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Increased Cardiovascular Disease and Premature Deaths: A Study on how does the Age, BMI, Body Fat Percentage, Blood Pressure, Arterial Elasticity Measured through Futrex NIR Affect the Progression of Atherosclerosis

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ABSTRACT

Contemporary society is up to date in almost all fields of life. Though they are strong in their abilities, they are fragile in maintaining a healthy lifestyle. In most premature death cases, cardiovascular disease (CVD) is the hidden reason. Globally, CVDs are taking an estimated 17.9 million lives each year. CVDs are a group of disorders associated with the heart and blood vessels. They include coronary heart disease, cerebrovascular disease, rheumatic heart disease, and other conditions. In the modern world, a person's physical condition can be calculated separately by different parameters like heart rate variability (HRV), autonomous nervous system, or other appropriate parameters. Let us go deeper into the physiological level. The blood circulatory system (BCS) plays a vital role in an individual's cardiovascular health. A medical practitioner can assess an individual's healthy BCS by using non-invasive measurement of pulse waveform and heart rate by photoplethysmography (PPG) and accelerated plethysmography (APG). The pulse wave is a snapshot of the cardiovascular system. It evaluates arterial elasticity (stiffness) related to the wave types (referred to in this paper as vessel type-VT) generated by the APG. Their interpretations can be classified into seven types. VT1 refers to good circulation, and VT7 refers to distinctively bad circulation. The purpose of the present study is to compare the progression of atherosclerosis with body mass index (BMI), body fat percentage (BFP), Blood Pressure (BP), Arterial Elasticity Score (AES) and determine the relationship between them and atherosclerosis through the progression of VT. The current statistical study analyses the VT conditions of the UAE male candidates having the age ranging from 18 to 70, based on the BMI, BFP, BP, AES. The study utilized Futrex NIR technology for fetching information regarding BMI, BFP, and BP and an FDA-approved device that uses PPG & APG technology to fetch blood circulation details and AES. However, the ANOVA and regression analysis show BMI, BFP, BP, and AES have a strong relationship with VT, which relates to atherosclerosis.

Since BMI, BFP, BP, and AES directly correlate with a person's lifestyle. The current study will give great insight into the importance of body composition analysis and leading a healthy lifestyle to retain the beneficial vessel type.

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PURPOSE

Atherosclerosis is considered one of the diagnostic criteria for cardiovascular disease. This study was conducted to see if it is possible to know the status of such significant Atherosclerosis using non-invasive technology parameters like body mass index, body fat percentage, blood pressure, arterial elasticity score.

MATERIALS AND METHOD

The data taken for the study were taken from 2016 October to 2020 March by a device using a non-invasive technology called Futrex. We found the relationship between the parameters and vessel type using regression analysis. The Correlation coefficient between the parameter classification and vessel type classification was found by correlogram. To find the p-value for each parameter and vessel type, we used a one-way ANOVA test. PSPPIRE software is used for the statistical analysis.

RESULT

Totally 1070 data points were used for this study. We considered only UAE male candidates having the age from 18 to 70. The r-square value in the regression analysis came to 68%. Moreover, in the ANOVA test, we found that the significant value is less than 0.05 for BMI, BFP, BP, AES. The correlogram diagram also shows a significant relationship between the above-said body parameters and vessel type classification.

CONCLUSION

Body mass index, body fat percentage, blood pressure, and arterial elasticity score are valid parameters for predicting Atherosclerosis from the non-invasive technology parameter vessel type.

KEYWORDS

Vessel type; Near-infrared technology; Futrex NIR; Body fat; Body mass index; Blood circulatory system; Cardiovascular disease; Photoplethysmography; Accelerated photoplethysmography

INTRODUCTION

According to WHO, CVD is a leading cause of global mortality, estimating almost 17 million deaths annually [1-6]. If CVD accounts for 37.7% of all deaths [7], nearly 10% are likely to be premature. The accelerated rate of CVD worldwide is an alarming situation for the entire human community. Cardiovascular problems will begin when the blood circulatory system blocks blood from moving through the cardiovascular system. One of the parameters, called vessel type, is an excellent means to establish the blood circulation system's health. Vessel type mainly depends on blood pressure (BP) and blood flow [8].

The risk of increasing CVD can be analyzed by monitoring BP and blood flow velocity (BFV) [9,10]. Moreover, suppose the blood circulatory system is not performing well. In that case, the oxygen delivery process is altered, which disturbs other organs' functions.

The shape of the APG waveform or the VT has been categorized into seven types, as shown in Table 1 [3]. The indices calculated from the APG waveforms are reported to correlate closely with the distensibility of the carotid artery [11], age [12], the blood pressure [13], the estimated risk of coronary heart disease [14], and the presence of atherosclerotic disorders [15,16].

