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Association of Metabolic Syndrome Parameters with Exercise Capacity and Cardiovascular Parameters

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Abstract

Context: Understanding the relationship of cardiovascular correlates of exercise parameters to metabolic syndrome parameters is especially important because cardiovascular endurance is a strong predictor of future morbidity and mortality in patients with diabetes. *Aims:* To examine the association of metabolic syndrome parameters with exercise capacity and cardiovascular parameters *Settings and design:* Present cross sectional study was conducted at Department of Physiology Gandhi Medical College, Bhopal. *Methods and Material:* 33 cases of diabetes mellitus type-II suffering from metabolic syndrome were studied and compared with age and sex matched 27 type-II diabetic subjects not suffering from metabolic syndrome. *Statistical Analysis:* All values were expressed as mean±standard deviation. Comparisons of means between the two groups were done using a student 't' test. *Results:* 55% patients were found to have metabolic syndrome. Mean anthropometric measurements were higher in metabolic syndrome group. All the biochemical parameters except HDL cholesterol were significantly higher in metabolic syndrome group. Resting pulse rate, pulse pressure, double product were significantly higher in metabolic syndrome group. Three minute exercise test mean values of maximum heart rate, pulse-pressure, double-product, Heart rate reserve were on higher side in metabolic syndrome group. Mean values of Vo_2Max, exercise capacity and recovery heart rate, were on lower side in patients of metabolic syndrome group. *Conclusion:* Regular physical activity and higher level of cardio-respiratory fitness are associated with reduced risk of coronary heart disease.

Keywords: Metabolic Syndrome; Diabetes; Exercise; Physical Activity.

Introduction

Diabetes increases the risk of heart diseases and stroke causing 50% deaths in the people with diabetes. Because of the severe pathologies complicating the clinical course of diabetes, one can easily speculate on huge economic and psychosocial impact of diabetes on individuals, families and health care systems. Patients with type-2 diabetes are at increased risk of coronary heart disease and stroke, which are the most common cause of death and disability and excess health care cost in diabetics. It is estimated that the large majority (~75%) of patients with type-2 diabetes or impaired glucose tolerance have the metabolic syndrome [1].

Metabolic syndrome is the constellation of risk factors acting synergistically and one or all of which may share a common etiology [2].

Aggregation of cardiovascular risk factors including hyperinsulinemia, systemic hypertension elevated serum cholesterol and triglyceride level, reduced HDL cholesterol as well as glucose tolerance comprised the syndrome. There fore identifying the metabolic abnormalities to prevent morbidity and mortality in type-2 diabetic patients due to cardiovascular disease is urgent need [3].

Clinical and observational studies have shown that exercise capacity is strong predictor of cardiovascular and overall mortality. Patients of type-2 diabetes mellitus often complaint of fatigue and reduced exercise capacity, the cause of reduced exercise

capacity in type-2 diabetes mellitus is unknown, cardiac autonomic dysfunction may play an important role [4].

Reduced heart rate recovery immediately after exercise is an important indicator of cardiac autonomic dysfunction. Higher level of blood pressure in diabetes patients with reduced exercise capacity may be a contributor to reduced myocardial function [5].

Wei M et al. [1], Cheng YJ et al. [2], Regensteiner JG et al. [3], Fanz ZY et al. [4] studied cardiovascular exercise performance in type-2 diabetic patients and reported impaired cardio-vascular response and reduced aerobic capacity in these patients.

Understanding the relationship of cardiovascular correlates of exercise parameters to metabolic syndrome parameters is especially important because cardiovascular endurance is a strong predictor of future morbidity and mortality in men and women with diabetes mellitus. Present work aimed to examine the association of metabolic syndrome parameters with exercise capacity and cardiovascular exercise parameters.

Methods

Study set-up

The present study was conducted in Department of Physiology Gandhi Medical College, and Associated Hamidia Hospital, Bhopal. The Biochemical investigations were done in the department of Biochemistry of the Institution.

Study Design

It was cross section study in which 33 cases of diabetes mellitus type-II suffering from metabolic syndrome were studied and compared with age and sex matched 27 type-II diabetic subjects not suffering from metabolic syndrome.

