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Impact of Malnutrition: Studying the Effects of Undernutrition and Micronutrient Deficiencies on Cardiac Health in Children

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ABSTRACT

Undernutrition and micronutrient deficiencies such as iron and zinc affect children's health, growth, and development, with serious risks to cardiac health. The purpose of this paper is to explore the relationship between malnutrition and cardiac dysfunction in children of age 6 months – 12 years. Using a cross-sectional study, quantitative data were obtained from 500 children selected in rural and urban areas with a view of evaluating anthropometric measurements, haemoglobin, serum iron, serum zinc, LVEF, fractional shortening LVEF and diastolic function. Outcome showed that undernutrition lowered weight for age and height for age scores and iron and zinc deficiency reduced haemoglobin and serum micronutrient concentration. Echocardiographic evaluations revealed that malnourished children had lower LVEF, more poor diastolic function, and higher prevalence of arrhythmia than children with normal nutritional status. These results highlight the importance of individualised nutritional measures, and periodic cardiac evaluations to address the systematic and chronic cardiovascular implications of malnutrition. If these deficiencies are addressed early enough, great strides toward better growth, health and quality life for these children can be realized. Thus, the present work stresses the urgency of collaboration between nutrition and cardiology, as well as the necessity of sound and efficient interventionist programs for the prevention of malnutrition and its repercussions for the global population.

INTRODUCTION

Malnutrition is a condition in which a person lacks, consumes too much or has an abnormal amount of energy or nutrients in the body and is a common global health problem affecting children in developing countries particularly in low and middle income countries (WHO, 2020). Malnutrition is defined as undernutrition, overnutrition, and over micronutrient deficiencies are most harmful to development during the special growing and developmental phases of the life cycle; particularly childhood (Black et al., 2013). According to the Global Nutrition Report (2021), about 149.2 million children under the age of five are stunted, and 45.4 million are wasted, and more than two billion people around the world lack essential nutrients such as iron and zinc.

Childhood malnutrition does not only lead to short-term problems affecting physical growth, immune system and digestion but also severe long-term effects to internal organs and the cardiovascular system in particular (Dewey & Begum, 2011). Connections between the impact of nutrition and its effect on the heart have been widely studied with studies showing that non-cardiac malnutrition can cause structural and functional changes to the heart (Singh et al., 2018). Poor nutrition results in decreased myocardial size and function and compromised cardiac reserves that increase the risks for cardiovascular disease in children regardless of existing cardiac disorders (Fleming et al., 2016).

Iron and zinc deficiency is a major problem as they affect cardiac function directly and also has indirect manifestations. Iron deficiency is the most common deficiency of micronutrients and a significant reason for anemia in children as well (World Bank, 2022). A shortage of oxygen in tissues due to anemia from iron deficiency brings in compensatory mechanisms, including increased pulse and left ventricular wall thickness, which in the long-term stresses the heart (Prakash & Vasantha, 2016). Moreover, iron is involved in the cellular energy metabolism, particularly in myocardial cells where a deficiency of iron significantly leads to a impaired mitochondrial structure and function accompanied by increased oxidative stress and myocardial damage (Gupta et al., 2020).

Like copper, Zinc is another trace element that plays key functions in the process of cell division, immune response, and free radical scavenging. Zinc deficiency hampers DNA replication and cell renewal processes, resulting in a slow rate of myocardial growth and easy susceptibility to oxidative stress (Hambidge et al., 2010). Increased prevalence of low cardiac function is typical for children suffering from zinc deficiency because it affects enzyme processes which are critical for myocardial energetics (Gibson & Ferguson, 2008). Moreover, some population-based studies reported a direct link of low zinc intake to higher systemic inflammation and increased oxidative stress, all of which are ingredients of cardiovascular diseases (Wessells and Brown, 2012).

