Early Cardiac Risk Prediction using Coronary Artery Calcium Score: A Comparative Study of Rural and Urban Genders in Northern India

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Abstract

The tremendous increase in Coronary Artery Disease (CAD) and Cardiovascular Diseases (CVD) is becoming the major cause of continuously reduced quality of current cardiac health. This research work presents the gender-based analysis of rural versus urban health to predict early cardiovascular health issues through Coronary Artery Calcium (CAC) Score of the patients across different age intervals. CAC score of the patients of Northern India are recorded randomly through Coronary Angiography (Computed Tomography (CT)), where female patients belonging to rural and urban areas are found in the ratio of 6:9 approximately, and male patients belonging to rural and urban areas are found in the ratio of 5:7 approximately. The paper conducts comparative analysis of the calcium scores of patients belonging to rural and urban regions, to predict CVD at early stage. The outcomes will surely impart awareness towards maintaining a healthy lifestyle in order to avoid severe cardiac ailments in future.

Keywords- Coronary Artery Disease, Calcium score, Cardiovascular Disease, Early Prediction, Rural vs. Urban Health, Coronary Angiography.

1.Introduction

In current scenario, severity of CVD, CAD and other cardiac ailments is increasing at an alarming rate. Research studies continuously and clearly express the fact that the current lifestyle is focused towards seeking more comfortable lifestyle rather than that, which involves physical hard work. People are risking their lives in the current situation, totally ignoring the importance of a healthy lifestyle, which involves physical work, daily exercising, avoiding the continuous consumption of alcohol, tobacco and unhealthy diet. United States is considered to be one of the most developed countries in the world. It is quite alarming that despite of having fully equipped with latest and modern technological and medical facilities, it is also being severely affected by Cardiac health issues including CVD and CAD etc., resulting to Sudden Cardiac Arrest (SCA) and Sudden Cardiac Death (SCD). About 6.7 % of the total population of United States of America i.e. Approximately 18.2 million adults having 20 years of age and more have developed Coronary Artery Disease. It spends about 219 billion US dollars every year on Heart Disease treatments, including medicines, healthcare facilities and medical services (Fryar et al., 2012).

In 2017, around 365914 persons died due to Coronary Heart Disease. Every 2 out of 10 deaths from CAD include the adults of 65 years of age or less (Benjamin et al., 2019). Heart diseases result to approximately one-fourth deaths in America. About 655,000 Americans lose their lives each year due to this severe disease (Virani et al., 2020). Cardiovascular disease or Heart disease is the major cause of deaths among the people belonging to most ethnic and racial groups in United States of America. In every 36 seconds, it approximately kills one person (Underlying Cause of Death, 1999–2020).

It is need of the hour to perform early diagnosis and prediction based on the medical reports analysis, lifestyle analysis, age-gender wise analysis, cardiac health key indicators-wise analysis etc. There are some medical-test based key indicators for the prediction of Cardiac Health of the individuals, mentioned like Coronary Artery Calcium (CAC) Score, Low-density lipoprotein cholesterol (LDL), High-density lipoprotein cholesterol HDL and Echocardiogram (ECHO), Electrophysiological Studies (EPS), Blood pressure monitoring, Specific Blood Tests,

Electrocardiogram (ECG or EKG), Computerized Tomography Scan (CT-Scan), Myocardial perfusion scans, Tilt table test etc. They are very beneficial for indicating the wellness of overall cardiac functioning and health. Also, there are some Human Characteristics and Habit-based Key indicators like Smoking and Tobacco consumption/intake, Physical inactivity, Lack of Physical Exercise, Comfortable/Lazy Lifestyle, Improper/Unhealthy Diet, Excessive consumption of junk/fast food, Improper Sleep and Stress leading to Hypertension and Anxiety, Busy daily schedule, activities and fast lifestyle, Lack of exposure to nature, Obesity, Alcohol consumption/intake, Family History of cardiac health issues etc.

