1. INTRODUCTION

Nutritional issues are main concern for the developing countries such as India. We are fighting against dual burden of undernutrition and over nutrition\textsuperscript{1}. Underweight due to poor nutrition is the last century challenge for India with development of overweight and obesity in last two decades\textsuperscript{1-5}. Overweight and obesity are existing in all age group people. India is facing a rising trend in childhood obesity with its progressive extension to adolescents. Obesity is increased in adolescent age group in both developed as well developing countries in last few decades\textsuperscript{6}. Globally, obesity is called the “New World Syndrome” which is causing severe economic and health burden on the community\textsuperscript{2,7}.

Epidemiology of Obesity:

Globally, it is considered that more than 22 million children of younger than 5 years of age are obese, and one out of 10 children is found to be overweight\textsuperscript{6,8}. The prevalence of obesity in children is increased drastically in recent years. Evidence have depicted that approximately one third of preschool children and half of school children that are obese turn as obese adolescents\textsuperscript{9,10}. Adolescents that are obese have higher chances of becoming obese in adulthood\textsuperscript{6,11,12}. According to the International Obesity Task Force and International Association for the Study of Obesity, about 200 million adolescents are belonging to the family of overweight and obesity\textsuperscript{1,13}, from which 40-50 million are obese\textsuperscript{13}.

The rate of obesity has elevated from 5 percent to 18 percent in adolescents among United States (US) population in 2008. There were 7\% obese children in the US (6-11yr) in 1980, which was elevated up to 20\% in 2008\textsuperscript{14}. There is an unceasing
rise in prevalence of overweight and obesity in India. The prevalence of overweight has risen from 9.7% (2001) to 13.9% (2010). Furthermore, there is increase in the prevalence of combined overweight/obesity in India from 15.9 percent before the year 2001 to 16.3 percent from 2001-2005 and 17.4 percent in the year 2006-2010 to 19.3 percent after the year 2010\textsuperscript{1}. Also, rate of increase in obesity for boys is 10 times (1.7 to 17.9%) and for girls is 4.5 times (2.4 to 10.9 %) in Seoul from (1979 to 2002)\textsuperscript{11}. Further, it was found that the prevalence of obesity was higher in upper socioeconomic status population than middle socioeconomic status\textsuperscript{1,2}, and the size of family and education of parents did not play a role in the prevalence of obesity\textsuperscript{1}.

**Causes of Obesity:**

Obesity has emerged as a global problem due to industrialization and urbanization\textsuperscript{15,16}. Life style changes in form of physical inactivity and high calorie dense foods are the main culprit for the obesity\textsuperscript{6,16}. Intake of high calorie diet, meals at fast food restaurants, large size of meal, high fat-low fibers meal, low vitamins, minerals, micronutrients and sweetened drinks contributes to increased rate of obesity. Sedentary life styles including watching television has been an adding factor to increased childhood obesity\textsuperscript{16,17}. Sedentary life style has increased because of automobile oriented life\textsuperscript{6} and better community and infrastructure\textsuperscript{6,18}. Moreover, numerous other elements like behavior, genetic and environmental causes play a role in establishment of obesity\textsuperscript{1,6}. Further, over usage of gadgets for long time and associates stress are responsible for sympathetic over-activation and obesity in adolescents and adults\textsuperscript{6,16}.
Co-morbidities Linked with Obesity:

Obesity is considered as an important contributing risk factor for associated cardiovascular morbidity and mortality. Obesity could create an adverse effect on heart by glucose intolerance, hypertension, dyslipidemia, increased inflammatory markers, obstructive sleep apnea, infertility, Poly Cystic Ovarian Disease (PCOD) and certain types of cancers$^{6,16,19,20}$. Further, Left Ventricular Hypertrophy (LVH) is very well documented in obese children and adolescents$^{6,21}$. Abnormal vessel wall is also seen in obese adolescents$^{6,22}$. Obstructive sleep apnea, a known risk factor for heart is seen in obese children and adolescents$^{6}$.

Moreover, social acceptance of obese adolescents is very less. Teasing by friends and family members is a very common phenomenon which leads to seclusion, poor self-confidence and finally hopelessness in them$^{6,23}$.

Risk Factors Associated with Body Fat Distribution and Visceral Fat:

In adults, approximately 80% of body fat is found in subcutaneous adipose tissue (SCAT) and 10-20% in visceral or Intra-Abdominal Adipose Tissue (IAAT)$^{24}$. Excess visceral fat is associated with metabolic risk in adolescents$^{11,24}$. Several studies have depicted that visceral obesity is the main culprit for risk of developing stroke, cardiovascular problems and non-insulin dependent Diabetes Mellitus (DM) than overall obesity$^{11,24-27}$. The distribution of body fat in particular to visceral region is responsible for development of DM and atherosclerosis$^{26}$.

