CHAPTER 2

REVIEW OF LITERATURE

The review of literature of the present research study entitled —**Metabolic syndrome in relation to body composition and lifestyle adaptation among selected adults residing in Bengaluru"** is presented under the following headings.

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2.1 Non- Communicable Diseases, prevalence and associated risk factors

2.1.1 Introduction and definition of Non- Communicable Diseases

Non- Communicable Diseases (NCD's) can be classified into two major headings- First group consists of four main types- Diseases such as Cardiovascular diseases, Cancer, Diabetes Mellitus and Chronic respiratory diseases. The second group comprises of Hypertension, Dyslipidemia, Obesity, Metabolic Syndrome (MetS), Rheumatoid arthritis, Cerebrovascular disease, Osteopenia/ osteoporosis, Degenerative disc disease Sarcopenia and Frailty, Depression, Cognitive impairment and Neurodegenerative disease.

Economics of Non- Communicable Diseases in India, November 2014, A report by the World Economic Forum and the Harvard School of Public Health stated that Industrialization, socio-economic development, urbanization, changing age structure, changing lifestyles has placed India at a position where it is facing a growing burden of NCD's. In India, NCD's accounted for 40% of all hospital stays and 35% of all outpatient visits in 2004 (Mahal *et al*., 2010). This accounted for disability-adjusted life years (DALYs) in India than communicable, a DALY represents one lost year of healthy life; economically, it is valued as equal to a country's per-capita GDP) (Institute for Health Metrics and Evaluation [IHME], 2015).

The impact of NCD's is felt not just in reduced health, but also in lower productivity. One estimate is that India will have lost $237 billion (in 1998 constant international dollars) between 2006 and 2015 from premature deaths due to heart disease, stroke and diabetes (Bloom 2014). Infact, cardiovascular disease deaths alone give India the ―highest loss in potentially productive years of life‖ of all countries in the world (Srinath *et al.,* 2005).

CVD's (including coronary heart disease and stroke/ischemic heart disease) resulting in 9.4% DALYs and 21.1% total deaths and Diabetes causing 2.2% death rate and 1.5% DALYs (World Health Organisation: Cardio vascular diseases, 2021).

NCD's kill 41 million people each year, equivalent to 74% of all deaths globally. WHO in their report on CVD's, in June 2021 stated, each year, 17 million people die from a non-communicable disease before age 70; 86% of these premature deaths occur in low- and middle-income countries. Of all noncommunicable disease deaths, 77% are in low- and middle-income countries. Cardiovascular diseases, cancers, chronic respiratory diseases and diabetes account for over 80% of all premature Non-Communicable Disease deaths (WHO: Non communicable diseases: September 2023). NCD's share five major risk factors: tobacco use, physical inactivity, the harmful use of alcohol, unhealthy diets and air pollution. *de Koning et al.*, (2007) in their study had shown an association between waist circumference and waist-to-hip ratio as predictors of CVD's. WHO's mission is to provide leadership and the evidence base for international action on surveillance, prevention and control of Non- Communicable Diseases. Urgent government action is needed to meet global targets to reduce the burden of Non- Communicable Diseases.

2.1.2 Prevalence of Non- communicable diseases

The WHO department of NCD's is responsible for global leadership, coordination, guidance and technical support to reduce premature mortality and morbidity from non-communicable diseases. In 2019, the World Health Assembly extended the World Health Organisation Global action plan for the prevention and control of NCD's 2013–2020 to 2030. The Implementation roadmap supports actions to achieve a set of 9 global targets with the greatest impact on the prevention and management of NCD's. NCD's are recognized as a major global challenge in the United Nations 2030 Agenda for Sustainable Development.

WHO plays a key leadership role in the coordination and promotion of the global fight against NCD's and the achievement of the Sustainable Development Goals target 3.4. (WHO, 2020). Nethan *et al.,* (2017) stated multiple surveys at the national/state level in India included single or multiple risk factors. An overall significant increase was noted in overweight and obesity while decline was noted in tobacco and alcohol use during the same period. From GATS 1 (2009-10) to 2 (2016-17) also, the prevalence of tobacco consumption decreased in India. The study conducted by them concluded that India has a much-delayed response on NCD risk factors surveillance and information of the same are sporadic and incomplete. They emphasised that there is

a need to regulate systems to increase information comprehensiveness, standard WHO non- communicable disease risk factors questions must be incorporated in the ongoing surveys. They also stated that India should plan for a cost and time-effective non-communicable disease surveillance system. Sowmya *et al.,* (2016) in their research have concluded that rural south Indian population's Dietary profile contributed to increase in NCD'S high blood sugars, high blood pressures and cardiac problems in rural areas and this emphasizes that remedial action has to be taken.

2.1.3 Risk factors and prevention of Non- Communicable Diseases

One of the most important ways of reducing deaths from NCD's is to control the risk factors that lead to their development. These include reducing the use of tobacco and the harmful use of alcohol, maintaining an active lifestyle and consuming a healthy diet and improving air quality. Accurate data from countries are vital to reverse the global rise in death and disability. In 2020 Budreviciute *et al.,* proposed a model to classify the risk factors of Non-communicable disease's as shown in the Figure 2.1.

