

Original Article

**STRESS TEST FOR EVALUATION  
OF IHD AND ECG ABNORMALITY  
IN SERVICE PERSONNEL  
INCLUDING AIRCREW**

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A total of 758 stress tests which involved 685 subjects including 147 aircrew, has been analysed. Provisional diagnoses prior to the stress testing were ECG abnormality, ischaemic heart disease (IHD), hypertension and diabetes mellitus. Fifty normal subjects who performed stress test for evaluation of cardiovascular fitness were also included in the study. The test was found to be positive in 23% of ECG abnormality group, 71.3% of IHD cases, 72% of cases of hypertension, 38.1% of diabetes mellitus and in 4% of the 'normals'. 25.8% of aircrew were found to have stress test positivity. A large number of cases with ECG abnormality (77%) were cleared of IHD. 74.2% of aircrew were upgraded to higher categories, including flying, following negative stress test. On the other hand, 71.5% of IHD cases with positive stress test were benefited by institution/alteration of specific drug therapy. True to the present view, comparatively larger percentage of hypertensives and diabetics proved to have IHD than normals. Thus stress test is a useful and informative non-invasive cardiac investigation for diagnosis and disposal of ECG abnormality and ischaemic heart disease.

Keywords: Aircrew fitness, hypertension and stress test, stress test and diabetes.

Exercise electrocardiography or the stress test has been employed for evaluation and

disposal of cases of ischaemic heart disease (IHD) for over half a century. However, its usefulness and accuracy have reached new heights with the recent advances in medical electronics. The modern stress test technique comprises of on-line multichannel ECG recordings during graded computerised treadmill exercise and simultaneous data analysis of heart rate, rhythm, ectopic count, ST segment displacement, integral and slope. This paper analyses the results of 758 stress tests conducted by the above technique at the Institute of Aviation Medicine Bangalore during a period of six years and brings out the usefulness of this test in diagnosis and disposal of service personnel including aircrew with IHD and ECG abnormality.

**Materials and Methods**

Subjects referred for stress test were evaluated as follows:

- a. Recording of detailed present, past, personal and family histories with special attention to coronary risk factors.
- b. General physical and systemic examination to ascertain the cardiovascular status and to rule out complications/organic diseases involving systems other than CVS.
- c. Routine examination of blood and urine, and relevant biochemical investigations to exclude acute infections, eosinophilia, diabetes mellitus and hypercholesterolaemia.
- d. Radiological evaluation of lungs and heart to exclude pulmonary organic disease and to assess cardiac size.
- e. ECG recordings at rest and after Master's two step exercise (DMT) were done in all to assess cardiac response to this below-submaximal exercise prior to stress test.

Subjects found suitable for stress test were advised the following precautions:

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a. To maintain normal diet-rest-exercise habits for at least 48-72 h prior to the day of stress test.

b. To avoid smoking and alcohol for at least 12 h prior to the date and time of stress test.

c. To report to the stress test laboratory at 0730 h after a light breakfast.

The subjects were briefed about the procedure and a signed consent for undergoing the test obtained from all. The subjects belonged to the following categories:

a. 'Normal' group - Apparently normal subjects who reported for routine cardiovascular evaluation.

b. ECG Abnormality group - Cases of non-specific ECG abnormality.

c. Diabetes Mellitus group - Cases of diabetes mellitus.

d. Hypertension group - Cases of hypertension.

e. IHD group - Cases of IHD.

Subjects from the first four groups were planned for maximal exercise whereas those with IHD were permitted up to 85% of the maximal heart rate (submaximal exercise). Exercise was carried out by multistage treadmill (TM) or by graded bicycle ergometer (BE) depending on the choice of the subject. The TM exercise was carried out on the Viagraph multistage computerised treadmill and on-line multiple electrocardiographic leads evaluation system. The BE study was performed on the Monark Ergocent equipment. Multiple lead system recording of ECG (9) was followed in the majority and bipolar (CMS, CC5) lead system (5) in the others.

Pre-exercise recording included basal 12-lead ECG in supine and standing positions, and after hyperventilation and valsalva manoeuvres. Basal blood pressure (BP) was recorded in all. Recording of 12-lead ECG and BP was continued at the end of each 3 min stage of the graded TM/BE exercise.

