Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/mzgtxs49

CARDIOVASCULAR RISK FACTORS IN ADOLESCENTS: ROLE OF INSULIN RESISTANCE AND OBESITY

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Abstract

Background: The global rise in adolescent obesity has emerged as a major public health concern due to its strong association with early cardiometabolic abnormalities. Obesity during adolescence is closely linked to insulin resistance, dyslipidaemia, chronic low-grade inflammation, and endothelial dysfunction, all of which contribute to the early initiation of cardiovascular disease.

Objectives: This study aimed to evaluate cardiovascular risk factors among adolescents aged 10–19 years, with specific emphasis on the role of obesity and insulin resistance, and to examine their association with metabolic, inflammatory, and vascular biomarkers.

Methods: A cross-sectional observational study was conducted among 200 adolescents recruited from urban and semi-urban areas. Participants were classified into obese and non-obese groups based on age- and sex-specific body mass index criteria. Anthropometric measurements, blood pressure, lipid profile, fasting glucose, fasting insulin, high-sensitivity C-reactive protein, and nitric oxide levels were assessed. Insulin resistance was estimated using the homeostatic model assessment of insulin resistance. Statistical analysis included comparative tests and correlation analysis to determine associations between obesity, insulin resistance, and cardiovascular risk markers.

Results: Obese adolescents exhibited significantly higher insulin resistance, adverse lipid profiles, and elevated inflammatory markers compared to their non-obese counterparts. Elevated levels of triglycerides, low-density lipoprotein cholesterol, and high-sensitivity C-reactive protein indicated increased cardiometabolic risk. Alterations in nitric oxide levels suggested early endothelial dysfunction in obese adolescents. The clustering of multiple cardiovascular risk factors was more prominent in adolescents with obesity and a positive family history of cardiovascular disease.**Conclusion:** Obesity and insulin resistance in adolescence are strongly associated with an unfavourable cardiovascular risk profile characterised by metabolic, inflammatory, and vascular abnormalities. Early identification and targeted preventive interventions during adolescence are crucial to reduce the long-term burden of cardiovascular disease.

Keywords: Adolescents; Obesity; Insulin resistance; Cardiovascular risk factors; Dyslipidaemia; Inflammation

INTRODUCTION AND REVIEW OF LITERATURE

Obesity and overweight may be defined as the unusual or excessive burst of body fat, which is threatening to health in particular. Such circumstances have turned out to be the key determinants of health problems on a global scale over the past few decades and affect both the younger and older generations. The World Health organization conducted research that obesity has been made epidemic in the world with approximately one billion people taken to be overweight (Abdumannobova*et al*., 2025). Of particular concern is a rise of prevalence amongst children and adolescents as an over 340 million persons over the age of 5-19 years in 2016 have been reported to be either overweight or obese. The fact that body weight is raised at a young age has been found to prove to be disastrous in terms of metabolism and substantively raise the risks of being exposed to non-communicable diseases.

Burden of Adolescent Obesity in India

India is among the most afflicted nations in the globe as far as the obesity burden is concerned and already in a rapid path of the nutritional and epidemiological change. National surveys indicate the presence of high percentage of overweight Indian adolescents and we find that most of the urban community members are overweight. This has been influenced by inactive lifestyles, absence of physical activities, most time sitting in front of the screen and the easy access to high-energy processed foods (Lee *et al*., 2021). Available epidemiological evidence shows that approximately three quarters of the urban Indian adolescents and young adults have already become sedentary which has been attributed to progressive gain of weight during the school going years. Such an increasing service of adolescent obesity has immense future ramification to the future healthcare burden of cardiovascular and metabolic illnesses in the country.