This research work focuses on the Coronary Artery Calcium (CAC) Score, which is considered to predict CVD most effectively at much early/prior stage. Coronary Artery Calcium (CAC) score associates with a non-invasive system, in which the Computed Tomography (CT) scan of the heart is performed through an electron beam. When calcium gets deposited in the arteries, it is termed as calcification of the arteries, which leads to blockage in the heart, heart- palpitation, pain in back and chest. This calcium deposited in the arteries is recorded to a metric called as CAC Score or simply a Calcium Score. It effectively predicts Coronary Artery Disease (CAD) (Cardiac calcium scoring (Heart scan), n.d.). If CAC score gives an abnormal reading, a cardiac expert should urgently be consulted viz. WebMD presents Calcium Score table representing high values of Calcium Score among males and females belonging to the age interval of 60-75 years (Coronary Calcium Score (Heart scan): Scoring Range & What It Means, 2016).

This research work presents the gender-based analysis of rural versus urban health to predict early cardiovascular health issues through Coronary Artery Calcium (CAC) Score of the patients across different age intervals.

2. Related Work

The research work proved that the trends in the health characteristics are related to the CVH (Cardiovascular Health) in Poland on the adult population. It also depends on the factors like physical activities performed, healthy diet, amount of smoking, diabetes etc (Nowicki et al., 2018). The research work (Bijukshe & Radha, 2018) concluded that there are higher CVD risk

factors in the people of urban areas in compared to rural population. In urban area people, insufficient vegetables and fruits intake, overweight and hypertension found and in rural areas use of smoking and alcohol consumption was found among people. In both urban and rural area male the consumption of alcohol and smoking was found.

In the study of rural and urban population, it was found that the risk factors were less likely controlled in rural areas when compared with urban areas. The residents of rural areas found to be with the rate of stroke and death also after risk factors adjustment. The actions that should be taken in future should also focus on other factors of health in rural areas (Kapral et al., 2019). Based on the study of heart failure patients of rural and urban areas, after diagnosis the urban patients receive more care and there are fewer chances for them to be hospitalized again in the first year after diagnosis when compared to the heart failure patients of rural areas (Gamble et al., 2011). The research work describes the changes in the health factors and health behavior between 1998 to 2008. By reviewing the data, if the future targets are calculated according to current trends then the improvement of overall cardiovascular will be only about 6% from 2006 to 2020. These trends include the effect of high cholesterol, high blood pressure, tobacco consumption etc (Huffman et al., 2020). Every year, the American Heart Association (AHA), in partnership with the National Institutes of Health (NIH), publishes the latest statistics concerning heart disease, stroke, and cardiovascular risk elements. This includes essential health behaviors such as smoking, exercise, diet, sleep, and obesity, as well as health indicators like cholesterol levels, blood pressure, glucose regulation, and metabolic syndrome, all of which play a role in cardiovascular wellness (Martin et al., 2025).

Based on the outcomes of the researchers work, the motive behind CVD (Cardiovascular Disease) prevention is to identify the factors and their treatment. A trial on active smokers, who want to quit smoking, was performed. It was found that the counseling with non –nicotine e-cigarettes was more effective when compared to other ways of counseling (Jia et al., 2020). By the research data, it has been proved that the polygenic score of CAD (Coronary Artery Disease) at all levels depends on the lifetime exposure of SBP (Systolic Blood Pressure) and LDL (Low Density Lipoproteins). A PGS (Polygenic Scores) for CAD has the capacity to adjust the prevention of cardiovascular disease by identifying the persons can get benefits from

the early interventions to decrease effects of lifetime exposure to LDL and SBP (Ference et al., 2019). The team of researchers analyzed 2 cohorts United States adults. The polygenic score of those adults was associated with coronary heart disease. In addition, they did not much improved risk reclassification, discrimination, calibration when it was compared with other predictors. The research data also indicates that in middle-aged persons the polygenic risk score may not contribute in risk prediction (Mosley et al., 2020).

