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Human Age Estimation: Use of Doppler Ultrasound Blood Velocity Measurement in the Human Carotid Artery

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Abstract
Assessment of a living person's age has gained prominence due to its numerous applicability: suspected criminals with no reliable records of identification where verifying age is essential for determining legal and/or financial responsibility; adults from developing nations with no reliable certificates or documents and falsification of age in order to merit appointments or participate in sporting events are a few to mention. In this work, the Peak Systolic Velocity (PSV) and End Diastolic Velocity (EDV) on the right and left Common Carotid Arteries were measured with the LOGIQ 5 EXPERT Ultrasound Machine using the technique of Doppler Ultrasound Velocity Measurement of blood flow in the carotid arteries of 50 volunteers (25 males and 25 females) whose blood pressures were taken. Use of The IBM SPSS shows that the Right Peak Systolic Velocity and Left End Diastolic Velocity were unrelated to the blood pressure for the hypertensive, pre-hypertensive and the non-hypertensive groups. However, results show that the Right End Diastolic Velocity (REDV) is positively correlated with age $(r = 0.315, p < 0.05)$, while the Right Peak Systolic Velocity (RPSV) is negatively correlated with age $(r = -0.356, p < 0.05)$ both indicating that the age of an individual could be estimated.
Keywords: Age, peak systolic velocity, end diastolic velocity, Doppler ultrasound, carotid artery.

1. Introduction

Age estimation is the determination of a person's age based on biometric features. The problem of determining the age of a living individual may not have a great deal of importance in the practice of medicine. However, aging and identifying living subjects can be important to certain legal and other scenarios. Such scenarios are addressed by forensic anthropology, forensic odontology, forensic pathology and forensic pediatric medicine. Cases which demand the assessment of a living person's age include: suspected criminals with no reliable records of identification where verifying age is essential for determining legal and/or financial responsibility; adults from developing nations with no reliable certificates or documents who, for instance, need to know their age in order to request age-contingent pensions and other benefits and age limits in sporting participation. Determination of age of living (and deceased) individuals can be made through the analysis of skeletal and dental development and morphology. Here, the techniques involved consider radiographic analysis of the carpal bones and evaluation of dental development, mineralization, and occlusal surface wear through clinical examination or evaluation of dental plain films. Obviously, there are problems with attempting to determine age through skeletal and dental analysis, as biological age does not always correspond to chronological (legal) age. Current research has explored the use of facial proportion analysis as an age indicator of photographic images (John, 2015). The Doppler ultrasound blood velocity measurements in the carotid artery has provided a powerful tool for non-invasive method, most frequently performed to detect stenosis of the carotid artery, a condition that substantially increases the risk of stroke. It is an important technique for non-invasively detecting and measuring the velocity of moving structures and particularly blood, within the body (Nowicki and Reid, 1981; Baker, 1970; Brandestine, 1978; Chivers, 1977; Peronneau *et al*., 1972). Blood pressure some, also referred to as arterial blood pressure, is the pressure by circulating blood upon the walls of blood vessels, and is one of the principal vital signs of carotid artery disease. A person's blood pressure is usually expressed in terms of systolic blood pressure (SBP) over diastolic blood pressure (DBP) and is measured in millimeters of mercury (mmHg). Normal resting blood present for an adult is approximately 120/80 mmHg. For an adult with low blood pressure (hypotension), the blood pressure reads less than 90 mmHg systolic and 60mmHg diastolic. Normal pressure ranges from 90 – 119 mmHg systolic and 60 – 79 mmHg diastolic. For pre-hypertension, the pressure ranges from 120 – 139 mmHg systolic and 80 – 89mmHg diastolic. A hypertensive blood pressure ranges from 140 – 159 mmHg for stage 1 and 160 – 179 mmHg for stage 2 systolic, while it ranges from 90 – 99 mmHg for stage 1 and 100 – 109 mmHg for stage 2 diastolic. Any blood pressure greater than or equal to 180 mmHg systolic and 110mmHg diastolic is a hypertensive emergency (Richard and Klabunde, 2013).