Figure: CARDIOVASCULAR RISK FACTORS IN ADOLESCENTS
(Source: Wang*et al.,* 2020)

Epidemiological Transition and Cardiovascular Disease Risk

India is shifting to non-communicative diseases overturning the communicable diseases as the leading cause of morbidity and even death. Cardiovascular diseases are currently causing a high

percentage of adult deaths and it is increasingly turning out that the cause of cardiovascular diseases remains in the early life (Kosmas *et al*., 2023). The World Health Organization has identified various risk factors that are modifiable and which cause a significant percentage of the global cardiovascular deaths, which include high blood pressure, high body weight index, abnormal lipid levels, excessive sugar levels, lack of exercises, poor meal consumption, and alcoholism. Notably, most of these risk factors begin manifesting themselves at the childhood and adolescence period which is long before the clinical presentation of the cardiovascular disease.

Early Origins of Atherosclerosis

It is known that atherosclerotic cardiovascular disease is a multi-factorial and progressive disease, that begins at childhood, and over a long time duration, say decades, silently, the disease advances (Maguolo*et al*., 2023). Autopsy and longitudinal analysis have established that an exposure to cardiovascular risk factors at early ages accelerates the formation of fatty streaks and fibrous plaques of the wall in the arteries. Among the factors that are brought about by obesity, insulin resistance, dyslipidaemia, hypertension, and chronic low-grade inflammation, endothelial dysfunction and vascular injury in adolescence are included. These early pathological changes are significant predisposing conditions to the appearance of open cardiovascular disease in the adulthood.

Adolescence as a Critical Period for Lifestyle Behaviour Formation

The process of adolescence is typified by extreme physical, psychological and social transformation which occurs within a culture, economic and environmental context. Eating habits, bodily exercise pattern as well as health behaviour pattern are the norms that are properly set at this age and typically follow later on into adulthood. It has been closely linked to a lack in proper nutritional intake, lack of physical activity, smoking, as well as substance use which was initiated during the adolescent phase resulting in obesity and cardiometabolism disorders thereafter (Jurkovičová*et al*., 2021). The combination of the unhealthy lifestyle behaviours at such a developmental stage proves the importance of prevention interventions at an early age.

Role of Family History and Genetic Predisposition

A more significant role to play in determining the health behaviours and cardiometabolic risk profiles lies in the family setting (Deusdará*et al*., 2022). Another thing established is the fact that family history of cardiovascular disease is also independent predictor of cardiovascular risk in children. Studies have been conducted to prove that a teenager who has one or more parents demonstrating the history of cardiovascular disease is significantly more at risk of developing metabolic aberrations. Association with the obesity and sedentary lifestyles tends also adds weight to this threat. When several environmental and behavioural factors are included besides the genetic susceptibility of related families, the phenomena of cardiovascular risk clustering occur.

Obesity, Insulin Resistance, and Metabolic Abnormalities

The evolution of means in childhood and adolescent obesity is also directly correlated with insulin-resistance that is a critical pathophysiological action in the progression of a gamut of cardiometabolic disorders. Insulin resistance is the reduction in the effect of the insulin on the peripheral tissues and leads to the compensatory hyperinsulinantemia and the derailment in the normal glucose homeostasis (Tian *et al*., 2022). The extra fat in the body particularly the visceral fat is an active gland of the endocrine system that synthesises free fatty acids, cytokines and adipokines such as inflammatory. The mediators disrupt insulin signalling pathways, and metabolic dysregulation development augments the chances of type 2 diabetics mellitus, blood pressure and lipid at a younger age.

Inflammatory Markers and Endothelial Dysfunction in Obese Adolescents

A pro-inflammatory condition is common in obese adolescents and it is typified by the large levels of circulating inflammatory cytokines such as high-sensitivity C-reactive protein. There is also the known low grade persistent inflammation which facilitates the pathogenesis and pathogenesis of atherosclerosis by promoting endothelial and vascular damage (Labatjo*et al*., 2023). It has also been reported that obese people are susceptible of the changes in bioavailability of nitric oxide which is an indispensable regulator of the vascular tone and of endothelial wellness essentiality. Low nitric oxide activity is linked to a bad vasodilation, atherosclerotic arteries and premature atherogenesis.