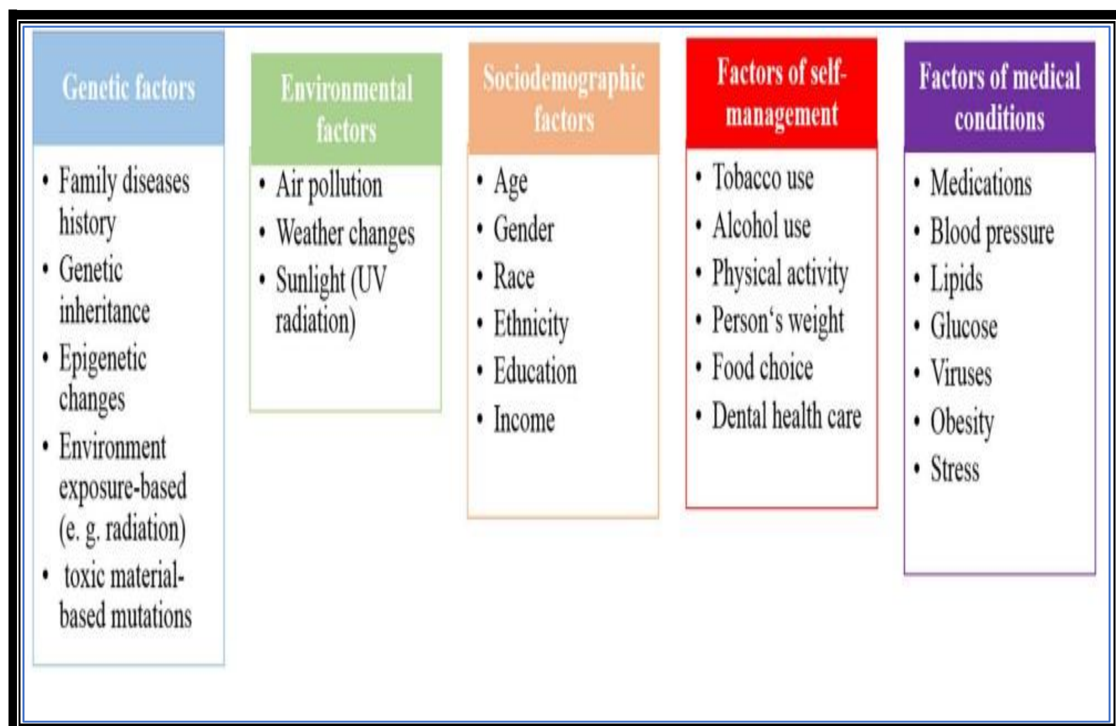

Figure 2.1: Risk Factors of Non-Communicable Diseases*

**Source: A proposed model to by Budreviciute et al., 2020*

Kalache and Kickbusch *et al*., (1997) as given in the below Figure 2.2 emphasized that early life and adult life have to be good at the functional capacity of ventilatory capacity, muscular strength and cardiovascular output which increases in childhood

and peaks in early adulthood, eventually followed by a decline. The rate of decline, however, is largely determined by factors related to adult lifestyle. The Changes in the environment can lower the disability threshold, thus decreasing the number of disabled people in a given community.

World Health Organisation guidelines stated that Tobacco use, physical inactivity, the harmful use of alcohol, unhealthy diets and air pollution all increase the risk of dying from a non-communicable disease. Detection, screening and treatment of non-communicable diseases, as well as palliative care, are key components of the response to NCD‘s (WHO, 2023).

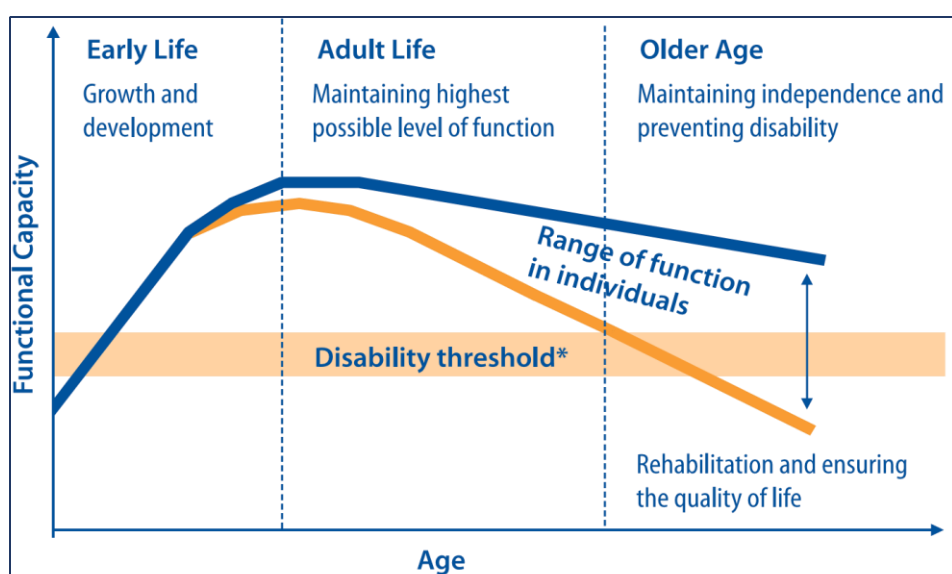

Figure 2.2:
Maintaining Functional Capacity over the life course
**Source: Kalache and Kickbusch. 1997*

2.2 Metabolic Syndrome, prevalence and causes

2.2.1 Various definitions of metabolic syndrome

Swarup *et* al., (2022, 2023), Grundy *et al.,* (2004), Deepa *et al*., [CURES-34 (2007)] and Kassi *et al.,* (2011) have given in detail regarding various metabolic syndrome definitions. Isomaa *et al*., (2001) recommended WHO definition for identifying subjects with metabolic syndrome and high cardiovascular morbidity and mortality. Venugopal *et* al., (2019) stated that the metabolic syndrome (IDF criteria was used) was 39.7% in >30 year adults. Deepa *et al.,* (2007) in their Prevalence of metabolic syndrome study using WHO, ATP III and IDF definitions in Asian Indians: the Chennai Urban Rural Epidemiology Study (CURES-34) as given in the below Table 2.1.

Table: 2.1 Definitions of Metabolic Syndrome

Criteria	WHO 1998	NCEP ATP III (2001)	Modified NCEP ATP III (2004)	IDF (2005)	Possible definition for South Asians *
		Three or more of the following	Three or more of the following	Central obesity and two or more of the following	Fasting hyper insulinemia and two or more of the following
Fasting glucose mg / dl	DM IGT IFG or insulin resistance with two or more of the following	≥110	≥100 or T2DM Diagnosis	≥100 or T2DM OR on treatment	IFG IGT T2DM or on treatment
Obesity	Central obesity WHR >0.9 in males >0.85 in females and Or BMI >30 kg/ m^2	Waist circumference >102cm in males or > 88cm in females	Waist circumference >102cm in males or > 88cm in females	Waist circumference >90cm in males or > 80cm in females	Waist circumference >87cm in males or >82cm in females and / or BMI >23
Blood pressure mmHg	≥140 by 90	≥130 by 85 or on treatment	≥130 by 85 or on treatment	≥130 by 85 or on treatment	≥130 by 85 or on treatment
Triglyceride mg / dl	≥150 and / or	≥150 or on treatment	≥150 or on treatment	≥150 or on treatment	≥150 or on treatment
HDL mg / dl	<35 in males or <39 in females	<40 in males and <50 in females	<40 in males and <50 in females	<40 in males or on treatment and <50 in females	<40 in males and <50 in females or on treatment
Others	Micro Albumuria (Urinary albumin excretion rate ≥20mg/min or albumin:creatinine ratio ≥30mg/g				Non alcoholic fatty liver disease; Subscapular skinfold thickness >18mm

* Lower cut offs may be probably necessary for blood pressure and lipid levels than that mentioned for South Asians which requires further studies to be defined

2.2.2 Prevalence of Metabolic Syndrome

Weiya *et al*., (2023) in their study have shown from 1999 to 2014, the incidence of metabolic syndrome in U.S. adults significantly increased overall, while the mortality rate of metabolic syndrome had a considerable downward trend. Lower risk in women compared with men.

Rajendran and Shankar (2021) in their study showed Metabolic Syndrome is highly prevalent (72.6% as per modified ATP III) among out-patients attending cardiology/ diabetology outpatient department of tertiary care hospital. However, extreme age beyond 60 years and physical inactivity had a higher prevalence of Metabolic Syndrome compared to others.