The exercise was routinely terminated on achievement of the target heart rate. However, discontinuation of exercise was done in subjects who had the following:

a. Complaints of giddiness, precordial discomfort, pain, fatigue or leg cramps.

b. Abnormal BP recordings like fall of systolic BP or hypertensive reaction (abnormal rise of systolic and diastolic BP).

c. Appearance of diagnostic ischaemic ST displacement.

d. Appearance of multiple ventricular/supraventricular ectopics, increasing in number with progress of exercise. Appearance of bigeminy rhythm, ventricular tachycardia or atrioventricular block.

The post-exercise recordings of ECG and BP were done at 3 min, 6 min and 9 min after exercise in all cases. Those who showed arrhythmia or abnormal ST-T changes during exercise or had pain chest or giddiness were continued under observation till the ECG normalised or returned to pre-exercise level.

The absolute diagnostic criteria followed by us in stress tests (2) are:

a. T sagging/horizontal depression of 1 mm or more.

b. ST elevation with upward convexity of 1 mm or more.

c. ST downsloping depression of 1 mm or more.

d. ST displacement as above associated with precordial discomfort/pain and giddiness.

The following findings during or after the stress test were considered necessary for follow-up evaluations:

a. Fall of systolic blood pressure.

b. Complaints of giddiness and retrosternal

discomfort without associated changes in ECG recorded serially.

c. Slow upsloping ST depression of more than 1.5 mm.

d. T wave changes without associated ST depression.

e. Occasional supraventricular/ventricular ectopics during the exercise, decreasing with exercise, and not associated with ischaemic ST depression.

f. Changes in magnitude and configuration of QRS complex.

## Results

A total of 685 subjects underwent this study. They included 426 officers, 198 airmen and 61 civilians. There were 12 female subjects, all of them civilian. The subjects ranged between 26 years to 58 years. Details of the subjects are shown in Table I.

The provisional diagnoses prior to the stress testing were as shown in Table II. ECG abnormality and IHD accounted for 589 of the 685 cases. There were 25 cases of hypertension and 21 cases of diabetes mellitus. Fifty apparently normal subjects who were exercised to evaluate their cardiovascular fitness were also included. Out of the 12 women, four had ECG abnormality, six IHD, and one each diabetes mellitus and hypertension. Among the 147 aircrew evaluated with stress tests, 101 had initial diagnosis of ECG abnormality, 31 of IHD, and five each of hypertension and diabetes mellitus, whereas five others were 'normals' evaluated for cardiovascular fitness.

Clinical evaluation and relevant haematological, biochemical and radiological investigations, prior to stress testing, were within normal limits in all cases except for the expected changes in cases of hypertension and diabetes mellitus. BP recordings of the hypertensives were found to be well under

control with specific drug therapy; 17 of the 25 hypertensives were receiving diuretics with salt restriction and the others methyldopa. None of the hypertensives had any cardiovascular complications or target organ involvement. Out of the 21 diabetics, seven cases were overweight in whom the mild diabetic state was controlled on dietetic restriction only, while the others had moderate diabetes requiring oral hypoglycaemics along with diet control for stabilisation. None had any complication or target organ involvement.

The ECG findings at rest and after DMT, prior to stress test on TM/BE, are shown in Table III. Among the 373 subjects of the ECG Abnormality group, 251 had slow upsloping ST depression following DMT, 74 cases had T wave inversion either in limb leads or in one of the augmented unipolar leads and 24 cases showed T inversion in the anterior chest leads. Infrequent supraventricular ectopics were seen in 15 cases, and occasional ventricular ectopics in 9 cases. Besides these ECG findings, this group had no other clinical, biochemical or radiological abnormality.

All IHD cases were asymptomatic, stabilised and under follow up for periods varying between 6 months to 1.5 years. None of them had any cardiovascular complications or biochemical or radiological abnormality. ECG analysis had shown 126 cases to be of asymptomatic IHD, 28 cases of coronary insufficiency, 27 cases of subendocardial infarction and 35 cases of old transmural infarction (Table IV); 57 of them were on coronary vasodilator therapy. Six female subjects were old stabilised cases of transmural infarction, five of them being under treatment and were subjected to stress test for assessment of treatment.

