# Effects Of Smoking On Cardiovascular Function During Maximal Treadmill Exercise

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*Abstract:*
*Background: Smoking is a major risk factor for cardiovascular morbidity and mortality. It deregulates cardiac autonomic function, blunts the chronotropic responses during exercise and lowers the maximum heart rate that can be achieved, substantially reducing the functional capacity and performance of the circulatory system. The aim of the study is to compare the cardiovascular functionamong smokers and nonsmokers during maximal exercise stress testing using TMT*
*Methods:A case control study was carried out on 90 young asymptomatic male first degree relatives of myocardial infarction patients attending Medicine and Cardiology department of GRMC Gwalior comprising of 60 smokers as cases and 30 nonsmokers as controls. Chronotropic response by heart rate at rest, maximum heart rate attained, heart rate reserve, chronotropic index, heart rate recovery at 1 minute and exercise capacity by maximal exercise duration was compared between smokers and nonsmokers. The results were analysed with t test for continuous variables and $\chi2$ test for categorical variables.*
*Results: Smokers had a higher heart rate at rest than nonsmokers(p<.05) while there is a negative relationship to maximum heart rate attained (p<.05), heart rate reserve (p<.05) chronotropic index (p<.05) and exercise duration (p<.05) and with increasing burden of smoking this relationship becomes stronger. No significant difference in heart rate recovery was observed between smokers and nonsmokers.*
*Conclusion: Cardiovascular prognosis as estimated by hemodynamic parameters like heart rate at rest, maximum heart rate attained, heart rate reserve, chronotropic index and exercise duration is poor in smokers compared to nonsmokers and the adverse effects become stronger with increase in severity of smoking.*
*Key Words: chronotropic index, exercise testing, exercise duration, heart rate, smoking*

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## I. Introduction

Cardiovascular disease (CVD) is now the most common cause of death worldwide.Before 1900, infectious diseases and malnutrition were the most common causes, and CVD was responsible for less than 10% of all deaths[1]. Over the past decade,cardiovascular disease has emerged as the single most important cause of death worldwide[2].

Smoking is a major risk factor for cardiovascular morbidity and mortality and is the leading preventable cause of death in the world.Smoking is estimated to cause nearly 10 per cent of cardiovascular disease and is the second leading cause of CVD, after high blood pressure[3].The odds ratio (OR) for acute MI in smokers was 2.95 compared with lifetime nonsmokers.If current smoking patterns continue, the global burden of disease attributable to tobacco will reach 10 million deaths by 2030.

The general mechanisms by which smoking results in cardiovascular events include development of atherosclerotic changes with narrowing of the vascular lumen,development of atherosclerotic plaque[4]and induction of a hypercoagulable state.Beyond its status as an independent risk factor smoking influences other cardiovascular risk factors, such as glucose intolerance and low serum levels of high-density lipoprotein cholesterol (HDLc)Cigarette smoke contains more than 4000 chemical substances that have harmful effects on cardiovascular function[5].These include nicotine, carbon monoxide (CO), oxidative gases, polycyclic aromatic hydrocarbons, carbonyls, butadiene, minerals, carbon disulphide, and benzene.Three constituents of cigarette smoke have received the greatest attention as potential contributors to CVD:nicotine[6], carbon monoxide (CO), and oxidant gases.

Exercise electrocardiographic testing is one of the most important and valuable noninvasive diagnostic tests in the clinical evaluation and management of patients with suspected or known cardiovascular disease particularly coronary artery disease. The exercise stress ECG test is also very useful tool as a screening procedure for healthy individuals who are considered to be at possible risk of coronary artery disease.The stress-

induced markers of ischemia used in diagnosis—ST-segment depression and angina—have prognostic value as well, but other variables are more powerful predictors of outcome. They are resting heart rate, chronotropic response, heart rate recovery, exercise duration and ventricular ectopy. Variables measured during exercise treadmill testing that predict outcome are actually indicators of general fitness and function of the autonomic nervous system.

The purpose of this study was to determine whether smoking altered these variables.The comparison of cardiovascular responses between apparently healthy, young adult smokers and nonsmokers was done during treadmill exercise.