Selvaraj *et al.,* (2019) did a cross-sectional based study which was conducted in the rural area of Kancheepuram District. In the prevalence of Metabolic Syndrome was found to be 16.7%. Higher prevalence was observed among the older age group 31-40 years with 32.4%. In Logistic Regression analysis, variables like Increased age, alcohol intake, high waist circumference, raised triglyceride level, raised fasting blood sugar level and high average diastolic blood pressure were strongly associated with Metabolic Syndrome as it was statistically significant.

As per Harikrishnan *et al.,* (2018) in a cross-sectional study conducted in three districts in Kerala, India, covering over 5000 participants, one out of four individuals had ATP III metabolic syndrome (24%). The prevalence estimates were even higher when using the IDF and Harmonization definitions (29% and 33%, respectively). Female gender, BMI and age were independent predictors of Metabolic Syndrome in this population. Metabolic syndrome was associated with higher propensity for the presence of definite Coronary Artery Diseases (CAD). Over the past few decades, the state of Kerala has experienced a rising burden of CAD and cardiovascular mortality. Kaur *et al.,* (2017) in their study have pooled the prevalence percentage (%) of Metabolic syndrome studies. Table 2.2 shows the Metabolic syndrome (NCEP ATP III-2005 criteria) prevalence percentage worldwide and in India.

Table: 2.2 Metabolic Syndrome (NCEP ATP III criteria) prevalence percentage worldwide and in India

Year	Author	State/ Population	Prevalence %
		WORLDWIDE	
2003	Al- lawati& associates	Oman (≥20 years)	21
2003	Erwin	United States of America	34
2005	Athyros et al.,	Greece (≥18 year)	23.6
2006	Loizou et al.,	Cyprus (20-80 years)	22.2
2010	Al Daghri et al.,	Saudi Arab (18-55 years)	35.3
2010	Soewondo et al.,	Indonesia (25-64 year)	28.4
2012	Metelskaya et al.,	Russia (≥55year)	34.2
2015	Bhowmik et al.,	Bangladesh (≥ 20-year rural population)	30.7
		INDIA	
2004	Gupta et al.,	Urban Indian population	31.6
2007	Chow et al.,	Andhra Pradesh	28.2
2008	Suran et al.,	Mumbai Diabetic population	77
2010	Kamble et al.,	Wardha	9.3
2010	Thiruvagounder et al.,	Salem	27.62
2011	Sawant et al.,	Mumbai	19.52
2013	Padmavathi et al.,	Adults attending OPD for routine medical checkups	46.3
2014	Kaur	Punjab	17.38
2014	Peixoto et al.,	Goa (Rural)	36.9
2015	Jain et al.,	Gujarat (Apparently healthy adults 2040Year)	16
2015	Walveker et al.,	Karnataka Bank male employees	45.2
2015	Bansal & Joshi	Delhi Muslim population	75
2016	Ismail et al	Kerala	28.3
2016	Madan & Narsaria	Mumbai (Apparently healthy men- 1865yr)	39.9

Table 2.2 has the prevalence percentage of research studies; in worldwide and India; that used NCEP ATP III for defining metabolic syndrome between 2003- 2016. The prevalence percentage (%) of metabolic syndrome worldwide was 28.68 ± 5.8 whereas in India it was 28.85 ± 11.8. Roberts *et al.,* (2013) stated that Metabolic Syndrome is more recently defined and investigated, exhibits a prevalence of nearly 25% of the US adult population. Pandit *et al.,* (2012) stated that South Asia is home to one of the largest population of people with metabolic syndrome. The prevalence of Metabolic Syndrome in South Asians varies according to region, extent of urbanization, lifestyle patterns and socioeconomic/cultural factors. Recent data show that about one-third of the urban population in large cities in India has Metabolic

Syndrome. All classical risk factors comprising the Metabolic Syndrome are prevalent in Asian Indians residing in India. The higher risk in this ethnic population necessitated a lowering of the cut-off values.

Prasad *et al.,* (2012) conducted study in Eastern India Orissa stated age standardized prevalence rates of metabolic syndrome were 33.5% overall, 24.9 % in males and 42.3% in females. Older age, female gender, general obesity, inadequate fruit intake, hypercholesterolemia and middle-to-high socioeconomic status significantly contributed to increased risk of metabolic syndrome. Pemminati (2010) in their study conducted in South India Mangalore; showed Metabolic Syndrome was prevalent in 134 of 451(29.7%); men 39 (26.5%) and women 95 (31.2%). Prevalence of individual components of Metabolic Syndrome were as follows: increased waist circumference, (common component) present in all; elevated TG in 38.8%; low HDLC in 59.7%; increased FPG in 57.4%; elevated SBP in 80.5% and DBP in 56.7%; body mass index (BMI) ≥ 25 kg/sq. m (obesity) in 58.9%. Increased waist circumference which is the essential criterion for diagnosis of Metabolic Syndrome and, Systolic hypertension emerged as the most frequent component in the population followed by low HDL-C and elevated FPG. Elevated TG was less prevalent in this population. Misra and Khurana (2008) stated that the prevalence of metabolic syndrome is rapidly increasing in East Asia and China. Using modified NCEP, ATP III criteria, the prevalence was 29.0 and 16.8% in South Korean men and women, respectively. A study done in Singapore not only highlighted the change in prevalence when criteria for abdominal obesity were modified but also showed ethnic differences. Tan *et al.,* (2008) showed that the prevalence was highest in Asian Indians (28.8%), followed by the Malays (24.2%) and then the Chinese (14.8%) and ethnic differences persisted in both genders. In many of these studies, higher prevalence rates of metabolic syndrome in women were reported, similar to the gender differences seen in the prevalence of obesity (Eckel *et al.,* 2005).

2.2.3 Causes/ Risk factors of Metabolic Syndrome

The causes or risk factors of metabolic syndrome are the individual criteria as per definition of Metabolic syndrome- that is abdominal obesity, Dyslipedemia or hyperlipedemia, Insulin resistance or type I diabetes mellitus and hypertension. Engin (2017) in his research indicated that the metabolic syndrome; clustering of

abdominal obesity, dyslipidemia, hyperglycemia and hypertension, is a major public health challenge.

2.2.3.1 Obesity

Han and Lean (2016) stated that the prevalence of metabolic syndrome and cardiovascular disease is expected to rise along with the global obesity epidemic: greater emphasis should be given to effective early weight management to reduce risk in pre-symptomatic individuals with large waists. Scarpellini and Tack (2012) mentioned that Obesity causes chronic low-grade inflammation that contributes to systemic metabolic dysfunction associated with obesity-linked disorders that fall under the definition of metabolic syndrome. Despres *et al.,* (2006) The presence of metabolic syndrome alone cannot predict global cardiovascular disease risk. But abdominal obesity — the most prevalent manifestation of metabolic syndrome — is a marker of 'dysfunctional adipose tissue' and is of central importance in clinical diagnosis.

