3. LITERATURE REVIEW

Obesity and its Associated Co-morbidities with their Prevalence:

Shani D et al. (2014)\(^{20}\) reported that obesity is considered as one of the major risk factors tied with chronic ill effects on various systems of the body. Obesity contributes to about 15% of the population worldwide. Obesity in adolescence can lead to obesity in adulthood leading to CAD, dyslipidemia, hypertension, type II DM, PCOD and metabolic syndrome. Obesity is a contributing factor to poor health of people and an important economic stress for the countries worldwide.

Senbanjo IO et al. (2012)\(^{76}\) said that an increase in level of overweight and obesity is due to inexpensive, abundant available junk food along with sedentary changes such as use of computer, video games and watching television. Further, in India, the increased prevalence of obesity among adolescents is 7.4% in well to do families.

Katchunga PB et al. (2015)\(^{77}\) stated that hypertension is one of the major public health concern globally, and one billion people worldwide are suffering from it. The elevation in prevalence of hypertension is associated with increased expectancy of life and metabolic syndrome. The linkage between arterial hypertension and obesity is complex but associated with resistance to insulin and resultant hyperinsulinemia.

Kehoe SH et al. (2014)\(^{78}\) reported that according to the World Health Organization (WHO) estimate, 53% of mortality in India is due to non-communicable diseases such as Type II diabetes and CVD. According to Patel V et al. (2011)\(^{79}\) the prevalence of mortality due to such disease is considered to increase up to 75% by the year 2030. Popkin BM (2002)\(^{80}\), Misra A et al. (2011)\(^{81}\), Popkin BM et al. (2012)\(^{82}\) said that there is change in the dietary pattern since 1970’s with increased intake of salt, meat
products, refined grains and reduced intake of pulses, vegetables, fruits and whole grain cereals in India. Further, Gouda J et al. (2014)\textsuperscript{16} added that, it is the perspective that because of “nutritional transition in developing countries” or “the shift to western diet” and lifestyles from traditional ones such as unsaturated food, transport facilities, reduction in physical activity, increased stress and better health care especially in urban area, the prevalence of obesity and overweight continue to increase, showing that burden of disease associated with obesity will continue to rise. More than 30 million people in India are obese, of which the numbers are thought to increase significantly. The problem of overweight and obesity is higher in women than men. The prevalence of overweight and obesity is higher in women by about 23% than men by 20%.

Similarly, Goyal RK et al. (2010)\textsuperscript{83}, Jain S et al. (2010)\textsuperscript{84} suggested that there is rise in prevalence of obesity in adolescents to about 20% in urban population. Gouda J et al. (2014)\textsuperscript{16}, stated that overweight and obesity lead to approximately 2.8 million deaths in adults worldwide every year and are the fifth leading cause of mortality. Moreover, overweight is thought to be linked with increased burden of diseases such as 44% of diabetes, 23% of ischemic heart disease and 7% to 41% of cancer.

Raj M et al. (2007)\textsuperscript{3} reported that there is increase in prevalence of overweight and obesity in children from childhood by 4.94% to 6.57% from 2003 to 2005 as per two cross sectional surveys in Kerala involving more than 20,000 children.

Pandey RM et al. (2009)\textsuperscript{85} depicted that the results from cross sectional surveys in Delhi portrays the rise in prevalence of obesity in adolescents to 11.7% in 2009 from 9.8% in 2006.
According to Goyal RK et al. (2010)\textsuperscript{83}, the prevalence of overweight in Ahmedabad was 14.3\% for boys and 9.2\% for girls, and 2.9\% obesity for boys and 1.5\% for girls among age group of 12-18 years.

**Visceral Fat, its Prevalence and Metabolic Syndrome:**

De Pergola G et al. (2012)\textsuperscript{86} stated that obesity is per se linked with the risk for developing hypertension. Further, Framingham Heart Study depicted that nearly 65\% to 75\% of overweight and obese subjects are prone for developing hypertension. He showed that visceral fat is the main culprit for rise in BP when we consider distribution of fat. He reported that sympathetic stimulation is more in persons with central type than peripheral type of fat distribution. Obese subjects have hyperinsulinemia and it is found that insulin excites sympathetic action, which happens even when insulin level is in normal range. The Renin Angiotensin System (RAS) has been recognized as an extra abnormality which can confirm the relation between obesity and hypertension.

