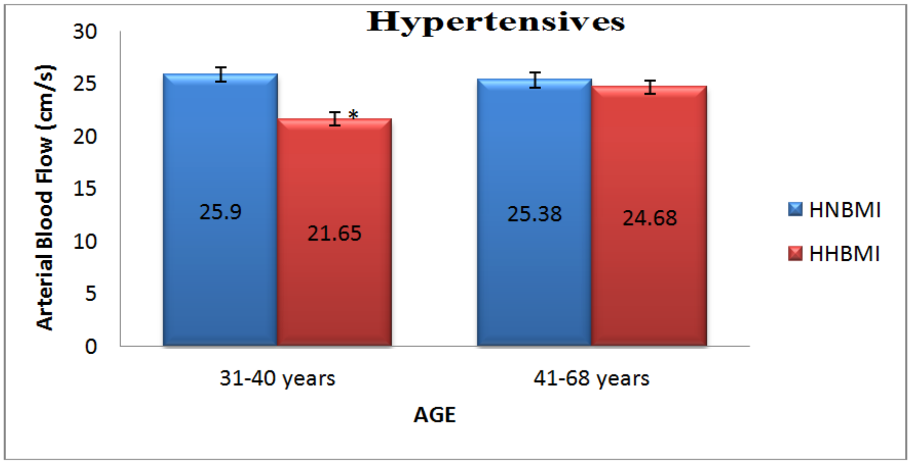

Figure 4. Mean arterial blood flow in resting hypertensives with normal and high BMI, based on age at rest

** P< 0.05, compared with other values. n=40*

Table 2. Sub-groups pairs of BMI and arterial blood flow under resting state

Group pairs	Parameters	N	Mean & STD error	T-test P-value		Correlation coeficient	Correlation P-value
PAIR 1	BMI	40	21.90± 0.34	0.185	Not	0.388	0.013
NNBMI 20-30YRS	ABF	40	23.08± 0.95		sig		
PAIR 2	BMI	40	28.50± 0.43	0.000	*	-0.090	0.582
NHBMI 20-30YRS	ABF	40	23.40± 0.95				
PAIR 3	BMI	40	22.07± 0.31	0.000	*	0.112	0.490
NN BMI 31-40 YRS	ABF	40	22.02± 0.61				
PAIR 4	BMI	40	29.78± 0.39	0.000	*	-0.158	0.332
NH BMI 31-40 YRS	ABF	40	21.29 ± 0.69				
PAIR 5	BMI	40	22.33± 0.26	0.000	*	0.140	0.390
HN BMI 31-40 YRS	ABF	40	25.90± 0.66				
PAIR 6	BMI	40	30.76± 0.33	0.000	*	-0.233	0.147
HH BMI 31-40 YRS	ABF	40	21.65± 0.72				
PAIR 7	BMI	40	22.16± 0.32	0.000	*	0.109	0.508
NN BMI 41-68 YRS	ABF	40	25.77± 0.65				
PAIR 8	BMI	40	31.44± 0.66	0.000	*	0.126	0.439
NHBM1 41-68 YRS	ABF	40	25.48± 0.65				
PAIR 9	BMI	40	22.50± 0.29	0.000	*	0.200	0.216
HNBMI 41-68 YRS	ABF	40	25.38± 0.65				
PAIR 10	BMI	40	32.36± 0.68	0.000	*	0.111	0.495
HHBMI 41-68 YRS	ABF	40	24.67± 0.60				
Total sample size	=	400					

Table 2 shows the statistical powers of the sub-groups
** P< 0.05, BMI compared with ABF values. n=40*

Table 3. The Correlation between arterial blood flow and BMI of normotensive and hypertensive subjects under resting state

Subjects	BMI level	Arterial blood fow level	Correlation coeficient	P-value	Remark
Normotensive at rest	25.98±0.31	23.50±0.32 n=240	0.048	0.462	Not significant
Hypertensive at rest	26.99±0.42	24.40±0.35 n=160	-0.19	0.015	Significant

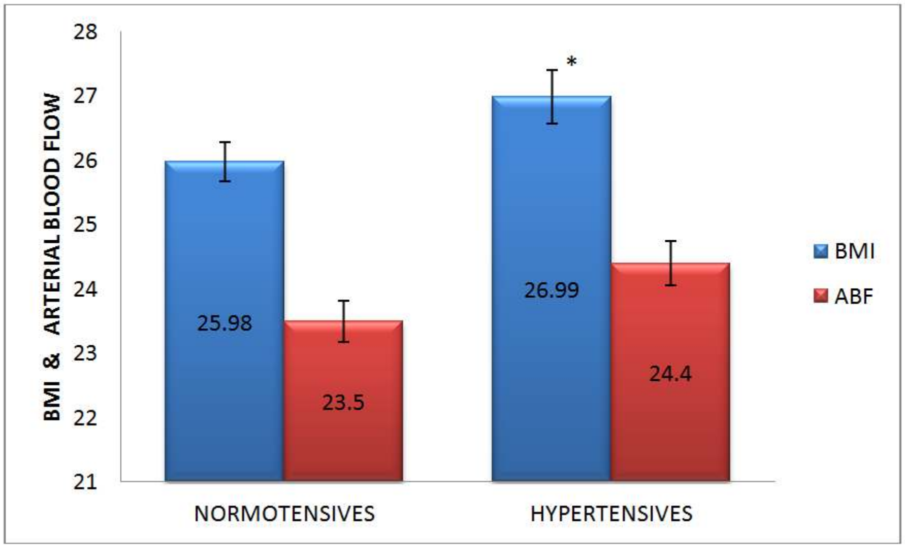

Figure 5. Mean BMI and arterial blood flow of hypertensives at rest
** P< 0.05, compared with BMI values. n=160,*
+ P> 0.05, compared with BMI values. n=240

