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Growth Parameters and Body Mass Index in Children with Chronic Diseases

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ABSTRACT

Background: Deviations from the normal pattern of growth may be the first clues to pathology as in many chronic diseases evaluated clinically by anthropometric measurements and body mass index (BMI).

Objective This study aimed to assess growth parameters (weight, height, head circumference, skin fold thickness, mid-arm circumference, and BMI in patients with chronic diseases.

Patients and methods: A cross-sectional prospective study was conducted among 1000 children with chronic medical diseases in the Paediatric Department at Sohag University Hospital (From April 2023 to April 2024). All patients were subjected to history taking, clinical examination, BMI, and anthropometric measurements

Results: Regarding the 1000 children with different chronic diseases, there were 200 cases diagnosed with chronic heart disease, 150 cases diagnosed with chronic endocrinal diseases, 80 cases diagnosed with gastrointestinal diseases, 100 cases diagnosed with chronic hematological diseases, 70 cases diagnosed with chronic immunological diseases, 100 cases diagnosed with chronic metabolic diseases, 100 cases diagnosed with chronic neurological diseases, 100 cases diagnosed with chronic renal diseases and 100 cases diagnosed with Chronic respiratory diseases.

Conclusions: Children with chronic diseases displayed growth and developmental issues. Growth and development were positively influenced by many factors such as parental health, genetic composition, environmental factors, and multiple chronic diseases. Early diagnosis and good evaluation by growth parameters, BMI, and growth chart could eliminate growth failure.

Keywords: Growth, Body mass index, Children, Chronic diseases.

INTRODUCTION

Deviations from the normal pattern of growth may be the first clues to pathology as in many chronic diseases evaluated clinically by anthropometric measurements and body mass index (BMI). Growth impairment in children with chronic diseases is associated with disruption of the growth hormone (GH) and predominantly results from undernutrition, chronic inflammation, and prolonged corticosteroid treatment. Undernutrition leads to major adaptations in the endocrine system towards conserving energy, diverting substrates away from growth and reproduction, and providing alternative sources of energy for critical body homeostasis. Chronic inflammatory processes exacerbate undernutrition through proinflammatory cytokines such as interleukin-1 & 6 and tumor necrosis factor. These growth-regulating mechanisms are disturbed further by corticosteroids used in some chronic conditions for their anti-inflammatory and immunosuppressive properties. Growth impairment occurs with many chronic conditions such as congenital heart disease (CHD), chronic pulmonary diseases such as bronchial asthma, gastrointestinal diseases such as inflammatory bowel disease (IBD), chronic liver diseases, chronic renal diseases, chronic hemolytic anemia, and chronic central nervous system diseases [1].

Rates of growth restriction range from 27% to 60%. The frequency and severity of growth restriction tend to be more apparent in children with cyanotic CHD compared to cyanotic CHD. The etiology of growth restriction in CHD is multifactorial significantly including fluid restriction, hemodynamic impairment, inadequate caloric intake, and hypermetabolism [2]. Severe growth impairment occurs among children with chronic kidney disease (CKD), in up to 35 % of this population before progression to end-stage renal disease [3].

In IBD: Growth retardation and delayed puberty can precede the development of the disease or can even be predominant at onset. Growth retardation is found in 40% of IBD patients [4].

In chronic liver diseases: There is limited data available on the effect of antivirals such as ledipasvir/sofosbuvir (LDV/SOF) used to treat chronic hepatitis C (CHC) on growth in children. However, some studies approved that there is a significant increase in patients' weight, height, and BMI with this treatment [5]. Therefore, the aim of this work was to assess growth parameters (weight, height, head circumference, skin fold thickness, mid-arm circumference, and BMI) in patients with chronic diseases.

PATIENTS AND METHODS

This cross-sectional prospective study was carried out on 1000 children aged < 12 years old, both sexes, with chronic medical diseases. The study was done from 2023 to 2024.

Exclusion criteria: Patients with acute diseases, malignancy, and chronic with surgical sequelae.

All patients were subjected to complete history taking and clinical examination.

Anthropometric measurements [6]:

Head circumference: For infants and toddlers less than two years of age, measure the largest circumference of the head using a non-stretchable measuring tape around the most prominent part of the head to the middle of the forehead. The tape measure should be pulled snugly around the head to compress

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the hair and underlying soft tissue. Repeat the measurement twice to obtain two readings within 0.2 cm or 0.25 inches. The average of the two closest measurements should be recorded.