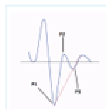
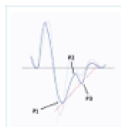
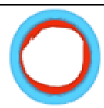
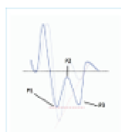
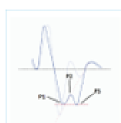
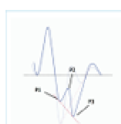
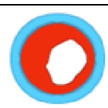
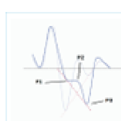
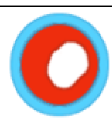
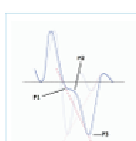
Grade	Progression of Arteriosclerosis	Wave Pattern	Symptom
Vessel Type 1			The wave type usually appears in both young, healthy individuals and those having good blood circulation. Even in middle age, this normal wave may appear in those who perform routine aerobic exercise.
Vessel Type 2			This wave usually appears in a person having less than ideal blood circulation but still in good condition. This wave's unique feature is that P2 is below the baseline but above P1, and P3 is also above P1. As P2, P3 are getting down, and blood circulation is moving toward the weak range.
Vessel Type 3			This wave indicates that blood circulation is in a relatively lousy range. A marked characteristic is that P3 is descending into the same level as P1 compared to waveform 2. **Symptoms:** Hands and feet are getting chilled or cold. A person showing this wave type needs to start modifying their lifestyle.
Vessel Type 4			This wave indicates that blood circulation is again reducing at a faster pace. A marked characteristic is that P2 is at the same level as P1, P3, in contrast to waveform 3. P1, P2, and P3 are becoming indistinguishable. **Symptoms:** Lower leg edema, hands & feet (finger & toes) are getting chilled/cold, feeling heavy in the head, or wearing a tight hat.
Vessel Type 5			This kind of wave appears in those individuals having lousy blood circulation. A unique feature is that P3 is below P1, and if the gap is widening, it represents that blood circulation is becoming even worse. **Symptoms:** Mild pitting ankle edema, abrupt general weakness and pain, skin colour abnormality, and thermo (heat/cold) anaesthesia.
Vessel Type 6			This wave indicates that blood circulation is in the terrible range. A marked characteristic is that P1 and P2 are almost at the same level, and P3 is below P1, P2. **Symptoms:** Hands and feet could be blue from complications due to lack of circulation.
Vessel Type 7			This wave indicates that blood circulation is in the worst possible state. In this case, ECG often detects the abnormalities. **Symptoms:** This individual is liable to infection, even following a slight injury (or trauma), risks of the stroke, or dementia due to cerebrovascular abnormalities. This condition may not improve even though medical treatment is being administered.

Table 1: Progression of arteriosclerosis.

In normal scenarios, when a patient visits a physician, he or she will check the patient's BP. However, his pulse wave type or VT will not be monitored in most cases as there are no commonly available devices to measure these values during normal triage operations. Blood circulation is measured and analyzed only for a tiny percentage of the patient population. Medical technology has developed non-invasive methods to measure VT's health. One such way is identification using PPG - Photoplethysmography & APG - Accelerated Photoplethysmography Technology.

In most cases, hypertension and VT have a connection to adiposity [17,18]. However, adiposity based on BMI calculation may give some false indications because BMI mainly depends on the height and weight parameters. According to the BMI scale, a person with higher muscle mass or bone mass or another person with higher fat mass or excess fat can come in the overweight or obese category. In the first case, the person remains normotensive [19] since the individual has higher fitness activities (increased muscle mass). In the latter case, the person may suffer hypertension or unhealthy BCS because of increased body fat [20,21].

The medical practitioners may instruct the patient to analyze the body system using body composition & blood circulation analysis to get information about the hearts' health, VT, body fat level, body water content, and other vital parameters. Since body fat depends on gender and age, it is good to advise every individual irrespective of gender and age, to do a body composition analysis twice or thrice a year. Several studies have shown that obesity due to higher body fat correlates with systemic arteriosclerosis in the general population [22].

Atherosclerosis

Atherosclerosis is the thickening or hardening of the arteries due to the deposition of plaque, a combination of deposits of fatty substances, cholesterol, and cellular waste products, calcium, and fibrin. Figure 1 shows the illustration of atherosclerosis [23].

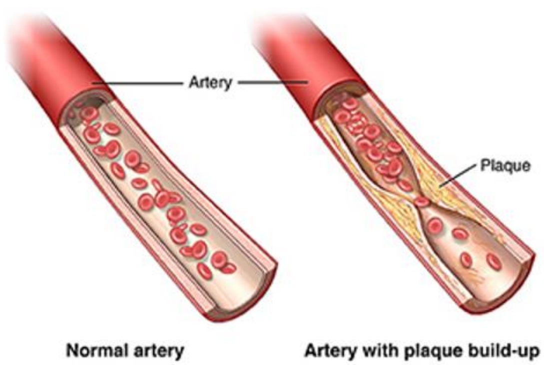


Figure 1: Illustration of atherosclerosis.

The above condition reduces blood flow and oxygen supply to the vital body organs and extremities. The study aims to reveal the impact of BMI, body fat, and age on BCS's healthiness using the VT parameter. The findings showed promising results for health assessment and early screening for cardio-related health problems.

Technology Explanation

PPG & APG (Photoplethysmography and Accelerated Photoplethysmography)

Approximately thirty years ago, Japanese researchers discovered a unique method of analyzing the pulse signal at the fingertip that provides a useful indicator of blood circulation quality. This research was summarized in several technical papers [24-27]. The technology is that blood circulation involves the heart pumping out blood, which flows through the arteries to the tissues and organs' capillaries and then returns to the veins.

The supply of oxygen and nutrients takes place at the capillaries. The quality of blood circulation is directly related to blood behavior in these smallest vessels. Therefore, changes over time and blood pressure in the capillaries serve as a good blood circulation measure. A slight difference in arterial and venial blood pressure gives rise to differences in the nutrients supplied and gas exchange at the capillary level. For this reason, medical researchers believe that organic physiological changes may occur in tissues and organs if the difference in arterial blood pressure increases over a more extended period.

One widely used method for observing the changes over time and the amount of blood contained in the capillaries is examining the fingertip pulse waveform - the gently undulating pulse waveform obtained at the fingertip, as shown in figure 2. Photoplethysmography is a waveform signal that indicates the chest wall's pulsation and great arteries followed by heartbeat.

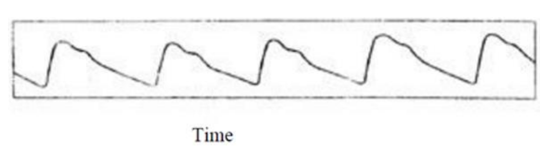


Figure 2: Pulse wave form.