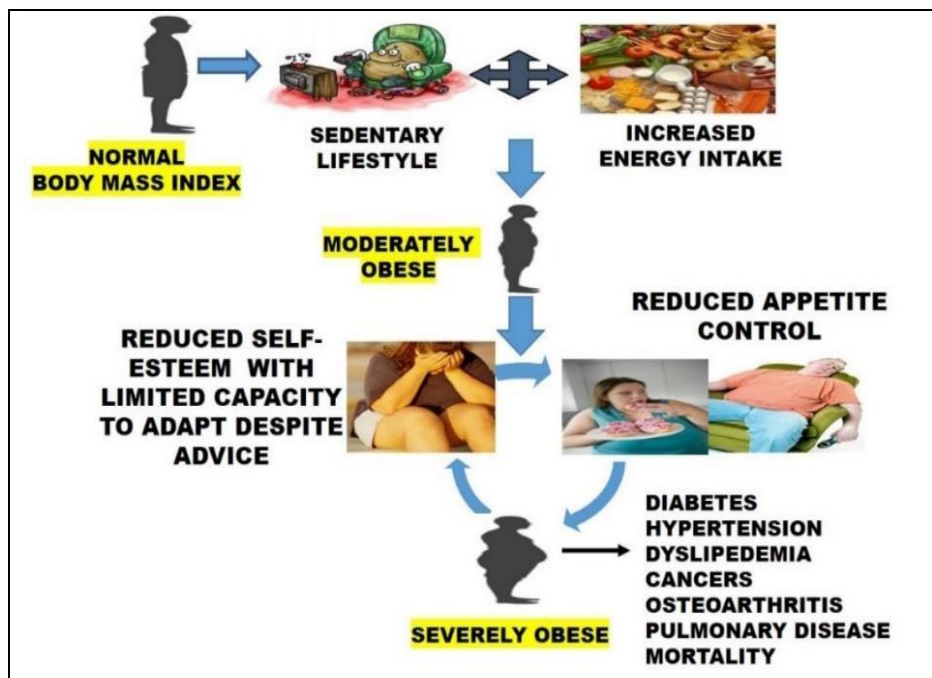

Figure 2.3: Risk factors and complications of obesity

Bosello and Zamboni (2000) indicated that visceral obesity seems to be the main driving factor by means of the increased production of free fatty acids whose activity, in turn, might interfere with the action of insulin. Després and Lemieux (2006) in their research study titled “Abdominal obesity and metabolic syndrome” stated that abdominal obesity as the most prevalent manifestation of metabolic

syndrome and is a marker of 'dysfunctional adipose tissue' and is of central importance in clinical diagnosis. Obesity is the major risk factor for Metabolic syndrome and many other NCD‘s. The above quoted researchers have stated, that overweight or moderate obesity if unmanaged can cause severe obesity and lead to diabetes, hypertension, dyslipidemia, cancers. osteoarthritis, pulmonary diseases and mortality. A sedentary lifestyle and increased energy intake for prolonged periods can cause obesity as shown in figure 2.3.

2.2.3.2 Dyslipedemia/ Hyperlipedemia

Kawamoto *et al.,* (2011) in his study concluded that in Japanese community-dwelling adults, lipid ratios of Triglycerides/High-Density Lipoprotein cholesterol, Total cholesterol/High-Density Lipoprotein cholesterol, as well as triglycerides and High Density Lipoprotein cholesterol, were consistently associated with Metabolic Syndrome, insulin resistance and serum High molecular weight adiponectin. Lipid ratios may be used as reliable markers. Denisenko (2020) in his research study reviewed the molecular mechanisms of metabolic syndrome driven by impaired lipid metabolism. Pedroza-Tobias *et al., (2014)* stated that a simple system to classify MS based on lipid alterations was useful to evaluate prevalences by diverse biologic and sociodemographic characteristics. Among patients with Metabolic Syndrome in Southwest Ethiopia, Haile *et al.,* (2021) observed a high (58%) prevalence of dyslipidemia. Prevention and control of dyslipidemia and its predictors among patients with metabolic syndrome were recommended. Mocciaro (2022) results suggested that central obesity and metabolic syndrome are associated.

2.2.3.3 Type I Diabetes Mellitus

Lann and LeRoith (2007) stated that insulin resistance plays a principal role in initiating and perpetuating the pathologic manifestations of the metabolic syndrome. A more in-depth understanding of the basic pathophysiologic mechanisms underlying insulin resistance may aid clinicians in treating and possibly delaying or even preventing the onset of the metabolic syndrome and its complications. Chopra *et al., (*2020) Insulin resistance is a complex entity with many associated biochemical and clinical consequences, especially diabetes, hypertension and CVD. James *et al.,* (2006) in their study found that people with normal weight and metabolic syndrome or insulin resistance or with obesity but no mats or insulin resistance were not

uncommon in their sample risk factor clustering or insulin resistance appear to confer much of the risk for diabetes or CVD's are associated with elevated BMI. Zhang *et al.,* (2021) mentioned insulin resistance may be a vital indicator of metabolic syndrome for identifying type 2 diabetes mellitus. Kiani *et al.,* (2016) observed that the Metabolic syndrome was present in 83% of the diabetics in the study conducted in Islamabad, mostly in females with decreased HDL-cholesterol being the most common in both genders. Risk factors of Type 2 diabetes and metabolic syndrome is useful, to identify overweight, obesity and dyslipidemia. Long term Type 2 diabetes mellitus patients may adopt the risk of the Metabolic syndrome. Study highlights the risk of Metabolic syndrome increases with the advancement of age in both male and female. Type 2 diabetes mellitus is increasing at rampant in Urban population due to changes in lifestyle and genetic factors. Routine monitoring and screening programs of Type 2 diabetes components are required for early detection of Metabolic Syndrome in the study population. Mogre *et al*., (2014) showed a comparatively low prevalence of the Metabolic syndrome (24%) among previously diagnosed type 2 DM patients. The study showed more females (27.3%) than males (13%) had Metabolic syndrome. Both uncontrolled diabetes and abdominal obesity were prevalent in 77% in their study.

2.2.3.4 Hypertension

Nsiah *et al.,* (2015) in their research found that hypertension being the commonest component, future cardiovascular disease prevention strategies should focus attention on its management and prevention, through education. Katsimardou *et al*., (2020) in their study population found Hypertension is present in almost 80% of patients with metabolic syndrome. Tachebele (2014) the prevalence of metabolic syndrome among hypertensive patients is high. Franklin (2006) revealed that increased blood pressure is considered an important component of metabolic syndrome. Hypertension is the leading metabolic syndrome risk factor that predisposes to increased cardiovascular morbidity and mortality.