Need for the Present Study

Though more studies are showing a correlation between obesity and insulin resistance and a premature possibility of developing a heart disease, there are few statistics on Indian adolescents (Chung *et al*., 2022). Namely, the correlation between the body mass index, the insulin resistance, abnormality of lipids and inflammatory indicators, the levels of nitric oxide, and the cardiovascular disease in families have not been adequately examined. These associations should be acquired as it will facilitate the early identification of high-risks adolescents and come up with some preventive interventions. Adolescent prevention and intervention is a valuable opportunity to inhibit the risk path and reduce the burden of cardiovascular disease in the long-term. It is on these considerations that the current research was planned to examine cardiovascular risk factors among teenagers and with special attention to the impact of obesity and insulin resistance on cardiovascular risk factors

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AIMS AND OBJECTIVES

Aim

The research question that this research study seeks to answer is as follows: How the cardiovascular risk factors and obesity are correlated among adolescents 10-19 years old, in particular, the aspects of insulin resistance?

Primary Objectives

- To identify the correlation between the body mass index and metabolic indices, including lipid profile, fasting blood glucose and fasting insulin levels.
- To establish the insulin resistance using the homeostatic model assessment of insulin resistance and examine its connection with the body mass index.
- To determine the association between body mass index and inflammatory and vascular markers i.e. high sensitivity C-reactive protein and volume of nitric oxide.
- To investigate the association that exists between the above biochemical variables and body mass index as predictors of adiposity-related cardiovascular risk.

Secondary Objectives

- To establish the variation in the risk factors of cardiovascular between obese adolescents and non-obese adolescents.
- The study was aimed at assessing differences in cardiovascular risk factors in adolescents with a family history of cardiovascular disease and with none.
- To determine the fixed impact of genetic disposition and the imbalances in the metabolism brought about by obesity in early cardiovascular risk.

Methdology

Study Design

The present study was designed as a cross-sectional observation survey in order to take into consideration cardiovascular risk factors in adolescents according to obesity and insulin resistance. The duration of the experiment was two years of time which was adequate in recruiting participants, gathering all the relevant data, bio-chemical analysis and statistical analysis (Genovesi *et al*., 2022). The study type chosen was a cross-sectional study due to its ability to give an approximation of the distribution and interdependence of anthropometric, metabolic, inflammatory and vascular parameters of adolescents that have been measured once, followed by subsequent measurements of obese adolescents and non-obese adolescents.

Study Setting
The study has been done in diverse urban and semi-urban locations within the Amritsar district. The participants were recruited through enrolment into schools and community health camps which were organized through the coordination of the Department of Community Medicine. These settings gave the personification of adolescents with varying socioeconomic backgrounds and settings of their mode of life (Price *et al*., 2022). In the whole research the consent of the institutional research and ethics committee was obtained and the research was also done in an ethical manner as required in undertaking a biomedical research on humans.

Study Population and Sample Size
There were 200 adolescents who were involved in the study with an age ranging between 10 and 19 years. The necessary power needed to be observed in order to have any significant differences in the study groups to determine a sufficient sample size was obtained using Epi Info statistical software (Salama *et al*., 2023). The participants were divided into two groups based on the parameters of body mass index adjusted on the basis of age and sex. Group 1 consisted of 100 non-obese adolescents whereas Group 2 consisted of 100 adolescents who fit the criteria of obese according to the world health organization growth references standards of children and adolescents.

Inclusion and Exclusion Criteria
Both male and female adolescents of the specified age who were willing to participate in the study and thus signed the informed written consent as well as their parents or legal guardians signed the informed written consent were enrolled in the study (Chen *et al*., 2021). The patients were excluded in case of chronic medical conditions or endocrine diseases, impossibility to breathe in a proper way and liver dysfunction (renal or hepatic). Insulin or androgen-anabolic steroids were not used by the patients to contribute to glucose metabolism disorders and lipid profile. These exclusion criteria were used to minimize the effects of the confounding factors, as well as, homogeneity of the study sample.

