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Review Article

Metabolic syndrome: The Indian public health perspective

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ABSTRACT

Metabolic Syndrome (MetS) is a clustering of specific risk factors, namely, central obesity, raised blood pressure, impaired fasting glucose, raised triglycerides, and low levels of high-density lipoprotein-cholesterol (HDL-C). This constellation is triggered by insulin resistance and its resultant hyperinsulinemia. The two most important and universally agreed causes of insulin resistance are increased body fat (particularly central obesity) and physical inactivity. Other causes include certain genetic/pro-genetic factors, unhealthy atherogenic diet, tobacco use, and excessive alcohol intake. Within 3 decades of the initial description of MetS by Reaven, various defining criteria have been developed by now, by leading international professional bodies, the most commonly used being the one given by the Adult Treatment Panel III (ATP III) report of the National Cholesterol Education Program (NCEP) [NCEP-ATP-III], the updated guidelines recently released by the American College of Cardiology (ACC) and the American Heart Association (AHA). MetS has been well documented to increase the risk of ischemic heart disease (IHD) by two to three times and of type 2 diabetes mellitus (T2DM) by five times. The world-wide prevalence is on the increase, with the overall global prevalence estimated to be 20%–25% of the adult population. In our country, various epidemiological studies undertaken across the country have consistently shown a high prevalence, which is likely to be as much as one-quarter of the adult population, with increasing age and female gender being at higher risk. The occurrence has also been recorded among the Armed Forces personnel as well as in adolescents. MetS has therefore become a priority issue for both, the public health providers as well as for the clinicians in our country, and needs concerted, all-round efforts for its prevention, early detection, management, and research. Against this background, the various public health measures for prevention and control of MetS have been suggested in this review.

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Introduction

It was in the year 1971 that Omran had forwarded the theory of “Epidemiological transition,” wherein it was hypothesized that development of the pattern of morbidity and mortality in a nation or community, over time, is characterized by various phases: (1) the ‘age of pestilence and famine’ (2) the ‘age of receding pandemics’ and (3) the ‘age of degenerative and man-made diseases’. In the early phases of this transition, the disease pattern was dominated by infectious diseases with very high mortality, especially at younger ages; the major economy during this earlier phase was primarily based on agriculture. Transition from a primarily agro-based economy to a predominantly market based economy would also gradually bring about a gradual transition in the disease profile, so that in the final stage of degenerative and man-made diseases, the causes of morbidity and mortality would be dominated by chronic, non-communicable (lifestyle) diseases and injuries, with a simultaneous decline in the overall mortality rate.¹ In this regard, a related and important concept is that of the Epidemiological Transition Level (ETL), which is based on comparison of Disability Adjusted Life Years (DALY) between Communicable and Non-Communicable diseases. ETL is defined as:

DALY due to Communicable, Maternal, Child & Nutritional causes
DALY due to Non – communicable disease and injuries

A decreasing ratio indicates advancing epidemiological transition with an increasing relative burden from non-communicable diseases as compared to communicable, maternal, neonatal, and nutritional diseases.

The predictions made in the theory of epidemiological transition seem to be coming true. In 1990, The ETL for our country was 1.56, indicating a predominant role of communicable disease vis-à-vis non-communicable diseases in profiling the morbidity and mortality; contrarily, in 2016, as per a recent report released by Indian Council of Medical Research (ICMR), the overall ETL for India is 0.50 indicating a major shift in the disease pattern and an overwhelming role of non-communicable (lifestyle) diseases and injuries in shaping the morbidity/mortality profile of our country. In 2016, ETL of all the states in our country was <1, indicating that the entire country has passed on through the epidemiological transition process, into the stage predominated by degenerative, non-communicable diseases and injuries; certain states have particularly low and concerning ETLs, namely, Kerala (0.16), Goa (0.21), Tamil Nadu (0.26), and Punjab (0.29), while Karnataka, Andhra Pradesh, Telangana, Maharashtra, West Bengal, Himachal Pradesh, Haryana and Jammu & Kashmir also have ETL levels between 0.3 to 0.4, indicating the major sweep made by non-communicable disease and injuries in these states.²

Among the concerning high occurrence of non-communicable disease in our country, Ischemic Heart Disease (IHD) has arisen as the number one killer, causing 132

deaths per lakh population, which translates into more than 17 lakh deaths per year due to IHD (or, 19% of all deaths) in India. Type-2 Diabetes Mellitus (T2DM) accounts for 23 deaths per lakh population, which translates into more than 3 lakh deaths per year (or, 3% of all deaths) in India.² Tackling just these two diseases, IHD and T2DM, would thus enable us to effectively address almost one-quarter of deaths and diseases in our country.