2.3 Parameters to assess the Nutritional Status of adults relevant to lifestyle

2.3.1 Anthropometric Measurements

Casadei and Kiel (2022) stated that Anthropometric measurements are the easiest method to assess the Nutritional status of individuals. Bhattacharya *et al.,* (2019) in her study stated Nutritional status of the population can be assessed by

taking their anthropometric measurements and accuracy results can be obtained by calculating the Composite Score of the measurements and it is a non-invasive and relatively correct way of identification.

2.3.2 Body Composition Analysis Parameters

Obesity was one of the major risk factors for raising Non-communicable diseases. As per Amin *et al.,* (2015) high prevalence of obesity among a sub-urban population of Karachi, which was even higher when BF % was measured. Considering the rising prevalence of non-communicable diseases, Body Fat%, Waist Circumference, Waist Hip Ratio and Body Mass Index measurements are convenient and feasible means of identifying population at risk. Poobalan *et al.,* (2016) in a study suggested that BMI, Body fat percentage estimation in young adults (18-25) is important and if found overweight or obese the lifestyle interventions are to be taken up to avoid the future health risk. Pradeepa *et al.,* (2015) in their study along with Indian Council of Medical Research - India Diabetes (ICMRINDIAB) presented the prevalence of generalized and abdominal obesity in urban and rural India based on phase I study.

The Chennai Urban Rural Epidemiology Study (CURES) conducted in Chennai city in Tamil Nadu reported age standardized prevalence of generalized obesity to be 45.9%, while that of abdominal obesity was 46.6%. Misra and Khurana (2008) in a systematic review said to prevent increasing morbidity and mortality due to obesity-related type II diabetes mellitus and cardiovascular disease in developing countries, there is an urgent need to initiate large-scale community intervention programs focusing on increased physical activity and healthier food options, particularly for children.

The Indian Council of Medical Research- India Diabetes (ICMR-INDIAB, 2015) survey, one of the largest, conducted in 31 states and union territories, also found that 254 million people had generalized obesity and 351 million had abdominal obesity. Misra (2015) in their research gave the definitions for overweight and obesity that are universally applied using body mass index, based on morbidity and mortality data derived from white populations. However, several studies have shown higher body fat, excess metabolic perturbations and cardiovascular risk factors at lower values of Body Mass Index in Asian versus white populations. Definitive guidelines have been published to classify a Body Mass Index of ≥ 23 kg/m^2 and ≥ 25 kg/m^2 as overweight

and obese, respectively, by the Indian Consensus Group (for Asian Indians residing in India) and a Body Mass Index of ≥ 23 kg/m^2 for screening for diabetes by the National Institute of Health and Care Excellence of the United Kingdom (for migrant south Asians) and, in an encouraging initiative recently (2015), by the American Diabetes Association (for all Asian ethnic groups in the United States). Overall, multiple studies and now several guidelines, emphasize early intervention with diet and physical activity in Asian ethnic groups for prevention and management of obesity-related non-communicable diseases. By application of these guidelines, an additional 10– 15% of the population in India would be labelled as overweight/obese and more South Asians/Asians will be diagnosed with diabetes in the United Kingdom and the United States. Additional health resources need to be allocated to deal with increasing numbers of Asians with obesity-related noncommunicable diseases and research is needed to evolve cost effective interventions. Finally, consensus based on data is needed so that the WHO and other international agencies could take definitive steps for revision of classification of BMI for Asian populations globally.

Pradeepa *et al.,* (2015) in collaboration with ICMR-INDIAB stated the prevalence of Abdominal Obesity (AO) as well as of Generalised Obesity (GO) were high in India. Extrapolated to the whole country, 135, 153 and 107 million individuals will have GO, AO and Combined Obesity (CO), respectively. However, these figures have been estimated from three States and one UT of India and the results may be viewed in this light. Liu (2013) in their study stated that higher Fat Mass Index (FMI) levels appear to be independently and positively associated with the presence of Metabolic Syndrome regardless of Body Mass Index and Body Fat%. FMI seems to be a better screening tool in prediction of the presence of metabolic syndrome than BMI and percentage of body fat in men and women. Seok Hui Kang *et al., (*2015) in their results demonstrated that the Visceral Fat Area, measured by Bioelectrical Impedance Analysis (BIA), is a simple method for predicting the risk of chronic kidney disease and metabolic syndrome. Sillanpaa *et al., (*2013) showed that BIA and skinfold methods compared to DEXA are not interchangeable to quantify the percentage of fat, fat mass and lean mass at the cross-sectional design in middle-aged women. Moreover, exercise training-induced small changes in body composition cannot be detected with BIA or skinfold method, even though DXA was able to measure statistically significant within-group changes in body composition after training. Bosy-Westphal *et al., (*2013) in their research study concluded that an

eight-electrode, segmental multifrequency BIA is a valid tool to estimate body composition in healthy euvolemic adults compared with the validity and precision of other two-compartment reference methods. Population specificity is of minor importance when compared with discrepancies between different reference methods.

Borga *et al.,* (2018) mentioned that there are several methods available that can measure whole-body adipose tissue (AT) or fat and lean tissue (LT). In terms of precision and accuracy, DXA and MRI are comparable as they show excellent agreement after a linear transformation. However, the agreement is much lower for compartmental measurements such as Visceral Adipose Tissue. Moreover, MRI gives access to accurate and direct measurements of diffuse infiltration of AT in muscles and ectopic fat. Rapid MRI scanning protocols, in combination with efficient image analysis methods, have promoted MRI to a competitive option for advanced body composition assessment, thus enabling a more complete description of a person's body composition profile from a single examination. Lee and Gallagher (2008) in their Assessment methods in human body composition stated that the measurement of body composition allows for the estimation of body tissues, organs and their distributions in living persons without inflicting harm. It is important to recognize that there is no single measurement method that allows for the measurement of all tissues and organs and no method is error free. Furthermore, bias can be introduced if a measurement method makes assumptions related to body composition proportions and characteristics that are inaccurate across different populations. The clinical significance of the body compartment to be measured should first be determined before a measurement method is selected, as the more advanced techniques are less accessible and more costly.

Waist Circumference and Waist–Hip Ratio: Report of a WHO Expert Consultation (Geneva, 2008) The 2002 WHO Expert Consultation on Appropriate Body Mass Index for Asian Populations and Its Implications for Policy and Intervention Strategies (WHO, 2004) reviewed the issue of ethnic differences in the meaning of BMI cut-off values. In populations with a predisposition to central (i.e. abdominal or visceral) obesity and the related increased risk of developing metabolic syndrome, the consultation recommended that, where possible, waist circumference should be used to refine action levels based on BMI. Duren *et al., (*2008) in their

research showed that the ability to monitor, diagnose and treat obesity and associated comorbidities such as type 2 diabetes is an important aspect of both research endeavors and clinical patient care. This ability is limited, in part, by our capacity to assess the tissue composition of the body, specifically body fatness. There is no universally recommended method for measuring or quantifying obesity and current methods are limited in their utility in the obese for a variety of reasons.