Healthcare is associated with a huge collection of data. Data mining techniques that can efficiently handle and process such data to get useful trends. In the current scenario, heart disease is witnessed to be the the major cause of deaths (Gavhane et al., 2018). The study (Li et al., 2025) focuses to utilize the integration of Internet of Things and artificial intelligence methods to develop a model for detecting cardiac diseases. This research work (Souza et al., 2024) introduces a preprocessing method that utilizes area under the curve (AUC) filters, enhancing the algorithms' efficiency by reducing the number of parameters. This results in improved memory utilization and computational performance. The researchers (Sadar et al., 2023) present a comprehensive review of different classification methods including Machine Learning, Feature Selection, Hybrid, Ensemble, and Deep Learning that have been utilized by researchers over the past ten years for predicting Heart Disease. An intelligent framework is proposed by the researchers (Vincent Paul et al., 2022) using Deep Learning for the Heart Disease Prediction. In order to enhance classification accuracy, the research study (Thakre et al., 2021) introduces an Automated Support Vector Machine (ASVM) model for classification tasks. The ASVM model employs data mining techniques for processing and classifying data within the network. The results from the experimental analysis indicate that the ASVM model demonstrates superior classification performance compared to currently existing classifier models.

3.Proposed Work

Medical tests results of the patients are recorded and collected from clinicians, medical practitioners, diagnostic labs and medical research laboratories etc. in order to perform a deep analysis. Medical tests may include CVD Test reports of ECG, LDL, HDL, Test reports of

Cholesterol, CT-Scan and Coronary Calcium score of patients. But our primary focus is to collect relevant CAC score data of the patients. These CT scan reports along with the CAC score reports will be used as a basis of comparative analysis and prediction. The collected data from the real time patients is to be converted to proper numeric values in order to perform appropriate analysis.

Patients' identities will be preserved by all the researchers following all research ethics. It will not be disclosed by any medium at all. All the medical reports and tests results, provided to the researchers are strictly bounded by the rules and regulations of the medical institutions.

The experiment is performed on the patient with the following medical technicalities

- Coronary Angiography test is performed.

- 64-Slice scanner is used for Coronary Angiography.

- Volume of the Nonionic intravenous contrast is 80 mL

- Rate of intravenous injection process is 5 mL/sec.

- After that, tracking of 40 cc of normal saline bolus, with 5 mL/sec rate is conducted.

The Coronary Artery Calcium Score directly depends on the following parameters and can be calculated as their summation wherever provided by the report:

- RCA (Right Coronary Artery)

- LAD (Left Anterior Descending Artery)

- PLV (Posterior Left Ventricular)

- OM (Obtuse Marginal) - Generally OM1 and OM2 (Branch)

- PDA Posterior Descending Artery)

- LCX (Left Circumflex Artery)

'CS' denotes the Calcium Score of the patient and 'P' denotes the probability of developing a heart disease, then WebMD expresses the following reference ranges for CS:

- If CS is zero, then the approximate value of P is 0.05 - It indicates very low probability of a diseased heart.
- If CS lies between 1 and 10, then P is less than 0.1 - It indicates less than 10% probability of a diseased heart.
- If CS lies between 11 and 100, then P is having a mild value – it indicates the initiation of blocked artery with plaque's presence.
- If CS lies between 101 and 400, then P lies between Moderate and High.
- If CS is greater than 400, then P is 0.9 - It indicates an alarming condition due to confirmed blocked artery, which further signifies a very high heart-attack risk.

4. Experimental Results and discussion

Coronary Artery Calcium (CAC) Score data of the patients through CT Coronary Angiography is analyzed, and it has been observed that Calcium Score depends on age. Hence the relationship established between them as CAC Score = f (Age) i.e. Calcium score is a function of age. As the age changes, it also changes mostly in all age groups. When the calcium score crosses the value of 10, the chances of developing CVD is likely to increase and it is a clear indicator of start of plaque building up in the arteries, which will result to various cardiac ailments in coming years. As per Table 1 and 2, a total of 225 patients (N=225) were included during this research. Approximately 31.6 % (N_f =71) were female and 68.4 % (N_m =154) were male. The degree of freedom in our research experimentation is 224 (N-1). Among females, 28 patients belong to Rural Area (R_f =28) and 43 patients belong to urban area (U_f = 43). Whereas, 65 patients belong to rural area (R_m =65) and 89 patients belong to urban area (U_m = 89), among males.

