Indian J Physiol Pharmacol 2019; 63(2) : 145–154

Original Article

Metabolic Syndrome in Young Urban Adults : Natural Evolution in One Year

Anumeha Bhagat[1]*, Ravi Rohilla[2], Shivani Jaswal[3] and Jasbinder Kaur[4]

Departments of [1]Physiology, [2]Community Medicine and [3,4]Biochemistry,
Government Medical College and Hospital,
Chandigarh, India

Abstract

Introduction: Metabolic syndrome (MS) is diagnosed in an individual if any three of the five risk factors for metabolic syndrome are present. These five risk factors are elevated waist circumference, blood pressure, fasting blood glucose, serum triglyceride and lowered high density lipoprotein. Although the long term natural evolution of MS has been reported yet there is insufficient research on the changes in risk factors of MS after one year of diagnosis.

Objective: To evaluate changes in risk factors of metabolic syndrome after one year of its identification in young college going students of an urban Northern India population

Material and method: Height, weight, body mass index and various risk factors for metabolic syndrome such as waist circumference, blood pressure, fasting blood sugar, triglycerides and High Density Lipoprotein were assessed at baseline and after one year. International Physical Activity Questionnaire was used to objectively assess physical activity levels of the participants.

Results: Out of 88 participants, 16 participants were diagnosed with MS at baseline but after one year the number reduced to 8.

Percentage decrease in triglyceride levels (13.5%) was maximum followed by decline in waist circumference (8.9%) fasting blood glucose showed an increase by 6.6%. However, HDL, blood pressure, weight and BMI showed no significant change after one year.

70.6% of participants showed reduction in WC followed by reduction in fasting blood glucose of and triglyceride levels of 66.7% participants. Elevation of HDL levels was observed in 38.5% of the participants. Thus there was least improvement in HDL in the study population after one year. The increase in IPAQ physical activity scores after one year as compared to baseline was not statistically significant but the total sitting and average sitting time showed a statistically significant decline after one year.

Conclusion: The incidence of MS shows a 49.7% decline after one year even when no specific dietary or physical activity advise is given to the participants. Although mean values of triglycerides showed the largest decrease after one year yet decline in waist circumference was seen in maximum percentage of participants. There was least improvement in HDL in the study population after one year.

***Corresponding author :**

Dr. Anumeha Bhagat, Associate Professor, Department of Physiology, Government Medical, College and Hospital, Chandigarh, India, Mob.: 91-9646121590, Email : anumehabhagat@gmail.com

(Received on May 28, 2018)

Introduction

In 2009 a joint interim statement of various associations such as the IDF task force on epidemiology and prevention, National heart lung and blood institute, American Heart Association, World Heart Federation, International Atherosclerosis Society and International Association for the Study of Obesity was published in which common criteria for the clinical diagnosis of the metabolic syndrome (MS) were proposed (1). As per the IDF consensus definition MS is diagnosed in an individual if any three of the five risk factors for metabolic syndrome are present. The five risk factors for MS include i) Waist circumference more than 80 cm in females and more than 90 cm in males ii) Systolic blood pressure more than or equal to 130 and/ or diastolic blood pressure more than or equal to 85 mm of mercury iii) Fasting blood glucose more than or equal to 100 mg/dl iv) Serum triglycerides more than or equal to 150 mg/dl v) Serum HDL less than 40 mg/ dl in males and less than 50 mg/dl in females (1).

Several studies are available for showing the effectiveness of various interventions for management of MS. These include interventions related to changes in diet, (2, 3, 4) changes in physical activity, (5, 6) both combined (7) and various other interventions such as surgery (8, 9, 10) and use of medications (11, 12).

For any intervention to be successful the natural progression of that particular disease should be well studied, same applies for MS too. In one study the inter-relationship of the features of MS over a time gap of 4.5 years was reported (13). In that study conducted on a cohort of 937 individuals aged 40-65 years who underwent oral glucose tolerance testing on two occasions at 4.5-year intervals. Principal component analysis identified three independent factors in men: a blood pressure factor (systolic and diastolic blood pressure and BMI), a glucose factor (fasting and 120-min postload glucose, BMI, waist-to-hip ratio [WHR], and fasting insulin level), and a lipid factor (triglycerides and HDL cholesterol, BMI, WHR, and fasting insulin level). In women, an additional factor was identified, which included BMI, WHR, fasting insulin, and triglycerides. Analysis of the contribution of these variables to the different sub dimensions indicated that BMI was the central feature of the syndrome in both sexes.