The growing epidemic of obesity in the United States and other developed countries creates a pressing need for an accurate assessment of body composition in this heavier population. As we have noted, current methods are powerful tools for assessing normal weight and overweight individuals, but there remain significant shortcomings for each. With knowledge of the utility and limitations of available methods, the clinician or researcher must choose the best-suited method for assessing body composition based on the patient population and specific characteristics desired for interpretation. As the questions under consideration vary across research or clinical settings, criteria for choosing a method for body composition assessment must be tailored to the given situation. For example, weight loss is a common clinical recommendation for type 2 diabetic patients to reduce comorbid conditions. The researcher or the clinician following serial changes in body composition during such a weight loss program will want to choose a method distinguishing between weight lost as fat versus weight lost as muscle and/or bone. Anthropometry may not be the first choice for this situation, as this method cannot make tissue-specific inferences.

Direct methods such as those described may provide a good option as each tissue can be evaluated individually. Additionally, criterion methods such as DEXA or other imaging techniques (CT, MRI) would also prove useful in these circumstances. Deurenberg *et al.,* (1999) The assessment of obesity: methods for measuring body fat and global prevalence of obesity. Given the impact of obesity on health, this is a public health issue that needs to be addressed seriously. Deurenberg *et al.,* (2000) Body Fat percentage is better compared to BMI. However, large-scale studies coordinating multiple research centers or clinics for data collection will want to consider methods that involve equipment producing consistent results across centres‘. An example of this type of study is the NHANES, where DEXA and BIA are

used to establish population norms and reference samples. Because obesity presents several challenges in body composition assessment, multiple assessment techniques used in combination may afford the investigator/clinician greater power in examining and characterizing adiposity in these populations, e.g., the use of anthropometry in conjunction with bioelectrical impedance. Improvements in and the addition of new, technology and body composition techniques will continue to improve our ability to assess and monitor individuals suffering from various health issues.

2.3.3 Energy/ Dietary Intake and Energy Expenditure

Prachi *et al.,* (2011) and Headey *et al.,* (2019) in their research have stated that ―Indian diets are unhealthy also because healthier calories are more expensive and their inflation is rising faster than cereals and edible oils.‖ de la Iglesia *et al.,* (2016) in their research paper- Dietary strategies implicated in the prevention and treatment of metabolic syndrome have summarised in a tabular form the Potential beneficial effects of different dietary patterns on the treatment of Metabolic Syndrome comorbidities. Energy-restricted diets (de la Iglesia 2016; Grams. and
Garvey 2015; Golay 2013; Fock and Khoo 2013; Wing 2011; Gregory 2011; Lazo 2010) have helped improve metabolic diseases like obesity, type 2 diabetes, inflammation and cardiovascular diseases. Diet rich in Omega 3 fatty acids has helped in reducing inflammation and cardiovascular diseases [Fleming (2014), Wen (2014); Lopez-Huertas (2012)]. Type 2 diabetes has been controlled by using low glycaemic index diets [Sun (2016), Thomas and Elliott (2009)]. Moderate high protein diets [Stocks (2013), Bendtsen (2013), Bray (2012), Koppes (2009)] and short frequent meal patterns [Leidy (2011), Bachman (2012)] has helped reduce obesity in the population. The Mediterranean diet [Davis (2015), Schwingshackl (2015), Sofi (2014), Mayneris-Perxachs (2014), Koloverou (2014), Esposito (2011), Kastorini *et al*., 2011] has reduced glycosylated haemoglobin levels, fasting glucose levels and total cholesterol.

The Mediterranean diet also helped to increase high density lipoproteins, increase the satiety of a person and reduce the body weight and waist circumference. Afshin *et al.,* (2019) conducted a systematic review of the Health effects of dietary risks in 195 countries and concluded stating overall, dietary risks were responsible for 22% of all deaths and all Disability-Adjusted Life Year‘s (DALY‘s) among adults. While studying the Indian state-level disease burden ICMR

initiative (2017) found diets low in fruits, vegetables and whole grains but high in salt, sugar and fat (which constitute dietary risk) are also responsible for India‘s increasing disease burden. Venkatesh *et al.,* (2021) in their study concluded that undernutrition and micronutrient deficiencies are due to unhealthy diets. This results in rising levels of overweight and obesity in India. They suggested that changes in production patterns towards to healthier diets is important too to increase the availability and hence keep at an affordable cost.

2.4 Strategies to combat Metabolic Syndrome

Senarathne *et al.,* (2021), Grundy *et al.,* (2005), *in* their study showed that the percentage of subjects with increased FBS, WC and Metabolic Syndrome was significantly higher in the hypertensive group compared with the non-hypertensive group. These findings emphasize the urgent need to develop national strategies for early detection and to take preventive measures to make people aware of the impact of metabolic syndrome.

2.4.1 Diet Pattern to reduce the risk of Metabolic Syndrome

Osadnik *et al.,* (2020) in their research concluded stating that Individuals with MS were more likely to adhere to the western dietary pattern and have a poor diet quality in comparison to metabolically healthy peers, independently of BMI and WHR. It may imply that diet composition, as independent factor, plays a pivotal role in increasing metabolic risk. Professional dietary advice should be offered to all metabolically unhealthy patients, regardless of their body mass status. Selvaraj *et al.,* (2019) study showed a high prevalence of Metabolic Syndrome and a strong association between Metabolic Syndrome and lifestyle risk factors could be a major health problem in rural area, indicating that it was not necessarily a result of modernization. These findings make it critical to plan further healthcare interventions to prevent the adverse consequences of the disease.

Saklayen (2018) in their ―The Global Epidemic of the Metabolic Syndrome.‖ The epidemic did not happen suddenly and it cannot be controlled quickly, but if there is a societal will, it can be done. As in the control of other epidemics, education of the population about the health hazard of the metabolic syndrome will be very important. Targeting the younger population to prevent Metabolic Syndrome before it happens is a better plan than trying to cure it after it happens. While a dedicated

group of public health planner can create a comprehensive plan for a given society or a given community. Pradeepa *et al.,* (2015) in collaboration with ICMR INDIAB suggested that in countries like India, the rise in obesity prevalence could be attributed to the increasing urbanization, use of mechanized transport, increasing availability of processed and fast foods, increased television viewing, adoption of less physically active lifestyles and consumption of more ―energy-dense, nutrientpoor‖ diets. This is exemplified by the higher prevalence of both General Obesity (GO) and Abdominal Obesity (AO) in the urban population where the above factors are more common.

