

Identifying and Analyzing Coronary Artery Calcium Score Metric to Predict Early Cardiovascular Health Issues

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Abstract

The paper emphasizes on identifying and analyzing Coronary Artery Calcium (CAC) score or Calcium Score metric to predict early cardiovascular health issues. There is a rapid increase of Cardiovascular Disease (CVD) or health issues day by day. The major concern is that medical practitioners and clinicians are consulted only when health issues get worse or can't be forwarded to further cure or improvement. Calcium Score metric is a good indicator for predicting the risk of CVD and Sudden Cardiac Arrest (SCA) or Heart Attack. It is heart's non-invasive CT scan. Right from birth, calcium deposition is initiated gradually in the coronary arteries. Calcium Score keeps track and measures the amount of calcium deposition or calcified plaque in arteries. Therefore, it has salient role to predict and assess the risk of development of Coronary Artery Disease (CAD). Keeping track of calcium score of an individual, can make aware of getting into the risk of CVD. The probability of occurrence of CVD depends on the calcium score. Lesser calcium score and percentile rank indicates lesser probability of a heart disease, cardiovascular health issues or heart attack. Therefore, there must be awareness and proper follow-up towards the calcium score in order to avoid CAD in future.

Keywords: Cardiovascular Disease, Sudden Cardiac Arrest, Coronary Artery calcium score, Calcium Score and Coronary Artery Disease

1 Introduction:

People are losing their lives now-a-days due to Cardiovascular Diseases (CVD) and other cardiovascular health ailments all over the world. Approximately 50% deaths are due to coronary artery disease (CAD) only [13]. There are no symptoms experienced by approximately one-fourth numbers of patients resulting to Sudden Cardiac Death (SCD) or Acute Myocardial Infarction [8]. There is utmost need to identify such asymptomatic persons, having higher risk of facing CVD or Cardiovascular health issues in near future, through early preventive planning and techniques. To initiate with, "Total risk scores" proves to be very important and beneficial for prediction of 65-80% of Cardiovascular health issues in near future [13][8]. Electron beam computed tomography emphasized the CAC score, which proved to be important in the scientific studies and surveys are then being based on that technique [2]. It shows its compatibility and equivalence with the cardiovascular risks and load of total coronary atherosclerosis [2]. Calcium Score or Cardiac Scoring basically is a heart scan which is generally heart's non-invasive CT (Computed Tomography) scan. Right from our birth, calcium deposition is initiated gradually in the coronary arteries. Calcium Score keeps track and measures the amount of calcium deposition or calcified

plaque in arteries. Therefore, it has salient role to predict and assess the risk of development of Coronary Artery Disease (CAD) [4]. The blood vessels which

are responsible to supply oxygen to the heart are called coronary arteries. These contain blood containing oxygen. The coronary arteries get narrow down or get closed due to plaque, which are calcium depositions, fat build-up and other deposits of substances in these coronary arteries. Presence of plaque may result in tingling of arm, back pain and chest pain [4]. Among cholesterol screening and various other risk factors, Calcium Scoring or Cardiac Scoring predicts the coronary health issues more

effectively and efficiently than cholesterol screening or other risk factors. The heart attack risk increases tremendously when narrowing of arteries takes place due to the fat build up, deposition of calcium and other substances. The exact amount of these deposits are assessed and measured by a computed tomography (CT) scan of the heart termed as Coronary CT Calcium Scan, according to Mayo Foundation for Medical Education and Research. Research study [10] presents the Gender-wise percentiles of Coronary Artery Calcium Score as obtained by an electron beam tomography test, expressing high average calcium scores for both 60-75 years old men and women. Cardiovascular health issues and cardiac mortality are independently highlighted by the CAC score. The other prognostic information of the various risk indicators of cardiac health issues are presented by the CAC score [14]. A Radiocontrast need not be used in performing a Coronary CT Calcium Scan, whereas Coronary CT Angiography is performed using contrast-enhanced images [17]. Table 1 represents the Cardiac Calcium