2. Materials and Methods

The materials used in this work included the Doppler Ultrasound Machine, Automatic Blood Pressure Monitor and Human Beings**.** Fifty (50) human subjects from Jos South Local Government Area of Plateau State Nigeria

selected using the stratified random sampling method of different ages (from 19 to 75 years), occupation, sex (25males and 25 females) and ethnic group. They were then taken to Jos University Teaching Hospital (JUTH) and after obtaining clearance from the ethical committee of the hospital, were subjected to various tests. The blood pressure of each human subject was measured using the Automatic Blood Pressure Monitor procedurally: The individual was made to sit on a chair with his/her arm at the chest level; the upper part of the arm was cuffed with the sphygmomanometer pressure embedded cuffing strip; the arm was inflated and both the systolic and diastolic blood pressures were recorded in mmHg. The peak systolic and end diastolic velocities of the blood flowing in the carotid artery of each human subject was measured using LOGIQ 5 EXPERT Ultrasound machine in the B-Mode Doppler ultrasound technique at 6MHz frequency with an insonation angle of 60^0. Each subject was made to lie in a supine position on an examination bed with the neck and chest of the person exposed and a few drops of water soluble semi-liquid gel were applied to the body surface around the neck. The probe was rotated on the right side of the neck region until the carotid artery was seen as displayed by the monitor in plate 1 and showing how the blood flows in the artery in as shown in plate 2. The peak Systolic Velocity and End Diastolic Velocity of the blood flow were automatically displayed on the screen as shown in plate 3. The same procedures were followed on the left side of the neck for all the patients.