Pandit *et al.,* (2012) in a research study hinted that combating the metabolic syndrome, either as it is commonly understood or through the various components of the syndrome at the population level, is complex and requires multisectoral policy approaches. Policy changes should focus on providing balanced nutrition and an enabling environment for improving physical activity. For physicians treating individuals at high risk, aggressive lifestyle modification will remain the mainstay, until such individuals reach thresholds for drug therapy. Dalle *et al.,* (2010) concluded stating General practitioners, as well as physicians working in metabolic units and treating patients with MS, should receive adequate training in cognitive behavioral therapy to engage patients in lifestyle modification. Engaged patients should then be referred to trained lifestyle counselors (eg, dieticians, psychologists, physical activity supervisors and case managers) working closely with them, ideally in the same lifestyle modification unit, to implement the full lifestyle modification program.

Various bodies gave strategies to combat Metabolic Syndrome. Where they mentioned cumulative effect of following a healthy diet and being Physically active with an exercise routine on a consistent and regular basis is more beneficial than sticking onto only one among Diet or exercise. Among them WHO (2003, 2010), Bhalwar *et al.,* (2012, 2019 and 2020), NIN, ICMR (2011) and US released a Scientific report of the 2015 Dietary Guidelines Advisory Committee, American Dietetic Association and American Heart Association have given various Diet and exercise guidelines to be followed to reduce the risk of individual criteria of metabolic syndrome. 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.

Diet pattern should be based on-

- 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.
- Gravied, 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.

ICMR NIN (2011) proposes macronutrients recommended for daily consumption is shown in Figure 2.4. The Recommendation is for energy yielding macronutrients carbohydrates 60%, body building proteins 15% and fats 25%.

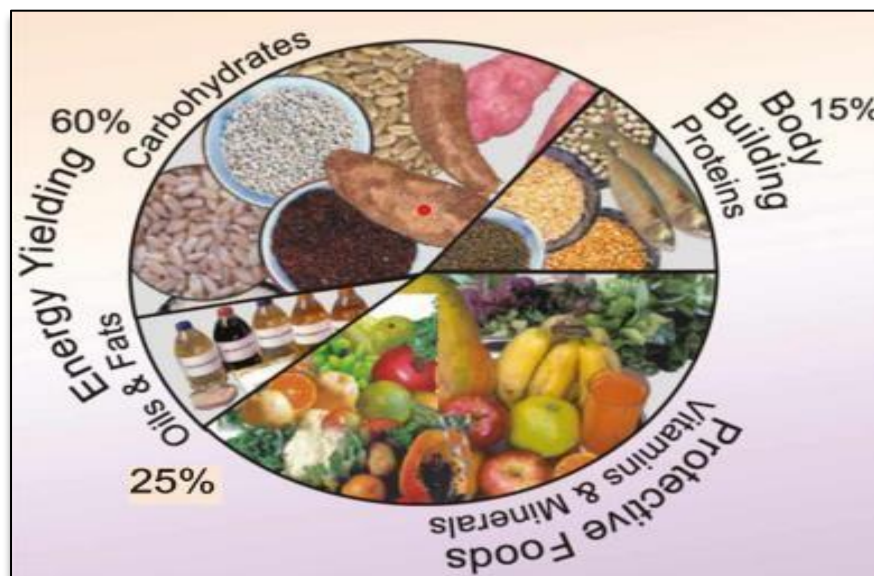

Figure 2.4: Macronutrients recommended for daily consumption

ICMR NIN (2011) proposes my plate as a recommendation for daily consumption is shown in Figure 2.5.

Figure 2.5: My plate for the day

This my plate helps to promote health, prevents hidden hunger and protects from diseases. A 2000 calorie diet comprised of cereals and nutri cereals 260 g, vegetables 400 g, fruits 100 g, pulses and flesh foods 85 g, nuts and seeds 30 g, fats and oils 27 g and milk and milk products.

2.4.2 Exercise Routine to reduce the risk of Metabolic syndrome:

Chun-Cheng Liao, (2020) in his study showed that if intra-abdominal fat are reduced in a 12-week Weight Reducing Program helped reverse Metabolic Syndrome (MetS) in men with obesity and Metabolic Syndrome. Some types of leisure time Physical Activities (PA) may contribute more than others to reducing Metabolic syndrome. Light and domestic PA play a complementary role in enhancing energy expenditure in the general population. TV watching time above 2 h/d counteracted the Metabolic syndrome risk reduction associated with PA level, but PA level also reduced the risk of Metabolic syndrome presented by those with a low level of PA and an excess TV watching time. In their study, PA had a significant correlation with MetS than age and BMI. PA explains a greater amount of the variance of MetS than any other factors of lifestyle, education, sex and family history. In 2019 Serrano-Sánchez *et al.,* have showed that Energy expenditure in PAs that includes walking and other moderate to vigorous intensity both of recreational nature and active transport were associated with

a reduction of Metabolic Syndrome. For each increment of one Metabolic Equivalent (MET)-h/day there was progressive reduction of MetS. Salonen in his 2015 research study concluded that MetS was prevalent in approximately every tenth of the young adults at the age of 24 years. Higher total mean intensity and volume rates as well as longer duration spent at moderate and vigorous PA level had a beneficial impact on the risk of MS. Longer time spent at the sedentary level of PA increased the risk of metabolic syndrome. Heden (2012) have stated in their research that exercise has helped in weight loss when energy expenditure is monitored. Akins *et. al.,* (2019) reported that inactivity in longer period of time could induce resistance to the benefit of exercise. Warm- up before starting the exercise and cool- down after the exercise is equally important.

<u>Exercise patterns should be as-</u>

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.

Syed and Syed (2018) stated Physical activity is important to our life, but the first step is the hardest. However, if we can overcome it, maintain an exercise for 21 days continuously. The Physical activity pyramid is in Figure 2.6. The activities to be planned every day activities: walking, house hold works, gardening, Five to six days a week do brisk walk, cycling, football, basketball, tennis, hiking; Two to three times a week stretching, push-ups, sit ups, weight lifting, leg press and Limit sitting for longer periods, sedentary habits.