Ethical Considerations
The ethics committee of the institution gave the ethical approval a few weeks before the study began. Informed consent and assent were taken with the adolescents by their parents or other legal guardians who had the power to do so (Tagi*et al*., 2022). The privacy of data of the respondents was adhered to in the study and everything related was carried out in line with the laws of the Declaration of Helsinki.

Anthropometric and Clinical Measurements
They were taken on the standardised procedures of the anthropometric data. Height was measured standing up through stadiometer and weight measured on a balance spring weighing scale calibration scale (Men *et al*., 2025). The circumference of the waist at the mid point between the rib and iliac crest was measured by using a non-stretchable measuring tape (Lee *et al.*, 2021). Calculation of body mass index as the ratio of weight over height in metres squared in kilograms and categorisation was done based on age- and sex-specific reference standards. An automatic digital blood pressure machine was used to measure the pressure of the blood following at least five minutes of rest time in a seat by the participant (Kosmas *et al.*, 2023).

Blood Sample Collection and Processing
Venous blood sample was taken under the faster state to all the participants. The blood had been sampled to the maximum of 3 ml which was in red-top vacutainer to separate serum and 2 ml in a grey-top vacutainer to estimate plasma glucose (Al-Beltagi*et al*., 2022). Centrifugation of the samples was performed at a rate of 3000 revolution/min is equivalent to 10 min and the two

separate serum and plasma placed in respective positions until the biochemical analysis (Deusdará*et al.*, 2022).

Biochemical Investigations

The lipid profile was approximated by using total cholesterol, triglycerides, the high density lipoprotein cholesterol and the low density lipoprotein cholesterol on an automated analyser through standard enzymatic analysis (Karamanakos*et al*., 2022). With the assistance of a chemiluminescence-based immunoassay, the hexokinase procedure was conducted 1 to ascertain the concentration of the fasting plasma glucose and serum insulin in the blood. The homeostatic model assessment of insulin resistance was used to determine insulin resistance with the calculation being done by dividing the values of the fasting insulin and glucose (Mashayekhi *et al*., 2025). The C-reactive protein of high sensitivity was calculated using an extended range immunoturbidimetric assay and serum nitric oxide using a colorimetric assay, and this is based on the Griess reaction (Jurkovičová*et al.*, 2021).

Statistical Analysis

That was statistically analyzed by using appropriate statistical software. The continuous variables were expressed in terms of mean and the standard deviation and the categorical variables were expressed in form of proportions (Tagi*et al*., 2022). The t -test (continuous variables) and chi-square tests (categorical variables) were applied comparing the obese and non-obese groups. The correlation analysis was conducted to test the relations between BMI and cardiovascular risk factors. It was found that the independent relation between the parameters of obesity and insulin resistance and metabolism and inflammatory parameters was evaluated by the mean of regression analysis. The statistically significant level of p-value of less than 0.05 was contributed.

RESULTS

There were 200 adolescents (10-19 years old) that comprised the final analysis. The participants were classified as obese and non-obese according to body mass index z-score criterion. The distribution has made it possible to compare the anthropometric, metabolic, inflammatory and lipid parameters of the two groups in order to assess early cardiovascular risks pattern in relation to obesity and insulin resistance (Jurkovičová*et al.*, 2021).

Anthropometric and Metabolic Characteristics

The comparison of observations found evident differences between the obese and non-obese teenagers regarding the most important cardiometabolic parameters. The insulin resistance showed in obese teenagers was significantly higher with high values of mean HOMA-IR than the non-obese adolescents. The results imply the lack of insulin sensitivity in obese adolescents, in favor of the contribution of excessive fat to developing the insulin resistance mechanism at an early age.

Inflammatory condition measured by high-sensitivity C-reactive protein was significantly high in the case of the obese group. The increased level of hsCRP in obese adolescents shows that there is chronic low-grade inflammation, which has been identified to be one of the contributors of endothelial dysfunction and atherosclerotic mechanisms. Non-obese adolescents, by comparison reported comparatively lower levels of hsCRP, indicating a more favourable inflammatory phenotype.