Unfortunately, changes in blood circulation are small and are sensitive to changes in the organisms' environment. It is challenging to interpret tiny changes in these types of pulse waveforms. However, the researchers have shown that the pulse waveform mathematically enhanced, called acceleration pulse waveform, is given in figure 3 or acceleration plethysmogram, provides meaningful information on blood circulation status. APG test measures the blood circulation and aging stages of blood vessels concerning vascular elasticity and hardening through the fingertip signal. APG is also called the "final analysis" waveform. APG uses the second derivative of the digital photoplethysmography waveform to stabilize the baseline and separate components of the waveform more clearly and distinctly.

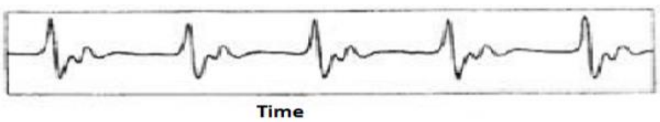


Figure 3: Acceleration pulse waveform.

Figure 3 is derived from the raw pulse waveform of figure 2 and provides easy to understand information. Figure 4 explains the various peaks and valleys of the acceleration pulse waveform. As shown in figure 4, the first four peaks and valleys - identified as a, b, c, and d - provide meaningful information on blood circulation quality. Such analyses can be performed at various body sites such as the fingertip, ear lobe, and others that have high capillary content. However, fingertip measurement is ideal because this is the site on the body where the capillaries are most developed. Also, the amount of blood contained in the capillaries is excellent.

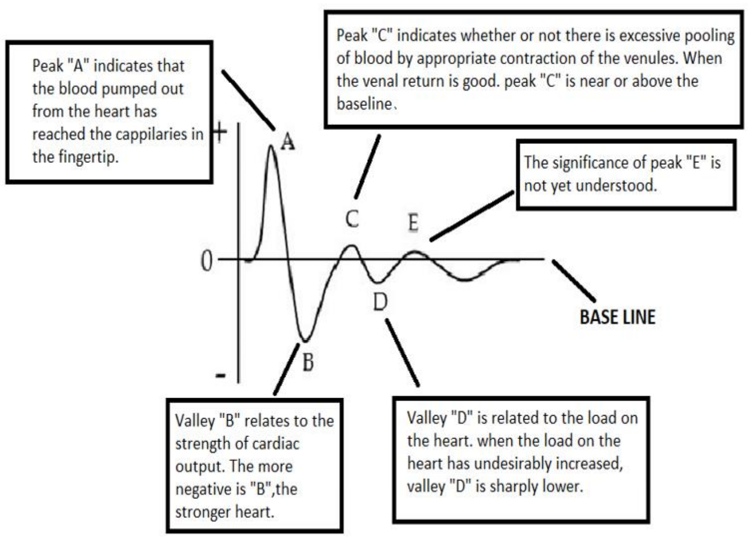


Figure 4: Significance of the peak and valleys of the acceleration pulse waveform.

NIR: Near Infra-Red

The near-infrared reactance method for measuring body fat is based on the principle of light absorption and reflection. More particularly, it is based on fat tissues' capacity to "retain" more infrared light than incline tissue, which can be measured as an alter within the infrared level.

As shown in figure 5, a monochromator or light wand sends a low-energy bar of near-infrared light having a wavelength of 900 nm into the biceps zone. The vitality is either reflected, retained, or transmitted, depending on the biceps' scrambling and assimilation properties. A locator inside the wand measures the re-emitted light and is given to a mathematical fitting equation to compute the BFP [28].

Figure 5: Light wand using NIR technology.

METHODS

Data Collection

The data set for the study was obtained from a health monitoring system called K-350 series kiosk, and it uses Futrex NIR sensor, which uses NIR technology for calculating vital parameters of the body like BP and body fat percentage. The data was collected across male individuals residing from various nationalities residing in UAE from October 2016 to March 2020. We used an FDA-approved blood circulation analyzer that uses PPG and APG technology for vessel type and AES measurement. A total of 1070 candidates having the age ranging from 18 years to 70 years of age were screened for obtaining the data. Female candidates have not been considered in the study since body fat analysis are gender specific. Before the screening, the following conditions were adhered to get accurate measurements.

- The candidate was allowed to relax 10 minutes to 15 minutes before the measurement.
- They were advised not to smoke, exercise, take medicines, or drink beverages 45 minutes before the screening.
- All personal belongings (watch, mobile, etc) were moved out from the kiosk to avoid electronic interference.
- The left index finger was cleaned with an alcohol swab to remove oil stains and dirt just before the screening to ensure PPG measurement accuracy.
- The kiosk operator ensured that the candidate's left upper arm was free of a tattoo to get accurate body fat.
- The candidates were advised not to move or talk during the screening.
- The operator ensured the left arm of the candidate was comfortably resting on the armrest.

Analysis

For the vessel type analysis, the mean and standard deviations of the data set were considered against age, BMI, body fat percentage, BP, and AES. One-way ANOVA test and Regression analysis were also plotted using the PSPPIRE software to find the influence of age, BMI, body fat percentage, blood pressure, arterial elasticity score on seven vessel types. The device was able to tell the subject's vessel type under test based on the PPG analysis, and it is found that the candidate will fall in one of the seven vessel types.

3. RESULTS

Data Set Characteristics

Table 2 shows the mean and standard deviation of the BMI samples. From table 2, it is clear that the average BMI lies in the range of 21.72 to 24.62 for the normal category (BMI: 18.5 to 24.9). The mean BMI varies between 27.35 to 28.53 for the overweight category (BMI: 25-29.9) and the BMI variation, 30.7 to 43.29 for the obese category (BMI: >30). Under the normal BMI, 42% were in the normal vessel type category (VT-1 and VT-2), 1% were in the bad vessel type category (VT-3 to VT-7), and for the overweight BMI category, 40% of samples were in the normal vessel type category, 7% samples in bad vessel type category. Finally, for the candidates falling under the obese BMI section, 8% of samples were in the normal vessel type category, 2% were in the bad vessel type category.