Plate 1: The Carotid Artery

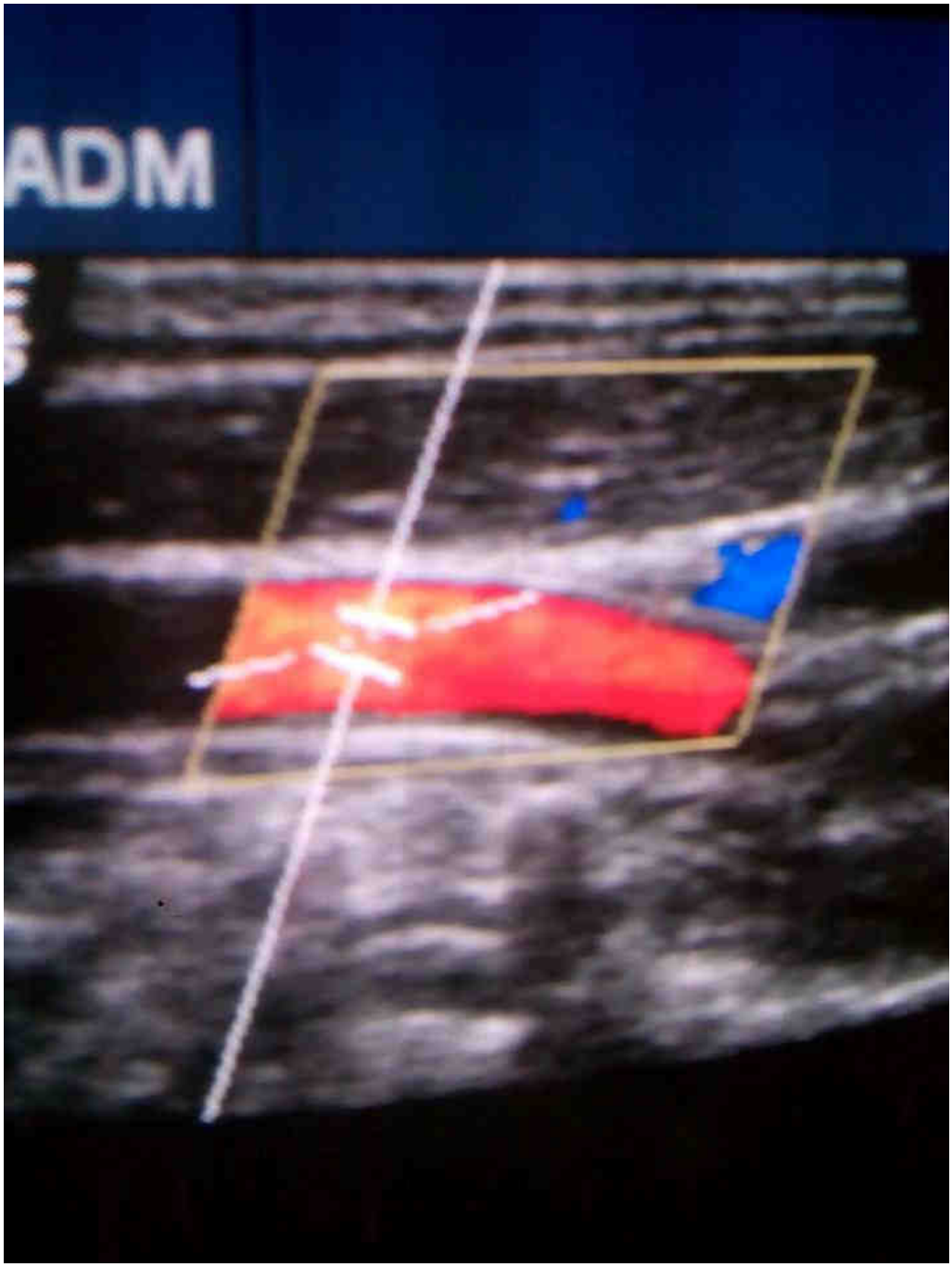

Plate 2: Blood Flow in the Carotid Artery

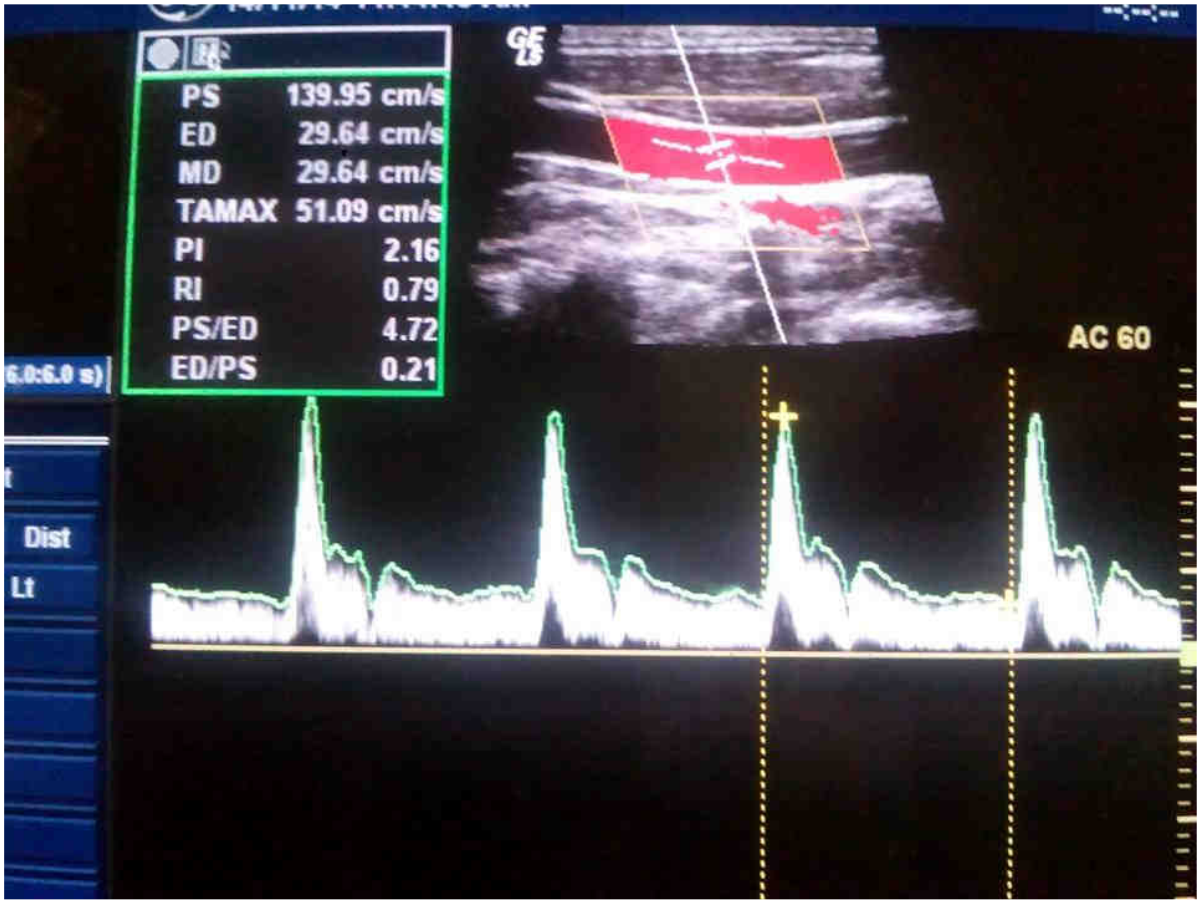

Plate 3: Blood Velocity Measurements

3. Results

The Right Peak Systolic Velocity (RPSV), Right End Diastolic Velocity (REDV), Left Peak Systolic Velocity (LPSV) and Left End Diastolic Velocity (LEDV) for 21 hypertensive, 19 pre-hypertensive and 10 non-hypertensive of the 50 subjects as recorded by the Doppler Ultrasound Machine in cms^{-1} are shown in tables 1, 2 and 3.

Table 1: Blood Velocity for Hypertensive Patients

S/N	AGE	SBP	DBP	RPSV	REDV	LPSV	LEDV
1	23	151	80	91.69	25.51	108.24	22.75
2	26	116	100	116.51	21.37	131.68	29.64
3	38	146	93	106.72	22.45	107.62	25.55
4	47	177	113	59.95	15.54	73.27	18.50
5	48	197	105	112.04	35.35	120.42	36.55
6	48	146	91	97.66	29.36	90.47	30.56
7	48	151	97	92.86	24.56	88.07	29.36
8	50	149	85	114.23	39.14	117.43	26.36
9	50	206	98	142.84	37.75	133.96	25.90
10	52	144	82	86.59	24.42	105.48	39.30
11	54	179	105	44.81	11.72	71.01	24.13
12	54	144	81	83.63	27.38	80.67	25.90
13	42	147	90	92.86	18.57	96.46	20.97
14	56	158	91	92.86	31.75	68.90	24.56
15	58	167	89	73.77	17.24	76.52	19.99
16	60	182	112	67.90	31.15	74.29	19.97
17	61	175	95	83.67	25.79	74.75	17.02
18	62	171	105	99.80	45.21	84.45	34.97
19	65	185	87	81.24	25.16	65.42	19.41
20	75	173	79	65.87	22.94	86.59	25.90
21	59	145	89	100.05	35.35	118.03	32.95

SBP = Systolic Blood Pressure, DBP = Diastolic Blood Pressure, RPSV = Right Peak Systolic Velocity, REDV = Right End Diastolic Velocity, LPSV = Left Peak Systolic Velocity, LEDV = Left End Diastolic Velocity.