Pradeepa R et al (2015)\textsuperscript{87} showed the prevalence of generalized obesity to be 31.3\% in Chandigarh and that of abdominal obesity be 36.1\%. They said that the prevalence of generalized as well as abdominal obesity is more in India.

Castro JA et al. (2016)\textsuperscript{88} has find out the prevalence of abdominal obesity on Southern Brazil adolescents. He concluded that one out of ten adolescents are suffering from central obesity.

There is increased fat accumulation in central regions compare to periphery in overweight individuals, leading to increased risk of DM, CAD and hypertension. Few studies depicted the association between body fat and prevalence of
non-communicable diseases such as DM and hypertension. Moreover, central obesity is found to be linked with increased risk of these diseases\textsuperscript{2,76}. Presently, visceral obesity is deliberated as the “Civilization Syndrome”\textsuperscript{25}.

**Després JP et al. (2008)\textsuperscript{26}, Després JP (2012)\textsuperscript{27}, Katchunga PB et al. (2015)\textsuperscript{77}** stated that accumulation of central fat mainly in the viscera produce greater pathologic changes than any other pattern of fat distribution. Central obesity is linked with metabolic changes such as hypertension, impaired glucose tolerance, dyslipidemia, insulin resistance, pro inflammatory and pro thrombotic state collectively known as metabolic syndrome. Metabolic syndrome is tied with increased visceral fat, disturbed glucose homeostasis, increased BP and dyslipidemia. Metabolic syndrome elevates the risk of morbidity and mortality associated with CVD, irrespective of gender. Approximately, more than 50 million Americans are suffering from metabolic syndrome and their prevalence is continuously rising.

**Kim JA et al. (2008)\textsuperscript{89}** stated that there is association between visceral fat and cardiovascular/metabolic risk factor in obese Korean adolescents. Visceral obesity is independently linked to blood triglyceride, BP, fasting blood glucose, blood HDL (High Density Lipoprotein)-C.

**Body Composition Indices and adiposity:**

A. **Bioelectrical Impedance Analysis (BIA)**

**Minghelli B et al. (2013)\textsuperscript{90}** stated that the definition of increased level of body fat is not clearly developed particularly in adolescence as body fat changes greatly in this period with age, gender and maturation level. Many methods can be helpful in
assessing body composition. Anthropometric measures are very crucial in assessing changes during adolescence.

**Hall DM et al. (2006)** stated that the validity of anthropometric measures to assess body fatness can be assessed by two main ways which include imaging and physiochemical. The physiochemical method measures the quantity of water in body using deuterium oxide by dilution, or using Bio-electrical Impedance or electrical conductivity of total body. Secondly, imaging techniques such as Magnetic Resonance Imaging (MRI) or Computed Tomography (CT) gives reliable and precise way to measure body composition.

**S. Rao et al. (2007)** stated that even though several ways to study body composition are available such as Dual Energy X-ray Absorptiometry (DEXA) or densitometry, they have disadvantage of being expensive and tedious, thus making them unfeasible to use for large studies. So, other simpler ways such as BIA can be used.

**Li YC et al (2013)** reported that BIA is a very useful tool to measure body composition. Some of the advantages of BIA in comparison with other techniques are that it is safe, inexpensive, fast, simple, easy to perform, portable and needs less training for operation. BIA is helpful in looking at % of body fat rather than using common measures such as Waist Circumference (WC), Waist Hip Ratio (WHR), BMI, Waist to Height Ratio (WHtR). Other tools to look at obesity do not measure body fat percentage as they cannot differentiate between fat and muscle.

**Katchunga PB et al. (2015)** stated that Omron monitor in which eight sensors are placed in hands and feet are used to accurately measure BIA of whole body, which are found to have significant correlation with MRI and DEXA to measure fat mass and
VF respectively. BIA is beneficial than MRI as it is cost effective and easy to use. The study depicted that BIA is used to estimate higher VF which is linked with high risk of CVD. The BIA measured with semi quantitative 0-30 level to measure VF is excellently associated with gold standard techniques such as DEXA and whole-body MRI in healthy, obese and overweight subjects.