Score	Presence of plaque	Recommendation/Comment
0	<input type="checkbox"/> Absence of plaque.	<input type="checkbox"/> Very low heart attack risk.
	<input type="checkbox"/> Less than 5% chance or probability of occurrence of heart disease.	
1-10	<input type="checkbox"/> Plaque present in a small amount.	<input type="checkbox"/> Low heart attack risk.
	<input type="checkbox"/> Less than 10% chance or probability of occurrence of heart disease.	<input type="checkbox"/> Healthy diet, physical exercise and quitting smoking are recommended.
11 – 100	<input type="checkbox"/> Plaque is present.	<input type="checkbox"/> Consult doctor for getting a healthy diet plan, physical exercise and quitting smoking and any other treatment you may need.
	<input type="checkbox"/> Mild heart disease.	
	<input type="checkbox"/> Moderate chance or probability of occurrence of heart disease.	
101 – 400	<input type="checkbox"/> Plaque present in moderate amount.	<input type="checkbox"/> Moderate to high heart attack risk.
	<input type="checkbox"/> Heart is diseased.	<input type="checkbox"/> There may be blocking of artery by plaque.
	<input type="checkbox"/> Moderate to high chance or likelihood of heart disease.	<input type="checkbox"/> More tests may be suggested by doctor to start proper treatment.
Over 400	<input type="checkbox"/> Plaque present in large amount.	<input type="checkbox"/> High heart attack risk.
	<input type="checkbox"/> Blocked artery	<input type="checkbox"/> More tests will be suggested by doctor
	<input type="checkbox"/> 90% chance or likelihood of heart disease.	<input type="checkbox"/> Proper treatment will be started.

Table 1: Cardiac Calcium Scoring Chart according to WebMD, 2007

Courtesy: Coronary Calcium Score (Heart scan): Scoring Range & What It Means, WebMD LLC, 2018

Scoring Chart expressing the corresponding amount of plaque present and the recommendations/comments for CVD. Our heart is scanned and heart's images are captured through Coronary Calcium Scan. Through this scan, Cardiologist identifies the deposition of the calcium in patient's coronary arteries. The calcium deposits narrow the arteries thereby increasing the risk of heart attack. This is presented in Fig. 1 which comprises of three images: A, B and C.

Image A: location of heart in human body is shown.

Image B: area or span of Coronary Calcium Scan image is displayed.

Image C: displays a Coronary Calcium Scan

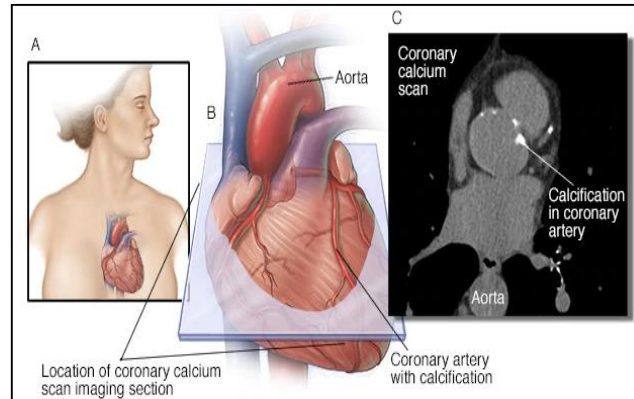


Fig. 1- Coronary Calcium Scan or Heart Scan

Courtesy: MAYO Foundation for Medical Education and Research (2019)

2 Related Work

The Researcher [16] in his paper has discussed and analyzed various big data techniques, methods and challenges regarding privacy issues. The Researcher [5] discusses the utilization of the Scientific Data Lifecycle Management (SDLM) model and Scientific Data Infrastructure (SDI) with various cloud services. The researcher [9] reviewed the deployment of data mining techniques in health informatics through big data. Scalable Noise mining is deployed by the Researcher [4] in Electrocardiographic (ECG) Time-Series (Long Term) for prediction of SCA and SCD. Heart attacks are predicted by the Researcher [12], using South African Medical Practitioners' database and deploying various Data Mining Techniques like Baye's Net, REPTREE, J48 and Naïve Bayes etc., Prediction of various hidden patterns present in the dataset is done using Data mining. A method to predict personal health index (PHI), is designed by the Researcher [3] named as MyPHI. The Researcher and medical practitioner [11] presented a Case Study showing reports that heart health problems are age-independent and can occur both in young and adults. The Researcher [6] performed Time-Frequency analysis of patient's HRV (High Rate Variability) data in the form of signal. Higher accuracy rate classification is achieved using Wigner Ville Transform. The Researcher [15] proposed the improvement of cardiac health and care of patients through big data analytics. He reviewed the benefits of Big data analytics and predictive modeling to improve and uplift cardiovascular care among the patients. The Researcher [1] proposed the salient role and importance of the usage of Big Data analytics to address cardiovascular health issues including occurrence of heart attack.