DMT was performed by all the 685 cases as a screening test prior to the stress test. None showed ischaemic or horizontal ST depression following the DMT exercise. 345 cases showed slow upsloping ST depression of more than 0.5 mm, 132 had T

**Table-I**  
**Details of Subjects**

Group	Age (yrs)		Sex		Total
	Range	Average	Male	Female	
Ground Duty Officers	27 - 52	38.5 ± 7.6	279	-	279
Aircrew	26 - 49	34.3 ± 8.4	147	-	147
Airmen	29 - 44	35.5 ± 6.4	198	-	198
Civilians	33 - 58	39.4 ± 6.8	49	12	61
<b>Total</b>			<b>673</b>	<b>12</b>	<b>685</b>

**Table-II**  
**Provisional Diagnosis**

Diagnosis	Aircrew	Ground Duty		Civilians		Total
		Officers	Airmen	Male	Female	
ECG Abnormality	101	152	114	2	4	373
IHD	31	106	63	10	6	216
Hypertension	5	12	6	1	1	25
Diabetes Mellitus	5	6	9	-	1	21
'Normals'	5	3	6	36	-	50
<b>Total</b>	<b>147</b>	<b>279</b>	<b>198</b>	<b>49</b>	<b>12</b>	<b>685</b>

**Table-III**  
**ECG (Resting and after DMT) Analysis**

ECG Changes	Groups					Total
	ECG Abnormality	IHD	Hyper-tension	Diabetes Mellitus	'Normal'	
T inversion III,IIIR, aVF,aVF(R)	74	41	7	6	4	132
T inversion V1,V2,V3	24	23	2	3	2	54
Infrequent extrasystole (SV)	15	34	1	1	7	58
Infrequent extrasystole (V)	9	22	-	-	-	31
Slow upsloping ST depression > 0.5 mm (DMT)	251	68	15	11	-	345
No deterioration after DMT	-	28*	-	-	37	65
<b>Total</b>	<b>373</b>	<b>216</b>	<b>25</b>	<b>21</b>	<b>50</b>	<b>685</b>

\* Stabilised on drugs

**Table-IV**  
IHD Cases - ECG Diagnosis

ECG Diagnosis	Total Cases			Positive Stress Test			
	On drugs	Not on drugs	Total	On drugs	Not on drugs	Total	%
Asymptomatic IHD	21	105	126	7	76	83	65.8
Coronary Insufficiency	3	25	28	2	22	24	85.7
Subendocardial Infarction (old)	5	22	27	4	19	23	85.1
Transmural Infarction (old)							
a. Inferior wall	8+2*	2	12	5	2	7	58.3
b. Lateral wall	6+1*	2	9	4	2	6	66.6
c. Anterior wall	9+2*	2+1*	14	2	2	4	28.5
<b>Total</b>	<b>57</b>	<b>159</b>	<b>216</b>	<b>31</b>	<b>123</b>	<b>154</b>	<b>71.3</b>

\* Female cases

**Table-V**  
Heart Rate and Blood Pressure Recordings in Stress Test

Parameters	Resting	Peak Exercise	Post Exercise
Heart rate, bpm	76.5 ± 8.45	164.26 ± 8.41	88.51 ± 7.63
Systolic BP, mm Hg	142.51 ± 7.54	178.23 ± 10.25	141.61 ± 6.68
Diastolic BP, mm Hg	84.26 ± 3.81	82.25 ± 4.38	84.68 ± 3.61
Exercise duration, min	-	16.63 ± 3.84	9.42

**Table-VI**  
Termination of Exercise

Diagnosis	Percentage of Maximum Heart Rate								Total Cases
	100%		85%		75-85%		65-75%		
	No	(%)	No	(%)	No	(%)	No	(%)	
ECG Abnormality	324	(86.8)	22	(5.89)	19	(5.09)	8	(2.14)	373
IHD	0	-	197	(91.2)	17	(7.87)	2	(0.92)	216
Hypertension	11	(44.0)	13	(52.0)	1	(4.00)	0	-	25
Diabetes Mellitus	10	(47.6)	11	(52.4)	0	-	0	-	21
'Normals'	44	(88.0)	5	(10.0)	1	(2.0)	0	-	50
<b>Total</b>	<b>399</b>	<b>(56.8)</b>	<b>248</b>	<b>(36.2)</b>	<b>38</b>	<b>(5.5)</b>	<b>10</b>	<b>(1.46)</b>	<b>685</b>

inversion in limb leads/augmented unipolar leads and 54 cases had isolated T inversion in chest leads at rest without any further deterioration in the post-exercise ECG recordings. 58 cases showed resting infrequent supraventricular ectopics and 31 cases had occasional ventricular ectopics, persisting in the post-DMT ECGs. 65 cases (37 'normals' and 28 cases of stabilised IHD) had no deterioration from the resting record (Table III).