In a recently reported study metabolic health defined as less than 1 risk factor for MS was studied for a follow-up period of 10 years. At the end of this period nearly half of the metabolically healthy abdominally obese subjects lost their metabolic health and 42.1% developed MS (14).

Although the long term natural evolution of MS has been reported yet there is insufficient research on the changes in risk factors of MS after one year of diagnosis. So in order to study the short term natural progression of MS we planned to follow up the changes in risk factors of MS after one year of initial diagnosis. Primary objective of this study was to evaluate changes in risk factors of MS after one year of its identification in young college going students of an urban Northern India population. Secondary objectives were to assess the level of non communicable disease awareness, assess the changes in physical activity as per the scores obtained by International Physical Activity Questionnaire and evaluation of self reported dietary and physical activity pattern of the participants.

Material and Method

The study was conducted in Department of Physiology, Government Medical College, Chandigarh, India. Approval of the institutional research and ethics committees was taken before starting the study. In a previously published study we had reported prevalence of MS of 18.3% in college going students of Chandigarh in the age group of 18-25 years using the IDF consensus definition (15) .

In the present study we planned to follow up the same cohort of students to study the natural progression of the risk factors of MS. All students who had enrolled for the previous study and had at least one risk factor for MS (15) were invited to participate in the present study. Verbal as well as written communication was sent to all such students regarding the purpose of the present study and they were requested to participate in this follow up study.

Written informed consent was obtained from all participants who reported for the follow up study.

The methodology for determining height, weight, Body ,mass index and various risk factors for MS such as waist circumference, blood pressure, fasting blood sugar, triglycerides and High density Lipoprotein have been described in detail in our previously published article (15).

In brief all participants were instructed to report to the laboratory for blood sample collection between 9-11 AM, after having had their last meal in the previous night no later than 9:00 PM. They were specifically instructed to dress in loose and light clothing. After reporting to the laboratory the subjects removed their shoes and rested for 10 minutes before the measurements.

Anthropometric profile

Waist circumference (WC) was measured using non-stretchable flexible tape in horizontal position, just above the iliac crest, at the end of normal expiration, with the subject standing erect and looking straightforward and observer sitting in front of the subject. Weight was determined with an electronic balance. Height was measured using a wall mounted, non-extensible measuring tape with subjects in standing position with no shoes and feet kept together.

***Body mass index (BMI)* was calculated using the standard formula: Weight (kg)/Height (m)^2**

With the subject in supine position right arm systolic and diastolic BP was measured by auscultatory method using mercury sphygmomanometer. Three readings were measured 5 min apart and mean of the three was noted.

Biochemical analysis

Blood sample was collected by veni puncture of ante cubital vein after an overnight fast. Venous blood was collected in oxalate and fluoride vials for measurement of glucose, and plain vials for estimating High Density Lipoprotein (HDL) and triglycerides TG). The plasma (in case of glucose)/serum (in case of HDL and TG) was separated after centrifugation at 3000 rpm for 10 minutes.

Physical activity levels of the subjects were measured using the long for self administered version of International Physical Activity Questionnaire (IPAQ). IPAQ assesses physical activity undertaken across a comprehensive set of domains which include leisure time physical activity, domestic & gardening (yard activities), work related physical activity and transport related physical activity.

Median values and interquartile ranges can be computed for walking (W), moderate intensity activities (M), vigorous intensity activities (V) and a combined total physical activity score (TPA). All scores are expressed in MET-minutes/week.

From the IPAQ questionnaire sitting variables which include sitting total in minutes per week and average sitting as total minutes per day are also calculated. Data was processed and analyzed as per the guidelines published by the IPAQ group (16). Participants also filled a questionnaire designed for assessing their NCO awareness, dietary & physical activity pattern.

