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GROWTH AND NUTRITIONAL STATUS IN YOUNG CHILDREN WITH CONGENITAL HEART DISEASE

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ABSTRACT

Background. Congenital heart disease (CHD) is frequently accompanied by growth faltering and malnutrition during early childhood. Aim. To assess physical development and nutritional status in children aged 0–3 years with CHD according to age, sex, and defect phenotype. Materials and methods. This prospective observational study included 159 children with CHD and 58 age-comparable controls. Anthropometric indices were calculated with WHO Anthro and WHO AnthroPlus, including weight-for-age z score (WAZ), height-for-age z score (HAZ), weight-for-height z score (WHZ), and body mass index-for-age. Results. Children with CHD had significantly poorer anthropometric indices than controls. The greatest impairment occurred during the first 6 months of life, when severe underweight and wasting were especially frequent among boys. Indicators improved modestly at 6–12 months but deteriorated again at 1–3 years. Children with cyanotic defects had critically low WAZ and WHZ values more often than those with acyanotic defects. Conclusion. Children with CHD require early and regular standardized growth and nutritional monitoring. Infants, boys, and children with cyanotic defects represent the highest-risk groups.

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Keywords: *congenital heart disease; children; physical development; nutritional status; underweight; stunting; wasting; WAZ; HAZ; WHZ; BMI.*

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INTRODUCTION

The global significance of this problem is determined by the fact that childhood malnutrition is recognized as one of the key public health challenges and is directly related to the achievement of Sustainable Development Goal 2.2 — ending all forms of malnutrition by 2030 [United Nations Children's Fund [UNICEF], World Health Organization [WHO], & World Bank Group, 2025]. According to joint estimates by UNICEF/WHO/World Bank, despite a decrease in the global prevalence of stunting among children under 5 years of age from 26.4% in 2012 to 23.2% in 2024, millions of children worldwide continue to suffer from chronic and acute malnutrition. In 2024, wasting was identified in 6.6% of children under 5 years of age, corresponding to 42.8 million children, while severe wasting was observed in 1.9%,

or 12.2 million children [UNICEF, WHO, & World Bank Group, 2025]. These data emphasize that WAZ, HAZ, and WHZ are not only anthropometric criteria but also important international indicators of child survival, health, and quality of development.

Nutritional status is of particular importance in children with CHD. In this category of patients, malnutrition develops under the influence of a complex combination of cardiac and non-cardiac factors, including hemodynamic overload, chronic hypoxemia, pulmonary hypertension, heart failure, increased energy requirements, sucking and feeding difficulties, gastroesophageal reflux, malabsorption, and frequent infectious complications [Centeno-Malfaz et al., 2023; Luca et al., 2022; Smith et al., 2024; Vazzana et al., 2025; Zhang et al., 2020]. As a result, a specific "vicious circle" develops in children with CHD: cardiovascular pathology aggravates nutritional deficiency, while body weight deficit and growth retardation, in turn, worsen disease tolerance, increase the risk of complications, and may negatively affect the outcomes of surgical treatment.

Current studies show that malnutrition among children with CHD occurs much more frequently than in the general population, and its severity depends on the child's age, the severity of hemodynamic disorders, and the phenotype of the defect [Centeno-Malfaz et al., 2023; Luca et al., 2022; Smith et al., 2024; Vazzana et al., 2025; Zhang et al., 2020]. The highest risk is typical for children in the first year of life, especially in the presence of cyanotic defects, pulmonary hypertension, heart failure, and delayed diagnosis. In this regard, assessment of physical development in children with CHD should be considered not as a secondary clinical indicator but as an essential component of comprehensive follow-up, early intervention, and preparation for cardiac surgery.

The relevance of this problem for the Republic of Uzbekistan is further strengthened by the fact that maternal and child health protection, early disease detection, improvement of the quality of medical care, and development of preventive medicine are important areas of state reforms. Presidential Decree of the Republic of Uzbekistan No. PF-60 dated January 28, 2022, "On the Development Strategy of New Uzbekistan for 2022–2026," pays special attention to improving the quality of medical and social services, as well as to measures aimed at strengthening children's health and well-being [President of the Republic of Uzbekistan, 2022]. It is also significant that, within the framework of this strategy, special social support measures for children are provided, including the organization of free meals for primary school pupils in the Republic of Karakalpakstan and Khorezm region, which reflects the state's intersectoral approach to issues of child health and nutrition [President of the Republic of Uzbekistan, 2022].

The further development of these priorities is reflected in the "Uzbekistan — 2030" Strategy and in Presidential Decree of the Republic of Uzbekistan No. PF-21 dated February 16, 2026, aimed at the consistent continuation of reforms and the alignment of national development with modern global challenges [President of the Republic of Uzbekistan, 2023, 2026]. These documents emphasize improving the quality of medical care and social protection, introducing measurable target indicators, and implementing digital monitoring of reform outcomes. Therefore, studies devoted to the early detection of physical developmental disorders in children with CHD fully correspond to national strategic objectives aimed at strengthening the health of the child population and improving the effectiveness of medical care [President of the Republic of Uzbekistan, 2023, 2026].