It is against the above background of the major public health importance of IHD and T2DM, that the present review is being undertaken in respect of Metabolic Syndrome (abbreviated as ‘Mets’ in this article). Earlier workers had named it varying as ‘Syndrome - X’, ‘Insulin Resistance Syndrome’ and ‘Deadly Quartet’. Over the past 30 years, this syndrome has been increasingly identified as an important risk factor for IHD and T2DM. Given the available evidence, there is a pressing need, both from public health as well as from clinical domains, to aggressively address this issue. From public health point of view, focused efforts need to be made to bring about lifestyle modifications among the general population to reduce obesity and to increase physical activity. In addition, individual patients with MetS, coming in contact with the clinical echelons, need to be identified and educated with a view to reduce their lifestyle risk factors coupled with specific treatment, if required.

Development of the concept of metabolic syndrome (MetS)

Clinical suspicions of clustering of various cardiovascular risk factors started almost a century back, when in 1923, Kylin gave a description of the association of hypertension, hyperglycemia, and gout.³ Subsequently, in 1947, Vague described that visceral (central) obesity was commonly associated with the metabolic abnormalities found in cardiovascular diseases and T2DM.⁴ However, the first ever full-fledged scientific concept of “clustering” of various metabolic risk factors came from the famous Diabetologist, Gerald Reaven. In 1988, during the Banting memorial lecture, Reaven hypothesized that central feature in many chronic diseases, especially Ischemic Heart Disease (IHD) and Diabetes Mellitus is development of resistance to insulin action, and as a compensatory mechanism for insulin resistance, hyperinsulinemia results. Factors which cluster under the influence of insulin resistance are hyperinsulinemia, impaired glucose tolerance, rise in blood pressure, and a specific dyslipidemia, which includes increase in triglycerides and lowering of HDL. It was hypothesized by Reaven that this syndrome is a major risk factor for IHD and Diabetes Mellitus.⁵ Reaven had termed such clustering of risk factors which occur under the influence of hyperinsulinemia, as ‘Syndrome X’, (‘X’ indicating some yet

unknown entity) and this term was retained for almost a decade, before being finally replaced by the current nomenclature 'Metabolic Syndrome'. Over the past 3 decades, since its first description by Reaven, MetS, as an entity, has gained international acceptance; the International Statistical Classification of Diseases and Related Health Problems (10th revision) [ICD-10] has given it the coding – E88.81.

What causes the MetS?

The two major factors which are universally accepted in the causation of MetS are insulin resistance and central obesity. In addition, certain genetic/progenetic factors, physical inactivity, advancing age, female gender, and pro-inflammatory state may also have a contributory effect, their role being variable and depending on the ethnic group.⁷

- **Insulin resistance:** insulin resistance occurs when the sensitivity of cells in the body, to the action of insulin, starts declining; eventually, they become resistant to the action of insulin; due to development of resistance to insulin action, peripheral utilization of glucose is adversely affected, and consequently a larger amount of glucose remains in the blood; this triggers the need for more and more insulin to be produced and secreted into the blood, in an attempt to utilize the increased quantity of retained blood glucose, thus resulting in hyperinsulinemia; such production of increasing amounts of insulin eventually wears out the beta cells; once the beta cells are no longer able to produce enough insulin, a person becomes hyperglycemic, resulting in T2DM. However, even before the state of T2DM occurs, much damage would have already occurred to the body, including an increase in triglycerides, which further impairs insulin sensitivity.
- **Central obesity:** generalized obesity is a well-documented risk factor for T2DM and IHD. However, more than generalized obesity (as seen in the form of raised Body Mass Index (BMI), it is the "central obesity" that occurs due to excessive deposition of fat in the intra-abdominal compartment (also known as visceral/peritoneal compartment), which is a much stronger risk factor for development of MetS. Central Obesity is quite easily and effectively measured by an increase in waist circumference (WC) or Waist Hip Ratio (WHR).

Definition of MetS

Metabolic syndrome (MetS) is a complex of interrelated but specific risk factors for cardiovascular disease (CVD) and T2DM. Development of resistance to insulin action and its consequent hyperinsulinemic state is the most likely central mechanism, which triggers such clustering. Development of resistance to insulin action may occur, besides a wide variety of heretofore unknown factors, due to: (1) inherent genetic/progenetic factors (2) advancing age (3) physical inactivity (4) habitual consumption of energy-dense atherogenic diet (5) obesity, particularly a predisposition to accumulate fat in the intra abdominal (visceral/peritoneal) compartment and at ectopic sites such as liver and pancreas (6) tobacco use and (7) alcohol abuse.⁶ Once

these triggering factors, as narrated above, become operative, either alone or in combination, the consequent onset of insulin resistance and its resultant hyperinsulinemia bring about a significant 'clustering' of specific risk factors. The factors which tend to cluster in MetS include: (1) increased deposition of fat in the intra-abdominal (visceral or peritoneal) compartment as seen by an increase in the waist circumference (WC) or an increase in WHR (2) rise in blood pressure (3) increase in fasting plasma glucose levels (4) rise in triglycerides level; and (5) lowering of highdensity lipoprotein (HDL) cholesterol levels. Once in place, MetS is a definite risk factor for CVD, (particularly coronary heart disease (CHD)) and T2DM. Thus, MetS can be defined as a significant clustering of specific CVD and T2DM risk factors, namely, intra-abdominal obesity, increase in serum triglycerides, decrease in HDL-Cholesterol, dysglycemia and rise in blood pressure usually triggered by insulin resistance (and its consequent hyperinsulinemia) and by various genetic/progenetic factors.