It is very well documented that impaired glucose tolerance in central obese persons’ mimic development of metabolic syndrome. Cardiovascular Disease (CVD) is one of the foremost causative factor accountable for morbidity and mortality globally$^{26}$. Even
though obesity is a major challenge to health, physicians are amazed with the variations in cardiovascular risk factors in viscerally obese individuals. For example, on one side severe obese persons are not suffering from major metabolic complications\textsuperscript{26,28}, while on the other side overweight person have diabetes and atherogenic metabolic complications\textsuperscript{29}. Després JP et al. (2008)\textsuperscript{26} stated that studies done in last 25 years have looked at various reasons for such variations in the risk factor for CVD among obese or overweight persons. One of such work by Jean Vague from University of Marseille in 1947 had stated that the regional distribution of fat in body is more important in the occurrence of complications than excess fat.

Moreover, increase visceral fat can be explained by activation of hypothalamic pituitary adrenal axis which causes enhanced control of lipid and carbohydrate metabolism by glucocorticoids. Thus, as visceral adipocytes contain higher number of glucocorticoid receptors than subcutaneous tissue, activated hypothalamic pituitary adrenal axis facilitates fat deposition preferably in visceral adipose tissue, simultaneously stimulating insulin resistance in skeletal muscle and liver. Also, evidence has shown that higher consumption of dietary fructose could prefer visceral site for deposition of extra calorie\textsuperscript{27}.

**Relation of Visceral Adiposity to Metabolic Syndrome:**

Several meta-analyses had depicted that metabolic syndrome elevates the risk of CVD by about 1.5 to 2 times\textsuperscript{30-32}. The Metabolic syndrome is a constellation of hypertension, hyperglycemia/insulin resistance, visceral obesity and atherogenic dyslipidemia\textsuperscript{33}. These problems of metabolic syndrome lead to increased rate of atherosclerosis in obese persons. The levels of visceral fat than the amount of obesity
plays a key factor in developing insulin resistance that is compensated by increased amount of insulin, which is an important factor for metabolic syndrome\textsuperscript{34}.

Visceral fat is increasingly linked as a risk factor for cardio metabolic diseases\textsuperscript{26,35,36}. Visceral fat act as an endocrine organ which releases and controls numerous adipocytokines like resistin, adiponectin, Interleukin-6, leptin and free fatty acids etc. which have hidden systemic or local effects. The amount of distribution of ectopic fat plays a critical role for the development of cardio metabolic risks. Distribution of extra ectopic fat in liver, muscle, heart, kidney, subcutaneous tissue and abdomen have different effect on cardio metabolic risks. These distributions of visceral fat at different places are important in understanding pathophysiology of metabolic disorder\textsuperscript{35}.

Currently, the ways by which different distribution of visceral fat is linked with cardio-metabolic risk is not well cleared. Recent studies have demonstrated that elevated levels of visceral fat lead to increased amount of systemic free fatty acid and inflammatory cytokines in portal vein which increases the risk of metabolic syndrome and increased insulin resistance\textsuperscript{35,37,38}. Excess level of free fatty acids because of visceral fat can cause increased lipid synthesis, gluconeogenesis and resistance to insulin. Thus, increased level of visceral fat can cause hyperlipidemia, hypertension, glucose intolerance and atherosclerosis. Further, a disease entitled, the “Visceral Fat Syndrome” is proposed which rises the risk for atherosclerosis\textsuperscript{39}.
**Adiposity and Baseline Cardiovascular Parameter:**

Increased resting Heart Rate (HR) is linked with elevated number of deaths from CVD and risk of sudden mortality due to myocardial infarction even in apparently normal individuals\(^{40-43}\). Increased level of abdominal obesity is linked with elevated risk of hypertension which could be culprit for early atherosclerotic changes in adulthood\(^{44}\). Further, obesity predicts the occurrence of hypertension in normal individuals\(^{45,46}\). However, it is uncommon that lean hypertensive patient is at higher risk of developing obesity. The incidence of developing hypertension among obese person has reached about 50 percent in particular age group. Also, obesity is found higher number of person with hypertension. However, even though the importance of problem is recognized, the type of link between hypertension and obesity is unclear\(^{45}\). Evidence has shown that hypertensive patient had more amount of fat in abdominal visceral area than normal individuals\(^{47}\). The baseline Diastolic Blood Pressure (DBP) and Systolic Blood Pressure (SBP) are more in overweight and obese adolescents than normal individuals\(^{46}\).