Against the background of the progress achieved in Uzbekistan in the field of child health protection, there remains a need for an in-depth study of vulnerable groups of children. According to UNICEF DATA, the under-five mortality rate in Uzbekistan in 2024 was 13.4 per 1,000 live births, reflecting a significant improvement compared with previous decades. At the same time, the modeled prevalence of stunting among children under 5 years of age is approximately 7%, early initiation of breastfeeding is observed in 40% of children, and the consumption of iodized salt is reported in 82% of households [UNICEF, n.d.]. These indicators demonstrate positive dynamics, but at the same time underline the need for targeted follow-up of children at high medical risk, including children with CHD.

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The particular scientific and practical significance of the present study lies in its focus on the physical development of young children with CHD in the Khorezm region using standardized anthropometric indicators: WAZ, HAZ, WHZ, and BMI-for-age. The study included 159 children aged 0 to 3 years with CHD and 58 children in the control group; assessment was performed using WHO Anthro and WHO AnthroPlus, ensuring comparability of the obtained data with international standards for child growth and nutrition.

The obtained data show that most children with CHD are born with normal body weight and body length; however, during the first year of life, especially in the first 6 months, delayed physical development develops in these children. At the same time, abnormalities in WAZ, HAZ, and WHZ are more frequent and more pronounced in boys than in girls, while critically low WAZ and WHZ values occur significantly more often in children with cyanotic defects than in those with acyanotic defects.

Thus, the study of physical development in children with CHD is a relevant scientific and practical task of global, national, and regional importance. Early assessment of WAZ, HAZ, WHZ, and BMI in children with CHD allows timely detection of nutritional disorders, identification of high-risk groups, individualization of therapeutic and preventive measures, and improvement of the effectiveness of comprehensive follow-up in young children. Special attention should be paid to children in the first year of life, boys, and patients with cyanotic defects, since these groups have the highest risk of critical body weight deficit and impaired proportionality of physical development.

AIM

To assess physical development and nutritional status in young children with congenital heart disease according to age, sex, and defect phenotype.

MATERIALS AND METHODS

A prospective observational analytical cohort study was conducted among 159 children aged 0–3 years with congenital heart disease (CHD), including 91 boys (57.2%) and 68 girls (42.8%), who were born in Urgench and followed at the Departments of Cardiology and Cardiorheumatology of the Khorezm Regional Children's Multidisciplinary Medical Center from 2023 to 2026. The control group comprised 58 age-comparable children. Overall, 217 children were examined.

The inclusion criteria for the main group were as follows: age under 3 years, diagnosed congenital heart disease, absence of acute infections, and no antibacterial therapy within 14 days prior to examination. The exclusion criteria included prematurity of less than 36 weeks of gestation, inability to receive enteral nutrition, such as gastrostomy, ileostomy, or short bowel syndrome, as well as concomitant infectious diseases and viral hepatitis B and C.

The study was conducted in accordance with the Declaration of Helsinki after written informed consent had been obtained from the parents or legal guardians. Boys and girls accounted for 91 (57.2%) and 68 (42.8%) participants, respectively, giving a male-to-female ratio of 1.34. Ninety-six children (60.4%) were younger than 1 year, and 121 children (76.1%) were older than 6 months (Figure 1).

There were 6 newborns aged 0–30 days (3.8%), 32 children aged 1–6 months (20.1%), 58 children aged 6–12 months (36.5%), and 63 children aged 1–3 years (39.6%). The control group included 58 children. The most common defects were atrial and ventricular septal defects and Tetralogy of Fallot; other congenital heart defects occurred infrequently.