Sample Size

A total of 60 type-II diabetic subjects were studies.

Study Protocol

The study comprised of type-II diabetes mellitus patients aged 40-50 years attending medical OPD Department of Medicine in Gandhi Medical College and Associated Hamidia Hospital, Bhopal.

Inclusion Criteria

- All the patients with diabetes type-2 proved by recent blood glucose studies.
- Fasting plasma glucose and lipid-profile estimated prior to exercise testing to categories into metabolic syndrome groups & non-metabolic syndrome group.
- All the cases should be free from chronic complication of diabetes and any other endocrinal and metabolic disorder.

Exclusion Criteria

- Type-II diabetic patient with past history of cerebro-vascular accidents.
- Patients with evidence of orthopedic impairment
- Patient with abnormal finding in resting ECG as well as clinical examination
- Chronic Alcoholic's

Patients were grouped in two categories based on the criteria of metabolic syndrome according to International Diabetic Federation (2005):

1. Metabolic syndrome group (33)
2. Non Metabolic syndrome group (27)

Methodology

All the patients selected for study were subjected to a detailed history taking by mean of planned-questionnaires. History of present and past illness was taken and family history especially of non-communicable disease, congestive heart failure was recorded. History of any medication was also taken. Users of all type of tobacco products were included in the study. Physical inactivity was measured by asking both work related and leisure time activities.

Patients underwent careful systemic clinical examination for the clinical evidence of existence of any such disease that may affect exercise-capacity.

Parameters Recorded

⊙ *Physical Characteristics*

⊙ Anthropometric measurement

- Weight (kg)
- Height (Cm)

- Body-mass index (kglm2)
- Waist circumference (cm)
- Hip Circumference (cm)
- Wais-Hip ratio

⊙ ***Cardiovascular Parameters***

- Parameter recorded to asses cardio-vascular fitness-

⊙ ***Pre-exercise evaluation-***

- Heart rate (beats per min)
- Blood- Pressure (mm of Hg)
- Double-product (mm of Hg X beats per min)
- Target Heart rate (beats per min)
- Heart-rate-reserve (beats)
- Resting Electrocardiogram

⊙ ***Exercise test-***

- Queens college step test

⊙ ***Post exercise Evaluation***

- Maximum Heart rate achieved (beats per min)
- Heart rate reserve (beats)
- Heart rate at 1 min of recovery
- Recovery Heart rate (beats per min)
- Peak blood pressure (mm of Hg)
- Peak double-product
- Age and Sex adjusted Vo2 max-absolute (L/ min), relative (L/M^2 /Min, Ml/Kg/Min)
- Exercise capacity (METs achieved)

Statistical Analysis

All values were expressed as mean±standard deviation. Comparisons of means between the two groups were done using a student 't' test,

Results

Table 1 shows classification of study population based on existence of metabolic syndrome. Based on international diabetic federation (2005) 55% patients were found to have metabolic syndrome. Remaining 45% diabetic patients could not be classified in this category.

Table 2 shows mean values of anthropometric parameter in type-II diabetic patients. The mean values of anthropometric data showed no gender difference in both the groups. The mean values of anthropometric measurements were higher in metabolic syndrome group as compared to non metabolic syndrome group.

Table 3 shows comparison of anthropometric parameter in type-II diabetic patients. An attempt has been made to compare anthropometric parameters of type-II diabetics patients with metabolic syndrome with those patients who were not having metabolic syndrome it was observed that all the measured anthropometric parameters were significantly ($p=<0.001$) higher in metabolic syndrome group.

Table 4 shows mean values of biochemical parameters in type-II diabetic patients. It is evident from the mean values that measured biochemical parameters were also on higher site in women as compared to men dyslipidemia was not observed in non metabolic syndrome group.