Table 3 shows the mean and standard deviation of BFP based on vessel type. In the BFP, the mean value lies in the range of 15.67 to 17.31 for the normal category (BFP: 8.01-19). Also, 63% of samples were in the excellent vessel type category, and 1% were in the wrong VT category. For the overweight category (BFP: 19.01-25), the average lies in the range of 21.51 to 24.64, and 25% of the samples were in the normal VT category, 7% were in the wrong VT category. In the obese category (BFP: >=25), the mean value lies in the range of 28 to 32, and 0% of the candidates were in the normal VT category, and 3% were in the wrong VT category.

Sl. NO	Gender	Age	BMI Range	VT	Mean (BMI)	Standard Deviation
Normal						
1	Male	18 to 70	18.51- 24.99	1	23.15	1.13
2	Male	18 to 70	18.51- 24.99	2	23.59	0.86
3	Male	18 to 70	18.51- 24.99	3	21.72	0.51
4	Male	18 to 70	18.51- 24.99	4	24.62	0.14
5	Male	18 to 70	18.51- 24.99	5	0	0
6	Male	18 to 70	18.51 - 24.99	6	0	0
Overweight						
1	Male	18 to 70	25-29.99	1	26.92	1.31
2	Male	18 to 70	25-29.99	2	27.35	1.38
3	Male	18 to 70	25-29.99	3	27.94	1.22
4	Male	18 to 70	25-29.99	4	27.67	1.22
5	Male	18 to 70	25-29.99	5	27.39	1.04
6	Male	18 to 70	25 – 29.99	6	28.53	0
Obese						
1	Male	18 to 70	>=30	1	30.7	0.83
2	Male	18 to 70	>=30	2	32.04	1.06
3	Male	18 to 70	>=30	3	31.58	0.7
4	Male	18 to 70	>=30	4	32.36	2.14
5	Male	18 to 70	>=30	5	43.29	4.28
6	Male	18 to 70	>= 30	6	0	0

Table 2: Mean and standard deviation of BMI dataset (N = 1070).

Sl. NO	Gender	Age	BFP Range	VT	Mean (BFP)	Standard Deviation
Normal						
1	Male	18 to 70	8.01-19	1	15.67	2.52
2	Male	18 to 70	8.01-19	2	17.31	1.07
3	Male	18 to 70	8.01-19	3	0	0
4	Male	18 to 70	8.01-19	4	0	0
5	Male	18 to 70	8.01-19	5	0	0
6	Male	18 to 70	8.01-19	6	0	0
Overweight						
1	Male	18 to 70	19.01-25	1	21.51	1.63
2	Male	18 to 70	19.01-25	2	21.9	1.65
3	Male	18 to 70	19.01-25	3	24.64	0.2
4	Male	18 to 70	19.01-25	4	22.54	1.21
5	Male	18 to 70	19.01-25	5	22.68	0.68
6	Male	18 to 70	19.01-25	6	0	0
Obese						
1	Male	18 to 70	>25	1	25	4.66
2	Male	18 to 70	>25	2	26.32	4.69
3	Male	18 to 70	>25	3	27.35	4.54
4	Male	18 to 70	>25	4	27.43	4.62
5	Male	18 to 70	>25	5	31.67	4.34
6	Male	18 to 70	>25	6	28.4	0

Table 3: Mean and standard deviation of body fat percentage dataset (N = 1070).

Table 4 shows the mean and standard deviation of the blood pressure based on vessel type. The average value lies between 110.89 to 111.47 for the standard BP value in the BP category, and 29% of samples were in the normal VT category, and 2% were in the wrong VT category. The mean value lies in 124.06 to 126.2 for the high BP range, and 24% of the candidates were in the normal VT category and 0% in the wrong VT category. For the hypertension-1 section, the average value lies between 133.18 to 135.67, and 18% were in the normal VT category, and 2% were in the wrong BP category.

In the hypertension-2 category, the mean value is 147 to 54.8, and 14% were in the normal VT category, and 4% were in the wrong VT category.

Sl. NO	Gender	Age	BP Range	VT	Mean (BP)	Standard Deviation
Normal						
1	Male	18 to 70	0-119	1	112.12	5.66
2	Male	18 to 70	0-119	2	113.21	5.07
3	Male	18 to 70	0-119	3	110.89	4.01
4	Male	18 to 70	0-119	4	111.47	7.66
5	Male	18 to 70	0-119	5	0	0
6	Male	18 to 70	0-119	6	0	0
Elevated						
1	Male	18 to 70	120-129	1	123.91	3.1
2	Male	18 to 70	120-129	2	124.06	2.87
3	Male	18 to 70	120-129	3	125.67	1.25
4	Male	18 to 70	120-129	4	126.2	2.48
5	Male	18 to 70	120-129	5	125.5	3.5
6	Male	18 to 70	120-129	6	0	0
Hypertension 1						
1	Male	18 to 70	130-139	1	133.9	2.6
2	Male	18 to 70	130-139	2	134.01	2.76
3	Male	18 to 70	130-139	3	135.67	2.83
4	Male	18 to 70	130-139	4	133.18	2.62
5	Male	18 to 70	130-139	5	134.25	2.05
6	Male	18 to 70	130-139	6	0	0
Hypertension 2						
1	Male	18 to 70	140-180	1	150.65	8.51
2	Male	18 to 70	140-180	2	148.23	7.37
3	Male	18 to 70	140-180	3	149.38	6.16
4	Male	18 to 70	140-180	4	154.5	13.25
5	Male	18 to 70	140-180	5	154.8	7.98
6	Male	18 to 70	140-180	6	147	0

Table 4: Mean and standard deviation of blood pressure dataset (N = 1070).