Diagnostic criteria of MetS

Though Reaven had forwarded the initial hypothesis,⁵ he did not specify the actual levels of the various risk factors that cluster in 'syndrome X' (now known as MetS), which could be used for diagnostic cut-off purpose. Thereafter, there have been various efforts by eminent bodies, starting with the definition given by the World Health Organization (WHO) in 1998 and followed by various eminent professional groups. These are presented in Table 1.

Out of the above, the most commonly used in various studies has been the NCEP-ATP-III criteria⁹ which requires any three of the following five to be fulfilled: (1) WC ≥ 102 cms for males or ≥ 88 cms for females (for South Asians, including Indian populations, this criteria has been revised to ≥ 90 cms for males or ≥ 80 cms for females (2) Triglycerides ≥ 150 mg/dL (3) HDL-C < 40 mg/dL in males or < 50 mg/dL in females (4) systolic blood pressure (SBP) ≥ 130 mm Hg or diastolic blood pressure (DBP) ≥ 85 mmHg or both and (5) Fasting plasma glucose ≥ 100 mg/dL. In addition, existing drug treatment for dyslipidemia/dysglycemia/raised blood pressure would also be qualifying criteria.

Epidemiology

It has been estimated that the risk of developing CVD over the next 5–10 years is two times higher among persons with MetS compared to persons without this syndrome. The risk over a lifetime undoubtedly is even higher. Furthermore, the metabolic syndrome confers a 5-fold increase in risk for type 2 diabetes mellitus. Available evidence also indicates that individuals with MetS have a 30%–40% increased probability of developing T2DM or CVD or both, over a period of 20 years.¹³

Magnitude of the problem

Globally speaking

Global estimates of MetS are more difficult to measure as compared to its outcomes, viz., coronary heart disease (CHD)

Table 1 – Diagnostic criteria for metabolic syndrome forwarded by various eminent professional bodies.

Component	Name of professional body				
	WHO	IDF	NCEP – ATP – III	Harmonizing joint statement	EGIR
Essential components	Evidence of insulin resistance ^a	WC ≥ 94 in males/ ≥ 80 in females ^b	NIL	NIL	Hyperinsulinemia ^c or IFG/IGT/T2DM
Other components (Other than essential)					
Insulin resistance or hyperinsulinemia	Essential criteria as above	Not Applicable (NA)	NA	NA	Essential criteria as above
Waist Circumference (WC) ^b	NA	Essential criteria as above	≥ 102 in males; ≥ 88 in females	≥ 90 in males; ≥ 80 in females ^d	≥ 94 in males; ≥ 80 in females
Waist: Hip Ratio (WHR)	≥ 0.90 in males; ≥ 0.85 in females ^e	NA	NA	NA	NA
Serum triglycerides (mg/dL) ^f	≥ 150	≥ 150	≥ 150	≥ 150	≥ 177
Serum HDL-C ^f	< 35 (males); < 39 (females)	< 40 (males); < 50 (females)	< 40 (males); < 50 (females)	< 40 (males); < 50 (females)	< 39
SBP/DBP mm Hg ^{f,g}	$\geq 140/90$	$\geq 130/85$	$\geq 130/85$	$\geq 130/85$	$\geq 140/90$
Fasting plasma glucose (mg/dL) ^{f,h}	Essential criteria as above	≥ 100	≥ 100	≥ 100	Essential criteria as above
Microalbuminuria	Urinary albumin > 20 $\mu\text{g}/\text{min}$ or albumin: creatinine ratio ≥ 30 mg/g	NA	NA	NA	NA
Final diagnostic criteria	Essential criteria as above (IR/IFG/IGT/T2DM) <i>plus any two of the other</i>	Essential criteria as above (increased WC) <i>plus any two of the other</i>	Any three of the five criteria (no essential criteria)	Any three of the five criteria (no essential criteria)	Essential criteria as above (Hyperinsulinemia) <i>plus any two of the other</i>
Reference No.	10	7	9	8	11

^a Insulin resistance (IR) as evidenced by clamp studies, or presence of impaired glucose tolerance/impaired fasting glucose/T2DM.

^b WC = waist circumference in centimeters.

^c Hyperinsulinemia as evidenced by plasma insulin levels of > 75 th centile.

^d The cut off for WC of 90 cm for males and 80 cm for females is specific for Asian Indian populations. Cut off levels for western countries are higher.

^e If Body Mass Index (BMI) is ≥ 30 kg/sq meters, then WHR need not be measured as per WHO criteria.