**CARO JF (1991)**\(^9\) conducted clinical reviews and reported that BIA is the first easy to operate, portable and reproducible way to look at the composition of body fat outside the laboratory. The composition of body fat can also be determined by skin fold thickness, which is not precise and is tedious.

**B. Waist Circumference (WC):**

**McCarthy HD et al. (2003)**\(^9\) showed that abnormal concentration of insulin and lipid are related with waist circumference. WC is a very reliable and sensitive tool to assess upper body fat in adolescents and therefore should be used to measure risk of metabolic complications among obese and overweight adolescents. On the contrary, **Katchunga PB et al. (2015)**\(^7\) reported that WC has some disadvantage that it is subjective as it is dependent on operators and affected by meal and respiratory cycle. Also, it does not differentiate subcutaneous fat from visceral fat. On the contrary, BIA is simple, objective, non-invasive and relatively cost-effective tool to measure VF.

**C. BMI:**

**Chung S et al. (2015)**\(^9\) depicted that BMI is thought as the representative of body fatness and is commonly used to assess obesity and predict risk to health. Higher BMI in childhood is linked with obesity in adulthood and risk of severe diseases such as atherosclerosis, diabetes and mortality. Even though, BMI is a very helpful as being
simple and non-invasive measure of body fat, it has limitation of differentiating lean mass from body fat. Many situations can affect BMI as athletes have higher BMI because of elevated muscle mass. The changes occurring in relation between weight and height with age can affect BMI. Women have increased level of body fat as compare to men with identical BMI. Also, older adults seem to have higher level of fat than younger adults with identical BMI. BMI increases faster from birth to up to 2 years of age, then reduces until 5-6 years of age then it increases throughout adolescence.

Schwandt P et al. (2012)\textsuperscript{97} depicted that BMI is widely used to categorize overweight and obesity in adolescents. But, BMI does not differentiate between lean and fat body mass which can mislead the available information on body fat distribution during growth, after physical training and between various ethnicities.

A study was conducted to see the capacity of BMI with 85\textsuperscript{th} and 94\textsuperscript{th} percentile to correctly identify children with higher level of body fat. They found that BMI cannot be used as diagnostic test, but screening test. For children with BMI between 85\textsuperscript{th} to 94\textsuperscript{th} percentiles, approximately half of the children had moderate amount of fat, 30\% had normal levels of fat and 20\% had increases fatness. An overweight adolescent can have higher Fat Mass (FM) or Fat Free Mass (FFM) and additional differences in ethnicity can be present. Body fat can be considered into two aspects, FM and FFM. FFM is very important factor and core of the body. FFM is strongly related to energy metabolism and physiological function of body, thus is the active metabolic component\textsuperscript{96}. 
D. Visceral fat measurement by BIA versus WC:

BIA helps to differentiate between hypertensive and normal subjects in better ways with respect to visceral fat in comparison to standard metabolic syndrome criteria inclusive of WC. Also, VF was significantly linked with risk of hypertension and CVD unlike WC. Thus, BIA is a better tool to assess body composition and to determine accumulation of VF, which is linked with insulin resistance in hypertensive subjects. Also the study by Aydin M et al. (2012), stated that VF by BIA was significantly linked with systemic inflammation in Turkish subjects.

E. Visceral Fat versus BMI:

Hall DM et al. (2012), observed that to look at the progress in the epidemics of obesity, the BMI values associates well with the levels of body fat to use as a tool for public health. BMI is recently the best anthropometric measure available to assess body fatness for public health. But, BMI is not the perfect representative of obesity as there are individual differences in the association between body fat and BMI risk factors for CVD and long-term health problems. He inferred that BMI has limitation in measuring body fatness as body composition which is the ratio between FM and FFM differs as per the gender and age. He further added that BMI and Fat Mass Index (FMI) are strongly associated but not as strong to make inferences in individual. The health risks do not rely entirely on BMI but is more dependent on visceral fat.

F. WC versus BMI:

Commonly used measures to assess obesity are waist circumference and BMI. However, BMI cannot be used as a good predictor of obesity in Asian Indians because they have obese phenotype with lower BMI but have central obesity. Visceral obesity
is linked with diabetes, so abdominal fat that is assessed with WC is more reliable to predict metabolic complications than generalized fat assessed by BMI\textsuperscript{15}. Several anthropometric measures used to estimate central obesity are WC, sub scapular skin fold thickness, WHR, WHtR\textsuperscript{76}.