Recumbent length: For infants and toddlers who cannot stand, the recumbent length should be measured. Align the infant's head against the top of the headboard of the infant meter. An assistant must straighten the infant's body and legs, ensuring the feet are parallel to the footboard. Repeat the measurement twice to obtain two readings within 0.2 cm or 0.25 inches. The average of the two closest measurements should be recorded.

Height: For children who can stand, a stadiometer should be used. The child should stand up straight, with buttocks, shoulder blades, and heels together touching the back of the stadiometer. The feet should face outward at a 60-degree angle. If the patient has genu valgum, separate the feet enough to avoid overlapping of the knees, while maintaining contact between the knees. Arms should be loosely hanging at the sides with palms facing the thighs. The horizontal bar of the stadiometer should be lowered until the hair is compressed to the crown of the head. Remove any objects on the head and hair that may obstruct the bar from compressing the hair to the crown of the head. The measurement should be read to the nearest 0.1 cm or 1/8 of an inch. Repeat the measurement twice to obtain two readings within 0.2 cm or 0.25 inches. The average of the two closest measurements should be recorded.

Weight: For children less than two years of age, use a calibrated beam or a digital infant scale. Ensure that the infant is not wearing any clothes and remove the diaper before measuring the weight. The weight should be measured to the nearest 0.01 kg or 0.5 ounces. For children older than 24 months, a balanced floor scale or electronic floor scale can be used.

Skinfold measurements: Common sites for skinfold measurements include the biceps, triceps, iliac crest, thigh, calf, subscapular, abdomen, and chest. The exact technique can vary, but we discussed one method using the triceps as an example. For the triceps skinfold, grab the skin 2 cm above the midpoint of the right upper arm with the thumb and index finger to create a skinfold. Then, place the calipers at the midpoint to obtain the measurement. Similarly, at other sites, the skinfold measurement is obtained by grabbing the skin 2 cm away from the measuring site. Despite standard measuring techniques, skinfold testing has high variability and has limited use thus far in the clinical setting.

Mid-arm circumference: The patient stands upright with the arm hanging freely at the side. The patient should not flex the arm muscles. Measuring tape should be placed snugly around the mid-point of the arm without compressing the skin.

Body mass index (BMI): BMI is a calculation based on the height and weight of the child and is recommended for all children older than two years of age. The formulas for the calculation of BMI in children are as follows: BMI = weight in pounds / [height in inches x height in inches] x 703. BMI = weight in kilograms / [height in meters x height in meters]. In adults, BMI is used to diagnose obesity as it correlates with body fat. However, it does not directly measure body fat and has its limitations when used in isolation. Percent body fat varies with age, gender, and ethnicity. Percent body fat increases with age even if the weight stays the same, making it a less accurate measure of obesity in adults. Also, in athletes, increased muscle mass for a given height and age increased their BMI, even though they have a very low percentage of total body fat.

Ethical consideration: After approval from The Ethical Committee of Sohag University Hospitals, Sohag, Egypt (IRB No.: Soh-Med-23-03-09MS). An informed written consent was obtained from relatives of the patients. The study adhered to the Helsinki Declaration throughout its execution.

Statistical analysis

Clinical data were collected through Excel 2015 for Windows and was analyzed using SPSS version 16.00 software. Categorical data were expressed as percentages and continuous data as mean and standard deviation in case of normally distributed data, and median and interquartile range, in case of abnormally distributed data. P value $\leq$ 0.05 was deemed significant.

RESULTS

The mean age was 66.9 ± 52 months. There were 516 (51.6%) males and 484 (48.4%) females. The socioeconomic level was low in 600 (60%) patients, moderate in 300 (30%) patients and high in 100 (10%) patients. 600 (60%) patients lived in rural, 300 (30%) patients lived in semi-rural, and 100 (10%) patients lived in urban. Consanguinity was positive in 547 (54.7%) patients (Table 1).

Table (1): Demographic data and consanguinity of the studied patients

		Patients (n = 1000)
Demographic data		
Age (months)		66.9±52
Sex	**Male**	516 (51.6%)
	Female	484 (48.4%)
Socioeconomic level	**Low**	600 (60.0%)
	Moderate	300 (30.0%)
	High	100 (10.0%)
Residence	**Rural**	600 (60.0%)
	Semi-rural	300 (30.0%)
	Urban	100 (10.0%)
Consanguinity		547 (54.7%)

Data are presented as Mean ± SD and frequency (%).