^f In addition to the cut-off for raised triglycerides, lowered HDL-C, raised BP or increased fasting glucose, existing drug treatment for these abnormalities will also be considered as an inclusion criteria.

^g Rise in either systolic blood pressure/diastolic blood pressure in mm Hg would be a criterion.

^h It may be mentioned that the World Health Organization (WHO) still maintains that the cut off for Impaired fasting glucose should be > 110 mg/dL and not at > 100 mg/dL as has been recommended by a number of other professional bodies. This decision was based on concerns about the significant increase in impaired fasting glucose/ impaired fasting hyperglycemia (IFG) prevalence which would occur with lowering the cut-point and the impact on individuals and health systems. There is a lack of evidence of any substantial benefit in terms of reducing adverse outcomes or progression to diabetes for people identified by the lower cut-point of 100 mg/dl compared with those above the current WHO cut-off point.¹²

and T2DM. An estimated one-fourth of the world's adult population (i.e. approximately a billion adults globally) are likely to be having MetS.¹⁴ A global review by Eckel et al., showing estimated prevalence of MetS according to various countries, by age and gender is depicted in Fig. 1. The data indicates very high prevalence among the adult US population, high prevalence in countries of the middle-east and low prevalence in France.¹⁵ However, estimates of MetS are quite variable, depending on the criteria used for defining it in the study. In Iran, a country wide survey undertaken in 2007 showed prevalence of MetS was between 34.7% and 41.6%, based on whether the NCEP-ATP-III or International Diabetes Federation (IDF) or the harmonizing-NHLBI criteria were used. In Tunisia, prevalence was 24.3% based on ATP III criteria but much higher (45.5%) based on IDF criteria. In most of the country-wide estimates, prevalence has been found to be much higher among women than men.¹⁶ Nearer to home, in China, Dongfeng et al., in 2005, found prevalence of MetS to be 9.8% in men (95% confidence interval [CI] 9.0–10.6) and 17.8% in women (95% CI: 16.6–19.0).¹⁷ In a more recent review, the incidence of MetS was reported to show an increasing trend in China, with higher prevalence in urban areas; It has been estimated that, in 2017, the prevalence of MetS in China would

be about 15.5%.¹⁴ In another report from our neighboring country, Pakistan, Basit et al. has reported the prevalence of metabolic syndrome, according to different definitions, as ranging from 18% to 46%, thereby placing MetS as a prime target for preventive medicine.¹⁸

MetS and the South Asian/Indian populations

The issue whether MetS is a much larger problem among south Asian populations, including India, has incited plenty of interest over the past 3 decades. The emerging population groups of south Asians, including Indians, who migrate to various affluent countries of western Europe or USA, have a phenotype of higher percentage of body fat at lower values of BMI, raised WHR or WC and less “lean” mass as compared to other ethnic groups. Migrant Asian Indians have these above-mentioned features as compared to both, the ethnic population of the country to which they migrate as also when compared with urban subjects living within India. High body fat, often at BMI values that are in the non-obese range, is another characteristic feature of Asian Indians. Thus, the emerging Asian Indian phenotype is characterized by a ‘high body fat to BMI’ ratio, high WC or WHR and less lean mass,

Fig. 1 – Country wise estimates of Metabolic Syndrome (Ref.: ¹⁵) (Horizontal axis denotes the name of country and the age group in years; vertical axis denotes the percentage of adult population estimated to be having Metabolic Syndrome.(Source: Eckel RH, Grundy SM, Zimmet PZ. The Metabolic Syndrome. Lancet 2005; 365 (9468): 1415–28.).

particularly in the lower limbs.¹³ In early 1990s, path-breaking studies by McKeigue et al.,¹⁹ and expert reviews by Vardan²⁰ gave the earliest but vivid indications that the frequency of IHD among migrant Indians was higher than the frequency of IHD among the local populations of affluent countries to which these Indians had migrated. The second observation was that while these migrant Indians had higher frequency of IHD, 'conventional coronary risk factors' (raised total cholesterol, high body weight and smoking) among these migrant Indians were not raised. On the other hand, certain 'non-conventional' factors like higher levels of triglycerides and lower HDL (in the face of normal total cholesterol levels), higher levels of central (abdominal) obesity (in the face of normal body weight) and impairment of glucose tolerance were noted. In addition, these subjects showed higher insulin resistance manifested by fasting hyperinsulinemia. The strong hypothesis which developed from these studies was that Indians, as a population group, were much more susceptible to develop syndrome X and the consequent adverse effects, notably IHD, as compared to other ethnic groups like Europoid or Caucasian populations.^{19–21}