\textbf{Motala AA et al. (2011)}\textsuperscript{99} observed that the most common factor tied with metabolic syndrome was high WC. It is well accepted that Indians have higher WC for any given BMI \textsuperscript{2,99}. Also, they have higher abdominal and truncal fat. They have elevated deposition of body fat for given WC and have higher insulin resistance to given body fat\textsuperscript{1,5,15}. These characteristics are termed as “Asian Indian Phenotype or Paradox” \textsuperscript{15}. WC is used to assess both visceral fat and subcutaneous fat. There is strong association between increased fat deposition and elevated blood pressure among adolescents\textsuperscript{76}. In contrast, \textbf{Chan RS et al. (2010)}\textsuperscript{100} concluded that nowadays BMI is considered as valid tool which is used to indirectly assess adiposity in children.

\textbf{Mazıcıoğlu MM et al. (2010)}\textsuperscript{101} concluded that in order to diagnose obesity and to evaluate recent and further metabolic risk along with BMI, additional tools to measure anthropometric indices are essential to correctly suggest distribution of fat in body. Skin fold thickness and WC are important indirect ways to evaluate body fat and screen children with obesity. BMI is used to assess body fat reserve but for individual with same BMI, body fat reserve can be different between them. Other disadvantage of BMI is that it gives no idea of distribution of fat in the body. It is shown that distribution of body fat especially intra-abdominal distribution is associated with risk of obesity linked comorbidities. Therefore, WC along with BMI is used as a tool to describe body fat distribution.
WC is thought as the best tool to assess abdominal central obesity. Rather than BMI, WC is suggested to use as a tool to assess obesity linked health issues. WC is a very strong, specific and sensitive tool to measure central obesity. Moreover, WC is associated with hypertension, insulin resistance, negative lipid profile and metabolic results linked with obesity\textsuperscript{101}.

Senbanjo IO et al. (2012)\textsuperscript{76} concluded that BMI gives more reliable prediction of blood pressure, even though WC was considered more direct measurable tool of body fat. One of the study conducted in Chennai showed that hypertensive subjects had higher waist circumference and BMI as compared to normotensive individuals\textsuperscript{15}. While, other study by Deshmukh PR et al. (2006)\textsuperscript{102} depicted that there is significant association between blood pressure and measures of obesity. They showed that BMI was better associated with BP than WC measurements. It could be because population was rural and unusually lean.

Minghelli B et al. (2013)\textsuperscript{90} suggested that according to the WHO, the suggested anthropometric measures to detect weight status in adolescents are subscapular skinfold thickness and BMI, but another study by Gläßer N et al. (2011)\textsuperscript{103} concluded that WC as well as BMI can predict excess body fat in adolescents. Although, BMI is highly specific and sensitive measure of body fat, large number of adolescent that are consider as obese or overweight does not have elevated body fat. So, the cut off points for BMI to look at higher level of body fat are still debatable. WC is thought to be highly specific and sensitive tool to look at central obesity and can be used to look at overweight children.
It is vital to use WC as an anthropometric measure to assess abdominal fat distribution\textsuperscript{2,76,101}. One of such study named the International Day for the Evaluation of Abdominal obesity (IDEA) by Balkau et al. (2007)\textsuperscript{104}, was a major cross-sectional study on about 1,70,000 subjects in 63 countries examined by primary care physicians. Out of them, 6400 physicians were told to measure height and weight of subjects and measure WC. They reported status of patients, which indicated that WC helps to predict heart diseases and diabetes at any level of BMI. Even though, IDEA study consists of large sample size, being cross-sectional design, it showed the prevalence of association of CVD and diabetes with central obesity\textsuperscript{26,104}.

Longitudinal study by Canoy et al. (2007) on European Prospective Investigation into Cancer in Norfolk (EPIC-Norfolk) depicted, the association of waist and hip circumference with prevalence of CAD. EPIC-Norfolk is a huge prospective study which includes 24,508 male and female subjects of 45 to 79 years of age that were followed for 9.1 years for prevalence of CAD. The results of this study demonstrated statistically significant result with 1708 men and 892 men diagnosed with CAD over the course of study. The study depicted that increased WC was linked with higher risk of CAD\textsuperscript{26,105}.