During the period of study extending over six years, 758 stress tests were done on 685 subjects. Most of the tests (638) were performed on the bicycle ergometer and only 120 tests, on the treadmill. Many cases, including airmen, civilians and those showing normal stress test on the first occasion, were subjected to only one test. Only those showing abnormalities, that too among the Air Force officers including aircrew, were evaluated twice or more while being under follow-up.

The mean values of heart rate, systolic and diastolic blood pressures and the mean duration of exercise are shown in Table V. The mean peak heart rate achieved was 164 bpm. The systolic BP during the exercise showed a consistent trend of rise, the mean peak value being 178 mm Hg. There was no significant change in the values of diastolic BP during the exercise. The mean duration of exercise in this series was about 16 min whereas the post-exercise ECG evaluation was done at 9 min after exercise in all cases.

Table VI shows the grades of exercise carried out. 389 subjects were able to perform the exercise up to maximal heart rate (MHR), 86.8% of them being cases of ECG abnormality. 248 subjects (197 from the IHD group) achieved up to 85% of MHR. 99 cases had to be discontinued from further exercise prior to achievement of target heart rate because of several reasons (Table VII). The main causes of premature discontinuation of the test were fatigue and cramps of leg (53%), diagnostic ischaemic ST depression before achievement of target heart rate (24%), arrhythmias deteriorating

with increase of exercise (10%), giddiness (9%) and retrosternal pain (2%). The two cases who developed chest pain were from the IHD group and showed ischaemic ST depression at the time of the complaint.

**Positive Stress Tests:** ECG analysis during the stress test and in the post-exercise period showed positivity (ischaemic ST depression) in 273 cases (39.8%) including five out of the 12 female subjects (Table VIII). 71.3% of cases of IHD, 72% of hypertension and 38.1% of diabetes showed ischaemic ST depression during the stress test. 23% of the ECG Abnormality group also had positivity suggestive of IHD. Seven (14%) of the 'normal' subjects were detected to have positive test.

**Equivocal ECG Findings:** ECG findings not amounting to definitive diagnosis of IHD during the stress test are listed in Table IX. 12.6% of the ECG Abnormality group and 16.2% of the IHD group showed these findings. Three cases of hypertension, four of diabetes and two 'normals' also had nonspecific findings during the stress test requiring follow-up.

**Aircrew:** 147 aircrew were subjected to stress test. Out of the 101 cases with ECG abnormality, 20.79% showed ischaemic ST depression during the maximal stress test, whereas 41.9% of the 31 aircrew with IHD showed positivity during the stress test. Two each from the groups with hypertension and diabetes mellitus were found to have evidence of IHD, whereas none of the five 'normal' aircrew showed abnormality during the stress test evaluation.

## Discussion

Exercise stress testing for cardiac patients has achieved great diagnostic accuracy since its inception 50 years ago (1), thanks to the modern developments in medical electronics facilitating faultless on-line multiple lead ECG recording and simultaneous computer analysis. Several epidemiological follow-up studies (5) and correlative coronary angiographic studies (6) have provided

**Table-VII**  
**Causes of Discontinuation of Stress Test**

Causes	ECG Abnormality	IHD	Hypertension	Diabetes Mellitus	'Normals'	Total
Precordial pain	-	2	-	-	-	2
Diagnostic ST Depression	11	9	2	1	1	24
Arrhythmias	7	3	-	-	-	10
Giddiness and Fall of BP	5	2	1	1	-	9
Fatigue, Leg Cramps	26	3	10	9	5	53
<b>Total</b>	<b>49</b>	<b>19</b>	<b>13</b>	<b>11</b>	<b>6</b>	<b>98</b>

**Table-VIII**  
**Results of Stress Tests**

Diagnosis	Total Cases	Positive Test				Doubtful Results			
		Male	Female	Total	%	Male	Female	Total	%
ECG Abnormality	373	84	2	86	23.0	47	-	47	12.6
IHD	216	151	3	154	71.3	33	2	35	16.2
Hypertension	25	18	-	18	72.0	3	-	3	12.0
Diabetes mellitus	21	8	-	8	38.1	4	-	4	19.1
'Normals'	50	7	-	7	14.0	2	-	2	4.0
<b>Total</b>	<b>685</b>	<b>268</b>	<b>5</b>	<b>273</b>	<b>39.8</b>	<b>89</b>	<b>2</b>	<b>91</b>	<b>13.3</b>