Hoskote et al., in a review, has provided the details of the 'thrifty gene' hypothesis, to explain the high levels of insulin resistance and its consequences among the Indians as compared to Europoid and other Caucasian populations.²² For many centuries, Indians have been largely a predominantly vegetarian population, and the economy was largely based on agriculture. This predominantly vegetarian diet provided lower energy density. On the other hand, the diet of Europeans, over many centuries, has been predominantly meat based (due to severe winters and consequent low agricultural production), and hence the European diet has been of high energy density. Dependence on vegetarian diet and a predominantly agricultural society also meant that the society had to face periods of food shortage and energy deprivation during the frequent famines and floods, for which the human body was required to adapt, with a view to store energy more efficiently to tide over such adverse circumstances. It has therefore been proposed that obesity, particularly abdominal obesity (since energy can be stored as fat more efficiently in the intra-abdominal compartment) and type-2 diabetes had their roots in a natural selection of these early humans, favoring a 'thrifty genotype', which enabled highly efficient storage of energy during periods of food abundance, to be utilized during periods of food scarcity. Thus, these genetic or phenotypic adaptations that are useful in an energy-deprived state turn into a disadvantage when the dietary energy intake becomes high and physical activity levels drop, as would happen when the same energy deprived populations become affluent, get enough food and do not exercise adequately. This is actually happening in our country now, given the industrialization and opening up of market economy, or else in case of Indians who migrate to more affluent countries; thus the same thrifty gene which had originally developed to save energy and store it for use in times of need, continues to store energy when there is food abundance, resulting in obesity, particularly central obesity. Similarly, the 'thrifty phenotype' also explains the 'Barker's hypothesis' which states that children born with low birth weight tend to store much larger amounts of energy as fat, thereby going on to develop T2DM in

Table 2 – Prevalence of metabolic syndrome as reported by various research studies in India.

Authors	Ref. No.	Place	Age/Sex of subjects	Type of Study	Prevalence of MetS			Diagnostic criteria used
					Overall (%)	Males (%)	Females (%)	
Bansal et al.	24	Western U.P. Urban	30–70 yrs Both sex	Population based	16.57	12.5	20.33	NCEP-ATP-III
Barik et al.	25	Birbhum (W.B.), Rural	≥ 18 yrs Both sex	Population based	15	10.7	20.3	NCEP-ATP-III
Prasad et al.	26	Odisha, Urban	≥ 20 yrs Both sex	Population based	33.5	24.9	42.5	NCEP-ATP-III
Khan et al.	27	Central U.P. Urban	Adults, both sex	Hospital based	40.9	26.2	59	NCEP-ATP-III
Harikrishnan et al.	28	Kerala Urban and Rural	Adults Both sex	Population based	24	20	28	NCEP-ATP-III
Bhat et al.	29	Kashmir Urban	Adolescents 10–18 yrs	Population based	3.5			NCEP-ATP-III
Venugopal et al.	30	Pudu-cherry	≥ 30 yrs Both sex	Population based	39.7			IDF
Madan et al.	31	Mumbai Urban	18–65 yrs, Males	Population based		40		NCEP-ATP-III
Kapil et al.	32	Uttara-khand, Rural	≥ 60 yrs, Both sex	Population based	28.6			NCEP-ATP-III
Bhalwar et al.	33	Armed Forces	35–60 yrs, Males	Population based		8.47		Original WHO criteria
Bhalwar et al.	34	Armed Forces	30–60 yrs, Males	Population based		6.2		NCEP-ATP-III

adulthood. Thus, the available evidence indicates that Indians are, most probably, metabolically different from Europeans, due to certain progenetic factors as thrifty gene and such other still unknown factors.²²

India

In India, insulin resistance and MetS are widely prevalent. Studies have reported that in urban Indian populations, age-adjusted prevalence of metabolic syndrome was found to be overall approximately 25% (approximately 31% in women and 18.5% in men). There is an escalating age-related prevalence in both men and women.²³ This is higher as compared to another international study which had estimated that approximately 13–15% of the adult population in India is having MetS, with females being more affected (approximately 8%–9% among adult males and 18–19% among adult females).¹⁵ The findings of various studies undertaken in the recent past, in India, on the prevalence of MetS, are summarized in Table 2.

In general, there is wide variation between the studies as regards the overall prevalence of MetS in different parts of India but, the following issues need to be flagged:

- It is likely that the prevalence of MetS, among adults in India, would be somewhere between 20% and 25%.
- Prevalence is consistently significantly higher among women than men.
- Prevalence is consistently and consistently, with increasing age.
- Even adolescents show the presence of MetS, albeit of a low prevalence.
- Middle-aged Armed Forces personnel, despite their high level of health and fitness, also have a prevalence of 6.2%–8.5%. The Indian Armed Forces personnel, drawn