The researcher of EPIC Norfolk also conducted regression study of WC values with risk of CAD, and proposed that decrease in WC by 5 cm can reduce the risk of CAD by 11% in men and 15% in women. It has been shown that reduction of weight by 1 kg can reduce WC by 1 cm. So, reduction of weight of 5 kg will be sufficient enough to produce decrease in CAD risk as per proposed by investigator of EPIC-Norfolk. Intervention studies are definitely needed to confirm proposed estimates, but they are supportive to the proven benefits of 5% weight reduction on metabolic risk profile. It
is considered that the risk of CVD because of increased WC can be result of increased visceral fat which is predictor and associated with thrombotic, inflammatory, proatherogenic changes and insulin resistance\textsuperscript{26,105}.

**Visceral Fatness and Basal Blood Pressure Profile:**

**Becker MD et al. (2007)**\textsuperscript{50} observed the differences in resting DBP between the genders. Greater values were observed with increase in age, particularly from 16 years onwards in both the gender. Resting systolic blood pressure was significantly more in males.

**Rajalakshmi R et al. (2011)**\textsuperscript{106} stated that, the baseline DBP and SBP were significantly higher in overweight and obese adults than normal individuals.

**Mertens IL et al. (2000)**\textsuperscript{107} stated that BMI was highly correlated with DBP and SBP irrespective of age, adverse addictions like smoking, alcohol consumption and sodium and potassium excretion.

**Hayashi T et al. (2003)**\textsuperscript{108} discussed in his cross-sectional study on 563 Japanese American that high visceral adiposity is associated with elevated SBP and DBP irrespective of Fasting Blood Sugar, PP2BS (Post Prandial Blood Sugar), age and gender. On the contrary, several studies\textsuperscript{48,49,109} observed that blood pressure during physical exertion is a more reliable predictor of future hypertension.
Visceral Fatness and BP Derivatives:

Zachariah JP et al. (2014)\textsuperscript{110} stated that the derivatives of SBP and DBP such as MAP, PP provides equally good road in forecasting risk of CVD and can unmask underlying pathophysiology of hypertension.

Franklin BA et al. (2009)\textsuperscript{71} stated that, the use of single versus combined BP derivate in projecting CVD is not clearly understood. Although, debate is still ongoing about which component of BP is better in predicting CVD, previously DBP was only reliable component of BP as it was reflecting resistance on heart to eject blood than SBP. After 1980’s, SBP was clinically accepted component to predict CHD, stroke and heart failure. Nevertheless, SBP is better than DBP. MAP is a reflection of peripheral resistance and cardiac output. He concluded that combining MAP with PP and DBP along with SBP gives reliable insight of CVD than single component of BP. PP and MAP gives more reliable prediction about arterial stiffness, but it is equally important in predicting peripheral resistance to detect CVD same like SBP and DBP. Studies\textsuperscript{86,111} have depicted that there is significant rise in PP and MAP in overweight and obese adolescents than normal. De Pergola G. et al. (2012)\textsuperscript{86} reported that there is an excellent association of 24-hour mean PP with BMI and WC.

Dipla K et al. (2012)\textsuperscript{58} stated that MAP rises during hand grip exercise and mental anxiety, but very scarce literature is available on correlation of visceral fat and BP derivatives.

Obesity is linked to elevated BP and PP in African American adolescents thus, elevating their risk for developing hypertension. PP amplification was negatively
linked with BMI, WC, Total Body Fat (TBF) % which was related with increasing body fat in adolescents\textsuperscript{112}.

**Chandramohan G et al. (1994)\textsuperscript{113}** stated that PP is a known factor to predict the risk of CVD. They conducted respective study of 4667 children of 6-17 years’ age and found that there occurs statistically significant association between wide PP and high WC. He depicted that PP is a tool to forecast risk of coronary heart disease and LVH in both hypertensive and normal individuals. It is considered more reliable tool of CHD than SBP and DBP. Vascular stiffness is directly related to alteration in PP for given stroke volume. Thus, PP is considered as a surrogate of vascular function and a risk factors for adults.

**Kristjansson K et al. (2003)\textsuperscript{114}** conducted prospective population study of 1462 women in Sweden to see association between BMI, BP and PP. They found that BMI was linked with PP while, SBP and DBP were associated with BMI and WHR.

