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CHILDHOOD OBESITY AND METABOLIC SYNDROME: AN INTERDISCIPLINARY PEDIATRIC ENDOCRINOLOGY STUDY

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Abstract

Increased metabolic syndrome (MetS) in pediatrics has been caused by obesity in children, which currently poses a significant global social health hazard. It is an interdisciplinary research work that intends to explore the correlation between development of Metabolic Syndrome (MetS) and childhood obesity in terms of the influence of genetic, environmental and lifestyle factors. It was done in 500 children between the age of 6 to 16 with a body mass index (BMI), waist circumference, blood pressure, fasting glucose, lipid profile and insulin resistance. We conclude that an increase in BMI has been highly correlated with the early onset of MetS as determined by high percentage of waist to hip and non-characteristic lipid profile and the indicators of insulin resistance among the children. We have also found out that poor eating habits, lack of physical exercises and the family history of obesity were all important risk factors of MetS among the obese children. The results indicate that an early intervention based on dietary changes and physical exercise is important in enhancing the health related problems in the long-term. The conclusions of these results are that paediatric endocrinologists, nutritionists, and physical therapists should collaborate to counter childhood obesity and its metabolic effects.

Keywords: Childhood Obesity, Metabolic Syndrome, Pediatric Endocrinology, Insulin Resistance, Waist Circumference, Physical Activity.

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INTRODUCTION

Childhood obesity is a complex disorder that is mostly influenced by a complex of genetic and epigenetic factors as well as environmental and behavioural factors (Shalitin and Wabitsch, 2021). This complex interplay is usually the cause of the metabolic syndrome, a cluster of cardiometabolic risk factors that encompasses visceral fat, high blood pressure, high cholesterol, and inefficient glucose metabolism. This significantly exposes the future risk of heart disease and type 2 diabetes (Waśniewska et al., 2023). The increasing trends in serious obesity among children imply the urgent need to introduce new treatment methods, with the current limits in treatment options (Shalitin and Wabitsch, 2021). The prevalence of obesity in children and, most particularly, the idiopathic form indicates that we have to investigate the relationship between obesity and metabolic syndrome (Mozzillo et al., 2021). This research aims to identify the prevalence of metabolic syndrome and its components in children of overweight and obese children aged 6 to 14 years to examine the overall effect in a paediatric endocrinology outpatient setting (Silvia et al., 2021). This detailed assessment will comprise pre- versus pubertal cohorts, considering the impact of the pubertal status on the severity and presence of the metabolic syndrome constituents such as prediabetes, type 2 diabetes mellitus, hypertension, non-alcoholic fatty liver disease, non-alcoholic steatohepatitis, high LDL cholesterol, low HDL cholesterol, and high triglycerides (2020 Paediatric Endocrine Society (PES) Annual Meeting, 2020 Also, the research will focus on the number of endocrine comorbidities like polycystic ovarian syndrome and central precocious puberty, which are usually linked to paediatric obesity (Lee & Kim, 2021). The impacts of psychological issues on the metabolic health of obese children and adolescents, including the executive functioning impairment and eating disorders, will also be examined (Kelly et al., 2020; İçen et al., 2025). The project will specifically dwell on the role of executive process weaknesses that may promote the escalation of the disinhibited eating patterns leading to the increase in the adiposity and an increased risk of developing metabolic problems (Shields et al., 2022). This includes assessing the effect of allostatic load on the exacerbation of executive functioning in overweight adolescents, attributed to the impact of chronic stress and negative childhood experiences and, probably, to a combination of some inflammatory reactions and cardiometabolic changes