Statistical analysis

Data was entered in Microsoft excel spreadsheet and checked for errors. Data entered was analyzed using SYSTAT software version 13.2 for Windows. Quantitative data was presented as mean and standard deviation. Qualitative data was presented as ratio and proportions. For qualitative data Chi Square test was used to measure the difference between variables. Normality of the quantitative variables was done using Kolmogorov-Smirhov test. Normally distributed quantitative data for the two groups was analyzed using T test. and Mann-Whitney U test was used for non normal data. Paired t-test was used for normally distributed dependent variables. Pearson coefficient was used to see correlation between quantitative variables. Linear regression and binary logistic regression was used to assess the continuation of independent risk factors towards dependent variable (>= 600 MET). Statistical

significance was considered when p-value was less than 0.05 (P<0.05).

Results

In our previous project 400 students who had at least one risk factor for MS were identified (15). Out of these only 88 participants came for follow up. So we compared the baseline data of only these 88 students participants with the data collected after 1 year of initial diagnosis of MS.

The number of male and female students was 26 and 62 respectively. Mean age of participants was 20.70±2.23 years. At baseline 16 participants were diagnosed with MS but after one year the number of students having MS was reduced to only 8.

If we analyze the gender differences in MS, then MS was present in 14 females and 2 male participant at the beginning of the study whereas after one year MS was present in 4 females and 4 males.

Table I shows the comparison of anthropometric and biochemical variables and risk factors of MS at baseline and after one year. Mean values of waist circumference, fasting blood glucose and triglyceride levels showed a significant change after one year in comparison to values at baseline. Percentage decrease in triglyceride levels (13.5%) was maximum followed by decline in waist circumference (8.9%) fasting blood glucose showed an increase by 6.6%. However, HDL, blood pressure, weight and BMI showed no significant change after one year.

Table II shows the change in the number of participants having a risk factor for MS. At baseline there were 34 participants with elevated waist circumference but after one year this number reduced to only 10. HDL was low in 52 participants in the beginning but at the end of one year it was low only in 32 individuals. 70.6% of participants showed reduction in WC followed by reduction in fasting blood glucose and triglyceride levels of 66.7% participants. Elevation of HDL levels was observed in 38.5% of

TABLE I: Comparison of anthropometric & biochemical variables and risk factors of metabolic syndrome at baseline and after 1 year.

	At baseline (Mean±SD)	*After 1 year (Mean±SD)*	*% change in mean value*	*P value*
Weight (Kg)	56.84±12.04	57.41±10.56	1.0%	0.35
Body Mass Index (Kg/m^2)	20.87±3.89	21.08±3.26	1.0%	0.34
Waist circumference (cm)	80.52±9.13	73.33±8.12	–8.9%	<0.001*
Systolic blood pressure (mm/Hg)	120.45±8.90	122.09±8.59	1.4%	0.29
Diastolic blood pressure (mm/Hg)	78. 91±8.11	80.75±7.24	2.3%	0.13
Mean blood pressure (mm/Hg)	92.76±7.42	94.53±6.87	2.2%	0.13
Fasting glucose (mg/dl)	86.43±10.16	92.55±8.11	6.6%	0.003*
High density lipoprotein (mg/dl)	46.74±8.17	49.14±13.71	5.1%	0.31
Triglycerides (mg/dl)	110.61±32.95	95.68±42.62	–13.5%	0.031*

*P value significant.
"-" sign in percentage change indicates a decline in the value after one year in comparison to value at baseline.

TABLE II: Number of participants with risk factors at baseline and after one year along with the percent reduction in number of participant having risk factor after one year.

Risk factor	*At baseline (n)*	*After 1 year (n)*	*Percent reduction*
Elevated Waist circumference (cm)	34	10	70.6%
Elevated systolic blood pressure (mm of Hg)	6	2	66.7%
Elevated diastolic blood pressure (mm of Hg)	24	8	66.7%
Elevated fasting blood sugar (mg/dl)	6	2	66.7%
Low high density lipoprotein (mg/dl)	52	32	38.5%
Elevated triglyceride (mg/dl)	12	4	66.7%

n=number of participants.

the participants. Thus there was least improvement in HDL in the study population after one year.

Figure 1 shows further analysis of risk MS on the basis of gender differences. Low HDL levels followed by high waist circumference were the most prominent finding in females. Of all the risk factors the waist circumference showed the most perceptible decline. After one year elevated waist circumference was seen in only 10 females as compared to 30 females at baseline.

Table III shows International Physical Activity Scores of the participants at baseline and after one year.