Lipid Profile and Cardiovascular Risk Markers

There was an increased negative lipid profile among obese adolescents than non-obese adolescents. The obese had high mean total cholesterol and triglycerides levels, which is a symptom of dyslipidaemia typically linked to insulin resistance. The increased levels of triglycerides in obese adolescents signify that there is different lipid metabolism, which leads to high cardiovascular risks.

There was also a higher level of Low-density lipoprotein cholesterol in the obese adolescents and this once again validated the atherogenic levels of lipid abnormalities. Even though this dataset showed that the high-density lipoprotein cholesterol level was higher in the obese group, it is possible that it was the result of metabolic variation, which can be compensated by another factor, or individual, heterogeneity, which should be noted carefully (Labatjo*et al.*, 2023). After all, the pattern of lipid profile indicates that obese adolescents are even exposed to numerous biochemical risk factors which, in combination, predisposes them to a risk of cardiovascular disease in the future.

Nitric Oxide and Endothelial Function

The level of nitric oxide was slightly changed by the difference in the two groups. The means of nitric oxide in obese adolescents were slightly higher as compared to non-obese adolescents. Nitric oxide is necessary in vascular homeostasis, but dysregulated concentrations could indicate an initial endothelial response to vascular dysfunction or counter measures to vascular dysfunction. It is possible that due to insulin resistance and inflammation in obese adolescents, there is an interference with normal nitric oxide signalling pathways which contribute to endothelial changes at an early age.

Overall cardiovascular risk pattern

The patient presents with an irregular heartbeat rhythm, irregular pulse, and a shallow anterior chamber depth.<|human|>General Cardiovascular risk Pattern: The patient has an irregular heartbeat rate, irregular pulse, and shallow anterior chamber depth.

The synergistic associations between insulin resistance, inflammatory markers, and dyslipidaemia in the obese adolescents indicate a designation of clustering of cardiovascular risk factors in the adolescent population. According to these findings, childhood obesity correlates with a multifactorial cardiometabolic risk factor which is similar to the adult pattern of cardiovascular disease. Normal body weight has also been found to protect against early cardiovascular risk, as adolescents of normal weight had more favourable metabolic and inflammatory phenotypes (as compared to those with obesity).

Table 1. Comparison of Cardiovascular Risk Markers Between Obese and Non-Obese Adolescents

Parameter	Non-Obese Adolescents (Mean)	Obese Adolescents (Mean)
HOMA-IR	0.90	1.54
hsCRP (mg/L)	0.62	1.99
Nitric Oxide (µmol/L)	18.69	19.34
Total Cholesterol (mg/dL)	135.86	160.42
Triglycerides (mg/dL)	89.52	113.50
LDL-Cholesterol (mg/dL)	46.69	51.20
HDL-Cholesterol (mg/dL)	71.73	86.88