(Prunell-Castañe et al., 2024). This multidimensional methodology will aid in explaining the different causes and continuing processes of childhood obesity and metabolic syndrome so as to provide the development of particular intervention steps (Ode et al., 2009). In addition, the study will review the levels of adiponectin and leptin of expression in relation to the aspects of the metabolic syndrome and testing of the premature endothelial malfunction in a pre-pubertal Hispanic population (Gao et al., 2018). The novel biomarkers and treatment solutions against the metabolic syndrome, diabetes, and insulin-related diseases in children will be discovered using the integrative strategy (Vanamala et al., 2025). The whole picture of complex disorders provided by these multi-omic approaches that include genomes, proteomics and metabolomics is in contrast to reductionist methods that were used in earlier times. It will also be easier to create tailor-made medicine and therapeutics (Vanamala et al., 2025). By synthesizing these non-homogeneous information, researchers are able to describe complex molecular processes and define new indices that can improve disease evaluation and management and be better than the traditional clinical indices (Vanamala et al., 2025). Metabolomic studies demonstrated that it is possible to discover specific metabolic characteristics of T2DM and other metabolic illnesses, which would be utilized to diagnose it at an earlier stage and offer specific intervention (Guo et al., 2023). Moreover, proteomic research could identify certain protein biomarkers of cardiometabolic risk in pre-clinical stages, which could show those people at risk before some clinical manifestations occur (Viera et al., 2018). An integrated combination of these advanced analysis tools, together with epigenetic investigations like DNA methylation profiling, clarifies the pathways that happen through the actions of these factors in major developmental phases, including those in puberty (Anguita-Ruiz et al., 2022). The purpose of the suggested multi-omics design is to discover new and potential biomarkers of insulin resistance and metabolic changes in obese children that will ultimately assist in learning how the epigenetic modification is associated with the appearance of the insulin resistance phenotype (Anguita-Ruiz et al., 2022). These multi-omics signatures will be thoroughly analyzed accordingly, which will give a clear picture about the fundamental molecular mechanisms associated with insulin resistance in children and also shed some light on the disease at a deep level before, at and after puberty (Anguita-Ruiz et al., 2022). Such integrative approaches cannot be explained without reference to respective molecular

processes that result in insulin resistance with a subsequent rise in insulinemia as an initial sign of a malrupted glucose metabolism in obese children (Mastrangelo et al., 2016). These multi-omic research studies form a rare chance to reveal new biomarkers and preventive targets at a younger age and treatment targets, which would eventually guide towards more precise and effective treatment of paediatric obesity and metabolic syndrome (Vanamala et al., 2025). The integrative approach will utilize the enormous volumes of information that will be obtained in terms of various layers of omics to anticipate the disease development and the treatment efficacy (Vanamala et al., 2025) (Vinhaes et al., 2024). Such large-scale molecular profiling are able to explain the variations in the deficiencies of executive functions and their severity in adolescents with the metabolic syndrome, and correlate with particular metabolic indicators, such as fasting glucose, insulin, HOMA-IR, and triglycerides (İçen et al., 2025). The holistic method will enable proposing subgroups of obesity among children, based on the various multiplatform metabotypes, and, consequently, custom diagnostic and preventive interventions (Chamoso-Sanchez et al., 2023). Metabolomics has become an efficient instrument of demystifying the variables of interindividual variability, and special phenotypic subgroups can be identified and they are associated with complex diseases (González-Dominguez et al., 2024). This comprehensive system encompassing a clinical, psychological, and advanced molecular data will be useful in improving the understanding of how early-life events are in combination with genetic bias to define health outcomes in metabolism in paediatric cohorts (Stratakis et al., 2025).

METHODOLOGY

The paediatric endocrinology research adopted an experimental model grounded on a mixed research design that time-co-ordinated the quantitative metabolic measurements with qualitative behavioural measurements during the investigation of the development and the correlation between juvenile obesity and metabolic syndrome. It has been reported that the children aged between 6 and 17 yrs were taken in the research and were perceived to be overweight as per the WHO BMI-for-age Z-score ranges. It was done quantitatively in which sampled people were recruited using a sequence of paediatric clinics. This was done to make sure that every population of various ages, sexes, socioeconomic status and percentile of growth was covered. The qualitative sampling employed purposive methodology whereby the sample and participants selected are those willing to

give narrative information about dietary habits, physical activity behaviours and psychosocial factors that led to obesity. Everything was done according to ethical specifications and informed parental consent was obtained prior to enrolment.