Development was normal in 719 (71.9%) patients and abnormal in 281 (28.1%) patients. Cognitive development was normal in 235 (71%) patients and delayed in 96 (29%) patients. Social and emotional development was normal in 228 (73.31%) patients and delayed in 83 (26.69%) patients. Language development was normal in 142 (67.94%) patients and delayed in 67 (32.06%) patients. Physical development was normal in 114 (76.51%) patients and delayed in 35 (23.49%) patients (Table 2).

Table (2): Development of the studied patients

		Patients (n = 1000)
Development	**Normal**	719 (71.9%)
	Abnormal	281 (28.1%)
Cognitive development	**Normal**	235 (71.0%)
	Abnormal	96 (29.0%)
Social and emotional development	**Normal**	228 (73.31%)
	Abnormal	83 (26.69%)
Language development	**Normal**	142 (67.94%)
	Abnormal	67 (32.06%)
Physical development	**Normal**	114 (76.51%)
	Abnormal	35(23.49%)

Data are presented as frequency (%).

The mean weight was 16.8 ± 11.17 kg. Mean height was 99.2 ± 32.27 cm. HC had a mean of 46.9 ± 5.96 cm. BMI had a mean of 14.8 ± 3.11 kg/m^2. MAC with a mean of 14.3 ± 4.03 cm. Skin fold thickness had a mean of 5.3 ± 3.14 cm. US had a mean of 53.7 ± 13.56. LS had a mean of 45.6 ± 19.08. Span had a mean of 99.2 ± 32.26 (Table 3).

Table (3): Weight, height, HC, BMI, MAC, skin fold thickness, US, LS and span of the studied patients

	Patients (n = 1000)
Weight (Kg)	16.8±11.17
Height (cm)	99.2±32.27
HC (cm)	46.9±5.96
BMI (Kg/m^2)	14.8±3.11
MAC (cm)	14.3±4.03
Skin fold thickness (cm)	5.3±3.14
US	53.7±13.56
LS	45.6±19.08
Span	99.2±32.26

Data are presented as Mean ± SD. HC: head circumference. BMI: body mass index, Mac: Mid-arm circumference, US: upper segment, LS: lower segment

Cardiac examination revealed murmur in 158 (15.8%) patients and normal in 842 (84.2%) patients. Chest examination, wheezes in 65 (6.5%) patients, crepitations in 18 (1.8%) patients, respiratory distress in 178 (17.8%) patients, hypopnea in 1 (0.1%) patient, and normal in 738 (73.8%) patients**.**

Neurological examination was normal in 949 (94.9%) patients, hypertonia in 31 (3.1%) patients, hypotonia and hyporeflexia in 14 (1.4%) patients, hypertonia and stiffness at both LL in 2 (0.2%) patients and unsteady gait in 4 (0.4%) patients**.** Abdominal examination was normal in 820 (82%) patients, distended in 55 (5.5%) patients, everted umbilicus in 2 (0.2%) patients, umbilical hernia in 4 (0.4%) patients, exomphalos minor in 2 (0.2%) patients, surgical dressing in 2 (0.2%) patients, enlarged liver in 38 (38%) patients, enlarged spleen in 6 (0.6%) patients, splenectomy scar in 1 (0.1%) patients, hepatosplenomegaly in 20 (2%) patients, marked ascites in 6 (0.6%) patients, diffuse enlargement, shifting dullness and tenderness in 17 (1.7%) patients, scaphoid abdomen in 5 (0.5%) patients and scar of bladder surgery in 1 (0.1%) patients (Table 4 and Figure 1).