from all across our land, from different religions and ethnic groups, represent the typical ‘unity in diversity’ of our country. In addition, the Indian Armed Forces have an organizational policy to maintain the highest level of health and fitness, by way of physical exercise, and regulated diet. Thus, studies on MetS undertaken in Indian Armed Forces may therefore be able to bring up interesting observations. In 2006, Bhalwar et al., published their findings of a large scale community based epidemiological study on more than 600 apparently healthy army personnel aged 35 years and above.³³ Various parameters, including fasting insulin, fasting and 2-h PP glucose, lipids, BP and anthropometry were recorded. The study gave a clear demonstration of ‘statistically significant clustering’ of various risk factors hypothesized to cluster in MetS. It was observed that *among subjects with fasting hyperinsulinemia*, there was very highly significant ($p < 0.001$) clustering of dyslipidemia (raised triglycerides or low HDL-C or both), raised blood pressure and impaired glucose tolerance; however, among subjects with *normal insulin levels*, there was no significant clustering ($p > 0.05$) between dyslipidemia, raised BP and impaired glucose tolerance (IGT). The overall prevalence of ‘syndrome X’ (MetS) was recorded as 8.47%, (95% CI: 6.27% to 10.47%). Increasing age, lower levels of physical exercise (spending <1400 Kcal per week in structured exercise) and increasing BMI were significant predictors of syndrome X. Bhalwar, subsequently undertook another multicentric, cross-sectional epidemiological study carried out on a large sample of 1,198 apparently healthy army personnel aged 30 years and above, located at six different garrisons across India. The study indicated a prevalence of metabolic syndrome as 6.2% (95% CI: 4.9% to 7.7%) using NCEP-ATP-III criteria. Increasing age, especially >45 years, lack of regular and

Table 3 – Advise regarding physical exercise for individuals and communities.

1 Endurance exercises

(a) Minimum:

- Do at least 150 min of moderate-intensity aerobic physical activity over 1 week (as an example, walk for 30 min a day, covering 2–3 km in these 30 min and do this on 5 days in a week; or walk for 15 min each in morning and evening, covering 1–1.5 km in these 15 min and do this on 5 days a week); OR,
- Do at least 75 min of vigorous-intensity aerobic physical activity throughout the week (as an example, do a combination of fast walking, 15 min in a day, covering 1.5 km in these 15 min and do this on 5 days a week); OR,
- Do an equivalent combination of moderate- and vigorous-intensity activities, as above.

(b) Preferable:

- Undertake moderate-intensity aerobic physical activity for 300 min per week (as an example, walk for 60 min once a day, covering 4.5–6 km in these 60 min and do this on 5 days in a week; or walk for 30 min each in morning and evening, covering 2.5–3 km in these 30 min and do this on 5 days a week); OR,
- Do 150 min of vigorous-intensity aerobic physical activity per week (as an example, do a combination of fast walking and running, 30 min in a day, covering 3.5–4 km in these 30 min, and do this on 5 days a week).
- Do an equivalent combination of moderate- and vigorous-intensity activities.

2 Muscle-strengthening exercises: these should be done involving major muscle groups on 2 or 3 days a week. This can be by freehand resistance exercises as push-ups/sit-ups/squats (traditional Indian “Dand-baithak”) or weight training exercises, using 5–10 kg for each major muscle group.

3 Flexibility exercises: gentle stretching exercises (including “Yoga”) should be undertaken for 5–10 min before and after an exercise session.

4 Advising individuals and communities regarding physically active lifestyle: advice should be rendered to develop an attitude of being always physically active and to incorporate certain simple changes in their daily lifestyle which makes them more active. For example, people may be advised to take stairs instead of the lift; stand while answering the telephone, use a bicycle, preferably walk, instead of an automobile, and so on.

(Source: ^{35,36})

Table 4 – Dietary guidelines for prevention of metabolic syndrome.Eat a diet, in which:

- Calories are as per requirement, based on age, gender and activity levels.
- Total fats provide < 30% (preferably < 20%) of daily calorie needs.
- Saturated fats provide < 10% (preferably < 7%) of daily calorie needs.
- Trans-fatty acids are eliminated from diet.
- Most dietary fats are polyunsaturated (up to 10% of calories) or monounsaturated (10–15% of calories).
- Refined sugars provide <10% of calorie needs.
- Salt consumption (all sources) is <5 g/day.
- Dietary Cholesterol intake is < 300 mg/day.^(a)
- Gravid, fried, creamed, and sugared food stuffs are low.
- Plenty of whole grains, cereals, legumes, beans, and pulses are present.
- Fresh fruits/vegetables 400–500 g/day are included.
- Low-fat dairy products are included.

^a The recent Dietary Guidelines for Americans (2015–2020) have removed the recommendations of upper limit of 300 mg/day of cholesterol from dietary sources. This is because there is a natural balance maintained between exogenous (dietary) cholesterol and its endogenous production in the body. However, the guidelines also clearly mention that intake of high levels of saturated fats and trans-fatty acids continues to be an important risk factor for CVD and many of the foods which are high in cholesterol are also rich in saturated fatty acids, with the exception of shrimps and whole eggs, which contain very low amounts of saturated fats (Ref. no. ³⁹). (Source: ^{36–39})

adequate physical exercise, non-vegetarian diet, and use of tobacco were identified as strong and statistically significant risk factors for MetS. The study identified the overall prevalence of previously undetected raised blood pressure ($\geq 140/90$ mm Hg) as 7.5%, and that of previously undetected IGT (fasting BS ≥ 110 mg/dL) as 2.9%. The study also identified that serum total cholesterol in isolation may not be an accurate predictor of low HDL or raised triglycerides.³⁴

based definition of this syndrome for our Indian populations, carefully reviewing as to what should be the appropriate cut-off levels for waist circumference, waist-hip ratio (WHR), and fasting plasma glucose.