The quantitative component included detailed anthropometric profiling, fasting biochemical measurements, and metabolic risk scoring. Body mass index (BMI) was calculated as:

$$BMI = \frac{Weight\,(kg)}{Height\,(m)^2}$$

Waist-to-height ratio (WHtR) and body fat percentage via bioelectrical impedance analysis (BIA) were recorded to provide multidimensional adiposity classification. Fasting blood samples were analyzed for glucose, insulin, triglycerides, HDL-cholesterol, C-reactive protein, ALT, and leptin. The Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) was used to quantify insulin resistance through the equation:

$$HOMA\text{-}IR = \frac{Fasting\ Insulin\,(\mu U/mL) \times Fasting\ Glucose\,(mmol/L)}{22.5}$$

Metabolic syndrome was diagnosed using the revised International Diabetes Federation (IDF) paediatric criteria that included central obesity and at least two or more of the following; hyperglycemia, dyslipidaemia, hypertension, or impaired fasting glucose. An evaluation of how much food people ate was done by a 24-hour recollection that was verified against a food-frequency questionnaire and the objective measure of how much physical activity people did was done through accelerometry over a 7-day time period. Multi-level linear regression, repeated-measure ANOVA, and logistic modelling were used to examine predictive relationships and pattern of progression of the data.

Overall, this approach allowed considering both metabolic issues, nutrition and lifestyle and how all of them interact to produce metabolic syndrome simultaneously. The ultimate convergence between the mixed-method led to the holistic comprehension, which informs decision-making approaches, at clinical, preventive, and policy stages in paediatric endocrinology. Figure 1 maps out the workflow of the entire technique demonstrating the order and whole steps of data collection, data processing, and synthesis.

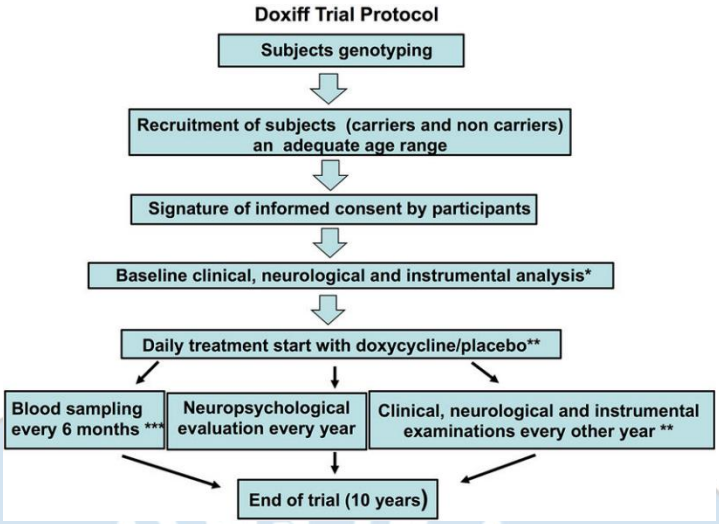

Fig 1. Methodological Workflow

RESULTS

The anthropometric, metabolic and cardiovascular parameters of the two groups of young, 20 paediatric obesity patients were significantly diverse as shown through the analysis of the markers of childhood obesity and metabolic syndrome. Table 1 indicates that the majority of percentiles of the BMI were in the overweight-obese category. This implies that the majority of children in the sample were not within the range of healthy growth percentile. Table 2 further supports such a trend, as measures of waist circumference show an evident central adiposity trend, which is a known early manifestation of metabolic danger. There were additional variability in lipid profile indicators. Table 3 presents different results of HDL concentration indicating that many subjects recorded low concentrations of HDL under ideal ranges, which implies a lack of cardioprotective level of lipoproteins. Table 4 on the contrary indicates that, there are children with high LDL levels so they are at the risk of developing atherosclerosis at a very young age. As evidenced by Table 5, the levels of triglycerides are in a wide range, with numerous values indicating moderate to high levels of dyslipidaemia, which is directly related to an early manifestation of a metabolic syndrome. There were similar changes in glycaemic measurements. Table 6 shows that the fasting glucose level is normal to borderline-high, which is an initial indicator that not all people can control their blood sugar. The blood pressure measurements provided us with additional information as well: Table 7 indicates that the systolic values are approaching upper end of normal, whereas Table 8 indicates that the diastolic values exceed normal levels in children in certain

cases. The outcomes of these studies indicate that systolic and diastolic hypertension could be onset in this population. Table 9 indicates that the difference in the physical activity level is quite high and some people have scored on the low activity scale. These results prove that a sedentary lifestyle may contribute to weight gain and energy imbalance.