3 Experimentation Results

CT Coronary Angiography is performed on 64 slice scanner by injecting 80 ml of nonionic intravenous contrast at the rate of 5 ml/sec followed by 40 cc of normal saline bolus tracking at the rate of 5 ml/sec. The vascular pattern obtained of the patient can be right or left dominant. Some very important terms for calculating Coronary Calcium Score of the patient are: LAD (Left Anterior Descending Artery), LCX (Left Circumflex Artery), RCA (Right Coronary Artery), PDA (Posterior Descending Artery), PLV (Posterior Left Ventricular), OM (Obtuse Marginals (Generally OM1 and OM2 Branch))

Total or Overall Calcium Score is calculated by summing up of any one of the three (ie. LAD and LCX, RCA and LCX, LAD and RCA) applicable to different patients as per their CT Coronary Angiography report:

Regression analysis is performed on the patient's data. The regression statistics can easily predict and forecast the dependent variable for every known or given value of the independent variable [7]. It is proposed in our analysis that 'Calcium Score' is the dependent variable depending on the independent variable 'Age' i.e. **Calcium Score = f (Age)**, through Tables 2, 3 and 4, representing the Regression Statistics 1, Analysis of Variance statistics and Regression Statistics 2 respectively on patient's data.

Total number of random observations of the patients are 110(n) where the number of females is 34(n2) and the number of males is 76(n1). Degree of freedom (df) in our research experiment is 109. The equation achieved is: **Calcium Score = 4.86 (Age) – 182.75 (Eq. 1)** (refer Table 5). The threshold value of age in Eq. 1 is 37 years which means that up to 37 years, the calcium deposition in coronary arteries is approximately zero. So, there is very low heart attack risk (refer Table 1). Research finding expresses that:

a) Crossing age of 40 years- Calcium Score crosses 11 ensuring moderate chance of having heart attack.

b) Crossing age of 58 years- Calcium score crosses 100 ensuring moderate or high heart attack risk.

Fig. 2 shows that overall calcium scores start elevating to greater values when age crosses the value 35-40 years. The respective overall calcium score reaches 250-300 in the age interval of 45-60 years which seems to be very critical.

Table 5 displays the age interval wise ACS for overall observations (n=110). It shows the maximum average calcium score of 206.47 for the age-interval 61-75 years and 2nd minimum average calcium score of 6.5 for the age-interval 16-30. Minimum value of individual calcium score is 0 in almost all the categories except 0-15 age interval. The maximum values of the individual calcium score are 19.5, 39, 287.1, and 410.9 for the age intervals 16-30, 31-45, 46-60 and 61-75 respectively.

The Fig. 3(a), (b) show that the young adults between 16-30 years are having heart risk symptoms too. As the age enhances the average calcium score (ACS) shoots up except in the age shoots up to 45.306 and keeps on elevating till 75 years of age is reached. So, aging plays a vital role in getting heart attack risk. Therefore, preventive measures must be taken in early age in order to avoid future cardiac risks. Fig. 3(c) shows the majority of contribution of 79% of ACS comes from the age group of 61-75. 17% contribution towards average calcium score is from 46-60 years age group

Regression Statistics	
Multiple R	0.56
R Square	0.32
Adjusted R Square	0.31
Standard Error	84.55
Observations	110

Table 2: Regression Statistics 1

	Df	SS	MS	F	Significance F
Regression	1	359573.37	359573.37	50.30	1.44E-10
Residual	108	772031.91	7148.44		
Total	109	1131605.28			

Table 3: ANOVA (Analysis of variance) statistics

	Coefficient	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-182.75	34.39	5.31	5.81002E-07	-250.92	-114.59
Age	4.86	0.69	7.09	1.43829E-10	3.50	6.22

Table 4: Regression Statistics 2

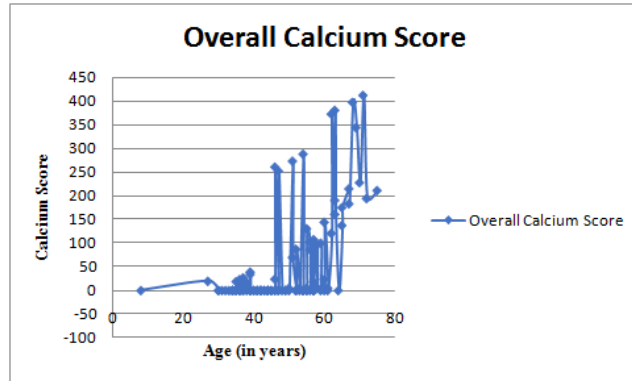


Fig. 2- Overall calcium score vs. age plot

Age Group Interval	Age Group (years)	No. of Patients	Average Calcium Score		
1	0-15	1	0	NA (Not Applicable)	
2	16-30	3	6.5	max= 19.5	min=0
3	31-45	42	3.769	max= 39	min=0
4	46-60	46	45.306	max= 287.1	min=0
5	61-75	18	206.47	max= 410.9	min=0