- **Total Patients**- N=225
- **No. of female patients**- N_f =71
- **No. of male Patients**- N_m =154
- **Ratio ($N_f : N_m$)** = 6:13
- **Total Rural female patients-**R_f=28,   (39.43 % females are rural residents)

- **Total Urban female patients-**U_f=43, (60.57 % females are urban residents)
- **Ratio (R_f: U_f)** = 6:9
- **Total Rural male patients**- R_m =28, (42.2 % males are rural residents)
- **Total Urban male patients**- U_m=43, (57.8 % males are urban residents)
- **Ratio (R_m : U_m)** = 5:7

CAC score (Calcium Score) data has been categorized into five age groups i.e. 1, 2, 3, 4 and 5, each corresponding to its age-interval range of 0-15, 16-30, 31-45, 46-60 and 61-75 years respectively. Table 1 and Table 2 represent Average Calcium Score (ACS) among rural and urban female patients across different age intervals, where 'NA' symbolizes Not Applicable case.

Table 1- Average Calcium Score (ACS) among rural females (R_f = 28)

| Age Group	Age Interval (years)	No. of patients	Average Calcium Score	Max. Calcium Score	Min. Calcium Score
1	0-15	0	0	NA	NA
2	16-30	2	0	0	0
3	31-45	9	17.48	82.4	0
4	46-60	9	56.2	252	0
5	61-75	8	108.88	210.6	38

Table 2- Average Calcium Score (ACS) among urban females (U_f = 43)

Age Group	Age Interval (years)	No. of patients	Average Calcium Score	Max. Calcium Score	Min. Calcium Score
1	0-15	0	0	NA	NA
2	16-30	3	4.33	8	0
3	31-45	16	24.86	98.2	0
4	46-60	19	142.31	291.2	0

5	61-75	5	153.66	215.8	88

Table 1 and 2 displays that, in age group 0-15, the ACS for both Rural and urban females are 0. ACS for Rural and urban females in age group 16-30 is 0 and 4.33 respectively. ACS for Rural and urban females is 17.48 and 24.86 respectively, in age group 31-45. Similarly, the ACS is 56.2 for rural females and 142.31 for urban females, in age group 46-60. Finally, in the age group 61-75, ACS for rural women shoots up to 108.88 and for urban females it swiftly reaches 153.66. These results overall reveals that urban females are at higher risk of developing a CVD (Cardiovascular Disease) than rural ones.

Figure 2(a) and **2(b)** displays Overall calcium score (OCS) vs. age plot in rural and urban females respectively. It is clearly visible that OCS in rural females is lesser than those of urban females. Among rural and urban females, the age group 46-60 years and 61-75 years is most vulnerable towards CVD. Therefore, it can be stated again that urban females are at comparatively higher risk of cardiac issues than rural females.
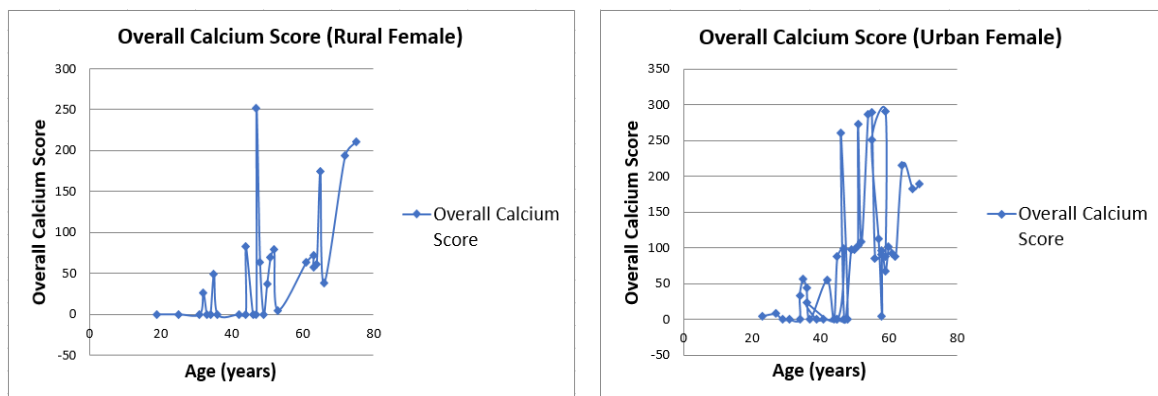