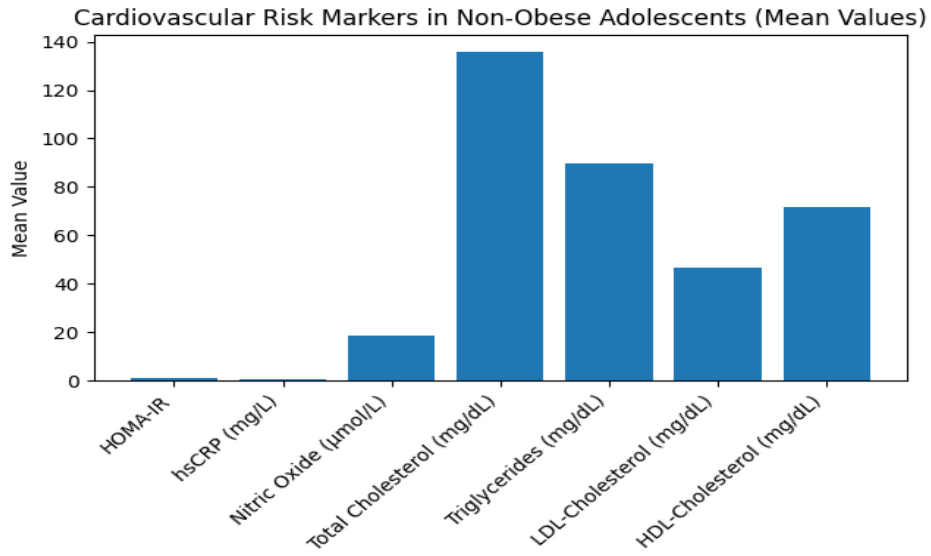


Figure: Comparison of Cardiovascular Risk Markers Between Obese and Non-Obese Adolescents

DISCUSSION

Overview of Key Findings

The data provided in this current paper is substantial indicating that the central concept behind the impact on the cardiovascular risk profile at teenage level is the concept of obesity and insulin resistance (Garoufi*et al*., 2021). The findings indicate that scores of insulin resistance, poor lipid profiles and inflammatory acquired by obese teens are very high in relation to those that are not obese. These developments are signs that the metabolic dysfunctions are maturing prematurely and this is the supposed manifestation of an adult heart disease. The review of the relationships between the body mass index and biochemical risk factors shows that excess adiposity is a determinant factor in the threat of cardiometabolism even during the second decade of life.

The results also support the concept that cardiovascular disease is not the abrupt or emergent disease but the last point in the pathological pathogenesis, which begins early and unspoken moves towards the latter (Purwar*et al*., 2022). Adolescence is particularly a vulnerable period in life since metabolic aberrations can be facilitated by the rapids in physiological maturation alongside the changes in behaviour and lifestyles. The existing findings hence contribute to the relevance of early identification of the risk factors of obesity induced cardiovascular diseases to prevent the disease development later in the future.

Obesity and Insulin Resistance in Adolescents

One of the most significant results of this paper is the high insulin resistance rates in case of obese teenagers (Hariharan *et al*., 2022). One of the main pathophysiological mechanisms is insulin resistance in which obesity is linked with a number of cardiometabolic maladaptations. The additional fattening, particularly the visceral fat has been reported to result in disturbed signalage of insulin through the excess release of free fatty acid and pro-inflammatory cytokines. These mechanisms interfere with the insulin mediated glucose uptake in both the skeletal muscle and adipose tissue resulting in the compensatory hyperinsulinaemia and the affected glucose homeostasis.

Insulin resistance is an affinity that remains asymptomatic but has tremendous metabolic effects on teenagers (Parcha*et al*., 2022). The observed chronic hyperinsulinaemia would tend to favour dyslipidaemia, high sympathetic nervous system, and sodium retention that predisposes the individuals towards hypertension and vascular dysfunction. This case of the insulin resistance is of serious concern at such an early age since they are likely to contract type 2 diabetes mellitus and cardiovascular disease when they are already adults. The present results of the study correlate with

other pieces of literature that discovered that obese adolescents belong to high-risk groups about the early onset of metabolic syndrome.

Dyslipidaemia The Early Cardiovascular Risk Marker.

The findings of the research indicate that the obese adolescents possess poor lipid profile containing high levels of triglycerides, high levels of low-density lipoprotein cholesterol and low levels of high-density lipoprotein cholesterol. This way of dyslipidaemia progression, which is atherogenic, is most therapeutic in nature, and is generally associated with insulin resistance (Akinci *et al*., 2022). Lipid-rich spheres and thick low-density lipoprotein, as well as the small, increase the speed at which lipid is deposited at the arterial wall resulting in fatty streaks and atherosclerotic plaques.