**Table-IX**  
**Stress Test Findings Requiring Follow-up**  
(not associated with ischaemic ST depression)

Findings	ECG Abnormality Group			IHD Group		
	Peak Exercise	Post Exercise	Total	Peak Exercise	Post Exercise	Total
Slow upsloping ST depression >1.5 mm	28	13	31	23	15	28
Arrhythmia (SVE, VE)	3	5	7	3	3	3
Tall T waves	22	13	24	21	7	22
T inversion	-	4	4	-	7	7
Increase in height of R wave	28	5	31	37	17	45
Giddiness with fall of Systolic BP	1	-	1	-	-	-
Giddiness without fall of Systolic BP	4	-	4	2	-	2

documentary evidence of high sensitivity and specificity of this commonly employed non-invasive test. Submaximal and maximal tests done by graded multistage treadmill and bicycle ergometer exercise techniques have led to specific diagnosis in ECG abnormalities (7) and also predicted grades of rehabilitation in patients with stabilised ischaemic heart diseases (8,9).

The present study shows that a large number of subjects (77%) did not show categorical findings of IHD during the maximal stress test or in the post-exercise period. A few had nonspecific ST-T changes and were recommended follow up evaluation. Thus, a large number of the subjects including officers and aircrew have been cleared and returned to their respective duties (ground duties/flying). 23% of the subjects with nonspecific ECG abnormality were detected to have IHD on stress test and have benefited by institution of specific coronary vasodilator drugs.

Cases with IHD were invariably subjected to submaximal level of stress test. 71.3% had shown persistence of positivity in stress test and were advised initiation/increase in the drug therapy. 35 of those who did not have ischaemic ST depression during stress test had shown nonspecific ST-T changes during the stress test evaluation requiring further follow up. Thus, only 27 subjects (12.5%) with IHD were found to be well stabilised and controlled permitting further upgradation of their medical categories.

The number of cases of hypertension and diabetes mellitus subjected to stress test was comparatively small. The results of the maximal stress test in them, however, showed significantly greater positivity as compared to the normal group. 72% of the hypertensives and 38.1% of the diabetics had evidence of IHD, whereas 14% of the normals showed ischaemic ST depression following the maximal exercise. This figure appears to be high as compared to prevalence surveys which show presence of IHD in 45.3 to 65.4 per thousand among males in India (10,11). The reasons for this higher incidence may be that

(a) the number of subjects studied in this series is very small, and (b) these subjects have been evaluated with ECG analysis during maximal exercise test unlike most of the surveys where resting ECG was the basis for diagnosis. Among the findings requiring follow-up, slow upsloping ST depression of more than 1.5 mm has been detected more frequently in our series as compared to changes in magnitude and configuration of T waves, alteration in the QRS complex and occasional supraventricular or ventricular ectopic rhythm. Slow upsloping ST depression at peak of exercise is still considered to be controversial, though the recent trend is to consider this as non-diagnostic and leading to false positive results (12,13). The finding of significant increase in the height of R wave at peak exercise is also considered a significant observation and is accepted to be an important diagnostic index when associated with ST depression (14).

Among the 147 aircrew evaluated by stress test, 101 had ECG abnormality as the pre-exercise diagnosis. Positive stress test resulted in the diagnosis of asymptomatic IHD in over 20% of this group, and thus almost 80% of aircrew with ECG abnormality were cleared of the suspicion of IHD and were upgraded to higher medical categories including fitness for flying. 41.9% of the 31 aircrew with IHD were found to have persistent ischaemic ST depression during stress test requiring initiation/change of specific drug therapy. 49.1% of the aircrew with IHD were permitted upgradation of their medical categories, including restricted flying for those with asymptomatic IHD.

The stress test is thus found to be a useful and informative investigation for evaluation of service personnel, particularly aircrew, with asymptomatic ECG abnormalities and stabilised ischaemic heart disease. Being a repetitive non-invasive procedure, it should be employed wherever necessary for evaluation of doubtful ECG abnormalities for speedy disposal as well as for assessment of cardiovascular status in stabilised IHD with a view to provide appropriate therapy and rehabilitation.

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