## II.  METHODS

### 2.1Design

A cross sectional study was conducted over a period from January 2016 to August 2017 on young asymptomatic first degree relatives of myocardial infarction patients attending Medicine and Cardiology department of GRMC Gwalior.A total of 90 subjects, 60 cases and 30 controls were included in the study.

### 2.2Participants

All subjects were first degree relatives of myocardial infarction patients less than 45 years of age with no history of diabetes, hypertension, dyslipidemia, CAD and were not obese. Cases were smokers with more than 5 years of smoking and controls were nonsmokers.

### 2.3Exercise treadmill testing

Participants underwent a maximal symptom limited treadmill test according to Bruce protocol. Heart rate and blood pressure were measured, and a 12-lead ECG was recordedbefore exercise, at the end of each exercise stage, at peak exercise and at 1-minute intervals during recovery, with continuous heart rate and rhythm monitoring throughout the duration of the stress test. The test was discontinued for limiting symptoms (angina, dyspnea, fatigue)abnormalities of rhythm or blood pressure, or marked and progressive ST-segment deviation or attainment of target heartrate.Measures of chronotropic response included the following:

- peak HR achieved with maximal exercise stress testing expressed as a percentage of age predicted maximum heart rate where age-predicted $HR_{max}$=220–age
- HR reserve HRR= HRpeak–HRrest
- ability to achieve >85% age-predicted HR
- chronotropic index

Chronotropic index takes into account age, physical fitness (exercise capacity), and resting HR. The chronotropic index is the ratio of the heart rate reserve (HRR) to the metabolic reserve (MR) used at peak exercise

For the usual application, the following formula defines the chronotropic index:

[(HRmax −HR rest)×100] [(220 − Age)−HR rest]

Failure to achieve a chronotropic index higher than 80% defines the presence of chronotropic incompetence.

Exercise capacity is assessed by maximal exercise duration.

### 2.4Statistics

Continuous variables were expressed as mean ± SD. Categorical variables were expressed as numbers and percentages. Statistical analysis was done using $\chi^2$ test and't' test and "p" value<0.05 was accepted as indicating statistical significance, p<.001 as highly significant.

Variables were compared between smokers and nonsmokers, andamong smokers based on pack years

Light smokers<9 pack years, moderate 10-19 pack years and heavy ≥20 pack years

## III. Results

Sixty asymptomatic young first degree relatives of MI patients who smoked for more than 5 years were subjected to symptom limited maximal exercise testing and was compared with 30 nonsmokers serving as the controlMajority of the study population belonged to 35- 44 year age group ie 57% of smokers and 66% of nonsmokers.Maximum smokers (75%) smoked 10-19 cigarettes or bidis per day, average of 7 to 13 per day.They have been smoking for around 12 to 22 years with 43% for 11 to 20 years and 37% for more than 20 years.Table 1 shows the distribution of smokers according to the number of pack years.The average smoking burden of the study population is 9.49±4.96 pack years with only 5% with ≥20 pack years.

Heart rate at restin smokers is more than that in nonsmokers(p=0.03).Heart rate at rest of heavy and moderate smokers is more than that of nonsmokers (p<.05).

Smokers attained lesser age predicted maximum heartrate compared to nonsmokers(p=.03) and heavy and moderate smokers attained lesser than mild smokers (p<.05).Only 43.3% of smokers could achieve >85% of

age predicted maximum heart rate compared to 70% of nonsmokers (p=.03).56.6% of smokers couldn't attain more than 85% of age predicted maximum heartrate. OR =3.05

Nonsmokers have a higher heart rate reserve than smokers (p=0.007)and mild smokers higher than moderate to heavy smokers.(p<.05).

80% of smokers had chronotropic incompetence while 60% nonsmokers also had chronotropic incompetence. OR=2.6  (p=.04)

This study showed no statistically significant difference in heart rate recovery in 1 minute between smokers and nonsmokers.