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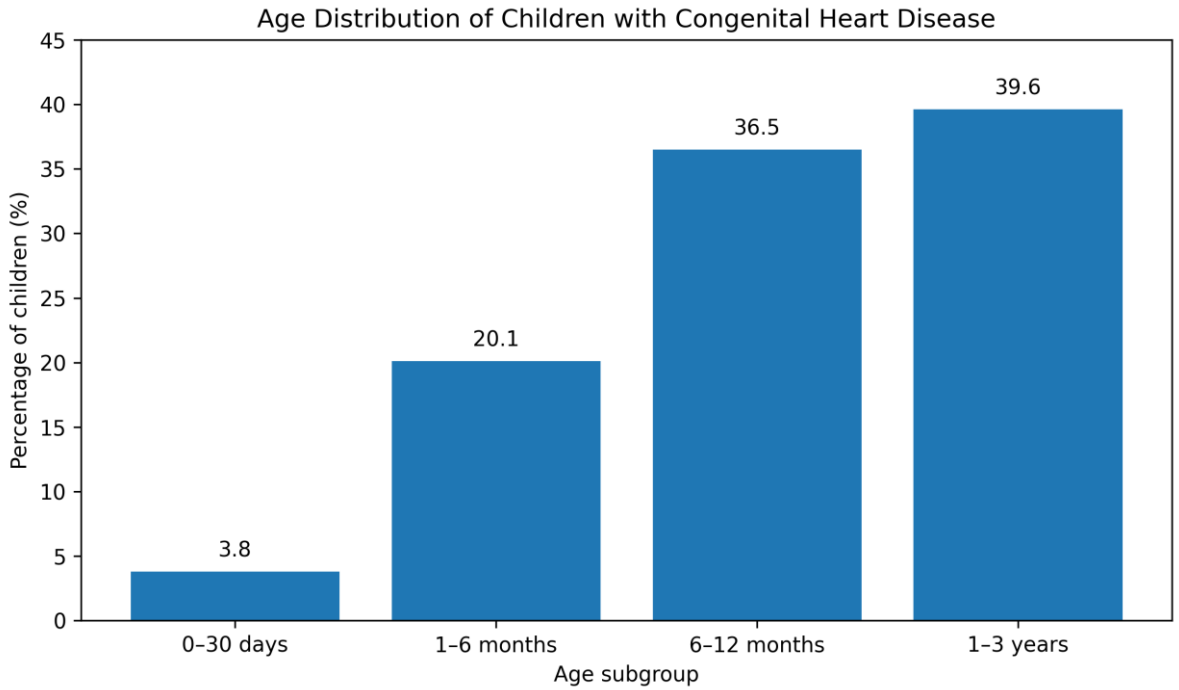


Figure 1. Age distribution of children with congenital heart disease (n = 159).

For analysis, defects were categorized as acyanotic or cyanotic according to anatomical and hemodynamic characteristics. Ventricular septal defect predominated among acyanotic lesions, whereas Tetralogy of Fallot was the most common cyanotic lesion. This grouping was preferred because administrative coding alone may not reliably capture anatomical CHD phenotypes (Ivey et al., 2023; Stephens et al., 2024).

Depending on the phenotype of the defect, we distinguished defects with left-to-right shunting, defects with right-to-left shunting, and combined defects. It was found that among acyanotic defects, VSD predominated, while among cyanotic defects, Tetralogy of Fallot was the most common. In addition, some children had CHD with potential transformation of an acyanotic defect into a defect with bidirectional shunting as a result of decompensation (Table 1).

Table 1. Distribution of children by age and CHD phenotype

Age Distribution of Children by Type of Congenital Heart Disease

Age subgroups	Cyanotic CHD, n	Cyanotic CHD, %	Acyanotic CHD, n	Acyanotic CHD, %	Total, n	Total, %
0–6 months, n (subgroup 1)	4	10.5	34	89.5	38	100
6–12 months, n (subgroup 2)	7	12.1	51	87.9	58	100
1–3 years, n (subgroup 3)	14	22.2	49	77.8	63	100
Total	25	15.7	134	84.3	159	100

A comprehensive examination of the children was conducted using standardized research methods. Analysis of life history and disease history was performed based on interviews with the children and their parents, as well as review of medical records, including Forms No. 111 and No. 25-u.

Assessment of anthropometric parameters was performed using the WHO Anthro software program (2009) and WHO AnthroPlus according to the following indicators: weight-for-age, weight-for-height, height-for-age, body mass index (BMI)-for-age, and z-score, reflecting the deviation of individual values from the mean reference values for the corresponding population.

Interpretation of the anthropometric measurement results in the observed patients was carried out according to the World Health Organization classification of malnutrition and ICD-10. Recent studies emphasize the importance of accurate anatomical and registry-based classification of congenital heart defects for epidemiological and outcome studies (Ivey et al., 2023; Stephens et al., 2024)

Anthropometric status was interpreted using World Health Organization growth standards. WAZ below −2 indicated underweight, HAZ below −2 indicated stunting, and WHZ or BMI-for-age below −2 indicated wasting or thinness. Values below −3 indicated severe impairment. Statistical analysis was performed in Statistica 10.0, SPSS 26.0, and Microsoft Excel. Quantitative variables are presented as mean

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± standard error and 95% confidence intervals; categorical variables are presented as numbers and percentages. Student's t test was used for continuous variables, while the chi-square test or Fisher's exact test was used for categorical variables. A two-sided p value < 0.05 was considered statistically significant.

RESULTS

Among children aged 0–6 months, severe underweight (WAZ ≤ −3) was present in 62.5% of boys and 28.6% of girls, whereas moderate underweight (−3 < WAZ ≤ −2) occurred in 25.0% and 35.7%, respectively. Severe stunting (HAZ ≤ −3) was identified in 37.5% of boys and 21.4% of girls, and moderate stunting in 25.0% and 14.3%, respectively.