At the end of one year there is increase in all the scores of physical activity i.e. total score of walking, total moderate activity, total vigorous activity and total physical activity although the increase was not statistically significant. The total sitting and average sitting showed a statistically significant decline after one year in comparison to values at baseline.

Table IV shows the correlation between variables such as age, BMI, waist circumference, fasting blood sugar and triglyceride levels with IPAQ scores.

There was no statistically significant correlation between any variable and the IPAQ scores except triglyceride levels which showed a significant negative correlation with average sitting score after one year.

Linear regression analysis for various risk factors of metabolic syndrome at baseline and at the end of

TABLE III : IPAQ scores at baseline and at the end of one year.

IPAQ scores Median (inter quartile range)	*At baseline*	*After 1 year*	*P value*
Total Score of walking (MET-minutes/week)	462 (272.3-1105.5)	841.5 (330-1237.5)	0.58
Total Moderate Activity (MET-minutes/week)	430 (120-1095)	620 (160-1140)	0.38
Total Vigorous Activity (MET-minutes/week)	80 (0-840)	120 (0-720)	0.22
Total Physical Activity (MT-minutes/week)	1209 (649.5-3665.3)	1867.5 (907-3368)	0.198
Sitting total (minutes/week)	3660 (2490-4500)	2640 (2280-3120)	0.027*
Average sitting minutes/day	522.9 (355.7-642.9)	377.1 (325.7-445.7)	0.027*

* P value significant

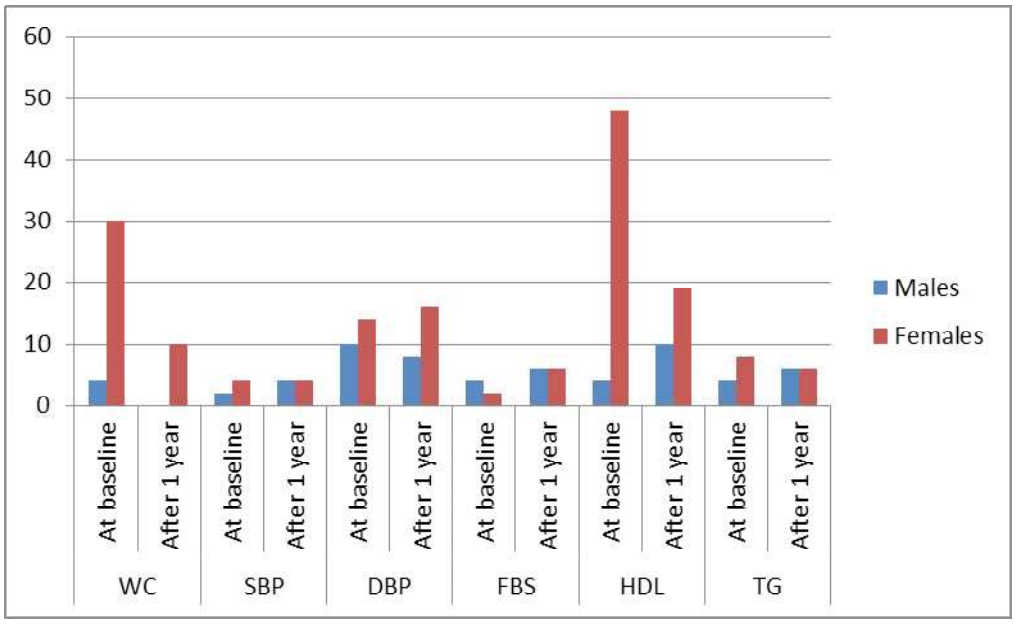

Fig. 1 : Number of participants with risk factor for MS on the basis of gender.

TABLE IV : Correlation between BMI, waist circumference, fasting blood sugar and triglycerides with IPAQ scores at baseline and after 1 year.

R value	*TSW*	*TMA*	*TVA*	*TPA*	*Average sitting*
BMI baseline	0.018	-0.021	-0.232	-0.098	0.02
BMI at 1 year	-0.165	-0.01	0.032	-0.063	-0.203
WC baseline	-0.078	-0.087	-0.216	-0.175	-0.049
WC at 1 year	-0.172	0.042	0.04	-0.04	-0.171
FBS baseline	0.084	-0.166	0.017	-0.029	0.072
FBS at 1 year	-0.238	0.123	0.067	-0.021	-0.284
TG baseline	-0.011	0.002	-0.135	-0.061	-0.028
TG at 1 year	-0.037	-0.24	-0.193	-0.223	-.343*

*p significant

one year revealed that none of the variables had a significant value except triglyceride value which was significant. The variance explained by this model is only 9.5% at baseline and 35% after one year.