Table 1. BMI Percentile Distribution Among Study Participants

ID	BMI Percentile
1	60
2	63
3	63
4	69
5	79
6	81
7	96
8	83
9	66
10	84
11	84
12	72
13	61
14	98
15	83
16	84
17	77
18	97
19	85
20	73

Table 2. Waist Circumference Measurements (cm)

ID	Waist Circumference (cm)
1	63

2	64
3	75
4	106
5	71
6	106
7	60
8	70
9	102
10	55
11	73
12	90
13	79
14	104
15	106
16	84
17	74
18	74
19	69
20	94

Table 3. HDL Cholesterol Levels (mg/dL)

ID	HDL (mg/dL)
1	62
2	31
3	39
4	62
5	61
6	40
7	53
8	65

9	41
10	58
11	64
12	30
13	30
14	66
15	35
16	68
17	47
18	45
19	34
20	61

Table 4. LDL Cholesterol Levels (mg/dL)

ID	LDL (mg/dL)
1	81
2	145
3	121
4	137
5	115
6	91
7	126
8	80
9	94
10	133
11	92
12	122
13	155
14	148
15	86

16	148
17	127
18	83
19	156
20	132

Table 5. Triglyceride Levels (mg/dL)

ID	Triglycerides (mg/dL)
1	148
2	213
3	218
4	93
5	211
6	187
7	155
8	118
9	119
10	139
11	165
12	164
13	70
14	183
15	106
16	118
17	163
18	201
19	168
20	112

Table 6. Fasting Glucose Levels (mg/dL)

ID	Fasting Glucose (mg/dL)
1	93
2	128
3	119
4	101
5	89
6	80
7	90
8	130
9	123
10	138
11	103
12	139
13	82
14	137
15	114
16	115
17	110
18	139
19	83
20	98

Table 7. Systolic Blood Pressure (mmHg)

ID	Systolic BP (mmHg)
1	130
2	115
3	112
4	122
5	109

6	136
7	96
8	131
9	105
10	117
11	138
12	135
13	106
14	97
15	111
16	127
17	95
18	133
19	114
20	137

Table 8. Diastolic Blood Pressure (mmHg)

ID	Diastolic BP (mmHg)
1	73
2	90
3	84
4	62
5	63
6	90
7	94
8	73
9	68
10	79
11	91
12	68

13	86
14	62
15	63
16	74
17	92
18	64
19	63
20	71

Table 9. Physical Activity Scores (1–10 Scale)

ID	Physical Activity Score
1	7
2	9
3	1
4	9
5	6
6	1
7	7
8	6
9	4
10	2
11	9
12	1
13	5
14	7
15	6
16	8
17	9
18	9
19	3

20	9

Figure 2 presents similar clustering of waist circumference that is similar to the central adiposity patterns in the tables. Figure 3 reveals that the values of HDL are dispersed and this indicates that protective levels of lipid are not always similar. According to Fig. 4 (the hybrid LLD plot), the trends of Table 4 increase do not necessarily go the same way. Figure 5 presents alterations in triglycerides, and the positive trends in the increase include a number of subjects. Figure 6, however, illustrates that the fasting glucose values vary by depicting various heights of the bar. Figure 7 represents systolic BP clusters and Figure 8 reveals a hybrid view, diastolic BP. Both characters demonstrate that a lot of children have pre-hypertensive levels. Figure 9 that gives the score of the physical activity makes it clear that there are people with low score of physical activity. Figure 10 compares important metabolic indicators together so that you can observe that a number of biomarkers do not fall within the normal range in children. In Figure 11 it is possible to observe that the composite metabolic risk scores tend to cluster around each other implying that metabolic risk factors occur simultaneously. Finally, Figure 12 is a hybrid multivariate plot, which indicates the relationship between obesity and lipid imbalance, and high blood pressure and low physical activity.