Table 5: Age interval-wise average calcium score (n=110)

It's a point of focus that young adults between the ages 16-30 years also contribute to 3% of ACS depicting the chances and rise of cardiac risks at such early age. Though the ACS of the age group 31-45 years is small i.e. 3.769 but the individual calcium score value is 39 falling into third range of Table 1 (11-100) ensuring the presence of plaque in the coronary arteries. And there is moderate chance or likelihood of having heart disease.

Tables 6.1 and 6.2 presents the age interval-wise average calcium score categorization into male and female. These tables display the age interval wise ACS for females ($n_1=34$) and males ($n_2=76$) respectively. From the tables it is observed that the ACS for both

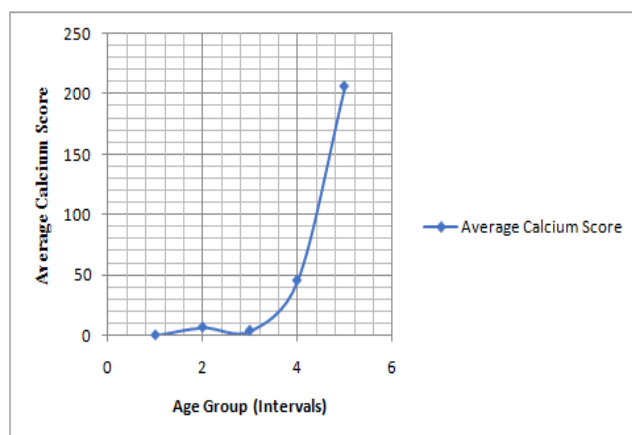


Fig. 3(a)- Average CAC score vs. age interval plot

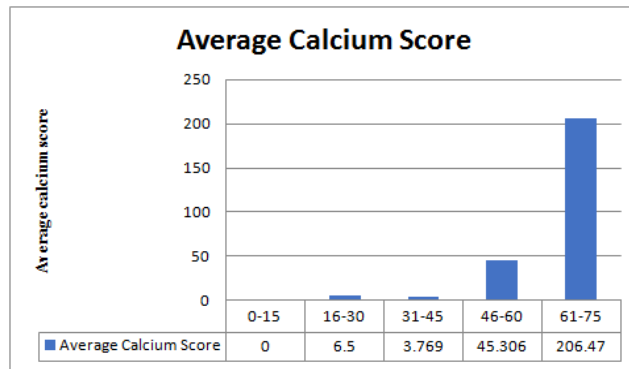


Fig. 3(b)- Average CAC score vs. age interval bar graph

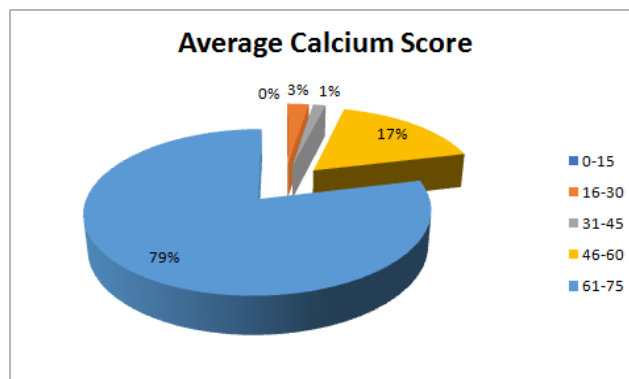


Fig. 3(c)- Contribution of various age groups to average CAC score

males and females is 0 in age group 0-15. In age group 2(16-30), ACS for males is 6.5 while that of females is 0 and in age group 3(31-45), it is 4.5 for males and 1.91 for females. Similarly, average CAC score is found to be 20.98 for males and 95.96 for females in age group 4(46-60). Lastly, in the age group 5(61-75), ACS for males is 268.19 and for females is 109.5.

Fig. 4(a) and (b) are calcium score vs. age plot for females and males respectively. It's overall visible that females are at low risk of cardiac issues than males.