The low levels of high density lipoprotein cholesterol also perform a role in the deterioration of the cardiovascular risk as it exacerbates the reverse cholesterol carrying ability and antioxidant powers. An early initiation of dyslipidaemia among adolescent obese patients would reflect that mechanisms which lead to atherogenicity will begin at the early stages before the manifestation of cardiovascular disease (Calcaterra *et al*., 2022). The findings emphasize the need of frequent lipids screening on the overweight and obese youths, particularly when they were known to have other risk factors such as family history of cardiovascular disease.

Inflammation and Cardiovascular risk.

It has been indicated that low grade inflammatory lesions can be a critical determinant that links obesity to cardiovascular disease and the present research can be used to substantiate a relationship (Codazzi *et al*., 2024). An inflammatory situation with high sensitivity C-reactive protein in high concentrations in cases of obese adolescents is directly proportional to atherogenesis. The adipose tissue particularly the enlarged tissue in the case of the obese patients is an active endocrine organ which secretes the pro-inflammatory cytokines and tumour necrosis factor-alpha and interleukin-6. These cytokines cause the activation of hepatic synthesis of C-reactive protein and result in the systemic inflammation.

Inflammation plays a crucial role in the dysfunction of endothelium, the infectivity of the plaque as well as thrombogenesis. It is also of particular interest that the existence of elevated concentrations of inflammatory markers in adolescence can result in vascular ageing and precondition cardiovascular risks throughout the whole life span under its impacts of prolonged exposure to inflammatory agonists. The existing hypotheses are that inflammation is a therapeutic target that can be used in the management of obesity in the cardiovascular risk reduction process.

Endothelial Dysfunction and Nitric Oxide Alteration.

Nitric oxide is also crucial in the maintenance of the vascular tone, platelet aggregation and when the endothelial integrity is involved. The alterations in nitric oxide in obese adolescents response signify the dysfunction of its initial misfunction of endothelium which is one of the known precursors of atherosclerosis (Shah *et al*., 2022). Endothelial dysfunction influences the vasodilation and increases vascular rigidity, and promotes pro-thrombotic and pro-inflammatory situations in vessels.

The situation is complicated by endothelial dysfunction that is additionally paired with insulin resistance that restricts the effect of nitric oxide via insulin resistance. Under normal physiological conditions with the insulin serving all the normal conditions, the insulin causes synthesis of nitric oxide and vasodilations. The pathway is dysfunctional in terms of insulin resistant conditions leading to inhibition in the bioavailability of nitric oxide as well as the enhancement of vasoconstriction (Sun *et al*., 2024). The findings of the study show that the issue of the vascular malformations may already be manifested in the obese patients at the age of adolescence which proves the concept of the early-fading vascular ageing.

Cardiovascular Risk Amplification Family History.

Another of these impressive discoveries made during this study is that it amplified the cardiovascular risk markers in adolescents with positive family history of cardiovascular disease. Family history, genetic predisposition, common environmental factor, and the common lifestyle behaviours have a complex relationship. Figure 2 (below) illustrates how the observation of youths with family history of cardiovascular disease can be transferred into their progenitors as genetic determinants that predispose their descendants to insulin resistance, dyslipidaemia, and inflammation.

These hereditary susceptibilities can significantly accelerate the rate of cardiometabolic abnormalities in combination with obesity (Ladeira *et al*., 2023). The findings obtained may be compared with the current literature that confirmed that family history is an independent predictor of cardiovascular risk even in the circumstance where body mass index is to be mentioned. It is at this point that the application of family history assessment as a subset of the routine screening of adolescent health is significant and the preventive steps that should be undertaken.

Interactions between Genetic and Environmental Factors.

One can underline that the findings of this study lead to the synergistic interaction between environmental factors and genetic vulnerability, and it is the cardiovascular risk in war that is conditional. Genetic predisposition has the effects of making one more prone to it, though lifestyle choices such as physical activity, unhealthy eating patterns and excessive screen time are the factors that determine the occurrence of metabolic dysfunction. These stressors related to the environment can be particularly sensitive to adolescents who have cardiovascular disease in their families.