Figure 2 (a) -Overall calcium score vs. age plot in rural females

Figure 2 (b) -Overall calcium score vs. age plot in urban females

Figure 2(c) displays Age interval-wise Rural vs. Urban female ACS curve. It depicts that the slope of the urban female ACS curve is quite comparable to that of rural females up to the age of 30 years. This means at lower age intervals viz. 0-15 and 16-30 years there is gradual increase in ACS with respect to age. But as the age increases ACS

curve slope increases swiftly and the average calcium score of the female urban residents shoots up tremendously as compared to that of female rural residents (significantly after the 3rd age interval i.e. 31-45 years).
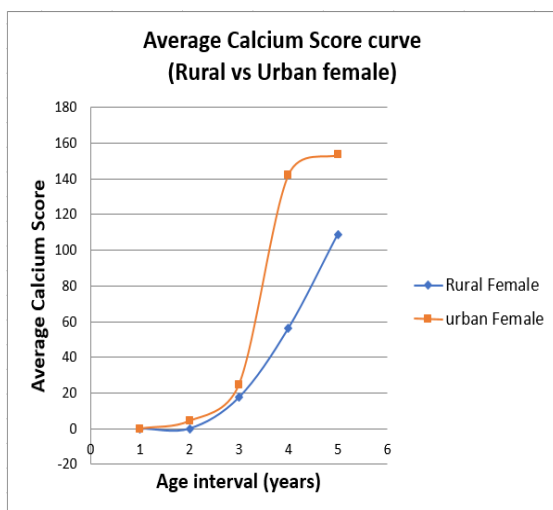
Figure 2(c) - Age interval wise rural vs. urban female average calcium score
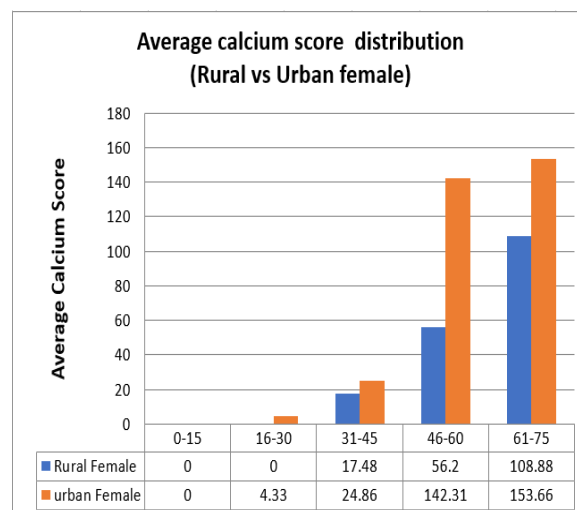
Figure 2(d) - Comparative Distribution of Age interval wise rural vs. urban female average calcium score

Figure 2(d) shows the comparative distribution of age interval wise Rural vs. Urban female average calcium score. The maximum average calcium score of rural and urban females are found to be 108.88 and 153.66 respectively. The 2nd maximum average calcium score of rural and urban females are found to be 56.2 and 142.31 respectively. Similarly, average calcium score of urban females possess a higher value in lower age groups too (viz. 16-30, 31-45 years). These results clearly express that female urban residents are more likely to get affected by cardiovascular ailments across all age-groups, severely risking their lives.