Sl. NO	Gender	Age	AES Range	VT	Mean (AES)	Standard Deviation
Good						
1	Male	18 to 70	70-100	1	78.67	7.69
2	Male	18 to 70	70-100	2	79	0
3	Male	18 to 70	70-100	3	0	0
4	Male	18 to 70	70-100	4	0	0
5	Male	18 to 70	70-100	5	0	0
6	Male	18 to 70	70-100	6	0	0
Normal						
1	Male	18 to 70	30-69	1	58.52	6.01
2	Male	18 to 70	30-69	2	40.49	5.97
3	Male	18 to 70	30-69	3	38.94	7.12
4	Male	18 to 70	30-69	4	45	0
5	Male	18 to 70	30-69	5	0	0
6	Male	18 to 70	30-69	6	0	0
Bad						
1	Male	18 to 70	<30	1	0	0
2	Male	18 to 70	<30	2	22.22	5.91
3	Male	18 to 70	<30	3	20.81	4.7
4	Male	18 to 70	<30	4	5.66	5.63
5	Male	18 to 70	<30	5	2	3.46
6	Male	18 to 70	<30	6	3	0

Table 5: Mean and standard deviation of AES dataset (N = 1070).

Table 5 shows the means and standard deviation of the AES based on vessel type. In the AES section, the average mean value lies between 78.67 to 79 for the good AES range (71-100), and 14% of samples were in the normal VT category and 0% in the wrong VT category. For normal AES (31-70), the mean value is in the range of 38.94 to 58.52, and 57% of the samples were in the normal VT category and 1% in the wrong VT category. For the bad AES range, the average value lies between 2 to 22.22, and 19% were in the normal VT, and 9% were in the wrong VT category.

Table 6 shows the regression analysis of BMI, BFP, BP, AES with VT. The linear regression table will establish the significant relationship between VT (dependent variable) and BMI, BFP, BP, AES (independent variables). From table 6, we can see that the 'r square' value showing the amount of variation in the dependent variable and the independent variables as 0.68. The dependency percentage between BMI, BFP, AES, and BP to VT is 68% from the analysis. The remaining 32% will depend on some other hidden parameters: clinical or family history or geographical. Also, we found that when BP goes up by one unit (mm/Hg), the unstandardized beta value will not change. It indicates VT will not change. However, when BMI is increased by one unit, VT will go down by 0.1 unit. Similarly, when BFP goes up by one unit, VT will go up by 0.4 unit, and when AES goes up by one unit, the VT will go down by 0.3 unit.

REGRESSION/VARIABLES = SYS BMI BFP AES

REGRESSION/DEPENDENT = VT

REGRESSION/METHOD = ENTER

REGRESSION/STATSTICS = COEFF R ANOVA

Model Summary (VT)					
R	R Square	Adjusted R Square	Std. Error of the Estimate		
ANOVA (VT)					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	537.27	4	134.32	557.41	0.00
Residual	256.63	1065	0.24		
Total	793.9	1069			
Coefficients (VT)					
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	2.33	0.18	0.00	12.69	0.000
SYS	0.00	0.00	0.03	1.77	0.077
BMI	-0.01	0.01	-0.05	-2.02	0.044
BFP	-0.04	0.01	0.21	7.73	0.000
AES	-0.03	0.00	-.72	-35.89	0.000

Table 6: Regression analysis for BMI, BFP, BP, AES with VT.

Distribution of Vessel Type Data

From Figure 6 it is evident that, almost 40% of the candidates have VT1, and 48% fall under VT2. However, the risky situation is around 6%, and 5% of the candidates fall under VT3 and VT4 respectively. Also, VT5 rate is coming closer to 2%. The chart indicates that most people have VT2, and a small percentage is going to risky VTs. Smoking habits, fast foods, hypertension, and low exercise levels may be the key reasons behind increasing dangerous VT percentage. Since modern society is living in a digital world with everything at a fingertip, VTs with high-risk factors will naturally grow in the upcoming years due to unhealthy lifestyle.

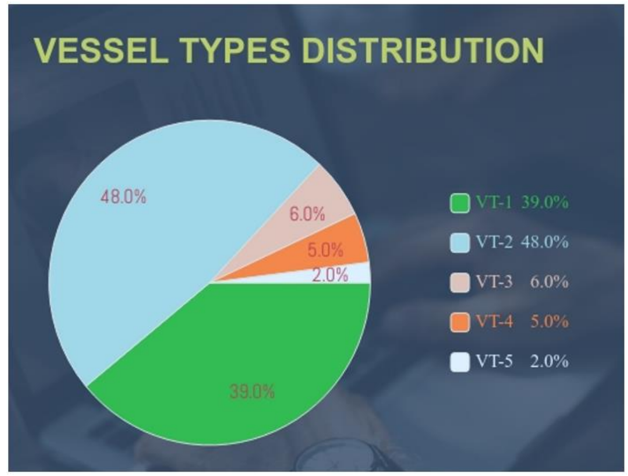


Figure 6: Pie chart showing the vessel type distribution among the population.

Analysis of VT Based on BMI Dataset

BMI based result analysis of VT based on age progression

Figure 7 shows the VT1 to VT5 distribution of the population based on age and BMI classification. In the normal category, candidates having the age range 18 to 30 fall under VT1. Higher BMI may be due to the higher muscle mass or bone mass rather than higher fat mass. We can also see the overweight percentage is higher in bad or wrong vessel type category VT-4 and VT-5, and normal BMI percentage get decreased in VT-3, VT-4, and VT-5. Having an overweight BMI category may lead to the wrong vessel type is proven here.