**Kwagyan J et al. (2005)\textsuperscript{115}** carried out cross sectional prospective study on 219 obese African Americans to see the effect of increased body mass and risk factors for CVD on PP. They found that higher levels of BMI are linked with reduced compliance of arteries.

**Soundariya K et al. (2016)\textsuperscript{116}** stated that RPP is an indirect and trustworthy tool to measure the levels of the oxygen consumption of the heart in healthy and patients with heart diseases. It is achieved by multiplying Systolic Blood Pressure (SBP) and resting Heart Rate (HR), which is an indicator of work load on the heart.

**Parkhad SB et al. (2015)\textsuperscript{117}** has seen that there is strong positive association between BMI and RPP in both the genders.
Nevertheless, Ravisankar P et al. (2005)\textsuperscript{118} found no such association. Rajalakshmi R et al. (2016)\textsuperscript{46} found that raised RPP in overweight and obese male adolescents, which is suggestive of an exaggerated sympathetic activity in obese male.

Sembulingam P et al. (2015)\textsuperscript{119} stated that RPP is a priceless indicator of the oxygen requirement by the heart. Further, he explained that as heart is muscular organ, it requires continuous source of oxygen and nutrients for its regular functioning. If it does not happen, heart will start malfunctioning. Its importance is more appropriate during exertion than at rest. Consequently, with regards to it, the author reported that RPP is valuable in defining physical fitness of a person at rest and during exercise. They concluded that RPP can be thought as a valuable tool to measure perfusion of the vessels of heart and functioning of myocardium in determining the needed oxygen at rest and exercise.

Shaikh WA et al. (2011)\textsuperscript{111} conducted the cross sectional study on 485 Gujarati adolescent boys and girls of 16 to 19 years of age to see how physical fitness alters blood pressure in them. They found that systolic blood pressure and mean arterial pressure were significantly elevated in moderate physical activity levels compared to low level among boys unlike girls.

Park HS et al. (2005)\textsuperscript{120} concluded that the resting heart rate and MAP can be lowered down with regular exercise as visceral fat decreases and vascular function is improved with it. Aerobic exercise, yoga and life style modification are known to improve parasympathetic tone which helps in prevention of early hypertension.
Cardiovascular Response to Treadmill Exercise Stress Testing:

Chiacchio Sieira M et al. (2010)\textsuperscript{121} stated that Exercise testing that is conducted on bicycle or treadmill is a cardiovascular excitatory test. It is relatively cost effective and generally helpful to forecast prognosis and to predict functional capacity as well as to know risk and severity of CAD. Further, it is used to judge physical training or treatment.

Fielding RA et al. (1997)\textsuperscript{122} conducted study to see the reproducibility of Bruce protocol on 17 women of 51-68 years and concluded that the commonly used Bruce protocol for exercise testing is reliable in producing reproducible results of VO\textsubscript{2max}. HR reaction to exercise may reveal a person’s degree of fitness. Kohli P et al. (2010)\textsuperscript{123} stated that the capacity to reach 85% maximum age predicted heart rate with exercise can be helpful to see the chances of developing CAD. A study on 200 women showed that failure to reach target HR during exercise testing was linked with higher chances of developing CAD.

A normal response of HR is needed to match cardiac output to metabolic demands during physical exertion. If maximal HR is not reached or instability of HR occurs during physical exertion, it is suggestive of altered chronotropic response. He observed that failure to reach 85% of maximum age predicted HR was linked with reduced survival in both male and female. Savonen et al. (2006)\textsuperscript{40} said that on the contrary, reduced maximal heart rate and failure to reach specific age predicted maximal heart rate is associated with increased risk of death from CVD.

Dipla K et al. (2012)\textsuperscript{58} stated that, a rise in SBP from Baseline to >10mmHg per metabolic equivalent (MET) or change of DBP>10mmHg during any stage of
exercise is termed as an exaggerated BP response during acute exercise stress test. During Isometric hand grip exercise, the change in blood pressure in response to excitation of SNS were same or slightly higher in both obese as well as lean subjects, while during Dynamic exercise, reduced blood flow to lower limbs muscle have been found in overweight children which could be related with endothelial malfunction.