Table 1: Classification of study population based on existence of metabolic syndrome (N=60)

Groups	Male		Female	
	Number	%	Number	%
Metabolic syndrome group	19	50	14	64
Non Metabolic syndrome group	19	50	8	36

Table 2: Mean values of anthropometric parameter in type-II diabetic patients

Variables	Metabolic syndrome group		Non Metabolic syndrome group	
	Male (N = 19)	Female (N = 14)	Male (N = 19)	Female (N = 8)
Age (Years)	45.9±2.86	45.9±3.71	44.4±3.44	45.3±2.71
BMI (Kg/M^2)	27.15±2.8	27.72±3.07	26.66±1.06	24.43±2.48
Waist Circumference (Cm)	94.26±4.88	98.28±7.12	87.47±5.02	86±8.84
Waist Hip Ratio	0.98±0.04	0.96±0.10	0.856±0.04	0.847±0.07

Table 3: Comparison of anthropometric parameter in type-II diabetic patients

Variables	Metabolic Syndrome Overall (n=38)	Non-Metabolic Syndrome Overall (n=22)	't' Value	P Value
Age (Years)	45.9±3.19	44.6±3.21	1.5	NS
BMI (Kg/M²)	27.39±3.91	23.89±1.6	5.5	< 0.001
Waist Circumference (Cm)	95.97±6.1	87.03±6.25	5.49	< 0.001
Waist Hip Ratio	0.97±0.08	0.85±0.05	7.17	< 0.001

Table 4: Mean values of biochemical parameters in type-II diabetic patients

Variables	Metabolic Syndrome Groups		Non-Metabolic Syndrome Groups	
	Men (n=19)	Women (n=14)	Men (n=19)	Women (n=8)
Fasting Serum Glucose (mg/dl)	156±18.2	172±25.4	136±8.84	138±16.1
Total Cholesterol (mg/dl)	257.8±33.6	291.5±62	192±12.84	194.4±1.41
Serum Triglyceride (mg/dl)	183±28.81	191±26.8	135±10.9	124±9.4
LDL Cholesterol (mg/dl)	186±28.2	216±60	121±12.4	115±13.3
VLDL Cholesterol (mg/dl)	33.9±3.44	37.1±6.6	27.0±2.18	24.8±1.88
HDL Cholesterol (mg/dl)	35.0±2	37.0±4.3	44.0±2.5	55.0±1.8

Table 5 shows comparison of biochemical parameters in type-II diabetic patients. Data revealed that all the biochemical parameters measured except HDL cholesterol were significantly higher ($p < 0.001$) in metabolic syndrome group. HDL cholesterol was significantly low ($p < 0.001$) in this group.

Table 6 shows mean values of pre-exercise cardiovascular parameters of type-II diabetic patients. Mean values of measured pre-exerci se cardiovascular parameters were also higher in women patients of metabolic syndrome groups as compared to men. Heart rate reserve at rest was significantly less in patients of metabolic syndrome group as compared to non- metabolic syndrome group. No abnormality in resting electrocardiogram was detected in both the groups.

Table 7 shows comparison of pre-exercise cardiovascular parameters of type-ii diabetic patients. It was observed that resting pulse rate, pulse pressure, double product were significantly higher ($p = < 0.001$) in metabolic syndrome group patients reflecting autonomic dysfunction.

Table 8 shows mean values of post exercise cardiovascular parameters of type-II diabetic patients. After performing three minute exercise test the mean values of maximum heart rate, pulse- pressure, double-product, Heart rate reserve were on higher site in patients of metabolic syndrome group. Mean values of Vo_2Max, exercise capacity and recovery heart rate, were on lower site in patients of metabolic syndrome group as compared to non-metabolic syndrome group.

Table 9 shows comparison of post exercise cardiovascular parameters of type-II diabetic patients. After performing 3 min. exercise test the maximum heart rate achieved was significantly ($p<0.001$) higher in diabetic subjects having metabolic syndrome as compared to the subjects of non-metabolic syndrome group. The absolute Vo_2Max which represents physiological ceiling for the ability of cardiovascular system and oxygen transport system to delivered oxygen to contracting muscle, both the absolute and related Vo_2Max were significantly ($p<0.001$) less in metabolic syndrome group. Exercise capacity measured in term of METs was also found less metabolic syndrome group as to compare to non-metabolic syndrome group.