Fig. 4(c) and (d) show the maximum average calcium score of males and females to be 268.19 and

Age Group	Age Interval (years)	No. of patients	Average Calcium Score		
1	0-15	0	0	NA	
2	16-30	0	0	NA	
3	31-45	12	1.91	max= 23	min=0
4	46-60	15	95.56	max= 287.1	min=0
5	61-75	7	109.5	max= 210.6	min=0

Table 6.1: Female Average Calcium Score (ACS) (n1=34)

Age Group	Age Interval (years)	No. of patients	Average Calcium Score		
1	0-15	1	0	NA	
2	16-30	3	6.5	max=19.5	min=0

3	31-45	30	4.51	max=39	min=0
4	46-60	31	20.98	max=143.8	min=0
5	61-75	11	268.19	max=410.9	min=0

Table 6.2: Male Average Calcium Score (ACS) (n2 = 76)

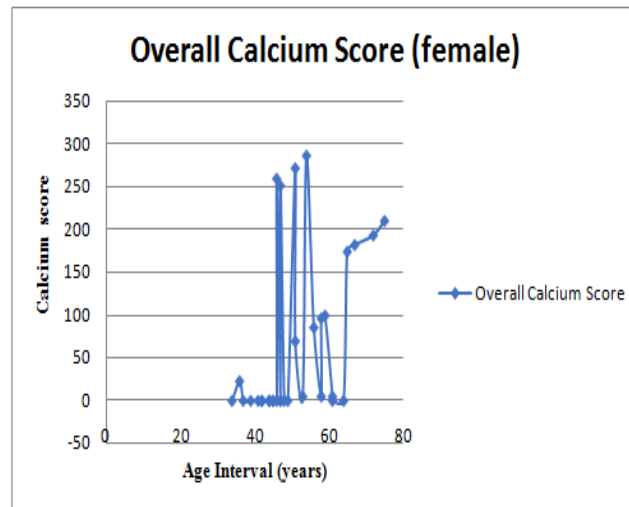


Fig. 4(a)- CAC score vs. age interval plot for females

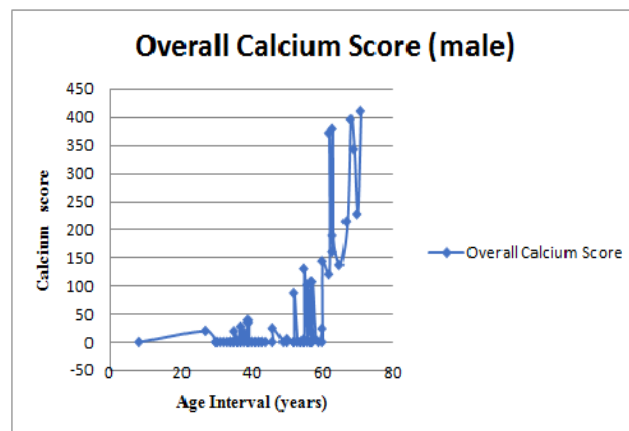


Fig. 4(b)- CAC score vs. age interval plot for males

109.5 respectively for the age-interval 61-75 years and 2nd maximum average calcium score of males and females to be 20.98 and 95.56 respectively for the age-interval 46-60 years. It is clearly visible that men are at

higher risk of heart disease after the age of 30. So, men have to consult a doctor for getting a healthy diet plan, physical exercise and quitting smoking, tobacco and alcohol etc. Lack of physical activity, lack of balanced diet is the major cause of cardiovascular health issues in both males and females.

Fig. 4(e) and (f) show the majority of contribution to ACS comes from the 61-75 years old men. 7% contribution towards average calcium score is from 46-60 years old men. It's a point of focus that the male young adults between the ages 16-30 years also contribute to 2% of total ACS, depicting the chances and rise of cardiac risks at such early age. In females, there is 1% contribution of women between 31-45 years of age, towards total ACS. The females of age group 46-60 years and 61-75 years contribute 46%

and 53% respectively, towards the total ACS. Therefore 61-75 years old men are more vulnerable than women of same age group towards cardiac arrest or cardiac deaths.

As is evident from our research findings, the number of male patients having serious ACS is significantly higher in most of the age-groups. Therefore, men seem to possess greater chances of developing a CVD/CAD.