Table (4): Clinical examinations of the studied patients

		Patients (n = 1000)
Cardiac examination	**Murmur**	158(15.8%)
	Normal	842(84.2%)
Chest examination	**Wheezes**	65(6.5%)
	Crepitations	18(1.8%)
	Respiratory distress	178(17.8%)
	Hypopnea	1(0.1%)
	Normal	738(73.8%)
Neurological examination	**Normal**	949(94.9%)
	Hypertonia	31(3.1%)
	Hypotonia & Hyporeflexia	14(1.4%)
	Hypertonia& stiffness at both LL	2(0.2%)
	Unsteady gait	4(0.4%)
Abdominal examination	**Normal**	820(82.0%)
	Distension	55(5.5%)
	Everted umbilicus	2(0.2%)
	Umbilical hernia	4(0.4%)
	Exomphalos minor	2(0.2%)
	Surgical dressing	2(0.2%)
	Enlarged liver	38(38.0%)
	Enlarged spleen	6(0.6%)
	Splenectomy scar	1(0.1%)
	Hepatosplenomegaly	20(2.0%)
	Marked ascites	6(0.6%)
	Diffuse enlargement, shifting dullness, and tenderness	17(1.7%)
	Scaphoid abdominal	5(0.5%)
	Scar of bladder surgery	1(0.1%)

Data are presented as frequency (%). LL: lower limbs.

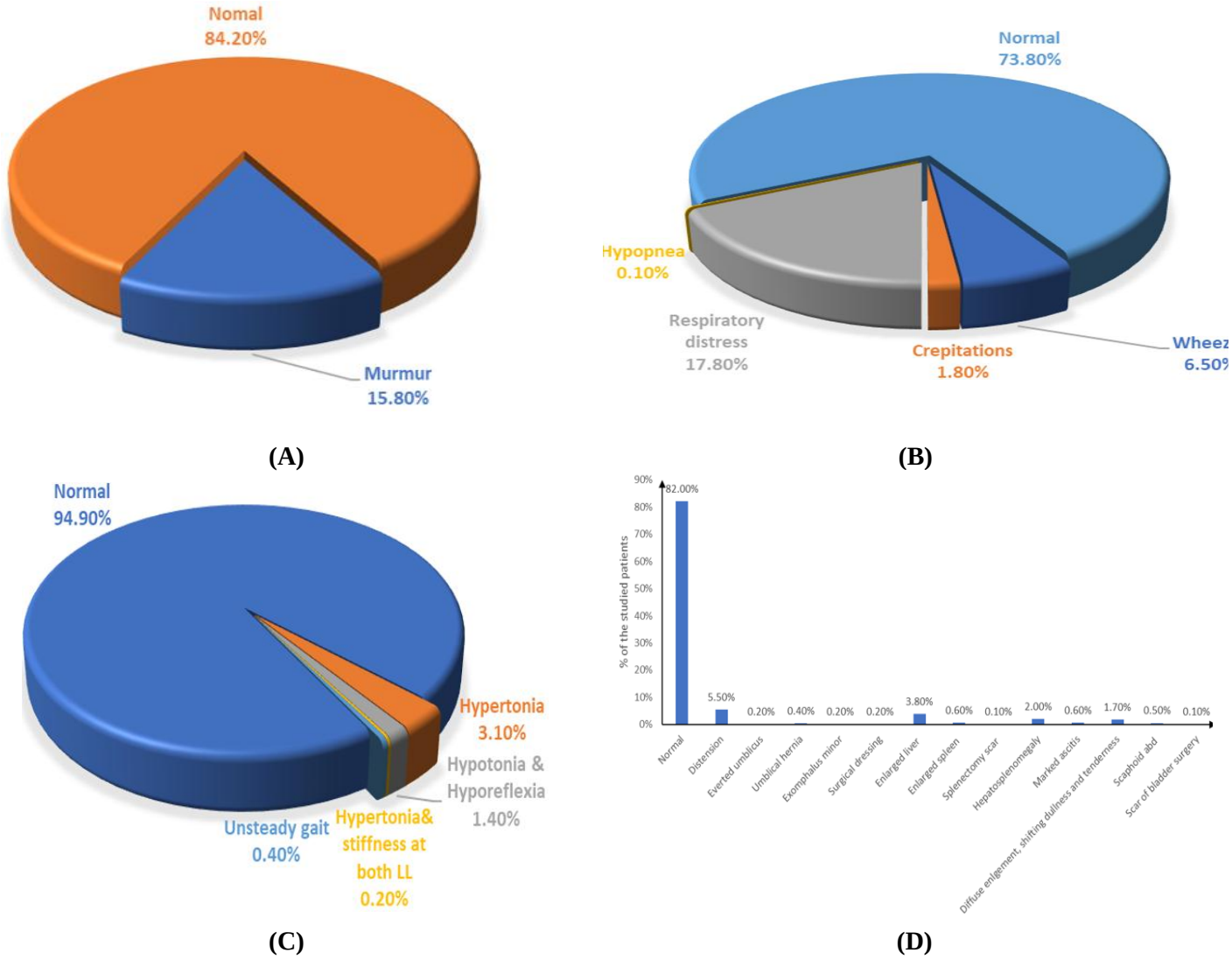

Figure (1): (A) Cardiac, (B) chest, (C) neurological, and (D) abdominal examination of the studied patients.