Normal-range HAZ values (−2 to +2) were found in 37.5% of boys and 64.3% of girls. Severe wasting (WHZ ≤ −3) affected 54.2% of boys and 28.6% of girls, while moderate wasting affected 33.3% and 42.9%, respectively.

Only 12.5% of boys and 28.5% of girls had WHZ values within the normal range (−2 to +2).

Girls aged 0–6 months showed a higher proportion of WAZ, HAZ, and WHZ values within the normal range than boys: 35.7% versus 12.5%, 64.3% versus 37.5%, and 28.5% versus 12.5%, respectively (Table 2).

Table 2. Distribution of children aged 0–6 months according to WHO growth z scores

Distribution of children with congenital heart defects according to their compliance with WHO growth curves at 0–6 months of age

Deviation (SD)	WAZ boys, n=24	WAZ girls, n=14	WAZ boys, %	WAZ girls, %	HAZ boys, n=24	HAZ girls, n=14	HAZ boys, %	HAZ girls, %	WHZ boys, n=24	WHZ girls, n=14	WHZ boys, %	WHZ girls, %
≤ −3 SD	15	4	62.5	28.6	9	3	37.5	21.4	13	4	54.2	28.6
−2 to −3 SD	6	5	25.0	35.7	6	2	25.0	14.3	8	6	33.3	42.9
−1 to −2 SD	3	4	12.5	28.6	3	2	12.5	14.3	3	3	12.5	21.4
−1 SD	0	1	0	7.1	5	6	20.8	42.9	0	1	0	7.1
Median	0	0	0	0	1	0	4.2	0	0	0	0	0
+1 SD	0	0	0	0	0	1	0	7.1	0	0	0	0
+1 to +2 SD	0	0	0	0	0	0	0	0	0	0	0	0
+2 to +3 SD	0	0	0	0	0	0	0	0	0	0	0	0
≥ +3 SD	0	0	0	0	0	0	0	0	0	0	0	0
Total	24	14	100	100	24	14	100	100	24	14	100	100

Note: WAZ — Weight-for-age z score, HAZ — Height-for-age z score, WHZ — Weight-for-height z score, SD — Standard deviation

Among children aged 6–12 months, severe underweight was present in 17.9% of boys and 20.0% of girls, while moderate underweight occurred in 17.9% and 16.7%, respectively. WAZ values within the normal range were observed in 64.3% of boys and 63.3% of girls.

Normal-range HAZ values were found in 89.3% of boys and 73.3% of girls. Severe stunting occurred in 3.6% of boys and 16.7% of girls, while moderate stunting was absent in boys and occurred in 10.0% of girls. Overall, linear growth was less impaired than body weight in this age subgroup.

Physical-development indices improved modestly during the second half of the first year. The proportion of boys with normal-range HAZ values increased from 37.5% to 89.3%, and the corresponding proportion among girls increased from 64.3% to 73.3% (Table 3).

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Table 3. Distribution of children aged 6–12 months according to WHO growth z scores Distribution of children with CHD aged 6–12 months according to WHO growth curves,2nd subgroup, 6–12 months

Deviation (SD)	WAZ boys, n=28	WAZ girls, n=30	WAZ boys, %	WAZ girls, %	HAZ boys, n=28	HAZ girls, n=30	HAZ boys, %	HAZ girls, %	WHZ boys, n=28	WHZ girls, n=30	WHZ boys, %	WHZ girls, %
≤ −3 SD	5	6	17.9	20.0	1	5	3.6	16.7	12	3*	42.9	10.0
−3 to −2 SD	5	5	17.9	16.7	0	3	0	10.0	6	13*	21.4	43.3
−2 to −1 SD	13*	9	46.4	30.0	5*	3	17.9	10.0	6	9*	21.4	30.0
−1 SD	4*	9	14.3	30.0	9*	6	32.1	20.0	4	3	14.3	10.0
Median	0	0	0	0	1	0	3.6	0	0	0	0	0
+1 SD	1	1	3.6	3.3	4*	9	14.3	30.0	0	2*	0	6.7
+1 to +2 SD	0	0	0	0	6*	4	21.4	13.3	0	0	0	0
+2 to +3 SD	0	0	0	0	1	0	3.6	0	0	0	0	0
≥ +3 SD	0	0	0	0	1	0	3.6	0	0	0	0	0
Total	28	30	100	100	28	30	100	100	28	30	100	100

Note: * — statistically significant compared with girls at $p < 0.05$.

Among children aged 1–3 years with congenital heart disease (CHD), the proportion of boys with normal WAZ, HAZ, and WHZ values was 33.3%, 55.8%, and 53.9%, respectively, whereas among girls these values were 66.7%, 66.7%, and 66.7%, respectively. These data indicate that underweight and growth retardation/stunting were significantly more common among boys, with weight deficiency being more pronounced than growth retardation(Table 4).