Conflicts of interest

The author has none to declare.

Public health measures for prevention and control

Despite initial apprehensions regarding the existence of a syndrome of constellation of risk factors, since multiple CVD risk factors can, in any case, occur in many individuals, it is by now clear that MetS (earlier known as ‘syndrome X’ or ‘insulin resistance syndrome’), is a reality. More than being a reality, there is enough evidence, globally, as well as from our country that it is a major public health issue in contemporary times and should get priority from all those who are concerned with the planning and execution of health care, whether public health policy makers or clinicians. In a nut-shell, prevention of MetS involves just two major actions – adequate physical exercise and proper diet. Based on the recommendations of various expert groups, the guidelines for physical exercise are presented in Table 3, while dietary and other guidelines are presented in Table 4. These would need to be utilized, both at the individual level for counseling patients and their family members, as well as while developing policy issues in the larger context. Early detection would be equally relevant, and a simple method could be to track central obesity by frequently measuring the waist circumference by auxiliary healthcare workers.

There is also a need to undertake focused research, basic, clinical as well as epidemiological into the various aspects of etiopathogenesis, epidemiology and management of MetS in our national context. We also need to develop an evidence-

REFERENCES

1. Omran AR. The epidemiologic transition; a theory of the epidemiology of population change. *Milbank Mem Fund Q.* 1971;49:509–538.
2. Indian Council of Medical Research (Government of India). *Public Health Foundation of India and Institute for Health Metrics and Evaluation. India: Health of Nation's States; the India State-Level Disease Burden Initiative.* New Delhi, India: ICMR, PHFI and IHME; 2017.
3. Kylin E. “Studienueber das Hypertonie-Hyperglyca “mie-Hyperurika” miesyndrom. *Zentral blatt fuer Innere Medizin.* 1923;44:105–127.
4. Vague J. Sexual differentiation. A factor affecting the forms of obesity. *Presse Med.* 1947;30:S39–S40.
5. Reaven GM. Role of insulin resistance in human disease. (Banting Lecture 1988). *Diabetes.* 1988;37:1595–1607.
6. Han TS, Lean MEJ. A clinical perspective of obesity, metabolic syndrome and cardiovascular disease. *J Royal Soc Med Cardiovas Dis.* 2016;5:1–13.
7. Alberti KG, Zimmet P, Shaw J. Metabolic syndrome – a new world-wide definition. A consensus statement from the international diabetes federation. *Diabet Med.* 2006;23:469–480.
8. Alberti KGM, Eckel RH, Grundy SM, et al. Harmonizing the metabolic syndrome: a joint interim statement of international diabetes federation task force on epidemiology and prevention; national heart, lung and blood institute; American heart association; world heart federation; international athrosclerosisi society; and, international