Majority of the overweight candidates fall under VT3. Interestingly, normal category persons are also falling under VT3. The graph also shows that the number of obese category candidates coming under VT3 is less than the number of normal category candidates coming under VT3.

The reason for normal category candidates coming under VT3 will be normal weight obesity syndrome or unhealthy lifestyle, which can be judged through body composition analysis. Genetic disorders may be the other reason. From VT4 and VT5 distributions, it is evident that obese and overweight candidates are filling the VT distribution graph.

Figure 7: Bar plot showing the VT distribution based on BMI and age classifications.

BMI - ANOVA Test Results

ONEWAY/VARIABLES = BMI BY VT
ONEWAY/STATSTICS = DESCRIPTIVES

Descriptives									
						95% Confidence Interval for Mean			
	VT	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
BMI	1	508	24.56	2.37	0.1	24.35	24.76	13.49	31.94
	2	455	26.92	2.99	0.14	26.64	27.19	20.99	36.39
	3	38	27.67	2.61	0.42	26.81	28.53	20.84	32.43
	4	57	28.67	2.85	0.38	27.92	29.43	24.45	37.06
	5	11	31.51	10.94	3.3	24.16	38.86	24.96	63.48
	6	1	28.53	NaN	NaN	NaN	NaN	28.53	28.53
	Total	1070	25.96	3.22	0.1	25.77	26.16	13.49	63.48
ANOVA									
		Sum of Squares	df	Mean Square	F	Sig.			
BMI	Between Groups	2292.12	5	458.42	55.41	0.000			
	Within Groups	8803.39	1064	8.27					
	Total	11095.52	1069						

Table 7: ANOVA test table for BMI and vessel type.

The One-way ANOVA test result for finding the relation between BMI and VT is shown in Table 7. Based on ANOVA, it is clear that the correlation between the BMI and vessel type is good because the p-value for this interaction is less than 0.05. The p-value less than 0.05 is taken as significant in the current research. We can conclude that BMI can be taken as one of the parameters to predict vessel types.

BMI - Correlogram Analysis

The correlogram shown in Figure 8 again tells that BMI has one of the influencers determining the subject's VT. According to the correlogram, BMI normal category candidates can fall in the good vessel type category. There is a high chance to fall in bad vessel type in BMI overweight category compared to good vessel type. Here we can conclude that the overweight category in BMI may lead to the wrong vessel type.

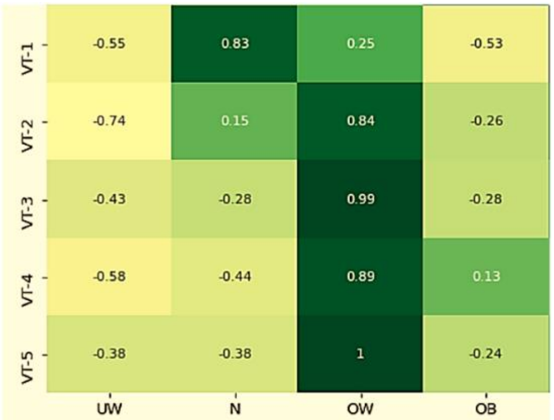


Figure 8: Correlogram showing the influence of BMI and age on VT.

Analysis of VT Based on BFP Dataset

Body fat-based result analysis of VT based on age progression

Figure 9: Bar plot showing the VT1 to VT5 distribution the population based on BFP and age classifications.

The Figure 9 indicates normal category candidates under BFP tend to have VT1 or less risky VT irrespective of the age. It is clear that lower body fat can provide less risky vessel types. Also, as the body fat increases the vessel type will shift from less risky group to riskier group. It is evident that certain candidates under normal weight category are coming under VT3, VT4 and VT5. The reason can be unhealthy lifestyles, smoking habits, hereditary problems, alcoholic consumption, lack of physical activities etc.

BFP - ANOVA Test Results

The One-way ANOVA test result for finding the relation between BFP and VT is shown in Table 8. Based on ANOVA, it is clear that the correlation between the BFP and vessel type is good because the p-value for this interaction is less than 0.05. Here we see that the p-value for the interaction is 0.000, which is less than 0.05, and it can be said that there is a significant relation between BFP and VT. Hence, we can conclude that BFP can be used as an indicator to predict vessel types.

BFP - Correlogram Analysis

The correlogram given in Figure 10 shows that normal BFP candidates have a high percentage of falling in VT1 or VT2. As the BFP moves to overweight, the candidate can have a chance to get VT3 and VT4. The situation can worsen; that is, the candidate can fall into VT5 if he has obesity in BFP. Hence, we can conclude that BFP is a good indicator for predicting VT. The correlogram clearly states that body fat or body composition analysis can correctly determine the correct VT of the candidate and can prevent early-stage cardiovascular morbidity.

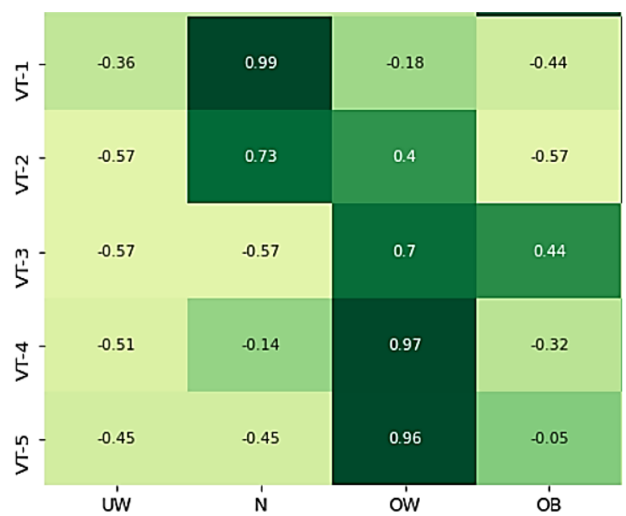


Figure 10: Correlogram showing the influence of bodyfat and age on VT.