Table 4. Distribution of children aged 1–3 years according to WHO growth z scores Distribution of children with CHD aged 1–3 years according to WHO growth curves,3rd subgroup, 1–3 years

Deviation (SD)	WAZ boys, n=39	WAZ girls, n=24	WAZ boys, %	WAZ girls, %	HAZ boys, n=39	HAZ girls, n=24	HAZ boys, %	HAZ girls, %	WHZ boys, n=39	WHZ girls, n=24	WHZ boys, %	WHZ girls, %
≤ −3 SD	12*	5	30.8	20.8	5*	1	12.8	4.2	12*	1	30.8	4.2
−3 to −2 SD	14*	3	35.9	12.5	11	5	28.2	20.8	6*	7	15.4	29.2
−2 to −1 SD	10*	12	25.6	50.0	11	6	28.2	25.0	12*	12	30.8	50.0
−1 SD	2*	2	5.1	8.3	5*	7	12.8	29.2	8	4	20.5	16.7
Median	0	0	0	0	2	0	5.1	0	0	0	0	0
+1 SD	0	1	0	4.2	3	2	7.7	8.3	1	0	2.6	0
+1 to +2 SD	1	1	2.6	4.2	1	1	2.6	4.2	0	0	0	0
+2 to +3 SD	0	0	0	0	0	0	0	0	0	0	0	0
≥ +3 SD	0	0	0	0	1	2	2.6	8.3	0	0	0	0
Total	39	24	100	100	39	24	100	100	39	24	100	100

Note: * — statistically significant compared with girls at $p < 0.05$.

In the control group, severe underweight and severe growth retardation/stunting were not detected. Changes in WAZ, HAZ, and WHZ within the range of −2Z to −3Z were observed only in 3.6% of cases among girls for HAZ and in 3.3% of boys for WHZ (Table5).

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Table 5. Distribution of control-group children according to WHO growth z scores
Distribution of children in the control group according to WHO growth curves, Control group, n=58

Deviation (SD)	WAZ boys, n=30	WAZ girls, n=28	WAZ boys, %	WAZ girls, %	HAZ boys, n=30	HAZ girls, n=28	HAZ boys, %	HAZ girls, %	WHZ boys, n=30	WHZ girls, n=28	WHZ boys, %	WHZ girls, %
≤ −3 SD	0	0	0	0	0	0	0	0	0	0	0	0
−3 to −2 SD	0	0	0	0	0	1	0	3.6	1	0	3.3	0
−2 to −1 SD	11	3*	36.7	10.7	3	0	10.0	0	11*	7	36.7	25.0
−1 SD	15	12	50.0	42.9	20	14	66.7	50.0	9	11	30.0	39.3
Median	1	2*	3.3	7.1	0	1	0	3.6	2	1	6.7	3.6
+1 SD	2	11*	6.7	39.3	7*	12	23.3	42.9	4*	7	13.3	25.0
+1 to +2 SD	1	0	3.3	0	0	0	0	0	2*	1	6.7	3.6
+2 to +3 SD	0	0	0	0	0	0	0	0	1	1	3.3	3.6
≥ +3 SD	0	0	0	0	0	0	0	0	0	0	0	0
Total	30	28	100	100	30	28	100	100	30	28	100	100

Note: * — statistically significant compared with girls at $p < 0.05$.

Birth weight below 2,500 g was observed in 18 children (11.3%); among them, 2 children (11%) had cyanotic congenital heart defects, while 16 children (89%) had acyanotic congenital heart defects. Assessment of the mean values and 95% confidence intervals for WAZ, HAZ, and WHZ demonstrated statistically significant differences compared with the control group in all age subgroups. Although birth weight did not differ between children with and without congenital heart disease, weight deficiency progressed during subsequent growth and development (Table 6).

Table 6. Physical-development indices in newborns with CHD (subgroup 1a)
Parameters of physical development in newborns with congenital heart defects (subgroup 1a)

Indicator	Control group		Subgroup 1a, 0–30 days		p
	M±m	95% CI	M±m	95% CI	
Birth weight, g;	3562±256	2747; 4377	3642±72.8	3489; 3796	>0.05
WAZ	0.34±0.42	-1.01; +1.69	-2.01±0.29	-2.77; -1.27	<0.05
HAZ	-0.27±0.09	-0.58; +0.05	-0.73±0.45	-1.90; -0.43	<0.05
WHZ	0.89±0.14	-1.47; 1.26	-2.45±0.25	−2.91 to −2.01	<0.05
BMI	14.9±0.9	12.2; 17.8	10.1±0.9	9.21; 10.6	<0.05

Note: CHD — congenital heart disease; HAZ — height-for-age z score; WHZ — weight-for-height z score; SD — standard deviation.