Table 5: Comparison of biochemical parameters in type-II diabetic patients

Variables	Metabolic Syndrome Overall (n=38)	Non-Metabolic Syndrome Overall (n=22)	't' Value	P Value
Fasting Serum Glucose (mg/dl)	162.67±22.54	136.70±11.22	5.3	< 0.001
Total Cholesterol (mg/dl)	271.87±49.65	192.7±12.7	7.92	< 0.001
Serum Triglyceride (mg/dl)	186.85±27.85	131.85±11.5	9.49	< 0.001
LDL Cholesterol (mg/dl)	198.9±46.27	118.8±12.52	8.5	< 0.001
VLDL Cholesterol (mg/dl)	35.3±5.18	26.32±2.35	8.4	< 0.001
HDL Cholesterol (mg/dl)	35.75±3.27	47.51±5.28	10.37	< 0.001

Table 6: Mean values of pre-exercise cardiovascular parameters of type-II diabetic patients

Variables	Metabolic Syndrome Groups		Non-Metabolic Syndrome Groups	
	Men (n=19)	Women (n=14)	Men (n=19)	Women (n=8)
Pulse Rate (Beats/Min)	82.0±8.3	86.0±8.2	74.0±10.4	76.75±7.77
SBP (mm of Hg)	141.8±1.61	142.3±1.72	122.4±9.90	123.5±12.19
DBP (mm of Hg)	91.58±1.95	91.0±1.51	80.74±6.96	79.25±7.85
DP (mm of Hg)	50.0±2.0	51.0±1.0	42.0±4.0	44.0±5.0
DP (Pulse Rate x SBP)	11632±1241	12242±1242	9094±1680	9515±1730
Heart rate reserve(Beats)	92.05±9.54	87.78±10.84	102.0±11.0	98.0±8.0

Table 7: Comparison of pre-exercise cardiovascular parameters of type-II diabetic patients

Variables	Metabolic Syndrome Overall (n=38)	Non-Metabolic Syndrome Overall (n=22)	't' Value	P Value
Pulse Rate (Beats/Min)	83.69±8.9	74.8±9.36	3.91	< 0.001
SBP (mm of Hg)	142±1.65	122.66±10.9	10.7	< 0.001
DBP (mm of Hg)	91.33±1.78	80.29±7.11	8.42	< 0.001
DP (mm of Hg)	50.66±1.78	42.37±4.43	9.65	< 0.001
DP (Pulse Rate x SBP)	11890±1259	9218±1672	6.93	< 0.001
Heart rate reserve (Beats)	90.24±10.17	101.0±10.0	4.21	<0.001

Table 8: Mean values of post exercise cardiovascular parameters of type-II diabetic patients

Variables	Metabolic Syndrome Groups		Non-Metabolic Syndrome Groups	
	Men (n=19) I	Women (n=14) II	Men (n=19) III	Women (n=8) IV
Maximum Heart Rate (Beast/Min)	151.3±7.18	148.3±3.72	133.1±6.23	128.8±3.84
SBP (mm of Hg)	199±6.7	202±10.6	176±12.6	177±16.3
DBP (mm of Hg)	100±3.17	103±5.75	101±7.61	96.8±7.09
PP (mm of Hg)	98.21±5.76	99.42±9.7	75.26±9.59	80.25±14.59
Double – Product	30084.84±2362.97	30025.71±1848.04	23475.79±2214.43	22809±2403.11
Heart Rate Reserve (Beats)	69.26±2.13	62.29±5.96	59.05±3.90	52±4
Heart rate at 1 min. of recovery	135.79±9.70	131.57±5.88	112.63±8.30	109.50±7.31
Recovery heart rate	15.47±3.12	16.71±3.56	20.42±2.36	19.25±3.54
Vo_2Max				
L/Min	3.43±0.11	2.56±0.15	3.88±0.21	2.71±0.12
$L/M^2/Min$	2.14±0.04	1.68±0.11	2.29±0.09	1.75±0.11
Ml/Kg/Min	47.80+3.02	38.42±0.59	55.45±2.62	42.03±0.71
Exercise capacity (METs) achieved	13.66±0.86	10.98±0.17	15.84±0.75	12.01±0.20

Table 9: Comparison of post exercise cardiovascular parameters of type-II diabetic patients