Table V shows the binary logistic regression analysis for BMI, waist circumference, fasting blood sugar and triglyceride with the dependent variable of MET minutes more than 600 as cut off for minimum physical activity as recommended by the WHO.

Both at baseline and after one year the model is non-significant and the variance explained by it ranges from 10.5%-16.3% and 9%-19.9% respectively.

Perception of the participants regarding their body weight revealed that 34.1% felt that they were bit fat, 34.1% felt that they were normal weight and 25% felt that they were bit thin. On the basis of BMI 29.5% were underweight, 40.9% normal and 29.5%

TABLE V : Binary logistic regression for BMI, waist circumference, fasting blood sugar and triglycerides.

	B	*Sig.*	*Exp (B) Odds ratio*	*95% C.I. for EXP(B)*	
				Lower	*Upper*
BMI baseline	0.199	0.445	1.22	0.732	2.035
BMI after one year	-0.165	0.595	0.848	0.461	1.559
WC baseline	-0.041	0.682	0.96	0.791	1.166
WC after one year	0.057	0.626	1.059	0.841	1.334
FBS baseline	0.076	0.097	1.079	0.986	1.179
FBS after one year	0.043	0.539	1.044	0.91	1.198
TG baseline	0.019	0.236	1.019	0.988	1.052
TG after one year	0.003	0.819	1.003	0.976	1.031

overweight/obese. All the participant were aware of what is obesity and diabetes mellitus. Regarding family history of diabetes mellitus and hypertension, 13.6% participants had either parents or grandparents undergoing treatment for diabetes mellitus, 18.2% participants had family members with both diabetes mellitus and hypertension and 40.9% had parents/ grandparents with hypertension alone. 27.3% participants had no family member with either diabetes mellitus or hypertension.

31.8% participants had a physical training/games/ sports class in their school whereas 65.9% participant had no such class in school.

When asked what the participants preferred to do in their free time, 22.7% participants revealed that they mostly played outdoors, 63.6% revealed that they primarily spent their free time by engaging in TV watching, talking on phone or reading, 5 participants involved themselves in outdoors as well as indoors activities. After 1 year 34.1% participants involved themselves primarily in outdoor games and 56.8% involved themselves in indoor activities in their free time.

On being asked how much time do you spend watching TV, playing video games or computer games, reading books or talking on phone every day, 20% participants responded that they spent less than one hour per day, 59.0% participants spent 1-3 hours and 18.1% spent 4-6 hours per day. After one year also similar numbers were obtained for the above question.

Questions about dietary details revealed that 61.4% were vegetarian and 34.1% were non vegetarians. 59.1% ate breakfast every morning. 9.1% participants never ate outside, 43.1% participants ate 1-3 days per month in a restaurant or hotel or form a street vendor, 34.1% had outside food 1-3 days per week and 11.3% had outside food 4-6 days per week.

Discussion

The response rate in our study was only 22%. From 400 students initially identified as having at least

one risk factor positive for MS the number of students who reported for the follow up study was only 88. In a previously conducted study for detecting the incidence of MS at 3 years it has been reposted that especially younger people (<40 years) and of Non Western European origin were less interested in follow-up measurements (6).

This 78% dropout rate in our study could be because the students were requested to report to the department for sample collection and other measurements. In our previous study we recorded all the variables and collected the blood samples on site which had ensured in a high compliance rate. Another reason could be that the students might have considered it as a futile exercise to get themselves reassessed for the risk factors in such a short span of time when they were apparently having no disease. At the time of initial assessment it was clarified to these students that having a risk factor does not mean that they have an abnormal finding, in fact all cut offs for risk factors of MS are well within the normal range. This was done so that we could study the natural progression of MS at one year of initial diagnosis.