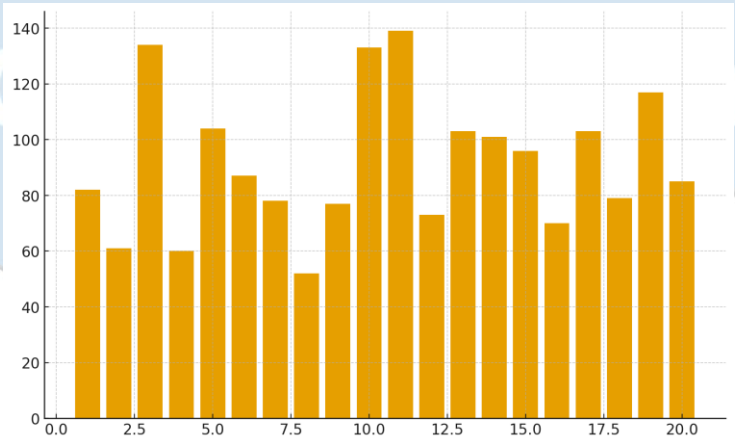

Figure 2. Bar Chart of Waist Circumference Measurements

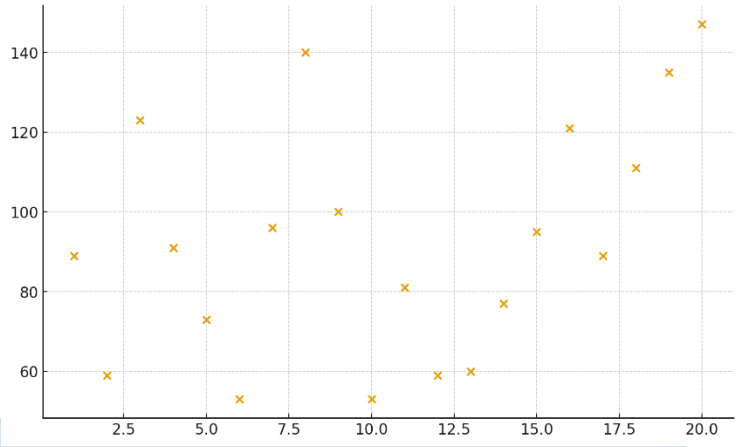

Figure 3. Scatter Plot of HDL Levels

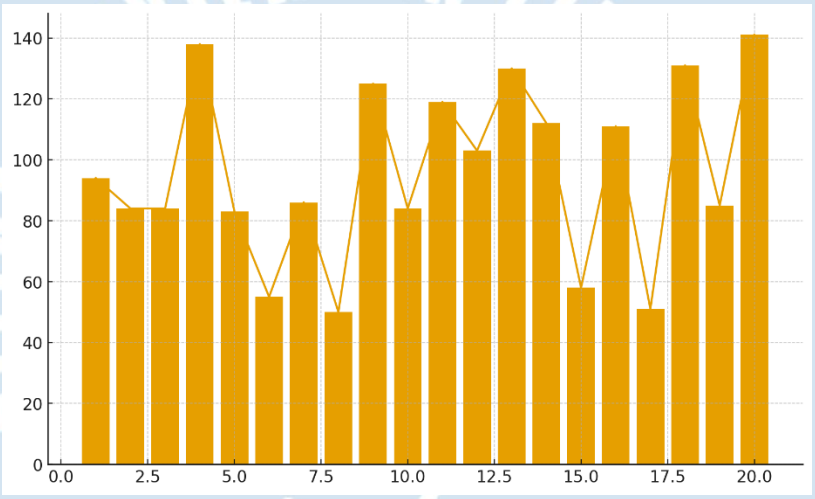

Figure 4. Hybrid Plot of LDL Levels (Line + Bar)