DISCUSSION

The childhood period is well known for its vulnerability as it is characterized by continuous variations in nutritional needs. Moreover, underlying medical conditions with chronic diseases can increase this vulnerability [7]. Despite distinct advancements in nutritional therapy, malnutrition, and growth retardation remain inevitable consequences of pediatric chronic diseases [8].

In the current study, the weight for children with chronic heart disease showed that the mean was 9.8 ± 7.87 kg and the mean height was 76.5 ± 26.46 cm, and the mean skin fold thickness was 3.8 ± 1.75 cm. The mean BMI was 14.3 ± 2.75 Kg/m^2. **Elmoghazy *et al.*** [9] showed that the mean weight was 7.01 ± 2.51 Kg, the mean height was 67.8 ± 12.3 cm, the mean BMI was 14.8 ± 1.93 Kg/m^2, the mean HC was 43.5 ± 4.85 cm and the mean MAC was 11.3 ± 1.26 cm.

In our study, children with chronic endocrinal diseases had a mean weight of 25.7 ± 10.61 kg, the height had a mean of 125 ± 23.97 cm, the head circumference had a mean of 50.6 ± 3.21 cm, the mid-arm circumference had a mean of 17.1 ± 3.04 cm, the skin fold thickness had a mean of 6.7 ± 3.5 cm and the BMI had a mean of 15.6 ± 3.03 kg/m^2. Most of the children had a BMI centile below the 10th centile (23.33%) or between the 10th and 25th centile (8%). In line with our findings, **Gabri *et al.*** [10] reported that the mean height of diabetic children was 1.48 ± 1.63 m, the mean weight was 47.541 ± 17.257 kg and the mean BMI was 21.06 ± 4.5. Also, **Khadilkar *et al.*** [11] and **Aljuhani *et al.*** [12] reported that there was no correlation between height, weight, and BMI z-scores and the duration of diabetes in their cases.

In the present study, the weight of children with chronic gastrointestinal diseases had a mean of 18.2 ± 9.73 kg, the height had a mean of 107.1 ± 27.16 cm, the head circumference had a mean of 48.6 ± 4.27 cm, the mid-arm circumference had a mean of 14.9 ± 3.17 cm, the skinfold thickness had a mean of 4.7 ± 2.06 cm and the BMI had a mean of 14.6 ± 3 kg/m^2. Most of the children had a BMI below the 10th percentile (27.5%). The weight, height, and head circumference were also lower than the normal range, indicating stunting and undernutrition in these children. In agreement with our results, **Chao *et al.*** [13] demonstrate that children with chronic constipation were more likely to be underweight, and the positive response to

treatment was associated with body weight gain. According to the authors' explanation, excessive fecal mass in the rectum weakens the appetite due to abdominal discomfort, fullness, and nausea.

In the present study, the mean weight of children with chronic hematological diseases was 19 ± 7.49 Kg, the mean height was 108 ± 22.77 cm, the mean skin fold thickness was 6.2 ± 1.81 cm and the mean BMI was15.6 ±2.49 Kg/m^2. A previous study by **Linga *et al.*** [14] reported that children with chronic hematological diseases had lower weight and height due to malnutrition and this is linked to poor outcomes and mortality.

According to the current study, the children with chronic immunology disease had a mean weight of 26.4 ± 12.09 Kg, the mean height was 125.1 ± 27.78 cm, the mean HC was 80.2 ± 3.42 cm. The man MAC was 16.8 (±3.72) cm, and the mean skin fold thickness was 6.4 (±2.74) cm. The mean BMI was 15.9 ± 2.84 Kg/m^2 and the mean US was 64.7 ± 10.85 with a mean LS of 60.4 ±17.01 and a mean span of 125.1 ±27.78. **Kaplan *et al.*** [14] showed that when the prevalence of autoimmunity was evaluated according to diagnostic groups, the frequency of autoimmune/inflammatory manifestations in defects of phagocytes (56%), combined immune deficiencies (53%) and diseases of immune dysregulation (52%) were observed higher than the other forms of PIDs.