Thus no specific advice was given to the students who has at least one risk factor positive. Despite the fact that no specific advice was given for lifestyle change the prevalence of MS the number of participants having MS declined from 16 to 8 after one year. At baseline the incidence of MS was 18.1% but after one year it was reduced to 9.0%. Thus there was a high remission rate in those who reported for the second assessment of risk factors after one year. In those students identified with MS at baseline 87.5% were males and 12.5 % were females but after one year the proportion of males and females having MS was 1:1. Review of literature shows that data about remission of MS without predefined intervention are scarce. In one study elevated WC was identified initially by self screening in apparently healthy individuals, to detect new MS cases. After three years more than half of the participants detected with MS at screening were no longer having MS. Remission was defined as having less than three MS components at follow-up, thereby no longer fulfilling the criteria for the presence of the MS. The presence of more than three MS components and a higher waist circumference, glucose level and systolic blood pressure were independently associated with a lower chance of remission (17). In two randomized controlled trials remission rates for their control groups of 9 and 18 % have also been reported (18, 19).

In our study risk factor for MS which showed the largest decline after one year is triglyceride levels followed by waist circumference with fasting blood glucose showing an increase. However, HDL, blood pressure, weight and BMI showed no significant change after one year.

At the end of one year the number of participants showing a decline in WC was maximal followed by TG and FBS. The least improvement was seen for HDL.

Our data also shows that the risk factor which showed the largest decline in one year was waist circumference followed by reduction in fasting blood glucose and triglyceride levels. So, although mean values of triglycerides showed the largest decrease after one year yet waist circumference decline was seen in maximum number of participants. There was least improvement in HDL in the study population after one year.

Although there was no statistically significant change in physical activity levels as determined by the IPAQ scores yet there was increase in total score of walking, total moderate activity, total vigorous activity and total physical activity after one year. Also the average time spent sitting also showed a significant decrease. The IPAQ scores were not correlated with BMI, waist circumference, fasting blood glucose or triglyceride levels.

Results of linear regression analysis for risk factors of MS were able to explain only 9.5 % variance at baseline and 35% variance after one year. Similarly results of binary logistic regression analysis using dependent variable of MET minutes more than 600 as cut off also could explain only less than 20% variance.

Subjective perception of body weight into categories such as bit fat, normal weight and bit thin was almost similar to the objectively measured BMI of the participants. In our study only 40.9% were having normal BMI while the rest were either underweight or overweight/obese. 27.3% of the participants had no family member i.e. parents or grandparents with diabetes mellitus or hypertension, rest of the participants i.e. 72.7% had at least one family member with diabetes mellitus or hypertension.

More than 60% of the participants revealed the absence of a physical activity class at the school level

At baseline more than 63.6% participants also revealed that they preferred to spend their free time in activities involving sitting, however there was a slight decline to 56.8% in the percentage of students preferring sitting activities after one year. Similarly preference for outdoor activities changed from 22.7% at baseline to 34.1% after one year.

These results suggest that the occurrence of metabolic syndrome cannot be completely explained by various variable that we have analyzed in our study. Probably dietary habits, physical activity patterns and genetic factors are also involved in the evolution of metabolic syndrome in an individual.

There is lack of any similar in depth study in literature which has tried to study the temporal evolution of various risk factors for MS in the Indian population. A limited number of studies have been conducted in other populations but in age groups and time duration which is different from our study.

A study was conducted in Britain in the age group of 40-65 years in which the changes in components of MS have been analyzed by testing at baseline and at 4.5 years. It has been suggested that obesity as measured by BMI, central obesity as measured by WHR and hyper insulinemia are the primary components essential for development of MS. BP, dyslipidemia and glucose intolerance were considered the secondary components (20).

In another study in White, Black and Hispanic participants the predictors of the incidence of MS in non diabetic adults were investigated at baseline and subsequently at 5 years (21). In that study WC was identified as the optimal predictor for the development of MS. The findings also suggested that obesity may precede the development of other metabolic syndrome components. Interventions that address obesity and reduce waist circumference may reduce the incidence of the metabolic syndrome in non diabetic adults.