As shown in the table, the mean WAZ values in children of subgroup 1a were within the 95% CI of −2.77 to −1.27; HAZ values were within the range of −1.90 to −0.43; and BMI values ranged from 9.21 to 10.6. In subgroup 1b, the 95% CIs for WAZ, HAZ, and WHZ were −3.1 to −4.6, −3.34 to −1.84, and −3.31 to −1.76, respectively. BMI increased over time but remained significantly lower than in the control group (Table 7).

Table 7. Physical-development indices in children aged 1–6 months with CHD (subgroup 1b)

Indicators of Physical Development in Children with Congenital Heart Disease (CHD), Subgroup 1b

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Indicator	Control group		Subgroup 1 b (1–6 months)		p
	M±m	95% CI	M±m	95% CI	
WAZ	0.07±0.12	-0.19;+0.32	-3.8± 0.37*	−4.60 to −3.10	
HAZ	-0.28± 0.11	-0.51;+ 0.06	-2.59± 0.36*	-3.34; -1.84	
WHZ	0.07± 0.18	-0.31; +0.45	-2.5± 0.38*	-3.31; -1.76	
BMI	16.8± 0.38	16.0; 17.7	12.70±,28*	12.1; 13.2	

At the age of 1–6 months, there was a progression of both weight deficit, exceeding −3Z, and growth retardation, ranging from −2Z to −3Z. At the age of 6–12 months, the rate of lag in both growth and weight decreased, and children with congenital heart disease (CHD) showed WAZ and HAZ deviations within ±2Z. Moreover, the HAZ indicator was within ±1Z, while the decrease in BMI was mainly due to weight deficiency (Table 8).

Table 8. Physical-development indices in children aged 6–12 months with CHD (subgroup 2)

Indicators of Physical Development in Children with Congenital Heart Disease (CHD), Subgroup 2

Indicator	Control group		Subgroup 2 (6–12 months)		p
	M±m	95% CI	M±m	95% CI	
WAZ	-0.81±0.07	−0.96 to −0.67	-1.87± 0.16*	-2.20; -1.55	<0.05
HAZ	-0.03±0.10	-0.26;+0.19	-0.49± 0.23*	-0.97; -0.03	<0.05
WHZ	-1.07±0.03	−1.14 to −1.00	-1.82± 0.13*	-2.08; -1.57	<0.05
BMI	15.3±0.04	15.2; 15.4	14.1± 0.2	13.39; 14.89	<0.05

The trend toward a slight improvement in physical development indicators in children with congenital heart disease, which became evident in the second half of the first year of life, disappeared by the age of 2–3 years. Weight-for-age deficit remained stable at −2.30±0.17 Z-score, while the height-for-age indicator worsened almost twofold, decreasing from −0.49±0.23 Z-score to −1.14±0.21 Z-score (Table 9).

Table 9. Physical-development indices in children aged 1–3 years with CHD (subgroup 3)

Mean physical development parameters in children with congenital heart disease, subgroup 3

Indicator	Control group		Subgroup 3 (1–3 years)		p
	M±m	95% CI	M±m	95% CI	
WAZ	−0.24 ± 0.09	−0.44 to −0.09	-2.00±0.10*	-2.2; -1.83	<0.05
HAZ	0.08±0.05	-0.02; +0.18	-1.14±0.21*	-1.57; -0.71	<0.05
WHZ	-0.55±0.10	-0.77;+0.34	-2.30±0.17*	-2.67;-1.97	<0.05
BMI	15.1±0.1	14.8 to 15.5	13.5±0.2*	13.1;13.8	<0.05

The assessment of changes in mean physical development indicators among children with congenital heart disease revealed persistently reduced WAZ values, remaining below −2 Z-scores. In contrast, the mean HAZ values were generally within the acceptable −2 Z-score limits in both newborns with CHD and children older than 6 months. The most marked impairment in linear growth was recorded in the 6–12-month age group, where the HAZ value was −2.59±0.36 Z-score (Table 10, Figure 2).

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Table 10. Mean physical-development indices by age subgroup

Dynamics of mean physical development parameters in children with congenital heart disease

Age subgroup	WAZ (M±m)	HAZ (M±m)	WHZ (M±m)	Linear-growth pattern	
0–30 days	-2.01±0.29	-0.73±0.45	-2.45±0.25	Underweight	Normal height
1–6 months	-3.8± 0.37	-2.59±0.36	-2.5±0.38	Underweight	Growth retardation / stunting
6–12 months	-1.87± 0.16	-0.49±0.23	-1.82± 0.13	Weight decrease within 2 Z-scores	Normal height
1–3 years	-2.00±0.10	-1.14±0.21	-2.30±0.17	Weight decrease within 2 Z-scores	Normal height