Nonsmokers could exercise for longer duration than smokers(p=.03) .Exercise duration of light smokers is longer than that of moderate and heavy smokers(p<.05).Only 19 out of 60 ie 31.6% of smokers could exercise to more than stage 4 compared to 56.6 % of nonsmokers. $\chi2 = 8.85$, p = 0.06(Table 4)

**Table 1:** Distribution of smokers according to number of pack years

| Pack years | No. of cases | % |
|---|---|---|
| 0-9 | 26 | 43 |
| 10-19 | 31 | 52 |
| > 20 | 3 | 5 |
| Total | 60 | |

**Table 2:** Comparison of exercise testing variables between smokers and nonsmokers

| | Smokers | Nonsmokers | p |
|---|---|---|---|
| Resting Heart Rate (bpm) | 92.13±8.83 | 87.53±7.23 | 0.03 |
| Percentage of maximum heart rate | 85±8.96 | 88±7.59 | 0.03 |
| Heart Rate reserve | 67.04±19 | 74.56±17.08 | 0.007 |
| Heart rate recovery in 1 minute | 27.53±10.19 | 29±6.4 | 0.47 |
| Exercise duration | 10.20±2.97 | 11.59±2.49 | 0.03 |

**Table 3:** Comparison of exercise testing variables between light moderate and heavy smokers

| Pack years | Smokers | | |
|---|---|---|---|
| | 1-9 (n=26) | 10-19(n=31) | > 20(n=3) |
| Resting Heart rate | 91.84±8.74 | 92.25±8.64 | 93.33±15.01 |
| Percentage of maximum heart rate | 87.80±7.89 | 80.51±9.41 | 82.66±8.73 |
| Heart Rate reserve | 74.30±12.99 | 54.77±19.43 | 55.66±0.57 |
| Exercise duration | 11.51±2.89 | 9.39±2.69 | 7.16±0.85 |

**Table 4:** Comparison of smokers and nonsmokers that attained different stages of TMT

| Stage of TMT | Smokers | | Non smokers | |
|---|---|---|---|---|
| | No. | % | No. | % |
| 1 | 0 | 0 | 0 | 0 |
| 2 | 2 | 3.33 | 1 | 3.33 |
| 3 | 23 | 38.33 | 4 | 13.33 |
| 4 | 16 | 26.66 | 8 | 26.66 |
| 5 | 11 | 18.33 | 13 | 43.33 |
| 6 | 8 | 13.33 | 4 | 13.33 |
| 7 | 0 | 0 | 0 | 0 |

## IV. Discussion

The results from our analysis indicate that smoking is negatively related to cardiovascular fitness as estimated by the heart rate responses to exercise and exercise duration.

### 4.1Resting Heart Rate

The resting heart rateis more in smokers. This finding is in line with data reported by Papathanasiou et al[7]  Minami et al[8]Yoshio Kobayashi et al[9].The effect of nicotine probably contributed to the significantly higher resting HR in smokers (Klausen et al,(1983)Turner and McNicol (1993) Smoking is associated with selective alterations in cardiac autonomic control.Smoking, acting at peripheral sympathetic sites, increases circulating levels of catecholamines,augments sympathetic outflow, and causes a long-term reduction in vagal drive.[10,11]This sympathetic predominance, seen even in young heavy smokers is also associated with impaired baroreflex function leading to a marked increase in heart at rest.Elevated resting heart rate is an independent risk factor for cardiovascular disease in healthy men and women[12]

**4.2Chronotropic Response**
**HRmax**

Smokers could attain only average 85% of age predicted maximum heart rate while nonsmokers attained an average of 88%.(p<.05) Smokers that could attain peak heart rate of >85% of the age predicted maximum heart rate is only 43.3% compared to 70% (p<.05).Of the 43 persons that couldn't achieve the target heart rate 79% were smokers.

HRreserve=HRpeak-HRrest

Smokers had a lesser heart rate reserve which decreased with increase in smoking burden.