In the current study, the mean weight of children with chronic metabolic diseases was 6.66 ±4.87 Kg, the mean height was 66.04 ± 17.37 cm, the mean HC was 41.04 ± 6.19 cm, the mean MAC was 10.61 ± 3.1 cm, and the mean skin fold thickness was 3.65 ± 2.99 cm. The mean BMI was 13.21 ± 2.56 Kg/m^2. The mean US was 40.04 ± 8.55 with a mean LS of 26 ± 9.27 and a mean span of 66.04 ± 17.37 cm.

Agreeing with our results, **Kostovski *et al.*** [15] reported that the mean weight was 73.74 ± 23.66 Kg, the mean height was 149.83 ± 17.87 and the mean BMI was 31.57 ± 4.67 Kg/ m^2.

In the current study, the mean weight of children with chronic neurological diseases was 12 ± 9.2 Kg, the mean height was 83.8 ± 24.17 cm, the mean HC was 45.6 ± 4.76 cm, the mean MAC was 12.4 ± 4.05 cm, the mean skin fold thickness was 5 ± 4.47 cm, the mean BMI was 15 ± 3.63 Kg/m^2, the mean US was 47.5 ± 10.31, the mean LS was 36.3 ± 14.29 and the mean span was 83.8 ± 24.17. **Melunovic *et al.*** [16] reported that patients with minor motor impairment, and severe motor impairment had lower weight, height, BMI, and HC indicating a small amount of fat tissue in these patients, and a reduced growth in height and growth of bone structures.

In the current study, the mean weight of children with chronic renal disease was 23.4 ± 9.37 Kg, the mean height was 116.2 ± 21.2 cm, the mean HC was 50.4 ± 2.55 cm, the mean MAC was 17.1 ± 3.19 cm, the mean skin fold thickness was 7 ± 3.76 cm, the mean BMI was 16.6 ± 2.75 Kg/m^2, the mean US was 60.2 ± 8.63, the mean LS was 55.8 ± 12.99 and the mean span was 116.2 ± 21.2. **Abd Allah Zahed *et al.*** [17] demonstrated that among cases with CKD, the highest percentage of cases (70%) was below the 5th percentile of weight. The mean weight was 21.3 ± 9.6 Kg. The mean height was 116.6 ± 21.8 cm with the highest percentage of cases (50%) below the 5th percentile. The mean MAC was 15.1 ± 1.7 cm. The mean BMI was 15.04 ± 1.9 Kg/m^2.

In the current study, the mean weight of children with chronic respiratory diseases was 25.5 ± 11.6 Kg, the mean height was 104.2 ± 30.66 cm. The mean HC was 47.8 ± 5.5 cm. The mean MAC was 14.3 ± 3 cm. The mean skin fold thickness was 5.4 ± 2.06 cm. The mean BMI was 13.9 ± 3.39 Kg/m^2. **Hamiwka *et al.*** [18] reported that the mean BMI was 18.27 ± 3.65 kg/ m^2 among children with chronic respiratory disease.

LIMITATIONS

The sample size was relatively small. Cross-sectional design limited the ability to assess the progression of chronic diseases over time and their long-term effects on growth and development. Also, it was a single center study.

CONCLUSION

Children with chronic heart disease exhibited significant developmental delays, undernutrition and a range of cardiac lesions, with a predominant occurrence of ventricular septal defects. Those with chronic endocrine disorders generally had normal development but were presented with lower weight and height percentiles compared to healthy peers. Chronic gastrointestinal conditions often resulted in stunting and undernutrition with a notable prevalence of celiac disease. Chronic hematological diseases were marked by severe anemia-related features, while chronic immunological diseases revealed diverse presentations with notable dysmorphic features. Children with chronic metabolic disorders were significantly affected by growth retardation, while those with chronic neurological conditions predominantly experienced developmental delays and various neurological impairments. Lastly, children with chronic renal and respiratory diseases showed distinct growth patterns and clinical signs, underlining the impact of these conditions on overall health and development.

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