Table 2: Blood Velocity for Pre-hypertensive Patients

S/N	AGE	SBP	DBP	RPSV	REDV	LPSV	LEDV
1	25	131	86	73.77	24.13	79.28	21.37
2	25	127	70	104.10	14.48	120.65	19.99
3	27	129	72	108.79	18.50	111.76	14.06
4	29	121	78	139.95	29.64	127.54	25.51
5	30	124	71	91.69	25.51	94.45	21.37
6	40	129	83	80.03	30.53	75.08	30.53
7	41	124	74	116.83	29.36	85.68	25.76
8	45	129	85	101.25	23.37	104.85	29.36
9	45	132	80	93.99	24.42	86.59	30.34
10	47	137	89	106.05	29.36	109.64	41.34
11	48	130	83	67.35	21.46	67.37	19.98
12	49	127	76	107.62	30.20	96.95	25.90
13	52	131	75	118.03	25.76	127.61	43.74
14	52	137	85	85.11	28.86	62.91	22.94
15	57	134	79	75.15	24.13	98.59	29.64
16	58	125	83	68.90	26.96	90.47	34.15
17	65	127	75	95.26	17.37	113.24	19.77
18	37	124	84	99.96	26.89	97.21	26.89
19	42	126	81	71.01	19.99	80.66	31.02

Table 3: Blood Velocity for Non-hypertensive Patients

S/N	AGE	SBP	DBP	RPSV	REDV	LPSV	LEDV
1	19	107	70	109.62	24.13	83.42	24.13
2	22	116	73	109.62	19.99	105.48	24.13
3	24	112	53	128.92	18.61	110.99	18.61
4	26	114	68	80.66	24.13	87.78	33.78
5	39	108	76	83.42	18.61	75.15	21.37
6	53	108	68	93.46	34.35	91.87	37.55
7	58	118	64	114.31	40.98	121.50	42.42
8	65	113	67	86.63	28.88	86.63	22.28
9	45	119	69	76.65	22.45	102.98	31.74
10	46	106	67	102.87	19.98	100.05	22.17

The results in tables 1, 2, and 3 were analyzed using IBM SPSS (Statistical Packages for the Social Sciences) tool to establish whether correlations exist among variables. Table 4 shows the correlations among the variables using the 2-tailed Pearson's correlation. The Pearson's correlations with one asterisk show that correlation is significant at the 0.05 level, while those with two asterisks show that correlation is significant at the 0.01 level.

Table 4 : Correlations

		AGE	SYST.BP	DIAST.BP	RPSV	REDV	LPSV	LEDV
AGE	Pearson Correlation	1	.413**	.303*	-.356*	.315*	-.265	.185
	Sig. (2-tailed)		.003	.033	.011	.026	.063	.198
	N	50	50	50	50	50	50	50
SYST.BP	Pearson Correlation	.413**	1	.826**	-.144	.172	-.069	-.095
	Sig. (2-tailed)	.003		.000	.317	.233	.635	.511
	N	50	50	50	50	50	50	50
DIAST.BP	Pearson Correlation	.303*	.826**	1	-.267	.138	-.203	-.022
	Sig. (2-tailed)	.033	.000		.061	.340	.158	.880
	N	50	50	50	50	50	50	50
RPSV	Pearson Correlation	-.356*	-.144	-.267	1	.378**	.747**	.171
	Sig. (2-tailed)	.011	.317	.061		.007	.000	.234
	N	50	50	50	50	50	50	50
REDV	Pearson Correlation	.315*	.172	.138	.378**	1	.179	.500**
	Sig. (2-tailed)	.026	.233	.340	.007		.214	.000
	N	50	50	50	50	50	50	50
LPSV	Pearson Correlation	-.265	-.069	-.203	.747**	.179	1	.343*
	Sig. (2-tailed)	.063	.635	.158	.000	.214		.015
	N	50	50	50	50	50	50	50
LEDV	Pearson Correlation	.185	-.095	-.022	.171	.500**	.343*	1
	Sig. (2-tailed)	.198	.511	.880	.234	.000	.015	
	N	50	50	50	50	50	50	50

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

4. Discussions

Results of correlations using SPSS as shown in table 4 reveal that Age is positively correlated with Systolic and Diastolic Blood Pressures at the 0.01 and 0.05 significant levels with p values of $p<0.01$and $p<0.05$ respectively. This means that the more the persons' blood pressure, the greater the age. It is also correlated negatively with the RPSV and positively correlated with the REDV both at a significance level of $p<0.05$. The Blood Velocities on the right and left of the Carotid arteries show no significant correlation with the Blood Pressure.