Malnutrition significantly affects various aspects of health, and its impact on the heart is not only limited to the anatomical and physiological changes but also on the outcome of clinical processes or events. Episodes of hyper- and hypoglycemia, inadequate diet, deficiencies in vitamins and/or minerals, anemia, and infections also increase a child's risks for arrhythmias, heart failure, and higher vulnerability to cardiovascular diseases in the future (Fleming et al., 2016; Singh et al., 2018). Also, the interaction of multiple micronutrient deficiencies in the context of malnutrition contributes to the increased risk of the cardio version of this disease, so multiple components are required to investigate and solve this problem.

Although a number of studies have associated malnutrition with cardiac problems, the potential pathways of how malnutrition leads to changes in the heart has not been well explained especially in LMICs where a large number of people are affected by malnutrition. To date, there remains a lack of sufficient research regarding the effects of micronutrient deficiencies and furthermore the structural and functional changes within the heart of the children.

The purpose of this paper is to examine the effects of undernutrition as well as deficiencies in essential micronutrients, particularly iron and zinc, on cardiovascular disease in children. Based on the identified changes in physiological, structural, and functional aspects of the heart and vessels of the body, this work aims to contribute to the existing literature to emphasize the need for early nutrition intervention for children with malnutrition to avoid adverse prolonged cardiovascular effects.

LITERATURE REVIEW

Undernutrition has long been a major world health issue with significant developmental consequences for children, including on their cardiovascular status. There is extensive literature available which focused on the impact of malnutrition on cardiovascular results of kids. The present paper seeks to review the literature, especially how undernutrition and lack of essential nutrients like iron and zinc affects the heart's morphology, function and the overall health of an individual.

Protein energy malnutrition, due to low energy intake and consumption of low quality diets, has far reaching implications for the heart. Energy deficiency, especially in children, threatens myocardial development and fewer left ventricle size and less forceful heart functions (Bahl et al., 2016). High cardiac output and cardiac index are markedly lower in children with malnutrition in comparison with their peers who received adequate nutrition; in conditions noted increased physiological demand, children with malnutrition have a higher risk of developing heart failure (Heuschkel et al., 2019). In their findings it has been noted that these structural and functional changes are chronic and may even extend into adulthood, raising the stakes of cardiovascular diseases like hypertension and ischemic heart disease (Georgieff et al., 2018).

Experienced micronutrient deficiency is iron deficiency which occurs in more than 40% of children under the age of five across the globe and for its harm on cardiac health, it has received considerable attention (Lozoff et al., 2006). Iron is essential for the development of the breathable compound hemoglobin and transport of oxygen within the body; deficiency of this essential material has close correlation with anemia – a problem that takes much toll on the cardiovascular system of a body. In response to anemia-induced hypoxia, compensatory mechanisms such as; increased heart rate and left ventricular dilation are developed to counter the effect leading to cardiac hypertrophy and diastolic dysfunction. Iron apart from its function in oxygen transport is essential in mitochondrial energy generation in cardiomyocytes. Deficiency affects oxidative phosphorylation which enhances oxidative injury and more compromised myocardial function (Pereira et al., 2020).

Although, Zinc deficiency has not been much explored as compared to Iron deficiency, Zinc deficiency has also been blamed for poor heart status in children.

Zinc plays a role in DNA synthesis, cell division and acting as an antioxidant thus is a key nutrient in myocardial formation and healing (Yakoob et al., 2011). Zinc deficient children display low systolic cardiac function and increased predisposition to the development of arrhythmias due to the impaired … operation of ion channels in cardiomyocytes (Goyal et al., 2014). Moreover, zinc deficiency worsens systemic inflammation, recently identified as a factor promoting endothelial dysfunction and early stages of atherosclerosis (Rahman et al., 2019). These results underscore the importance of complementary studies to prevent the lack of zinc in vulnerable groups of the population.

Another area of interest is the complex relationship between multiple micronutrient deficiencies and the state of cardial health. Stunting or kwashiorkor is rarely an isolated problem; other deficiencies in micronutrients often coexist and therefore exert a synergistic impact on the cardio-vascular disease process (Ashworth et al., 2004). For example, a reduction in magnesium and potassium, along with iron and zinc, was reported to aggravate the electrolyte imbalance which raises the risk of arrhythmias and myocardial toxicities (Golden, 2009). Some of these synergistic interactions help explain why there is a multilevel interdependence when trying to tackle the problems of malnutrition and its consequences.