ONEWAY/VARIABLES = BFP BY VT
ONEWAY/STATSTICS = DESCRIPTIVES

Descriptives									
						95% Confidence Interval for Mean			
	VT	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
BMI	1	508	17.95	4.04	0.18	17.6	18.3	2	25
	2	455	21.28	3.41	0.16	20.97	21.6	15	28
	3	38	26.64	1.58	0.26	26.12	27.16	24.3	29.4
	4	57	24.86	3.1	0.41	24.03	25.68	20.2	33.8
	5	11	27.58	6.94	2.09	22.92	32.25	21.8	45
	6	1	28.4	NaN	NaN	NaN	NaN	28.4	28.4
	Total	1070	20.15	4.46	0.14	19.88	20.42	2	45
ANOVA									
		Sum of Squares	df	Mean Square	F	Sig.			
BMI	Between Groups	6583.62	5	1316.72	95.63	.000			
	Within Groups	14650.66	1064	13.77					
	Total	21234.27	1069						

Table 8: ANOVA test for BFP and vessel type.

Analysis of VT Based on Blood Pressure Dataset

BP based result analysis of VT

Figure 11 shows that the BP categories coming under hypertension-1 and hypertension-2 are the lowest count than the normal and elevated category in the VT-1 and VT-2. Hypertension-1 and hypertension-2 count more in the bad or wrong vessel types like VT-3, VT-4, and VT-5.

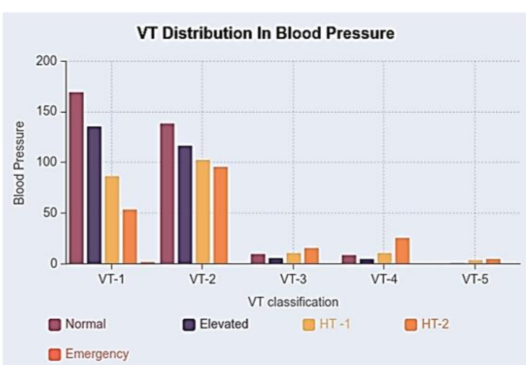


Figure 11: Vessel type distribution in blood pressure.

Particularly in VT-5, there are 0% samples in normal and elevated BP ranges against hypertension-1 and hypertension-2 sections. From this graph, we can clearly say that hypertension will lead to the wrong VT category.

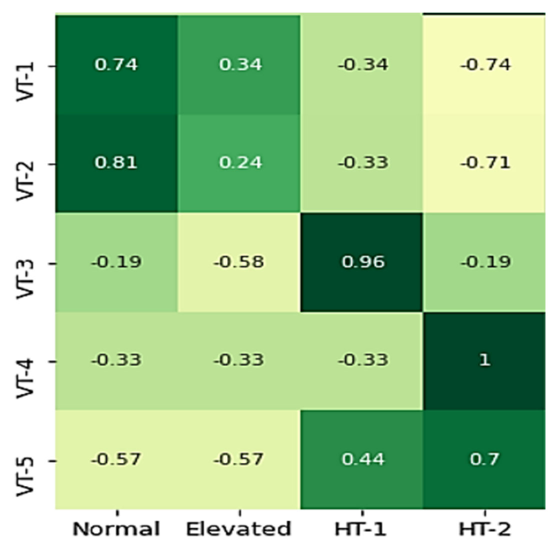


Figure 12: Correlogram analysis of BP and vessel type.

BP - ANOVA Test Results

Table 9 describes the One-way ANOVA test analysis of BP and Vessel type. The significant value is 0.000, which is less than 0.05. Here, the p-value is less than 0.05, indicating a meaningful relationship between the BP and VT. Hence, we can conclude HT-1 and HT-2 will create the impact on bad vessel type category.

ONEWAY/VARIABLES = SYS BY VT
ONEWAY/STATSTICS = DESCRIPTIVES

Descriptives									
						95% Confidence Interval for Mean			
	VT	**N**	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
BMI	1	508	127.89	15.97	0.71	126.49	129.28	73	190
	2	455	128.1	13.74	0.64	126.83	129.36	95	174
	3	38	134.11	17.44	2.83	128.37	139.84	105	181
	4	57	136.58	20.71	2.74	131.08	142.07	86	179
	5	11	142	14.01	4.23	132.59	151.41	122	162
	6	1	147	NaN	NaN	NaN	NaN	147	147
	Total	1070	128.82	15.59	0.48	127.89	129.76	73	190
ANOVA									
		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**			
BMI	**Between Groups**	7415.66	5	1483.13	6.25	0			
	Within Groups	252348.6	1064	237.17					
	Total	259764.3	1069						

Table 9: ANOVA test for BP and vessel type.

BP - Correlogram Analysis

Figure 12 shows the correlation coefficient value between the vessel type category and BP category. Normal BP ranges have the coefficient values 0.74 and 0.81 in normal vessel type category VT-1 and VT-2. This indicates high chances of getting a good vessel type category (VT-1, VT-2) if the person has the normal BP range. But when we come into HT-1 and HT-2, we can see a high chance of falling in the bad or wrong VT category (VT-3, VT-4, VT-5) if the person has HT-1 or HT-2.

Analysis of VT Based on Arterial Elasticity Score Dataset

AES based result analysis of VT

Figure 13 describes the arterial elasticity score distribution in VT. In the normal VT category (VT-1), the good and normal AES score count is higher, and there are 0% of samples in the wrong VT category. In VT-2, the normal AES score count is higher compared to the bad VT class.

When we come into the bad VT category (VT-3, VT-4, VT-5), there are 0% of samples in good AES. The bad AES class is the dominant category in the bad VT category.