**Chiacchio Sieira M et al. (2010)**\(^{121}\) concluded that both, the American Heart Association and the American College of Cardiology considered an exaggerated response of SBP and DBP during stress testing as a warning sign of developing hypertension in asymptomatic individual. Likewise, hypotensive response of SBP during exercise has an important capacity to see prognosis of developing future hypertension.

**Dlin RA et al. (1983)**\(^{48}\) found that changes in exercise BP helps the best in predicting future hypertension. The subjects which are normotensive at baseline but depicts an exaggerated change in BP with exercise are at higher risk of developing future hypertension.

Moreover, **Singh JP et al. (1999)**\(^{49}\) emphasized that, an increased DBP to physical exertion is a predictor of developing new onset hypertension in normal individuals. Further, a Framingham heart study depicted that increased DBP during treadmill stress test was a predictor of developing future risk of hypertension within approximately 8 years. While, **Matthews CE et al. (1998)**\(^{124}\) concluded that elevated BP than normal during treadmill stress test have higher risk of developing hypertension within 4-12 years.
Further, Rajalakshmi R et al. (2011)\textsuperscript{106} reported that response of BP during stress testing is used to evaluate cardiac status. Inability of the BP to rise with increase in load or hypotensive response is one of the indicator of significant heart disease. Increased response of blood pressure with exercise is a significant risk factor for developing hypertension in future. He conducted treadmill exercise test on 85 subjects (30-normal weight, 25-overweight and 30 obese) of age group 18-22 years and found that the baseline blood pressure was elevated in overweight and obese subjects. Also, elevated response of SBP and HR was observed in obese groups compared to normal individuals. Mohan B et al. (2004)\textsuperscript{125} found that elevated blood pressure was found in obese children than lean subjects which could be linked with sedentary life style, changes in eating habits and elevated contents of fat in their diet. Van Woudenberg M et al. (2015)\textsuperscript{126} concluded that visceral fat was significantly associated with response of blood pressure in overweight or obese subjects.

**Association of Visceral Fatness and VO\textsubscript{2max}**:

Davison K et al. (2010)\textsuperscript{127} stated that obesity and cardiorespiratory fitness helps to predict mortality. Increased level of fat especially visceral fat is related to diminished function of endothelium. Endothelial functions show the ability to form and release nitric oxide. Decreased production of nitric oxide is linked with elevated inflammation, thrombosis, impaired vascular permeability and decreased vasodilatation which are related to cardio-vascular risk factors.

Patkar KU et al. (2011)\textsuperscript{128} conducted study to look at cardiorespiratory efficiency via VO\textsubscript{2max} in 30 obese and 30 non-obese individuals of 18 to 20 years of age which was assessed by Queen’s College Step Test. They found that VO\textsubscript{2max} per kg body weight was reduced in obese subjects in comparison to non-obese individuals. So, exercise
programs should be emphasized to elevate energy expenditure and reduce body fat instead of enhancing aerobic fitness.

**Chatterjee S et al. (2005)**\(^{129}\) stated that \(\text{VO}_{2\text{max}}\) is the instrument to measure functional capability of cardiorespiratory system and the most reliable tool of maximal exercise capacity. They conducted study to see \(\text{VO}_{2\text{max}}\) in 49 obese boys residing in West Bengal, India of 10-16 years. \(\text{VO}_{2\text{max}}\) is significantly affected by body mass, but higher level of fat mass causes extra burden on function of heart and oxygen consumption. This suggests decreased utilization of oxygen by fat tissue, thus decreased \(\text{VO}_{2\text{max}}\) with exercise. Loss of fat during weight reduction program is associated with relative improvement in \(\text{VO}_{2\text{max}}\) in overweight and obese.

**Berndtsson G et al. (2007)**\(^{130}\) performed submaximal Bicycle Ergometry test on 219 obese children (102 boys and 117 girls) and concluded that obese adolescents had comparatively lower \(\text{VO}_{2\text{max}}\), thus involve less in physical activity.

**Norman AC et al. (2005)**\(^{131}\) concluded that both normal and overweight adolescents had same level of \(\text{VO}_{2\text{max}}\) but reduced exercise tolerance in healthy subjects is due to elevated metabolic demands in response to greater loads rather than decline in cardiorespiratory fitness. Further, **Dhara S et al. (2015)**\(^{132}\) conducted study to find association between BMI and \(\text{VO}_{2\text{max}}\) in physical education students. They found that there was negative correlation between BMI and \(\text{VO}_{2\text{max}}\).