Table 3 and Table 4 represent Average Calcium Score (ACS) among rural and urban male patients across different age intervals. It displays that, in age group 0-15, the ACS for Rural and urban males are 0 and 2.5 respectively. ACS for Rural and urban males

in age group 16-30 is 6.875 and 12.33 respectively. ACS for Rural and urban males is 10.58 and 8.61 respectively, in age group 31-45. Similarly, the ACS is 12.39 for rural males and 34.75 for urban males, in age group 46-60. Finally, in the age group 61-75, ACS for rural men shoots up to 260.29 and for urban women, it swiftly reaches 307.1. This overall result reveals that both the rural and urban males (60 years of age or more) are at highest risk of developing a CVD (Cardiovascular Disease) than rural ones.

**Table 3-** Average Calcium Score (ACS) among rural males ($R_m = 65$)

Age Group	Age Interval (years)	No. of patients	Average Calcium Score	Max. Calcium Score	Min. Calcium Score
1	0-15	1	0	0	0
2	16-30	4	6.875	0	19.5
3	31-45	22	10.58	61.2	0
4	46-60	27	12.39	107	0
5	61-75	11	260.29	372.5	110.1

Table 4- Average Calcium Score (ACS) among urban males ($U_m = 89$)

Age Group	Age Interval (years)	No. of patients	Average Calcium Score	Max. Calcium Score	Min. Calcium Score
1	0-15	2	2.5	5	0
2	16-30	6	12.33	27	0
3	31-45	28	8.61	43.4	0
4	46-60	36	34.75	151.3	0
5	61-75	17	307.1	433.2	120.5

Figure 3(a) and **3(b)** displays Overall calcium score (OCS) vs. age plot in rural and urban males respectively. It is clearly visible that OCS in rural males is lesser than those of urban males. Among rural and urban males, the age group 46-60 years and 61-75

years is most vulnerable towards CVD. Therefore, it can be stated again that urban males are at comparatively higher risk of cardiac issues than rural males.
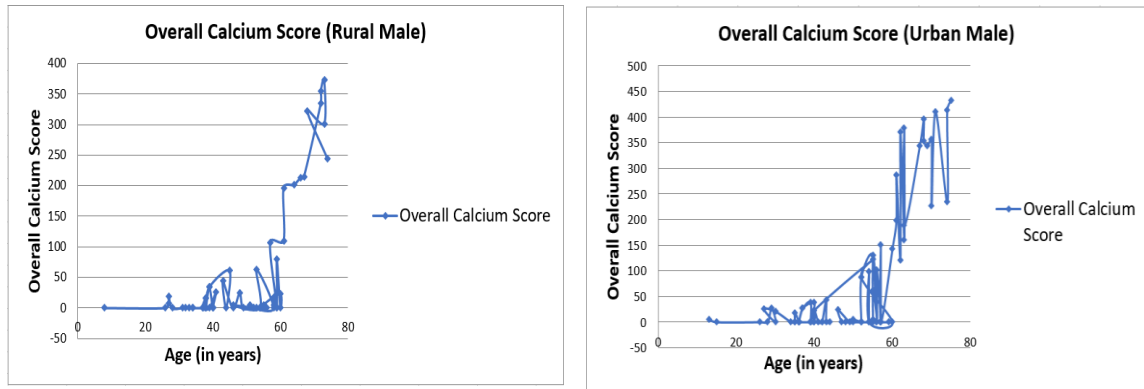
Figure 3 (a)-Overall calcium score vs. age plot in rural males