Since MS has a multifactorial etiology it has been seen from varied angles by different specialists. However both anthropometric variables as well as lipid levels need more Asian Indian validation. The body fat pattern and lipids are particularly making the Asian Indians coronary prone. Unfortunately the Asian Indian studies outside India are in much larger numbers as compared to Indian studies (22). Two different clusters have been reported from two groups from North Western India. One is the lipid cluster form Chandigarh (23) and the other is the low socioeconomic cluster form Jaipur (24). The group from PGI Chandigarh has reported, isolated lipid abnormalities in 47 to 51% in rural-urban non diabetic cohort essentially highlighting the low HDL and elevated Triglycerides. The classical Indian lipid triad is low HDL, elevated triglyceride and elevated LDL cholesterol is the most common finding in most other Indian studies (25, 26).

Conclusion:

The incidence of MS shows a 49.7% decline after one year even when no specific dietary or physical activity advise in given to the participants. Although mean values of triglycerides showed the largest decrease after one year yet decline in waist circumference was seen in maximum percentage of participants. There was least improvement in HDL in the study population after one year. Physical activity as measured objectively by IPAQ scores and also self reported questionnaire showed an increase after one year.

Lacuna of this study is that we have not taken history of any intervention during one year which could affect the risk factors for MS. Also the small sample size

and the predominance of females is another limitation of this study.

Future:

Studying the temporal profile of development of MS will give an insight into the evolution of the disorder which will help in formulating adequate management strategies for MS specifically in the Indian scenario where there is a double burden of these non communicable disorders.

Acknowledgements

I thank all the participants of this study for their co-operation without which this study would not have been possible.

Grant supporting this project:

This project is a part of the grant received by Department of Science and Technology- UT, Chandigarh, India vide letter number S&T/Sanc/09/2013/1091-1096 dated 09/09/2013.

References

1. Alberti KGMM, Eckel RH, Grundy SM. Harmonizing the Metabolic Syndrome. A Joint Interim Statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. *Circulation* 2009; 120: 1640–1645.
2. Lerman RH, Minich DM, Darland G, Lamb JJ, Schiltz B, Babish JG, Bland JS, Tripp ML. Enhancement of a modified Mediterranean-style, low glycemic load diet with specific phytochemicals improves cardiometabolic risk factors in subjects with metabolic syndrome and hypercholesterolemia in a randomized trial. *Nutr Metab* 2008; 5: 29.
3. Salvado J, Fernandez-Ballart J, Ros E, Martinez-Gonzalez MA, Fito M, Estruch R, Corella D, Fiol M, Gomez-Gracia E, Aros F, Flores G, Lapetra J, Lamuela-Raventos R, Ruiz-Gutierrez V, Bullo M, Basora J, Covas MI. Effect of a Mediterranean diet supplemented with nuts on metabolic syndrome status: one-year results of the PREDIMED randomized trial. *Arch Intern Med* 2008; 168: 2449–2458.
4. Lundgren JD, Malcolm R, Binks M, O'Neil PM. Remission of metabolic syndrome following a 15-week low-calorie lifestyle change program for weight loss. *Int J Obes* 2009; 33: 144–150.
5. Hightower KR, Olson RE, Gellish RL, Russi GD, Goslin BR, Moudgil VK. Reversal of metabolic syndrome characteristics. *Metab Syndr Relat Disord* 2007; 5: 69–76.
6. Maxwell MS, Goslin BR, Gellish RL, Hightower KR, Olson RE, Moudgil VK, Russi GD. Metabolic syndrome status changes with fitness level change: a retrospective analysis. *Metab Syndr Relat Disord* 2008; 6: 8–14.
7. Anderssen SA, Carroll S, Urdal P, Holme I. Combined diet and exercise intervention reverses the metabolic syndrome in middle-aged males: results from the Oslo Diet and Exercise Study. *Scand J Med Sci Sports* 2007; 17(6): 687–695.
8. Lee WJ, Huang MT, Wang W, Lin CM, Chen TC, Lai IR. Effects of obesity surgery on the metabolic syndrome. *Arch Surg* 2004; 139: 1088–1092.
9. Nugent C, Bai C, Elariny H, Gopalakrishnan P, Quigley C, Garone M Jr, Afendy M, Chan O, Wheeler A, Afendy A, Younossi ZM. Metabolic syndrome after laparoscopic bariatric surgery. *Obes Surg* 2008; 18: 1278–1286.
10. Rossi M, da SR BF, Chaves AG Jr, Regina PF, Martin Bianco RF, Serpa NA, Zimberg CE. Remission of metabolic syndrome: a study of 140 patients six months after Roux-en-Y gastric bypass. *Obes Surg* 2008; 18: 601–606.
11. Filippatos TD, Kiortsis DN, Liberopoulos EN, Georgoula M, Mikhailidis DP, Elisaf MS. Effect of orlistat, micronised fenofibrate and their combination on metabolic parameters in overweight and obese patients with the metabolic syndrome: the FenOrli study. *Curr Med Res Opin* 2005; 21: 1997–2006.
12. Orchard TJ, Temprosa M, Goldberg R, Haffner S, Ratner R, Marcovina S, Fowler S. The effect of metformin and intensive lifestyle intervention on the metabolic syndrome: the Diabetes Prevention Program randomized trial. *Ann Intern Med* 2005; 142: 611–619.
13. Maison P, Byrne CD, Hales N, Day NE, Wareham NJ. Do Different Dimensions of the Metabolic Syndrome Change Together Over Time? Evidence supporting obesity as the central feature. *Diabetes Care* 2001; 24: 1758–1763.
14. R Eshtiaghi, S Keihani, F Hosseinpanah , M Barzin & F Azizi. Natural course of metabolically healthy abdominal obese adults after 10 years of follow-up: the Tehran Lipid and Glucose Study. *Int J of Obs* 2015; 39: 514–519.
15. Bhagat A, Malhotra A, Kaur G and Kapoor N. Metabolic Syndrome : Not Even the Urban Indian Youth is Spared. *Ind J Physiol Pharmacol* 2017; 61(4): 368–377.
16. Craig CL, Marshall AL, Sjostrom M. International Physical Activity Questionnaire: 12 country reliability and validity. *Med Sci Sport Exerc* 2003; 25: 1381–1395.
17. Engelsen C, Gorter KJ, Salomé PL, Donk MV, Rutten GE. Remission of screen-detected metabolic syndrome and its determinants: an observational study. *BMC Public Health* 2012; 12: 778.
18. Orchard TJ, Temprosa M, Goldberg R, Haffner S, Ratner R, Marcovina S, Fowler S. The effect of meformin and intensive lifestyle intervention on the metabolic syndrome: the Diabetes Prevention Program randomized trial. *Ann Intern Med* 2005; 142: 611–619.
19. Bo S, Ciccone G, Baldi C, Benini L, Dusio F, Forastiere G, Lucia C, Nuti C, Durazzo M, Cassader M, Gentile L, Pagano G. Effectiveness of a lifestyle intervention on metabolic syndrome. A randomized controlled trial. *J Gen Intern Med* 2007; 22: 1695–1703.