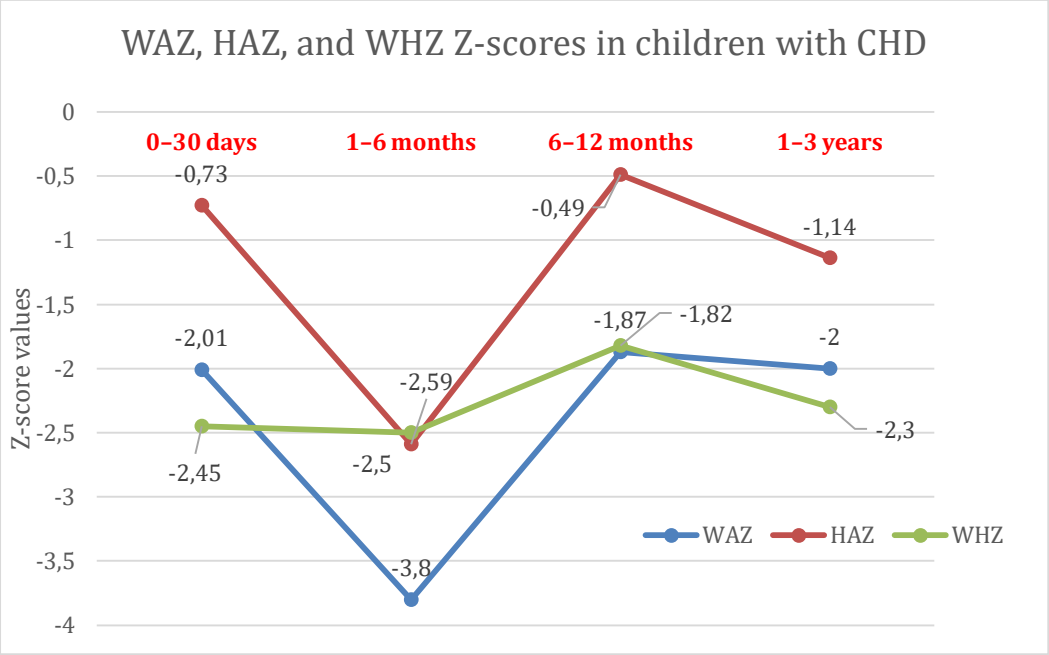


Figure 2

Figure 2 shows that nutritional impairment was greatest during the first 6 months of life. Among boys, severe underweight (WAZ ≤ −3) and severe stunting (HAZ ≤ −3) occurred in 62.5% and 37.5%, respectively; the corresponding proportions among girls were 28.6% and 21.4%. Normal-range WHZ values (−2 to +2) were found in only 12.5% of boys and 28.5% of girls ($p < 0.05$).

During the second six months of life, the parameters of physical development improved slightly: the proportion of boys without growth impairment increased 2.4-fold, from 37.5% to 89.3% ($p < 0.05$), while the proportion of girls without growth impairment increased from 64.3% to 73.3%. However, among children aged 1–3 years with CHD, the proportion of boys with normal WAZ values decreased 1.9-fold, from 64.3% in subgroup 2 to 33.3% ($p < 0.05$), and the proportion with normal HAZ values decreased 1.6-fold, from 89.3% to 55.8% ($p < 0.05$). In girls, the proportion with normal WAZ and HAZ values did not change significantly: the proportion of girls with normal WAZ values slightly increased from 63.3% to 66.7%, whereas the proportion with normal HAZ values slightly decreased from 73.3% to 66.7%. Normal WHZ values within ±2Z in subgroup 3 were observed in 53.9% of boys and 66.7% of girls.

These data indicate that, in children aged 1–3 years with CHD, underweight and growth retardation/stunting were significantly more common among boys, with weight deficiency being more pronounced than growth retardation. WHZ was −2.30±0.17, while the mean height-for-age z-score changed from −0.49±0.23Z to −1.14±0.21Z.

Most children with CHD (88.7%) had normal birth weight and length. During the first 6 months, however, severe underweight and wasting developed frequently, particularly among boys. Anthropometric indices improved modestly at 6–12 months but worsened again at 1–3 years, when weight deficit remained more pronounced than linear-growth impairment. These findings support intensified nutritional surveillance during infancy and early childhood.

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DISCUSSION

Malnutrition is common among children with CHD and reflects increased energy expenditure, feeding difficulties, chronic hypoxemia, pulmonary hypertension, heart failure, gastrointestinal dysfunction, and recurrent infection (Centeno-Malfaz et al., 2023; Luca et al., 2022; Smith et al., 2024; Vazzana et al., 2025; Zhang et al., 2020). The present finding that most children were born with normal anthropometric measurements but developed nutritional deficits during infancy is consistent with previous reports. The higher frequency of severe WAZ and WHZ impairment in cyanotic CHD further supports the role of hypoxemia and hemodynamic burden in growth failure. Regular assessment of WAZ, HAZ, WHZ, and BMI-for-age should be integrated into cardiology follow-up and perioperative nutritional planning.