Figure 3 (b)-Overall calcium score vs. age plot in urban males

Figure 3(c) displays Age interval-wise Rural vs Urban male ACS curve. It depicts that the slope of the urban male ACS curve is quite comparable to that of rural males up to the age of 45 years. This means at lower age intervals viz. 0-15, 16-30 and 31-45 years, there is gradual increase in ACS for both rural and urban males with respect to age. But after the age of 45 years, the slope of ACS curve start to increase and the average calcium score of the both rural and urban male residents shoots up tremendously as compared to that of female rural residents (significantly after the 4th age interval i.e. 46-60 years).
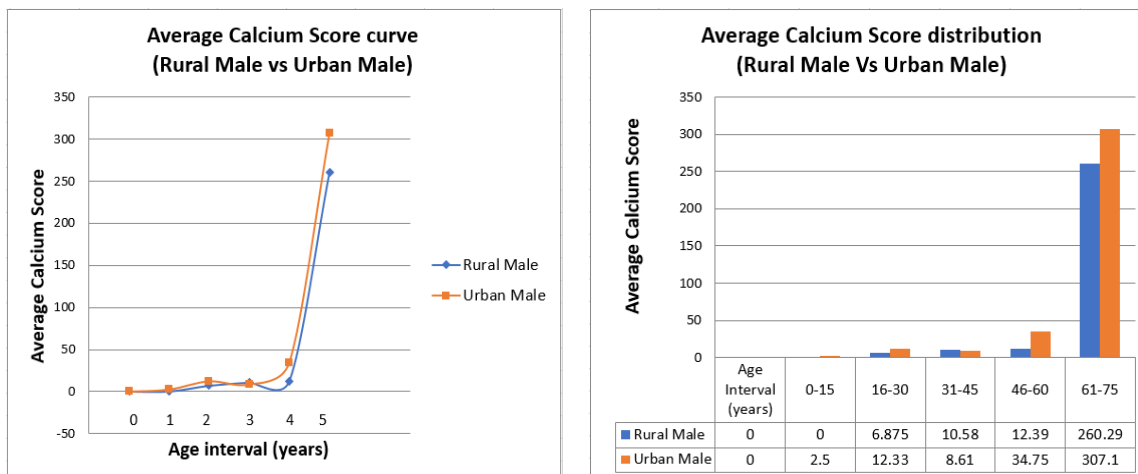
Figure 3(c) - Age interval wise Rural vs. Urban male average calcium score

Figure 3(d) - Comparative Distribution of Age interval wise rural vs. urban male average calcium score

Figure 3(d) shows the comparative distribution of age interval wise Rural vs. Urban male average calcium score. The maximum average calcium score of rural and urban males are found to be 260.29 and 307.1 respectively. The 2nd maximum average calcium score of rural and urban males are found to be 12.39 and 34.75 respectively (significantly very low as compared to corresponding rural and urban females). Similarly, average calcium score of urban males possess lesser value in lower age groups too (viz. 0-15, 16-30, and 31-45 years). These results clearly express that both rural and urban older residents (60 years or more) are significantly more vulnerable towards cardiovascular ailments across all age-groups.

5. Conclusion and Future Scope

Among all the patients recorded randomly in Northern India, overall females and males affected by cardiac ailments are 31.6 % and 68.4 % respectively. Therefore, women are less affected to cardiac health issues than men. All research findings clearly indicate that urban residents appear to be more vulnerable to cardiac ailments than rural residents. The urban cardiac health status is more severe than the rural one. The research also presents that at lower age intervals up to 30

years there is gradual increase in ACS with respect to age. The average calcium score of the female urban residents shoots up tremendously with age as compared to that of female rural residents (significantly after 40-45 years). But, through proper follow-up, keeping track of CAC score, lifestyle moderation, consuming healthy diet full of vegetables, fruits and other nutritious items instead of alcohol or tobacco intake, physical exercise etc. the individuals can significantly improve the cardiac health and avoid the severity of CVD and CAD at an early stage.

The research outcomes express that the urban population is at a higher risk for CVD than rural population. The most affected age groups by heart diseases among the Rural and urban females are 46-60 and 61-75 years and that of males is 61-75 years. Females are less vulnerable than males of same age-group, towards CVD risk. The research outcomes evidently express that the Coronary Artery Calcium (CAC) has great potential to predict cardiac issue at much early stages providing great scope to researchers for early prediction of Sudden Cardiac Death (SCD) and Sudden Cardiac Arrest (SCA) etc. Various data mining techniques can be deployed along with leading health indicators like CAC score of the patients to predict CVD at much prior stage.

Conflict of Interest

The authors confirm that there is no conflict of interest to declare for this publication.

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