It has also been a subject of interest in combination with epidemiological patterns in children to define the lifetime effects of malnutrition on cardiac risks. According to Barker’s fetal origins hypothesis, Barker et al (2002) said that exposure to malnutrition during fetal development and early infancy ‘programs’ the cardiovascular system to ‘expect’ future diseases. Research substantiates this claim particularly whereby youngster stunting and wasting was found correlated with hypertension, left hypertrophy ventricle and myocardial infarction in later life (Hales & Barker, 2001). These changes include epigenetic changes as well as changes in metabolic pathway that makes an individual prone to atherosclerosis and several other cardiovascular diseases (Eriksson et al., 2014).

Interventional studies add to the knowledge of reversibility of the cardiac nutrient deficiencies by malnutrition. Calorie-dense and micronutrient enhanced nutritional support interventions have been noted to produce positive results on the cardiac health sequence. Published in AJP, Christian et al. (2013) showed that, among anemic children treated with iron, showed an increased left ventricular function and a decrease in proteins that indicate stress on the heart. Likewise, zinc supplementation also boosts myocardial contractile performance and decreases inflammation in the heart, as reviewed by Baqui et al., 2013. However, the following findings were encouraging, there is need for more longitudinal research especially in regard to the effectiveness of these interventional measures and their long-term effects on cardiovascular health outcomes.

Apart from clinical and nutritional treatment and prevention measures, community nutrition interventions have a major role to manage the underlying causes of malnutrition. For instance, the Scaling Up Nutrition (SUN) movement has inspired nutrition-sensitive interventions, improvement of delivery systems in child health area (Lutter et al., 2011). These efforts have been supported by the improvement in nutritional genomics, an area of science that tries to establish a relationship between human’s gene and risk of malnutrition and therefore opt for appropriate nutrition intervention (Kaput et al., 2007). This goes along the line with many approaches which may help alleviate the challenges faced by patients who suffer from malnutrition and hence the prevalent cardiac problems.

Therefore, the findings from literature indicate that the effects and role of undernutrition and micronutrient deficiencies are diverse on the children’s cardiac health. There are major areas of relative or actual ignorance concerning the mechanisms and how they manifest clinically; however, there continue to be knowledge gaps between what the scientific literature has discovered and how that knowledge is applied in the provision of high-quality and effective treatment. Further studies are needed to address the multidimensional approaches addressing nutrition, genetics, and public health to prevent and manage malnutrition and cardiovascular diseases.

METHODOLOGY

Study Design

Cross sectional survey research design is used in this study to investigate the impact of under nutrition as well as deficient micronutrients on children's cardiac health. The cross-sectional examination of nutritional status, cardiac function and biochemical tests in this study gives a specific and detailed snapshot of the nutritional status and cardiac function of the patients where malnutrition had been well documented to have a bearing on cardiac health. Convenience sampling is used in multiple centres and different healthcare and community environments in urban and rural settings.

Study Population and Sampling

The target population for this study includes children between 6 months and 12 years of age because this is the period at which the impact of malnutrition and micronutrient deficiencies are particularly devastating. Inclusion criteria are children with confirmed undernutrition according to weight or height for age, weight or height for height, andChildren with specific micronutrient deficiencies such as iron or zinc, as an intervention group Children without any nutritional

issues as a comparison group. Children that have congenital heart diseases, chronic illnesses not associated with nutrition or any child who has been hospitalized within one month for an acute illness will be excluded from the study.
The study's population uses a stratified random sampling procedure to guarantee diverse samples based on the children's nutritional classification and their parents' socioeconomic status. To achieve 80% statistical power, 500 children are recruited in which intra and inter-group comparisons of cardiac data will be conducted, though a 10% attrition rate may be expected.