20. Palaniappan L, Carnethon MR, Wang Y, Hanley AJG. Predictors of the Incident Metabolic Syndrome in Adults : The Insulin Resistance Atherosclerosis Study. *Diabetes Care* 2004; 27: 788–793.
21. Joshi SR. Metabolic Syndrome- Emerging Clusters of the Indian Phenotype. *J Assoc Physicians India* 2003; 51: 445–446.
22. Malhotra P, Kumari S, Singh S, Varma S. Isolated Lipid Abnormalities in Rural and Urban Normotensive and Hypertensive North-West Indians. *J Assoc Physicians India* 2003; 51: 459–463.
23. R Gupta, VP Gupta, M Sarna, H Prakash, Rastogi S, KD Gupta. Serial epidemiological surveys in an urban Indian population demonstrate increasing coronary risk factors among the lower socioeconomic strata. *J Assoc Physicians India* 2003; 51: 470–477.
24. Mohan V, Deepa R, Rani SS, Premalatha G. Prevalence of coronary artery disease and its relationship to lipids in a selected population in South India: The Chennai Urban Population Study (CUPS No. 5). *J Am Coll Cardiol* 2001; 38: 688–689.
25. Mohan V, Shanthirani S, Deepa R, Premalatha G, Sastry NG, Saroja R. Intra-urban differences in the prevalence of the metabolic syndrome in southern India - the Chennai Urban Population Study (CUPS No. 4). *Diabet Med* 2001; 18: 280–287.
26. Deepa R, Shanthirani CS, Premalatha G, Sastry NG, Mohan V. Prevalence of insulin resistance syndrome in a selected south Indian population—the Chennai urban population study-7([CUPS-7). *Ind J Med Res* 2002; 115: 118–127.