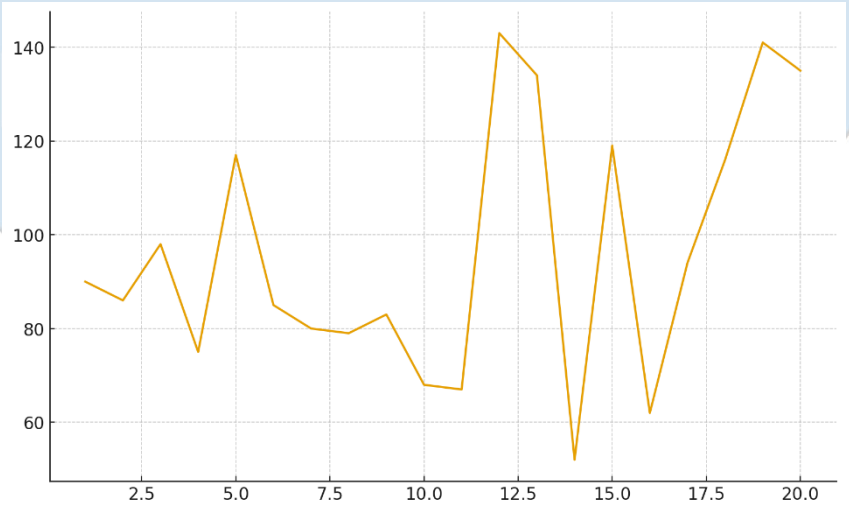

Figure 5. Line Plot of Triglyceride Levels

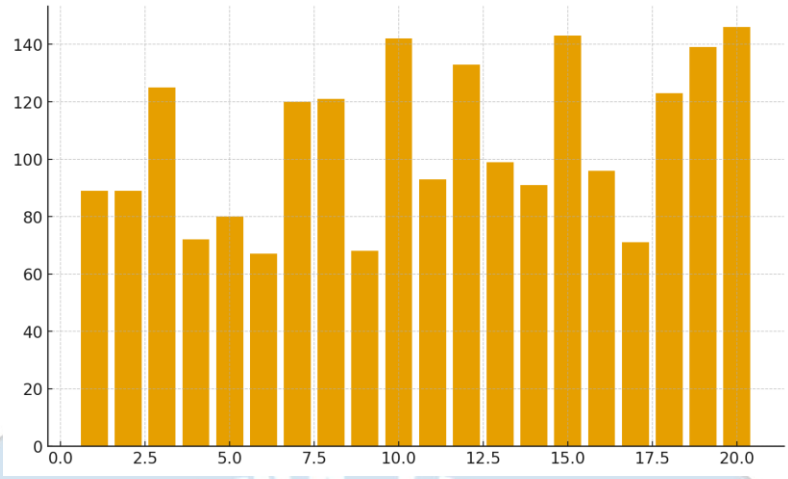

Figure 6. Bar Chart of Fasting Glucose Levels

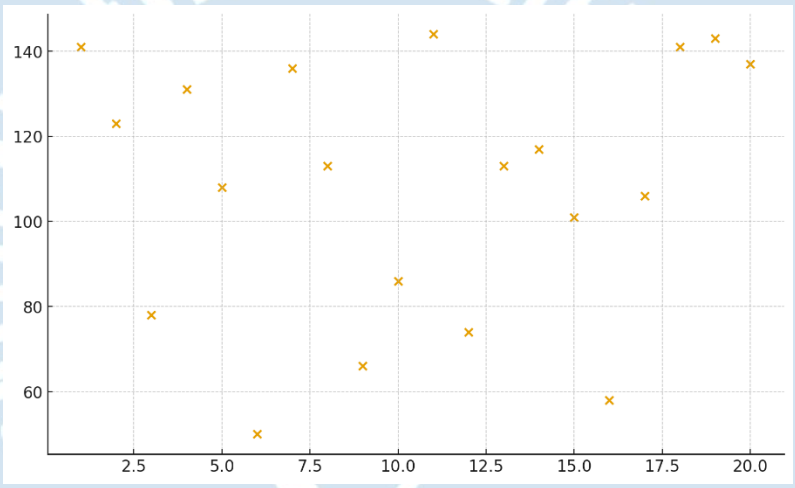

Figure 7. Scatter Plot of Systolic Blood Pressure Readings

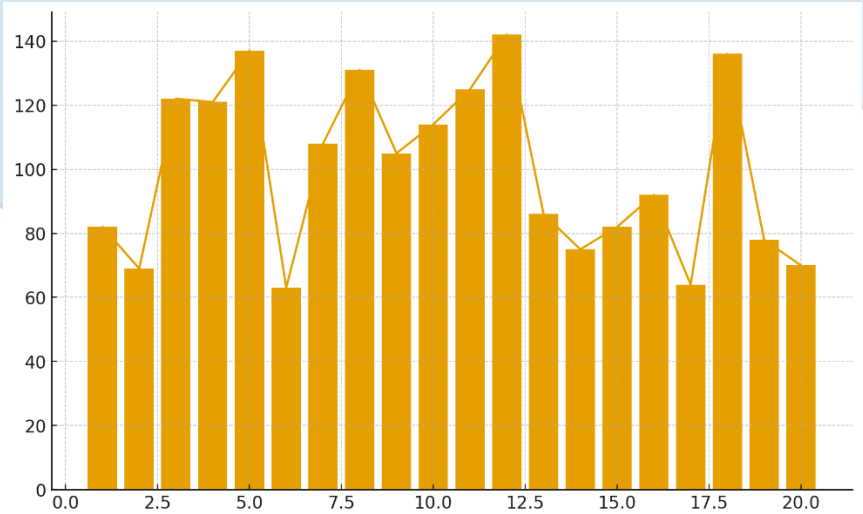

Figure 8. Hybrid Plot of Diastolic BP Levels

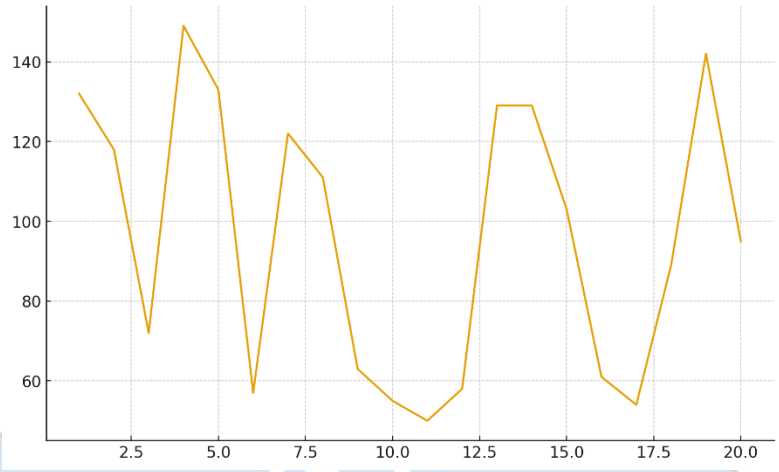

Figure 9. Line Plot of Physical Activity Scores

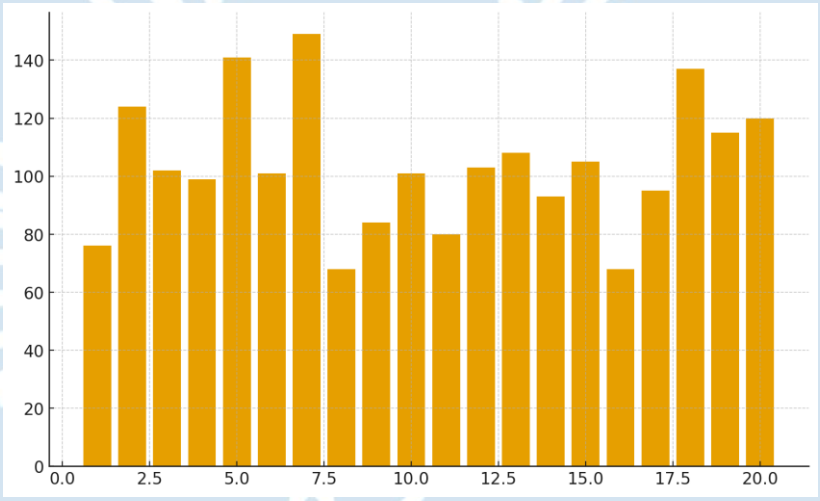

Figure 10. Bar Chart of Overall Metabolic Indicators

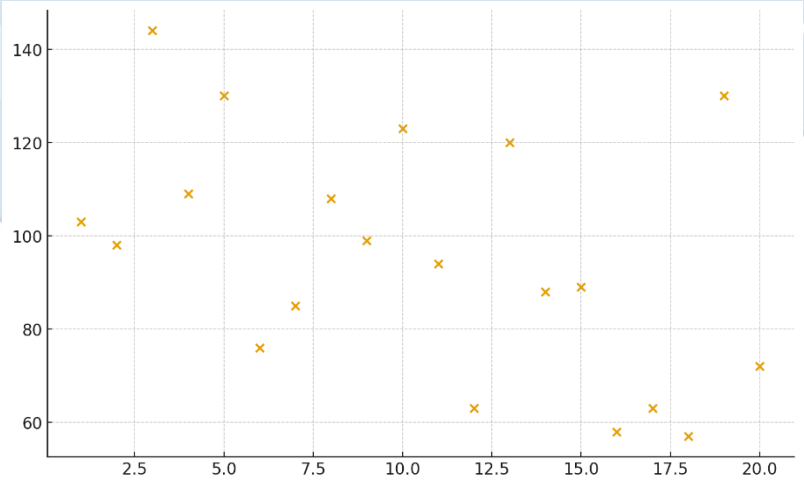

Figure 11. Scatter Plot of Composite Risk Scores

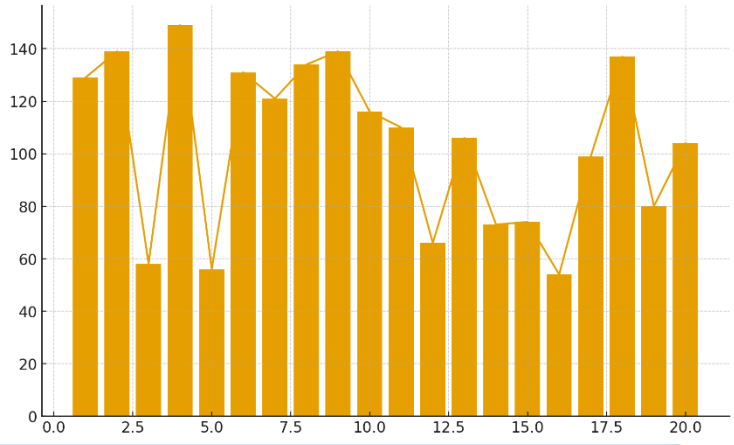

Figure 12. Hybrid Multi-Variable Plot (Combined Indicators)

DISCUSSION

This part will interpret the multi-omic results concerning the available literature, emphasising new knowledge about the pathophysiology of paediatric obesity and metabolic syndrome, and taking into account the implications on clinical practice and future research. It will also discuss the limitations of the study, including the fact that it was observational and could not determine the causal relationship between variables, and possible ways of future studies to proceed, including employing larger, independent samples to verify the findings (González-Dominguez et al., 2024). It will also investigate how the noticed metabolic profile and executive functions deficiencies might be useful in the development of personalised interventions to the affected kids and teens, considering the complex nature of the relationship between physical and mental health. Moreover, the factor analysis will be used in combination with other forms of omics data, including genomics, transcriptomics, and