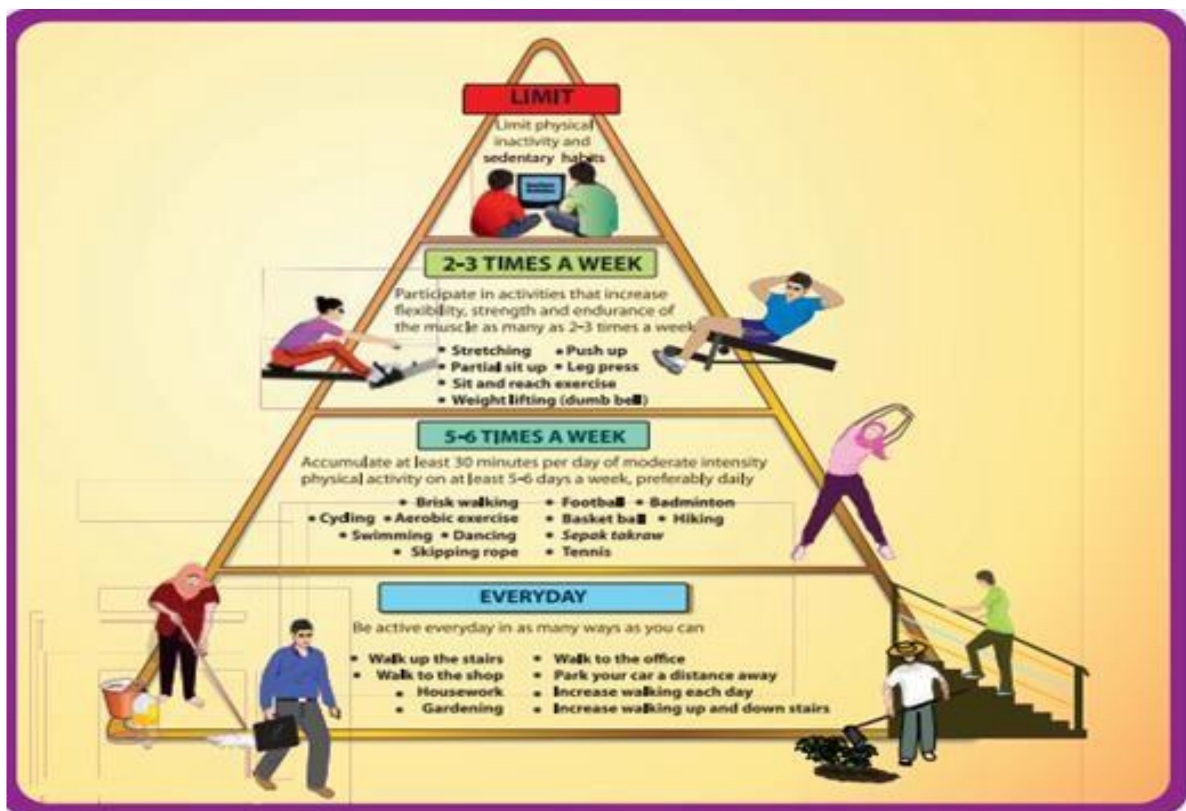

Figure 2.6: Physical Activity Pyramid [Ali (2018)]

2.4.3 Habits of alcohol and smoking cessation to reduce the risk of Metabolic Syndrome: Yu *et al.,* (2014) stated in their study that smoking and drinking is associated with higher prevalence of Metabolic syndrome. Interactions between smoking and drinking on the risk of Metabolic syndrome in men in China may also exist. And they even mentioned there must be future studies conducted to be confirmed their findings in future case-control or cohort studies. Slagter *et al.,* (2014) through their study indicated that light alcohol consumption may moderate the negative associations of smoking with metabolic syndrome. Our results suggest that the lifestyle advice that emphasizes smoking cessation and the restriction of alcohol consumption to a maximum of 1 drink/day, is a good approach to reduce the prevalence of metabolic syndrome. Trisrivirat *et al.,* (2021) results suggest that alcohol drinking tends to be associated with an increased risk of metabolic syndrome. This condition should be screened regularly especially in those with heavy drinking or at-risk drinking habits. Sun *et al.,* (2014) and Ala'a *et al.,* (2009) meta-analysis of prospective studies suggested that heavy alcohol (Alcohol >40g/day in men and >20g/day in women) consumption might be associated with an increased risk of metabolic syndrome while very light alcohol consumption (Alcohol <40g/day in men and <20g/day in women) seemed to be associated with a reduced risk of metabolic syndrome. Sun *et al.,* (2012) concluded active smoking is associated with development of metabolic syndrome. Smoking cessation appears to reduce the risk of metabolic syndrome. A booklet produced by the Surgeon General in 2024 , Centers for Disease Control (CDC) and Prevention creates awareness on quit smoking. Esser et *al*.,(2024) stated that e*xcessive* alcohol use was responsible for about 178,000 deaths in the United States each year during 2020–2021, or 488 deaths per day.

2.4.4 Creating awareness about healthy lifestyle, body composition and Metabolic Syndrome to increase the Knowledge, attitude and practice of the population: Alefishat *et al.,* (2017) stated that the knowledge about metabolic syndrome and the attitude towards health affected the adherence rates in patients this lead to a high risk of metabolic syndrome. Swami *et al.,* (2021) observed that in their study group the Knowledge and perception of the individuals regarding the Type 2 Diabetic Mellitus was found to be good. But practicing them in their daily life is often found missing, this reiterated the importance of creating awareness and doing counseling constantly. Paley and Johnson (2018) in their study said there is moderate evidence supporting the use of programmes of exercise to reverse metabolic

syndrome. Denisenko (2020) stated that the correction in lifestyle and nutrition is considered as the main way to minimize complications caused by an imbalance in the body between saturated and polyunsaturated fatty acids. Gluvic *et al.,* (2017) stated that considering the high prevalence of metabolic disorders, preventive healthcare should focus on changing lifestyle to reduce obesity and increase physical activity. Creating awareness can be carried through various ways and means as given in Figure 2.7: Awareness of Metabolic syndrome.

Figure 2.7: Creating awareness on metabolic syndrome

Creating awareness on metabolic syndrome is necessary to reduce the risk of mortality occurring due to NCD‘s (Li *et al* ., 2023 and Anjana *et al*., 2023). Awareness can be through personalized nutrition, nutrition awareness camps for the community spread the message through medical or dietetic association’s enhance the knowledge attitude and practise of healthy lifestyle family and psychological support to follow a healthy lifestyle and also spread awareness through media handouts stalls and workshops.

2.5 Research gap in the existing literature:

Thus, after a thorough review of the literature, it is observed that there is a significant rise in NCD‘s and Metabolic syndrome. The research gaps identified are metabolic syndrome is always cured after the onset rather than prevented through individual factors for its mere occurrence. There is a need for a holistic approach to treat metabolic syndrome is very much essential. Counselling on lifestyle adaptations is most important and emphasis on regular reviews is essential. To empower young adults and make them aware of metabolic syndrome and the ways to prevent the onset of the condition. There are very few studies, in India, that show the relationship between metabolic syndrome and body composition.

The current research aimed to study Metabolic Syndrome in relation to Body composition and aimed at educating the participants with the educational material to reduce the individual criteria of Metabolic Syndrome and also Metabolic Syndrome in total among the studied group of subjects.