Variables	Metabolic Syndrome Overall (n=38)	Non-Metabolic Syndrome Overall (n=22)	't' Value	P Value
Maximum Heart Rate (Beast/Min)	150±5.9	131.77±5.9	117	< 0.001
SBP (mm of Hg)	200.25±3.6	176.91±30.45	4.1	< 0.001
DBP (mm of Hg)	101.51±4.55	99.77±7.59	1.07	NS
PP (mm of Hg)	98.72±7.59	76.74±11.24	8.85	< 0.001
Double – Product	30059±2130	23278±2246	11.7	< 0.001
Heart Rate Reserve (Beast/Min)	66.3±5.41	56.9±5.06	6.77	< 0.001
Heart rate at 1 min. of recovery	134±8.46	111.70±8.01	10.22	< 0.001
Recovery heart rate	16±3.32	20.07±2.74	5.08	< 0.001
Vo_2Max				
L/Min	3.06±0.46	3.53±0.58	4.8	< 0.001
$L/M^2/Min$	1.95±0.24	2.13±0.27	4.08	< 0.001
Ml/Kg/Min	43.82±5.24	51.47±6.62	5.52	< 0.001
Exercise capacity (METs) achieved	12.52±1.50	14.71±1.89	5.51	< 0.001

Discussion

The present study analyzed the association between resting heart rate and presence of metabolic syndrome in type-II diabetic patients. Diabetic patients with metabolic syndrome exhibited significant ($p < 0.001$) higher mean values of resting pulse (83.69±8.9 beats per min) pulse pressure (50.66±1.78 mm of Hg) double-product (11890±1259 mm of Hg X beats per min) and lower value of heart rate reserve (90.24±10.17 beats) as compared to non metabolic syndrome group. The women showed higher mean values as compared to men.

Resting heart rate can be used as a crude estimate of sympathetic tone. Mensink GB et al. [5] and Greenland P et al. [6] evaluated resting heart rate as predictor of increased cardiovascular morbidity. They reported that higher resting heart rate was associated with sympathetic over activity, various cardiovascular risk factors including hypertension, higher fasting blood glucose and mortality, even after an adjustment for other risk factor.

There are multiple lines of emerging evidence which suggested that resting heart rate associated with the presence and/or potential to develop cardiovascular disease.

Diaz A et al. [7] recognized resting heart rate as risk factor for cardiovascular disease.

Wilson PW et al. [8] reported relatively strong association between resting heart rate and metabolic syndrome suggesting a shared pathophysiological pathway.

Jidong S et al. [9] studied 248 subjects having metabolic syndrome and 1184 subjects not having metabolic syndrome they reported significantly ($p<0.01$) higher resting heart rate (64±10bpm) in patients of metabolic syndrome group as compared to subjects not having metabolic syndrome (62±9.0bpm).

Rogowski O et al. [10] studied a sample of 7706 individuals full-filling the criteria of metabolic syndrome. The participants were divided into quintiles of resting heart rate the prevalence of metabolic syndrome was found to be 62% and 52% for men and women respectively in 1st quintile resting heart rate 21.1% and 13.3% in 5th quintile of resting heart rate.

Sympathetic over activity and parasympathetic under activity might underlie the aforementioned observations.

In present study resting heart rate showed a significant ($p< 0.001$) negative correlation with BMI, serum glucose, total cholesterol, triglyceride, systolic blood pressure, double product, heart rate reserve and heart rate recovery.

In the present study diabetic patients with metabolic syndrome exhibited higher pre-exercise pulse pressure (50.66±1.78 mm of Hg), double product (11890±1259 mm of Hg X beats per min) as well as post exercise pulse pressure (98.72±7.59 mm of Hg) double product (30059±2130 mm of Hg X beats per min) as compared to patients of non-metabolic syndrome groups.

Mule G et al. [11] studied relationship metabolic syndrome with pulse pressure in patients with essential hypertension and suggested that increased pulse pressure at rest is mainly associated with arterial wall stiffness.

In the present study Vo_2Max and exercise capacity was measure by Queens's college step test.

Vo_2Max is a measure of functional limit of cardio respiratory system and single most valid measure of maximum exercise capacity.

The Vo_2Max relative to body mass evaluates the ability of an individual to perform exhaustive work i.e., their aerobic performance.