**Adiposity and Various Cardiovascular Parameters during Exercise Stress Test:**

Exercise induced rise in blood pressure is used for assessing the risk of hypertension in future as studies have found a positive correlation between exercise blood pressure and future hypertension\(^{48-51}\). Blood pressure is one of the main component which is used to indirectly assess the heart’s ionotropic activity and response to physical stress linked with the amount of exercise tolerance. The increased or exaggerated response of blood pressure to physical stress in normal person is a prognostic predictor for the risk of future hypertension, which is 2-4 times higher\(^{50}\).
Exercise Stress Testing (EST) gives prediction of change in blood pressure with response to physical stress, which are reproducible. Moreover, it is proposed that physical stress can unmask the risk of developing hypertension. It has been depicted that hypertension follows pre-hypertensive stage\(^49\). Pre-hypertensive stage is seen as an abnormal cardiovascular response to behavioral and environmental stress such as isometric and dynamic physical exertion test, mental arithmetic challenges and immersion in cold water\(^51\).

Exercise testing gives very significant idea about circulatory health and about prognosis of person’s life as it detects physical fitness along with coronary atherosclerosis. Exercise stress testing is commonly used for patient with Coronary Artery Disease (CAD) in which changes, chiefly in ST segment of the Electro Cardio Graph is a strong predictor of the pathology\(^50\).

Treadmill Stress Test (TST) is a useful method for diagnosis among children and adolescents in which the velocity and inclination of treadmill are adjusted as per the capacities of the subject. The most common used protocol for stress testing is Bruce protocol. The risk associated with TST in adolescents (age \(\leq 19\) years of age) is minimum compare to adults. The complications posed with TST are rare even if carried with adolescent with cardiomyopathies\(^52\). The EST in adolescents is used for many purpose which includes capacity to take part in sports, vocational and leisure work along with observing the changes in BP with physical exertion\(^48\).

Several components tend to affect blood pressure response to exercise stress in children and adolescents which includes obesity, age, gender, resting arterial blood pressure, physical fitness, ethnicity, dyslipidemia, genetics and family history of
hypertension. Out of these described factors, studies have shown that obesity is a very important component to affect the response of blood pressure to exercise\textsuperscript{53}.

The circulatory variations that occur from a baseline to exercise are complex. Blood pressure is associated with cardiac output and peripheral vascular resistance. They can change intensely during exercise. The normal rise in cardiac output during exercise is thought to result in an increase in systolic blood pressure. As exercise intensity increases, there is a rise in cardiac output, and so systolic blood pressure is also increased with each progressive stage of an exercise test. The diastolic blood pressure remains unaltered due to vasodilation during exercise\textsuperscript{51,54}. An absence of proper rise in systolic blood pressure with exercise may reflect cardiac dysfunction. Reduction in systolic blood pressure during exercise may reflect cardiac abnormalities\textsuperscript{54}.

Acute changes in blood pressure to physical stress has been used as presage for developing hypertension. Systolic pressure at submaximal exertion helps in predicting hypertension by 89.7\%. It was found that at maximal intensity exertion (100\% of \( \text{VO}_{2\text{max}} \)), the rise in systolic blood pressure was higher in obese adolescents compare to normal. These hemodynamic responses suggest that higher cardiac load occur among obese adolescents at maximal exertion showing significant relation between Body Mass Index (BMI) and systolic blood pressure. This increased response is associated with enhanced sympathetic activity\textsuperscript{53}.

The hemodynamic response of increased blood pressure with high visceral fat during Cardiopulmonary test can be explained by various mechanisms. The hemodynamic changes include higher cardiac load at maximal exertion which can be explained by increased sympathetic activity\textsuperscript{53,55}, metabolic dysfunction and increased insulin resistance\textsuperscript{53,56}. 

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According to Casonatto J et al. (2011), other possible hypothesis for association between visceral obesity and hypertension includes decreased sensitivity to insulin which leads to compensatory hyperinsulinemia\textsuperscript{57}. Increased levels of insulin seen in obese adolescents is linked to presence of visceral fat. These increased insulin levels lead to elevated sodium retention thus increasing blood pressure\textsuperscript{50,57}.

Studies have also shown that the exercise induced rise in blood pressure is associated with the level of adiposity in the body\textsuperscript{58-60}. The association of adiposity with exercise blood pressure is attributed to the variation in sympathetic activity associated with obesity. But, controversies exist in terms of sympathetic activity in obese individuals such that low Sympathetic Nervous System (SNS) activity is causative in development of obesity while high SNS activity is an effect of obesity. These controversies could also be due to the distribution of fat in the body\textsuperscript{58}.