Chronotropic index

80% of smokers had chronotropic incompetence ie chronotropic index less than 80% as compared to 60% of nonsmokers.p=.04

Claire M. Bernaards[13] et al stated that a negative longitudinal relationship was found between moderate to heavy smoking and HRmax.Asha Asthana et al[14] had also found that heavier smokers had lower peak HR increase (p< .05), and HR reserve (p<.01).The CARDIA[15] study reported that the mean maximum heart rate was lower in smokers than in nonsmokers although maximum rating of perceived exertion was nearly identical in smokers and nonsmokers. Chronic smoking appears to blunt the heart rate response to exercise, so that exercise duration to submaximal heart rates is increased even though maximal performance is impaired.Lauer MS et al[16] the Framingham Offspring Study reported that smokers were more likely to fail to reach target heart rate than were nonsmokers.Men who were smokers and failed to achieve target heart rate were at particularly high risk for death.Martin Unverdorben et al reported that chronotropic response / heartrate recovery were more pronounced in nonsmokers than in smokers

An impaired heart rate response to exercise and failure to reach >80% of the age-predicted HRmax, known as chronotropic incompetence are associated with autonomic imbalance and are important prognostic markers of cardiovascular healthMyers J et al[17] reported that both heart rate recovery and chronotropic incompetence were stronger predictors of risk than pretest clinical data and traditional risk markers. Multivariately, chronotropic incompetence was similar to the Duke Treadmill Score for predicting cardiovascular mortality, and was a stronger predictor than heart rate recovery.Savonen KP et al[18]found that a blunted HR increase at 40-100% of maximal workload was associated with increased CVD mortality.Sandvik L et al [19]found that both heart-rate difference and maximal exercise-induced heart rate were strong, graded, long-term predictors of cardiovascular mortality among apparently healthy middle-aged men, independent of age, physical fitness and conventional coronary risk factors.

**Heart Rate Recovery**

In this study no significant difference in HR recovery was observed between smokers and nonsmokers.

In many epidemiological HR-related studies in healthy middle-aged populations, smoking was inversely associated with HR decline during recovery.Kobayashi et alhad found that return of heart rate to resting levels after exercise was slower in chronic smokers.Asha Asthana **et** al reported that HR recovery was correlated inversely with smoking burden.But in multivariate analysis no significant independent association has been found.Attenuated HR decline during recovery is an important surrogate for underlying autonomic dysfunction that is associated with increased cardiovascular morbidity and mortality as was reported in many studies like that done by Morshedi-Meibodi A et al[20],Cole C R et al[21],Myers J et al, Vivekananthan DP et al[22]

**4.3 Exercise Duration**

The mean exercise duration of smokers were shorter than that of nonsmokers(p<.05).Exercise duration is progressively decreasing with increasing burden of smoking.

Exercise duration is the strongest prognostic variable measured during exercise test. Its prognostic value has been demonstrated in healthy subjects being screened for coronary artery disease Ekelund LG et al[23], Blair SN et al[24], Mora S et al, Gulati M et al[25], and in patients being evaluated for suspected or known coronary artery disease as by Roger VL[26] et al, Myers J et al,Snader et al[27] Goraya TY et al[28] J. Frederick Mcneer et al[29] reported that patients who achieved Stage IV or greater exercise durations with either negative or indeterminate ST-segment response had less than a 15% prevalence of three vessel disease and less than a 1% prevalence of left main coronary artery disease.

Mora S et alfound that low exercise capacity, low heart rate recovery (HRR), and not achieving target heart rate were independently associated with increased all-cause and cardiovascular mortality.Several studies have reported that smokers have lower exercise capacity like Asha Asthana et al, Claire M Bernards et al, Papathanasiou G et al[30]S Sidney et al

## V. Limitations

The assumption that interaction between smoking and time is linear is erroneous. Also conversion of tobacco consumption which is a continuous variable to discrete variable smokers ,nonsmokers ,light, moderate and heavy smokers poses problems like 1 pack year is grouped with 9 pack years where as 9 packyears is considered different from 10 pack years. Again passive smoking was not addressed in the study.

## VI. Conclusion

Hemodynamic parameters like resting heart rate,maximum heart rate achieved,heart rate reserve, chronotropic index,heart rate recovery in 1 minute and exercise duration assessed by exercise testing are useful in estimating cardiovascular prognosis.Our study showed greater risk for CAD in smokers compared to nonsmokers as per resting heart rate, maximum heart rate achieved,heart rate reserve, chronotropic index and exercise duration.

But HR recovery in 1 minute showed no significance. The negative relationship between cardiovascular fitness and smoking increases with increased amount and duration of smoking.

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