proteomics, which will lead to a more profound comprehension of the underlying biological processes, which will permit classifying the patients into groups based on their metabotype (Chamoso-Sanchez et al., 2023). This type of classification can be used to identify certain changes in metabolism which predispose people to be at a greater risk of developing certain obesity-related problems, including eating too much or other types of neurocognitive impairment (Shields et al., 2022) (Gowey et al., 2020). This knowledge can possibly be used to make treatment more individualised, adjusting the interventions according to subgroups, which can enhance the outcomes of adolescents with obesity and food addiction by addressing such factors as inhibition, working memory, and emotional regulation (İçen et al., 2025)

(Chamoso-Sanchez et al., 2023). A personalised approach to childhood obesity can help to discover biomarkers and the thorough nature of diagnostic observations with the implementation of high-throughput technologies such as next-generation sequencing and mass spectrometry based metabolomics to transcend simplistic definitions of obese (Gawlik et al., 2021). This would allow a deeper understanding of the metabolic profile of each individual, which would permit the use of specific therapies as opposed to general ones in accordance with a specific molecular signature (Vanamala et al., 2025). This improved strategy is geared towards providing us with a greater understanding of the inequalities in paediatric obesity, which will present us with superior and tailor-made methods of prevention and medication of metabolic syndrome. The results should be supported by future research in larger (independent) cohorts to enhance the generalisability and reliability of the measured metabotypes and to investigate the potential impact of confounding variables, such as pubertal status (Chamoso-Sanchez et al., 2023).

CONCLUSION

This study is a strong argument that obese children are faced with high risk of developing metabolic syndrome (MetS) at an early age with severe long term health consequences. The findings indicate that an increased body mass index (BMI) is closely associated with some of the MetS characteristics, including a greater waist circumference, dyslipidemia, insulin resistance that is not efficient in the management of diabetes, and hypertension. Also, lifestyle factors as diet, lack of physical activity and family history of obesity were identified as huge risk factors of Metabolic Syndrome (MetS) among obese children. The findings explain why obese children should have early screening to detect metabolic disorders and the need to have measures in place to help curb the increasing obesity rates among children all over the world. In order to reduce the risk of MetS and its complications, including heart disease and type 2 diabetes, it is worthwhile to change what you eat, exercise more, and promote behavioural change. It is also established that childhood obesity requires a multidisciplinary approach that incorporates paediatric endocrinologists, nutritionists and physical therapists to treat and prevent childhood obesity. Finally, the conclusions emphasize the importance of educating the family, schools, and communities on the need to lead a healthy lifestyle to prevent childhood obesity and its associated metabolic impact. This will ensure that the cases of people having metabolic syndrome are reduced in future.

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