4. DISCUSSION

From Figure 1, study reveals that the arterial blood flow of normotensive subjects was insignificantly altered by their BMI status, though reduced in the case of high BMI subjects. While the mean arterial blood flow of subjects with normal BMI was 23.60 ± 0.45 cm/s, that for subjects with high BMI was 23.39 ± 0.47 cm/s. This observation may agree with previous report that shows a reduction in arterial blood flow in high BMI subjects. In line with above argument, is the report that high BMI is associated with a reduction in cerebral blood flow velocity and increases cardiovascular resistance [24].

It was also found that a minimal reduction in arterial blood flow exists in high BMI normotensive subjects (Figure. 1). Figure 2 also reveals that the arterial blood flow in hypertensive subjects with high BMI was significantly (p < .05) reduced compared to the situation in subjects with normal BMI. Also, while the mean arterial blood flow of subjects with normal BMI was 25.64± 0.46 cm/s, that for subjects with high BMI was 23.16 ± 0.50 cm/s. Also, a minimal and significant reduction in arterial blood flow for high BMI normotensive and hypertensive subjects was respectively observed in this study, suggesting the involvement of some factors capable of increasing vascular resistance in subjects with high BMI. Noted with these observations are previously documented evidence that high BMI is associated with abnormal endothelial function [16], metabolic dysregulation associated with dyslipidaemia, inflammation [25], insulin resistance, sympathetic nervous system, substances released from adipocytes and sleep apnoea; are factors that put direct effects of high BMI on cardiovascular hemodynamic; resulting in vasoconstriction, and increased peripheral vascular resistance. Such increase in peripheral vascular resistance will eventually diminish arterial blood flow.

When the age of the normotensive subjects was considered, it was found that, irrespective of age of subjects, arterial blood flow was still not significantly altered by their BMI status. When hypertensive subjects were used, the arterial blood flow of high BMI subjects was reduced; though this reduction was significant (p < .05) only in high BMI subjects within the age brackets of 31 – 40 years. This arrays with what was observed by Magdy et al. [26]. The effect of high BMI on arterial blood flow was not exactly the same in normotensive and hypertensive subjects as this effect was age dependent. The study could not be extended to subjects below 31 years of age because hypertensive subjects within such age group could not be found.

With respect to normotensive subjects, it was observed that irrespective of their BMI status, arterial blood flow was higher in ages within 41 – 68 years compared with subjects in the lower age brackets. Subjects within 41-68 years had much greater muscle mass compared to subjects in the lower age brackets (20-30 years and 31-40 years). Greater muscle mass will normally have greater need for blood flow (Van Guilder et al., 2006; Pierce et al. 2008 and Sturm et al. 2009). The greater arterial blood flow observed in this study in subjects with normal and high BMI within 41-68 years age bracket may be explained by this fact. It is unlikely that the high arterial blood flow will be sustained at much older age; especially in the high BMI subjects. This opinion is because of the realization of the impact of arteriosclerosis on peripheral vascular resistance as one ages, and the impact is more in high BMI subjects.

As shown in Fig. 5, the mean arterial blood flow of resting hypertensive subjects (n=160) within 31-68 years age group was significantly ($p<0.05$) less, compared with their BMI. Whereas, mean arterial blood flow of normotensive subjects between 20—68 years (n=240) was insignificantly altered with BMI. For the hypertensive group, the study could not be extended to subjects between 20-30years because hypertensives were not found.

The result of this present study (Table 3), found a significant negative correlation between arterial blood flow and BMI in hypertensives under resting state, though the correlation coefficient was weak ($r = -0.19$). This is reflective of the fact that in humans, BMI may be producing its effect, at least partly by affecting the integrity of blood vessels. In contrast, fractional glucose extraction (which is independent of blood flow) was actually decreased which suggests that in hyperthyroidism or high BMI, in addition to the liver, skeletal muscle is also resistant to insulin that may result in decreased arterial blood flow as was observed in this study. The impaired endothelium-dependent vasodilation found in excess body weight has been implicated in the decrease in cerebral arterial blood flow [26]. This is comparable to the observation in this present study, that the mean arterial blood flow in hypertensives with high BMI was significantly ($p<0.05$) lower compared to that of normal BMI (Fig. 2).

5. CONCLUSION

Within the ambient of vulnerability to possible errors, this study has found, using 240 and 160 normotensives and hypertensives respectively, that there was a significant but weak ($r = -0.19$) negative correlation between arterial blood flow and BMI in hypertensive subjects compared to insignificant correlation for normotensives.

6. SOCIETAL BENEFIT OF STUDY

This study will be of relevance to clinicians, physiotherapists and other related health practitioners as its findings will help guide in the management of patients with hypertension cases complicated with high BMI. The study will invariably be beneficial to both research participants and communities as its findings will guide researchers in narrowing their efforts towards obtaining specific solutions on hypertensive cases of vascular disease origin complicated with high BMI.

CONSENT

As per international standard or university standard, patient's written consent has been collected and preserved by the authors.

ETHICAL APPROVAL

As per international standard or university standard, written approval of Ethics committee has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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