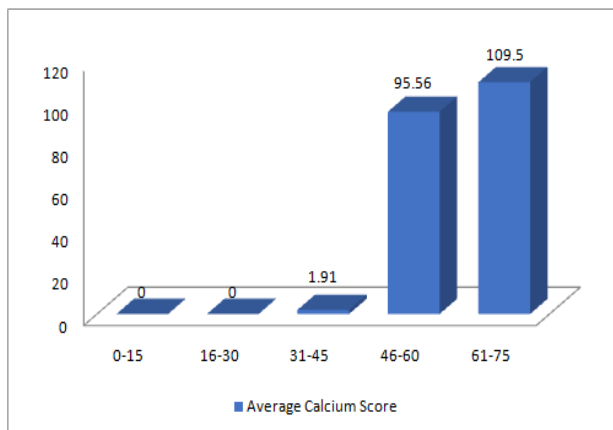


Fig. 4(c)- Distribution of average CAC score over various age intervals in females

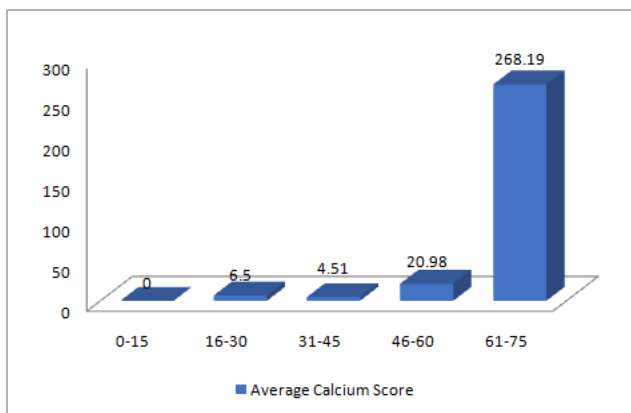


Fig. 4(d)- Distribution of average CAC score over various age intervals in males

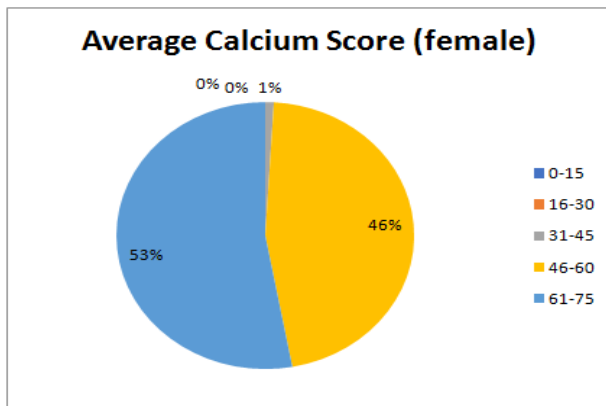


Fig. 4(e)- Female contribution towards the average CAC score (age interval-wise)

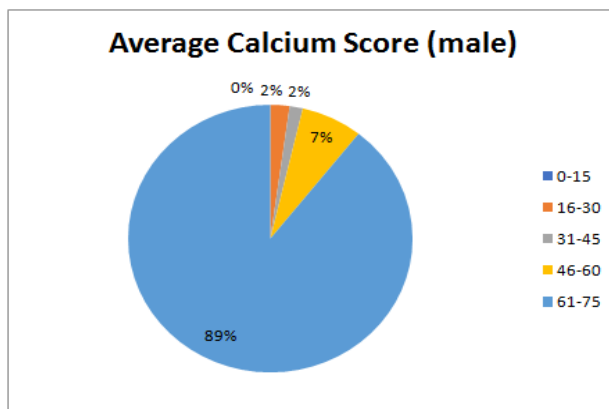


Fig. 4(f)- Male contribution towards the average CAC score (age interval-wise)

4 Conclusion And Future Scope

Cardiovascular disease (previously considered as old-aged problem) is severely affecting the young or old-aged individuals. We have identified and analyzed Calcium score being a good indicator can be used for predicting and forecasting CVD or health issues at much early stage. Women have low heart attack risk than men of same age. This research finding expresses that after 40 years of age, the Calcium Score crosses the value of 11 ensuring the presence of plaque and 10% or more chance (approximately) of having heart attack. Therefore, one must consult a doctor for getting a healthy diet plan, physical exercise and quitting smoking and any other treatment one may need (refer Table 1). It is predicted that the calcium score crosses 100 after the age of 58 years, ensuring moderate or high heart attack risk (upto 90% approximately). Therefore, physical activity, healthy diet, quitting smoking, avoiding alcohol and tobacco are highly recommended. Keeping track of one's calcium score, life style moderation and proper follow-up accordingly can increase the likelihood to predict and then help to avoid major cardiovascular issues at much early stage.

There is great potential towards generating a decision model which can automate the process of decision making through predictive analytics.

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