The major finding from present study revealed that subjects with higher BMI and metabolic syndrome had reduced Vo_2max (43.82±5.24 ml/kg/min) as compared to subject not having metabolic syndrome (51.47±6.62 ml/kg/min).

In the present study exercise capacity expressed as METs achieved in patients of metabolic syndrome group was (12.52±1.50) significantly ($p < 0.001$) less as compared to non-metabolic syndrome group (14.71±1.89). Significant negative correlation was found between peak exercise capacity BMI (r-0.43) waist circumference (r –0.439), S. Glucose (r-0.549) total cholesterol (r-0.554), triglyceride (r-0.482), LDL cholesterol (r-0.524), and a positive correlation was found with heart rate reserve at peak (r-0.689).

Ugur-Altun B et al. [12] demonstrated a negative correlation between insulin resistance & peak exercise capacity. In diabetic patients glycosylation may impair the function of a number of protein and vascular or endothelial dysfunction may be a plausible paucity and metabolic disturbances associated with poor diabetes control.

Fang ZY et al. [4] studied determinants of exercise capacity in 17 patients with type –II diabetes, they concluded that reduced exercise capacity with type-II diabetes is associated with diabetes control, sub clinical left ventricle dysfunction and impaired heart rate recovery, They found exercise capacity negatively associated with age, BMI, duration of disease,

glycosylated hemoglobin, history of hypertension and negative co-relation with heart rate recovery.

Reduced heart rate recovery immediately after exercise is an important indicator of cardiac autonomic dysfunction and contributes to cardiovascular mortality and morbidity.

In the present study diabetic patients with metabolic syndrome showed delayed heart rate recovery (16±3.2bpm) as compared to normal heart rate recovery (20.07±2.74bpm) in non-metabolic syndrome group.

Vanninen et al. [13] studied effect of metabolic control and autonomic function in newly diagnosed type-II obese patients. The persistence hyperglycemia in diabetes may weaken parasympathetic control and enhance sympathetic activity.

Jidong S [9] studied the association of delayed heart rate recovery with metabolic syndrome, They reported lower heart rate recovery (10.3±11.6/ min.) and higher resting heart rate (64.3±10.3/ min.) as compared to subjects not having metabolic syndrome (13.6±9.7/min., 61.6±9.1/min.) The metabolic syndrome parameters were associated with delayed recovery.

During exercise sympathetic stimulation increases markedly, where as vagal tone is withdrawn, thus increasing heart rate, myocardial contractility cardiac output distribution and myocardial oxygen utilization during recovery from exercise, vagal influence waxes and adrenergic tone wanes. Recovery of heart rate after exercise is a function of vagal reactivation.

The cardiovascular risk association with metabolic syndrome may be mediated by failure of vagal reactivation is addition to sympathetic over-activity.

The diabetic patients with metabolic syndrome exhibited significant ($p<0.001$) higher mean values of heart rate reserve (90.24±10.17 beats) as compared to non-metabolic syndrome group. The women showed lower mean value as compared to men.

Salvadori et al. [14] studied oxygen uptake and cardiac performance in obese and normal subjects during exercise and reported reduced cardiac performance during progressive work rate exercise in obese subjects.

Cheng YJ et al. [2] examined the relationship of heart rate reserve and cardiovascular mortality in 27,459 healthy subjects, They reported that among younger men (20-39 years) heart rate reserve was only factor associated with cardiovascular disease mortality (instantaneous relative risk (RR) and 95% CI for heart rate reserve 0.6, 0.5-0.9 for CVD mortality by 10 beats per min increment) where as only cardio-respiratory function and BMI were associated with all cause mortality among older men, heart rate reserve was inversely associated with cardiovascular disease and all cause mortality.

Conclusion

From the observations of present study it is concluded that regular physical activity and higher level of cardio respiratory fitness are associated with reduced risk of coronary heart disease low physical fitness has been associated with increased clustering of metabolic abnormalities associated with metabolic syndrome in type-II diabetic patients.

Key messages

Regular exercise can improve cardia functions even in patients with type II diabetes. Hence they should be encouraged to improve their quality of life.

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