The graphs of Age against RPSV and REDV are shown in figures 1 and 2. These graphs give regression equations between the Age as the dependent variable while RPSV and REDV as the independent variables as:

$$y = 68.44 - 0.24x_1 \quad \text{..... 1}$$

$$y = 0.62x_2 + 29.86 \quad \text{..... 2}$$

Where y is the Age, x_1 is the RPSV and x_2 is the REDV

Adding equations 1 and 2 gives:

$$y = 49.15 - 0.12x_1 + 0.31x_2 \quad \text{..... 3}$$

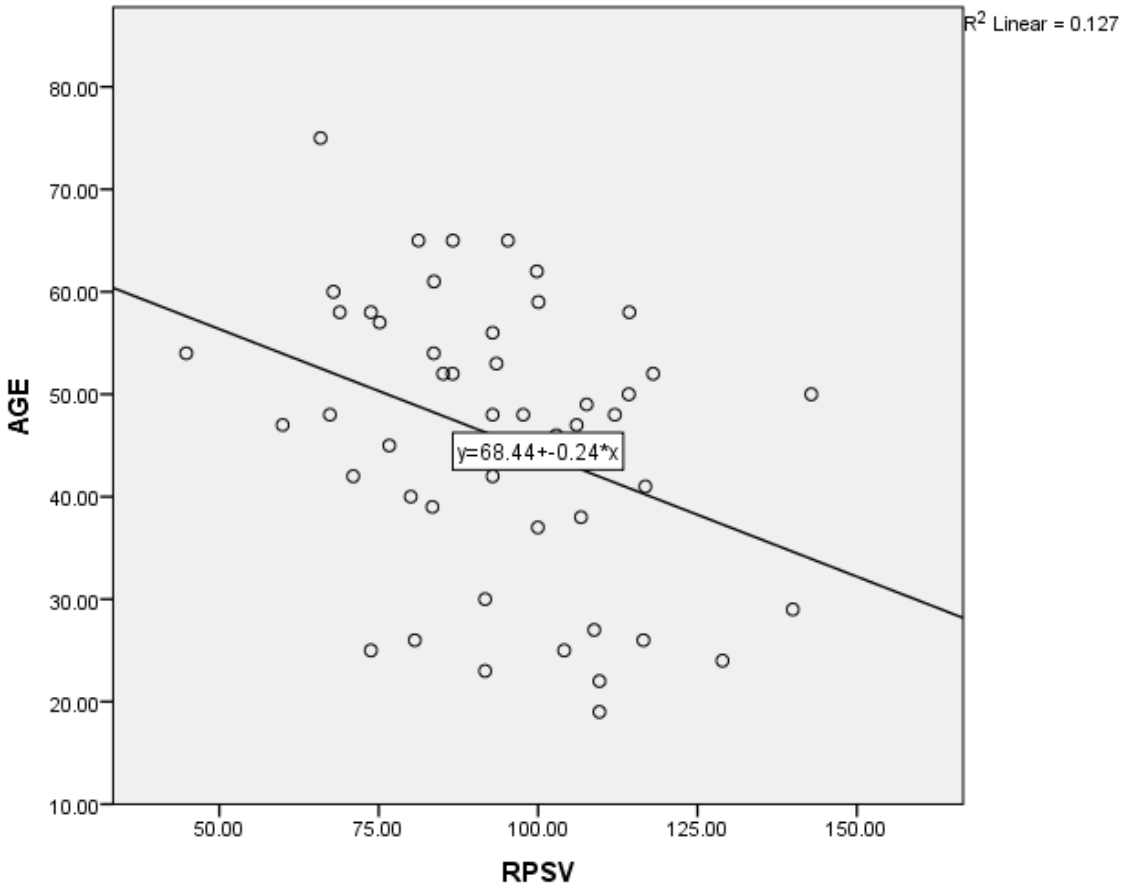

Figure 1: Graph of Age against Right Peak Systolic Velocity (RPSV)