**VO\textsubscript{2max} and Adiposity:**

Aerobic fitness (VO\textsubscript{2max}) is one of the significant factor to measure physical fitness\textsuperscript{61,62}. VO\textsubscript{2max} gives maximal level of oxygen consumed per kg by body per minute of physical activity. It determines cardiorespiratory endurance of the subjects. Larger amount of oxygen consumed suggest better cardiorespiratory system. VO\textsubscript{2max} is linked with physical\textsuperscript{61,62} and mental well-being along with predicting mortality\textsuperscript{61}.

Physical fitness is used to assess functions of several systems such as respiratory, cardiovascular, hemato-circulatory, muscular, and neuroendocrine system. Regular physical activity, fitness and goal specific physical exercise are used to reflect collective function of several systems of body. Therefore, physical fitness is a very helpful health indicator\textsuperscript{63,64}. Cardiorespiratory fitness is a very strong marker to predict cardiovascular and overall mortality. Thus, reduced aerobic fitness is one of
the risk factor for cardiovascular system that is modifiable. Some of the factors that affects the VO$_{2\text{max}}$ are age, gender, genetics, physical activity and body composition. Cardiovascular fitness is found to be different in subjects with varying body mass. Cardiovascular fitness needs to be checked to see linkage between body composition and occurrence of mortality. Less evidence persists to check association between aerobic fitness and visceral adiposity in Indian subjects.

Higher VO$_{2\text{max}}$ is linked with reduced visceral obesity and BMI, and vice versa. Supply of oxygen to the working muscles is decreased in overweight due to fatness. Increased aerobic fitness is thought to improve cholesterol level, arterial blood pressure and status of weight in adolescents. Reduced cardiovascular fitness is known to cause CVD later in adulthood. According to Silva LR et al., obese adolescents had lower than normal VO$_{2\text{max}}$ as per the respective age and gender of the subject. Physical activity helps to elevate VO$_{2\text{max}}$ along with preventing fatness.

**Cardiovascular Parameters during Recovery Phase of Exercise Stress Test:**

Heart Rate Recovery (HRR) is termed as decrease in heart rate after stoppage of exercise. So, it should come to baseline or near baseline level after the physical exertion. HRR is shown to have association with cardiovascular health in which slower decrease in them are directly linked to reduced cardiovascular function and associated risk of mortality. HRR depicts the functional capacity of autonomic nervous system, chiefly the parasympathetic component which is identified to be high in physically fit persons.

During resting stage, there is predominant parasympathetic tone and during exercise there is activation of sympathetic system with withdrawal of parasympathetic tone. After physical exercise, heart rate recovers to normal level by activation of
parasympathetic system followed by withdrawal of sympathetic system\textsuperscript{70,72,73}. So, delayed HRR after physical stress is suggestive of impaired reactivation of parasympathetic nervous system. Also, increased sympathetic functions are linked with insulin resistance or hyperinsulinemia, which is associated with metabolic syndrome. Study have depicted that abnormalities of both sympathetic and parasympathetic system are linked with type II diabetes, insulin resistance, and obesity\textsuperscript{70}. Recovery of HRR was found to be delayed in obese subjects as compared to normal individuals\textsuperscript{73}. Thus, HRR and VO\textsubscript{2max} are used to indicate fitness and health parameters. Moreover, subjects with greater aerobic fitness have earlier HRR\textsuperscript{61}.

The unusual changes in blood pressure after exercise and prolonged duration for recovery of blood pressure and heart rate are early indicator of heart diseases. They are suggestive of imbalance in autonomic nervous system. The response of blood pressure to exercise is very important measure to assess the heart status instead of resting blood pressure and heart rate, both in normal and hypertensive individuals\textsuperscript{74,75,49,53}. 
Rationale:

Most of the studies conducted till recent times had used BMI as the physiological variable for assessing adiposity and reviewing the association of BMI with the cardiovascular responses. Meanwhile, BMI does not reflect visceral adiposity equally across populations as found that Asian population have a relatively higher amount of adipose mass at similar levels of BMI as compared to other populations. Since, the association of visceral adiposity and exercise induced change in blood pressure in Indian adolescents of 18-19 years’ age group has not been reported so far. So it is crucial to know how visceral adiposity influences the cardiovascular response to exercise stress in Indian adolescents as ethnic differences exist in the pathogenesis of diseases. So it is mandatory to know the association of visceral adiposity and cardiovascular responses to exercise stress, as the results of the study will guide in understanding the cardiovascular response to exercise with respect to the level of visceral adiposity. Moreover, it may help us in determining which form of adiposity has a stronger influence on the cardiovascular responses during exercise stress test and thus would assistance us in outlining some preventive strategies in this said population.