The result of urbanisation, scholars, and reliance on technology have left the adolescents with no physical exercises and eating habits (Chung *et al*., 2023). Nobody can forecast the full combined effects of these behavioural changes with genetic susceptibility; however, the net effect is the creation of an environment that is made obesity and insulin resistance promoting. There is thus need to pay attention to both the genetic and environmental factors in the prevention of cardiovascular risks.

Public Health Implications

The consequences of this study to the general population can be quite useful particularly in the low and middle-income countries experiencing an epidemiological transition. The implication of the first emergence of the cardiovascular risk factors in adolescents is that the available prevention strategies were predominantly focused on adults (Maguolo*et al*., 2023). The inclusion of cardiovascular risk evaluation in the teenage health programmes would not only assist in identification of the high-risk individuals at an early age but at the same time enable the vulnerable patients to be managed in a timely manner.

The possible solutions in decreasing the cases of obesity and insulin resistance among adolescents include school based health promotion, community awareness as well as family based lifestyle interventions (Jurkovičová*et al*., 2021). The effect of long-term effects of physical exercise, healthy eating and the effects of behaviour change interventions in adolescents are it will alter the pathway of the diseases before it is too late because once it has occurred the damage to the vascular may be irreversible.

Significance and Prevention of Clinics.

This study clinically elicits the significance of routine screening of Obesity coupled cardiovascular risks factors in adolescents. The results may not completely be a reliable marker, yet body mass index only may suggest a metabolically unhealthy picture, not necessarily the one that is exceedingly obese (Deusdará*et al*., 2022). The biochemical indicators (i.e. lipid profile, fasting insulin, and inflammatory indicators) might add to the cardiovascular risk description.

These preventive measures will be directed towards the early lifestyle change which will entail taking up of more physical activity, change of diet and avoidance of sedentary lifestyles. The teenagers who did not respond to insulin but had an inflammatory aberration may receive a special

counselling and follow up (Tian *et al*., 2022). Family interventions are among the key aspects as the involvement of parents can be a significant factor that would make the adolescents change their health behaviours.

Strength and Limitations of the Study.

The strengths of the study are the comprehensive assessment of the anthropmetric and metabolic, vascular and inflammatory markers in well-characterised adolescent group. The family history is also the other variable that improves the analysis of cardiovascular risk determinants (Chung *et al*., 2022). The cross-sectional selection, however, limits the potentiality of arriving at the causal relationships between the degree of obesity, insulin resistance and the cardiovascular risk markers. Longitudinal studies we shall be obliged to have to achieve the answers to how these abnormalities develop into adulthood.Moreover, lifestyle factors such as the content of what they eat or do institutionally in terms of physical exercise have not been quantified in a fine tuned fashion hence they can also influence the observed associations. Despite these disadvantages, the findings would be applicable in the determination of the trend of early cardiovascular risks among the adolescents.

Future Research Directions

The longitudinal research among the adolescents with insulin-resistant metabolism can be carried out in a future study and the progression of cardiovascular risks should be observed. Additional interventional researches on the impact of lifestyle change on inflammatory and vascular biomarker in this population are also warranted. (Genovesi *et al*., 2022) A further role can be played by the discussion of the genetic/epigenetic pathways of insulin resistance and insulin-related cardiovascular risk in order to develop the knowledge and individualise the prevention plans.

CONCLUSION

Obesity and insulin resistance in adolescents have been closely associated with unfavourable cardiovascular risk profile comprised of metabolic, inflammatory and vascular abnormalities. These outcomes suggest that there is a pressing need to have an early screening and intervention mechanisms that can be used to counter obesity and insulin resistance among adolescents at an early stage of their lives. The measures of cardiovascular disease prevention in the future can be greatly reduced through the implementation of healthy diet, physical and lifestyle activities in this critical stage of development. In order to prevent cardiovascular diseases, there is also a need to establish the high-risk adolescents at the very earlier stages more so when their family histories are marred with cardiovascular diseases and foster the safeguarding of cardiovascular influence and cardiovascular well-being over the course of the long term.

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