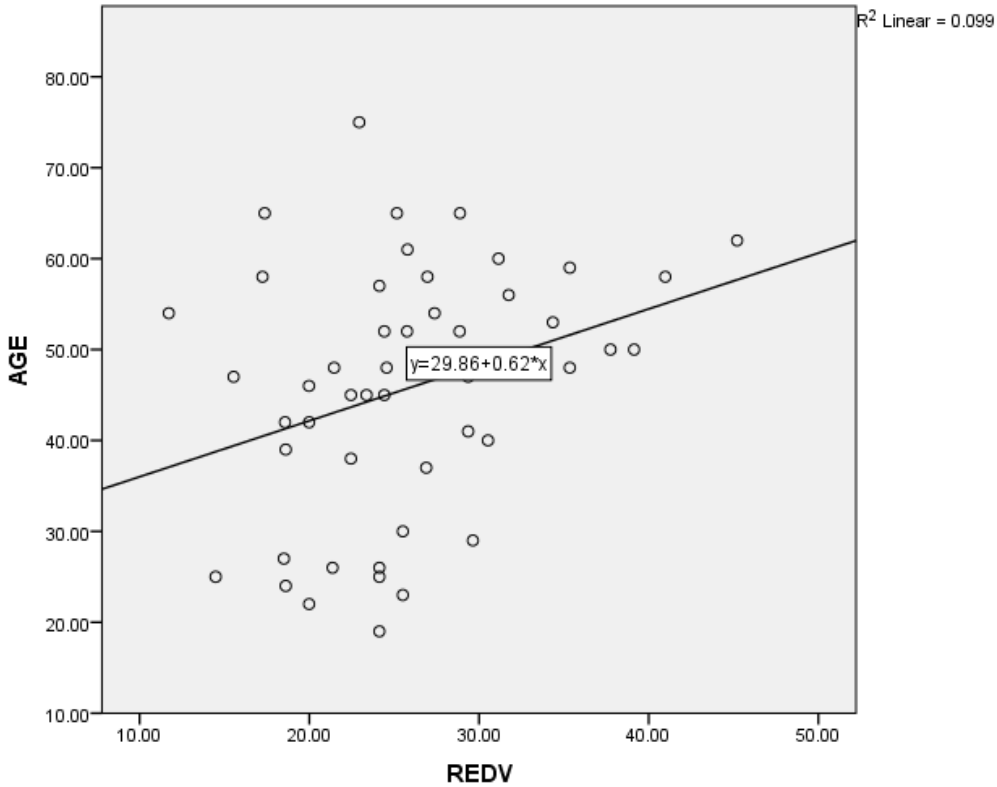

Figure 2: Graph of Age against Right End Diastolic Velocity (REDV)

5. Conclusion and Recommendations

Measurements of blood velocities and blood pressures for the age range of 19 to 75 years reveals that Age is found to have a positive correlation with both the Systolic and Diastolic Blood Pressures. The complication here is that a persons' blood pressure depends on other factors as blood cholesterol, food intake and exercise. Therefore, a persons' age cannot be accurately estimated using the blood pressure since a young persons' blood pressure can be higher than an elderly person who takes note of the factors mentioned above.

Age is found to have a negative and positive correlation with the Right Peak Systolic Velocity (RPSV) and the Right End Diastolic Velocity (REDV) respectively. Since both the RPSV and the REDV have no correlation with blood pressure, they are better considerations for estimating the age of a person than the blood pressure. Therefore, if the RPSV and the REDV of a person is obtained from the Doppler Ultrasound Machine; the age can be estimated using equation 3.

From this work, it is recommended that further research should be carried out on the topic to cover a larger sample size. This will help in having a more concrete way of determining the age of a person with a view of solving the problem of age falsification as requirement for some categories of jobs.

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