Approximately two thirds of children with CHD are born with normal body weight, while nutritional disorders develop during the first year of life. This is consistent with our data. As shown by our results, among full-term children with CHD, with prematurity being an exclusion criterion in the study, 141 children (89%) did not have fetal growth restriction syndrome, and their birth weight and length were normal and did not differ from those in the control group. At the same time, nutritional disorders developed in these children during the first year of life, especially during the first 6 months.

The type of heart defect has a strong influence on nutritional status. Early correction of patent ductus arteriosus, atrial septal defect, and pulmonary stenosis almost completely eliminates the risk of nutritional disorders. Pulmonary atresia, Tetralogy of Fallot, combined septal defects, transposition of the great arteries, and hypoplastic left heart syndrome are associated with a high risk for impaired nutritional status. In general, according to Vazzana GF et al. (2025), acyanotic defects are associated with a moderate and sometimes high risk of nutritional disorders, whereas defects with a right-to-left shunt, that is, cyanotic defects, always carry a high risk, especially in the presence of pulmonary hypertension and late diagnosis of the defect. The distribution of children according to the severity of nutritional disorders depending on the type of heart defect showed the following. Weight-for-age deficiency was more frequent and more severe in children with cyanotic congenital heart defects (C-CHD) compared with children with acyanotic congenital heart defects (A-CHD), since the proportion of children with WAZ deviations exceeding −3Z was 1.4 times higher among patients with C-CHD (Table11). Recent regional data also indicate that metabolic changes associated with short-chain fatty acids may be involved in the perioperative condition of children with congenital heart disease (Agzamova & Babadjanova, 2025).

Table 11. WAZ distribution according to CHD phenotype

Indicator	WAZ	A-CHD, n	C-CHD, n	A-CHD, %	C-CHD, %
Deviation (SD)	≤ −3 SD	40	10*	29.9	40.0
	−2 to −3 SD	34	4	25.4	16.0
	−1 to −2 SD	41	10	30.6	40.0
	−1 SD	14	1	10.4	4.0
	Median	0	0	0.0	0.0
	+1 SD	4	0	3.0	0.0
	+1 to +2 SD	1	0	0.7	0.0
	+2 to +3 SD	0	0	0.0	0.0
	≥ +3 SD	0	0	0.0	0.0
Total		134	25	100.0	100.0

Height-for-age deviations did not depend on the type of heart defect, whereas the proportion of children with WHZ deviations below −3Z was significantly higher among patients with cyanotic defects: 32% versus 22.4% ($p < 0.05$) (Table 12).

Table 12. HAZ and WHZ distributions in acyanotic and cyanotic CHD

Deviation (SD)	HAZ acyanotic CHD, n	HAZ cyanotic CHD, n	HAZ acyanotic CHD, %	HAZ cyanotic CHD, %	WHZ acyanotic CHD, n	WHZ cyanotic CHD, n	WHZ acyanotic CHD, %	WHZ cyanotic CHD, %
≤ −3 SD	20	3	14.9	12.0	30	8	22.4	32.0
−3 to −2 SD	24	4	17.9	16.0	32	8	23.9	32.0

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Deviation (SD)	HAZ acyanotic CHD, n	HAZ cyanotic CHD, n	HAZ acyanotic CHD, %	HAZ cyanotic CHD, %	WHZ acyanotic CHD, n	WHZ cyanotic CHD, n	WHZ acyanotic CHD, %	WHZ cyanotic CHD, %
−2 to −1 SD	24	7	17.9	28.0	53	4	39.6	16.0
−1 SD	37	5	27.6	20.0	16	5	11.9	20.0
Median	0	0	0.0	0	0	0	0.0	0
+1 SD	15	4	11.2	16.0	2	0	1.5	0
+1 to +2 SD	9	1	6.7	4.0	0	0	0.0	0
+2 to +3 SD	2	0	1.5	0	0	0	0.0	0
≥ +3 SD	3	1	2.2	4.0	1	0	0.7	0
Total	134	25	100.0	100	134	25	100.0	100

Note: CHD — congenital heart disease; HAZ — height-for-age z score; WHZ — weight-for-height z score; SD — standard deviation.

CONCLUSION

Young children with CHD had substantially poorer growth and nutritional indices than controls. The greatest impairment occurred during the first 6 months of life, particularly among boys. Although some improvement was observed at 6–12 months, weight deficit persisted or re-emerged at 1–3 years. Cyanotic defects were associated with a higher frequency of critically low WAZ and WHZ values than acyanotic defects. Standardized, repeated anthropometric monitoring should begin early and should guide individualized nutritional, preventive, and therapeutic interventions.

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