- association for the study of obesity. *Circulation*. 2009 October 19;120:1640–1645.
9. National Cholesterol Education Program (NCEP). Expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III). Third report of the national cholesterol education program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III) final report. *Circulation*. 2002;106:3143–3421.
 10. Alberti KG, Zimmet PZ. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus provisional report of a WHO consultation. *Diabet Med*. 1998;15:539–553.
 11. Balkau B, Charles MA. Comment on the provisional report from the WHO consultation: European group for the study of insulin resistance (EGIR). *Diabet Med*. 1999;16:442–443.
 12. World Health Organisation. *Definition and Diagnosis of Diabetes Mellitus and Intermediate Hyperglycemia Report of a WHO/IDF Consultation*. Geneva: WHO; 2006. ISBN 978 92 4 159493 6.
 13. Mohanan PP. Metabolic syndrome in Indian population: public health implication. *Hypertens J*. 2016;2:1–6.
 14. Saklayen MG. The global epidemic of the metabolic syndrome. *Curr Hypertens Rep*. 2018 Feb 26;20:12. <https://doi.org/10.1007/s11906-018-0812-z> (published online). PMID: PMC5866840; PMID: 29480368.
 15. Eckel RH, Grundy SM, Zimmet PZ. The metabolic syndrome. *Lancet*. 2005;365:1415–1428.
 16. Delvari A, Forouanafar MH, Alikhani S et al. First Nationwide Study of the Prevalence of the Metabolic Syndrome and Optimal Cutoff Points of Waist Circumference in the Middle East.
 17. Dongfeng Gu, Reynolds K, Wu Xigui, Chen Jing, Duan Xiufang, Reynolds RF. Prevalence of the metabolic syndrome and overweight among adults in China. *Lancet*. 2005;365:1398–1405.
 18. Basit A, Shera AS. Prevalence of metabolic syndrome in Pakistan. *Metab Syndrome Relat Disord*. 2008;6:171–175.
 19. McKeigue PM, Shah B, Marmot MG. Relation of central obesity and insulin resistance with high diabetes prevalence and cardiovascular risk in south Asians. *Lancet*. 1991;337:382–386.
 20. Vardan S, Mookherjee S, Vardhan S, Sinha AKS. Special features of coronary heart disease in people of Indian sub continent. *Indian Heart J*. 1995;47:399–407.
 21. Reddy KS. Cardiovascular diseases in India. *World Health Stat Q*. 1993;46:101–107.
 22. Hoskote SS, Joshi SR. Are Indians destined to be diabetic? *JAPI*. 2008;56:225–226.
 23. Deedwania PC, Gupta R. Management issues in the metabolic syndrome. *JAPI*. 2006;54:797–810.
 24. Bansal S, Paliwal A, Verma V, Chauhan J. A study on prevalence of metabolic syndrome in general population in Western Uttar Pradesh, India. *Int J Res Med Sci*. 2017;5:2641–2643.
 25. Barik A, Das K, Chowdhury A, Rai RK. Metabolic syndrome among rural Indian adults. *Clinical*. 2018;23:129–135.
 26. Prasad DS, Kabir Z, Dash AK, Das BC. Prevalence and risk factors for metabolic syndrome in Asian Indians: a community study from urban Eastern India. *J Cardiovasc Dis Res*. 2012;3:204–211.
 27. Khan Y, Lalchandani A, Gupta AC, Khadanga S, Kumar S. Prevalence of metabolic syndrome crossing 40% in Northern India: time to act fast before it runs out of proportions. *J Fam Med Prim Care*. 2018;7:118–123.
 28. Harikrishnan S, Sarma S, Sanjay G, et al. Prevalence of metabolic syndrome and its risk factors in Kerala, South India: analysis of a community based cross-sectional study. *PLoS One*. 2018 Mar 27;13, e0192372. <https://doi.org/10.1371/journal.pone.0192372>. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/29584725>. Accessed 8 July 2019.
 29. Bhat RA, Parray I, Ahmad Z. Prevalence of the metabolic syndrome among North Indian adolescents using adult treatment panel III and pediatric international diabetic federation definitions. *J Diabetes Metab*. 2014;5:352. <https://doi.org/10.4172/2155-6156.1000352>. Available at: <https://www.omicsonline.org/open-access/prevalence-of-the-metabolic-syndrome-among-north-indian-adolescents-2155-6156.1000352.php?aid=24757>. Accessed 28 June 2019.
 30. Venugopal V, Dongre AR, Saravanan S. Prevalence and determinants of metabolic syndrome among the rural adult population of Puducherry. *Ind J Community Med*. 2019;44, 21 – 5.
 31. Madan JG, Narsaria AM. Prevalence of metabolic syndrome in Mumbai City, India. *J Obes Metab Res*. 2016;3:16–22.
 32. Kapil U, Khandelwal R, Ramakrishnan L, et al. Prevalence of metabolic syndrome and associated risk factors among geriatric population living in a high altitude region of rural Uttarakhand, India. *J Fam Med Prim Care*. 2018;7:709–716.
 33. Bhalwar R, Ohri VC, Somani BL, Kasthuri AS. Differentials and determinants of syndrome 'X' and its role as coronary risk among healthy middle aged Indian army personnel. *MJAFI (Med J Armed Forces India)*. 2006;62:146–152.
 34. Bhalwar R. A multi-centric study to uncover the real load of metabolic syndrome and its associated risk factors among army personnel. In: *Armed Forces Medical Research Committee (AFMRC) Project No: 3743/2007. Project Sanctioned under Aegis of DRDO and DGAfMS*. 2012. Report submitted in 2011 and presented as Best AFMRC Project in February.
 35. World Health Organisation. *Global Recommendations on Physical Activity and Health*; 2010. Available at: <http://www.who.int/dietphysicalactivity/publications/9789241599979/en/>. Accessed 22 July 2018.
 36. Bhalwar R, Dudeja P, Jindal AK, Bhatnagar A. *Textbook of Community Medicine*. 3rd ed. Wolters Kluwer India; 2019 [Chapter 92], p-824 and chapter – 93, p-837).
 37. World Health Organisation. *Diet, Nutrition and the Prevention of Chronic Diseases*. WHO; 2003. Tech Rep Ser No. 916.
 38. National Institute of Nutrition (Indian Council of Medical Research), Hyderabad, India. *Dietary Guidelines for Indians – A Manual*. 2nd ed. 2011:1–127.
 39. Dietary Guidelines Advisory Committee. *Scientific Report of the 2015 Dietary Guidelines Advisory Committee: Advisory Report to the Secretary of Health and Human Services and the Secretary of Agriculture*. Washington, DC: U.S. Department of Agriculture, Agricultural Research Service; 2015.