**Schembre SM et al. (2011)**\(^{133}\) stated that cardio respiratory fitness (CRF) is inversely linked with risk of obesity, non-insulin dependent DM, osteoarthritis, CVD, colon cancer and osteoporosis.
Shah H et al. (2016)\textsuperscript{63} revealed that there were significant elevated levels of VO$_{2_{\text{max}}}$ in normal subjects compared to overweight adults. The overweight person cannot handle exercise load because of high level of fat. The oxygen supply to muscles is diminished due to high levels of fat in overweight subjects with higher muscle mass.

Esmaeilzadeh S et al. (2011)\textsuperscript{64} depicted that aerobic capacity reduces progressively with the rise in body fat mass. It was also found that aerobic training is more effective than other training like resistance training and can be used as preventive tool for subjects at risk to develop CVD because of obesity or hypertension.

Kurl S et al. (2001)\textsuperscript{134} found that elevation in SBP during exercise testing and maximum SBP at two minutes’ post exercise were significantly linked with risk of stroke. So, exercise SBP testing can be used as an additional measure to predict risk of future hypertension. However, Fixler DE et al. (1985)\textsuperscript{135} conducted dynamic and isometric exercise stress test on 131 adolescents to look at the blood pressure levels response. They found that the heart rate and BP during exercise testing did not significantly help in predicting SBP and DBP in future.

Recently, VO$_{2_{\text{max}}}$ is measured by standard tests, which surrogates’ upper limit of tolerance of aerobic exercise via maximal exercise testing. But, VO$_{2_{\text{max}}}$ measurement by exercise testing needs proper assessment, is tedious and not feasible to use in large epidemiological or clinical studies.
Cardiovascular Parameters During Recovery Period:

Lira MJ et al. (2016)\textsuperscript{69} reported that HRR is linked with function of cardiovascular system. So, HRR can be used as a predictor of cardiorespiratory fitness. HRR after termination of exercise is a function of reactivation of parasympathetic nervous system, usually in 1st 30 seconds.

Sung J et al. (2006)\textsuperscript{70} also said that prolonged HRR post exercise is a function of reactivation of parasympathetic system. Besides, metabolic syndrome is correlated with impaired vagal reactivation along with the over-excitation of sympathetic system.

Nakashima M et al. (2007)\textsuperscript{74} stated that among Japanese men, SBP and DBP measured at 4th minutes after physical exertion were strong predictor for developing hypertension in future.

Dipla K et al. (2012)\textsuperscript{58} stated that blunted capacity of vasodilatation is observed after exercise session in an attempt to recover from isometric exercise in obese boys, which is an early presage of vascular dysfunction.

DIMKPA U et al. (2008)\textsuperscript{136} stated that in normal subjects, systolic blood pressure usually reduces to baseline and reaches back to pre-exercise values within 5-6 minutes. An abnormal response is seen if there is delay in return to pre-exercise values of SBP. The delayed post exercise Systolic Blood Pressure Recovery (SBPR) are linked with elevated risk of stroke, CAD, hypertension and acute myocardial infarction. Also, the decreased SBPR after dynamic exercise are linked with VO\textsubscript{2max}, vascular resistance, sympathetic and parasympathetic nervous system response and baroreflex sensitivity.
McHam SA et al. (1999)\textsuperscript{137} conducted symptom limited treadmill testing in 493 subjects and found that there was association between severe angiographic coronary disease and delayed decrease in raised SBP.

Taylor AJ et al. (1998)\textsuperscript{138} stated that SBP is known to rise 5 to 10 mmHg per MET during treadmill stress test in normal subjects. Normally SBP attains a plateau at peak exercise and persist near this value till about first min of recovery post exercise. After this, SBP reduces to reach pre-exercise levels within 5 minutes. A longer time in reaching SBP to baseline is suggestive of abnormal response. They stated that delayed decrease in HRR can be due to decrease in vagal tone and increase in SBP due to elevation in sympathetic excitations in overweight and obese subjects, which are responsible for variation in blood pressure response during exercise testing.