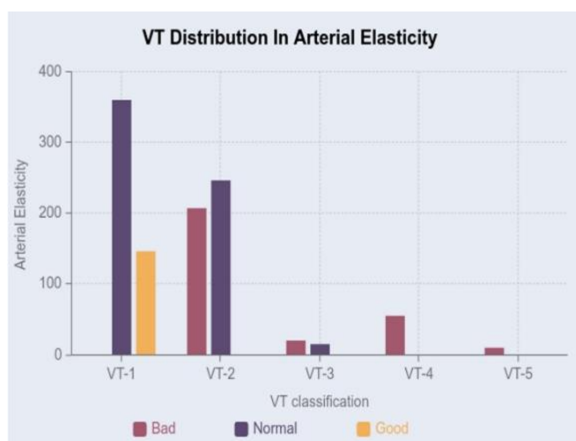


Figure 13: Arterial elasticity score distribution in VT category.

AES - ANOVA Test Result

Table 10 describes the ANOVA test analysis between AES and VT. The significant value is 0.000, which is less than 0.05. There is a substantial relationship between the AES and VT. Hence, we can conclude that bad AES score will impact bad VT category, and a normal and good AES will affect the good VT category.

ONEWAY/VARIABLES = AES BY VT
ONEWAY/STATSTICS = DESCRIPTIVES

Descriptives									
						95% Confidence Interval for Mean			
	VT	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
BMI	1	508	64.35	11.25	0.50	63.37	65.33	41	100
	2	455	32.13	10.88	0.51	31.13	33.14	7	63
	3	38	29.97	13.48	2.19	25.54	34.41	14	79
	4	57	6.35	7.67	1.02	4.32	8.39	.00	45
	5	11	2.00	3.63	1.10	-.44	4.44	.00	11
	6	1	3.00	NaN	NaN	NaN	NaN	3	3
	Total	1070	45.64	21.82	0.67	44.33	46.95	.00	100
ANOVA									
		Sum of Squares	df	Mean Square	F	Sig.			
BMI	Between Groups	380917.5	5	76183.50	632.98	.000			
	Within Groups	128060.4	1064	120.36					
	Total	508977.9	1069						

Table 10: ANOVA test for AES and VT.

AES - Correlogram Analysis

Figure 14 shows the correlation coefficient values for AES ranges and the VT category. From this correlogram, normal and good class AES have a high correlation with VT-1 and VT-2.

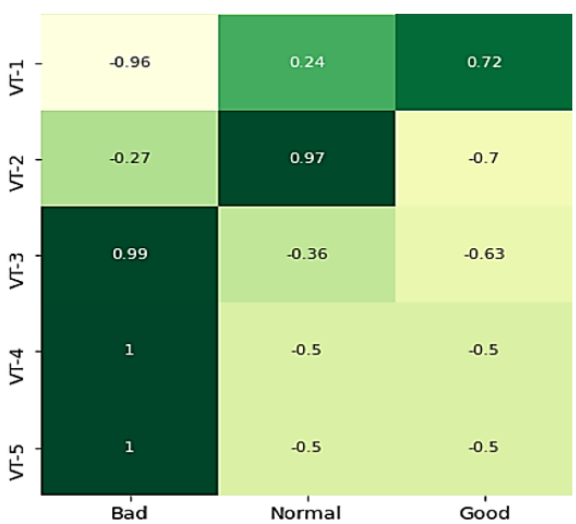


Figure 14: Correlogram analysis of AES and VT.

The bad category AES shows the high correlation with the bad vessel type category (VT-3, VT-4, VT-5). Hence, we can say AES is one of the parameters to predict the vessel type.

4. CONCLUSION

Recent prospective studies have provided compelling evidence that obesity, high blood pressure and bad arterial elasticity conditions are risk factor for clinical coronary events. We conducted this cross-sectional study to investigate the relationship between atherosclerosis progression and arterial elasticity using the photoplethysmography method and using Futrex NIR technology parameters like body mass index, body fat percentage, blood pressure. Obesity has several consequences for accelerated atherosclerosis, including hypertension, diabetes, and dyslipidaemia [29-34].

The obesity in adolescent and young adult men is associated with the extent and severity of early atherosclerotic lesions [35,36]. The increasing prevalence of obesity among young individuals [3] emphasizes the need for obesity control efforts. From this study, we will be able to make a few conclusions related to BMI, BFP, BP, and AES on the vessel type classification.

- Blood Circulation indicator - Vessel type - VT moves from a healthy or less risky category to a riskier category as the body mass index and body fat percentage moves from normal to overweight and obese region.
- VT moves from healthy or less category to a riskier category as the blood pressure moves from normal to hypertension-1 and hypertension-2.
- VT moves from healthy or less category to a riskier category as the arterial elasticity score moves from good to normal and bad category.
- One-way ANOVA test reveals that BMI, BFP, BP, AES has the impact on VT determination.
- Regression analysis shows that there is a significant relationship in determining the VT based on the BMI, BFP, BP, AES.

So, the claim we can predict from this study is that obesity in BMI and BFP terms, hypertension in BP terms, bad arterial elasticity expressions can lead to risky vessel types. Hence, good blood flow or healthier BCS may depend on their body weight, blood pressure, arterial elasticity. Better blood flow can also be achieved by adopting a balanced diet, exercise, and good habits like yoga, quitting smoking, staying well hydrated, avoid sitting for long period of time, and managing the blood pressure. The causes of poor circulation are many. Between our diets, our lifestyle choices, and may be the occasional vice here and there, we all do things to contribute to poor blood circulation. On the bright side, one doesn't have to suffer from poor circulation any longer. By incorporating the above tips into the daily life will help increase blood flow to lead a healthy life.

5. CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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