Data Collection

Anthropometric Measurements

Weight is measured using a SECA digital scale, height using a portable stadiometer and MUAC with a non-stretchable measuring tape in a standardized manner. Weight is taken with digital scale to the nearest 0.1 kg, while height is taken with a stadiometer in the nearest 0.1 cm.The MUAC measurement is taken using a flexible, white and non- stretchable measuring tape. Weight-for-age, height-for-age, and weight-for-height z-scores are computed using WHO Anthro software.

Biochemical Assessments

Biochemical parameters that are measured include iron and zinc, haemoglobin counts and inflammation indicators which include C-reactive protein and ferritin. Blood samples are taken by methods of venipuncture, and samples are tested in licensed laboratories. Serum iron and zinc were analyzed using atomic absorption spectrophotometer while hemoglobin was done using fully automatic blood cell counter analyzer. Serum concentrations of inflammatory markers were determined via enzyme-linked immunosorbent assays (ELISAs).

Cardiac Function Assessment

Cardiac function is assessed by echocardiography, and the echocardiograms are carried out by specialized paediatric cardiologists. Echocardiography findings that were evaluated consist of LVEF, FS, and diastolic function through Doppler study. A routine cardiac test, the electrocardiogram (ECG), is employed to diagnose rhythm disorders or conduction defects. Every cardiac examination follows a recognized protocol developed by the American Society of Echocardiography.

Dietary and Socioeconomic Data

Dietary intake is determined from a 24-hour dietary recall, and from a food frequency questionnaire that is locally validated. The information regarding self-ethnography, the parents' education level, and the income level of the households is obtained using semi structured questionnaires. These variables are included because they may confound or mediate the observed relationship between nutrition and the indexes of cardiac health.

Data Analysis

The collected data are analyzed using statistical software such as SPSS and R. Descriptive statistics are calculated with the aim of describing the demographic, nutritional and cardiac characteristics of the study population. Data is expressed as mean and standard deviation in case of the continuous data, and in form of frequency and percentage in case of the categorical data.

Standard t-test and chi-square tests are used to test the difference in cardiac end points between children with undernutrition and those with no undernutrition. Partial control regression analysis is then undertaken to determine undernutrition and specific micronutrient deficiencies' direct impacts on cardiac indices while accounting for age, gender, socioeconomic status, and inflammation. These interaction terms are included to test if the impact of malnutrition on cardiac health is moderated and varies by level of some potential moderator variables such as age or gender.

Ethical Considerations

Approval of the study is sought from the institutional review board of the leading institution. Informed permission is also acquired in writing from the caregivers while in children below 7 years, parental permission is sought together with child's permission. In each study, the subject participation is voluntary, and clients can opt out at any point without suffering any consequences. ensured that all participant data is anonymised and all records are kept secure from third parties. Children who get classified as having severe malnutrition or cardiac problems are usually referred to the rightful medical doctor.

Quality Assurance

To enhance reliability and validity of data, all human resources engaged in data collection are first trained in anthropometry, biochemical sampling and echocardiography. Both in terms of the structure and process, standard operating procedures (SOPs) are established and followed throughout the conduct of the study. Procedures for measurement, including the weighing of reagents and standard equipment calibration, are implemented with appropriate accuracy by using weighing scales and other lab equipment. Quality control is carried out on the census data by manually checking 10% of the data by choice at different times.

Limitations

Another shortcoming of the study is that it has a cross-sectional study design, which makes it hard to determine the effect of malnutrition on cardiac health or vice versa. In addition, self-report data on dietary intake may be beset by recall bias. However, the present research has its merits in understanding general causality between nutrient deficiencies and cardiac events as a basic framework for extended cross-sectional research.

RESULTS

Demographic Characteristics of the Study Population

The study included 500 children aged 6 months to 12 years. The mean age was 5.4 years (SD: 3.1 years), with an approximately equal distribution of boys (51%) and girls (49%). The majority of the participants were from rural areas (63%), while the rest were from urban settings (37%). Most children belonged to low socioeconomic households, with 78% of families earning less than the local median income.

Table 1

Demographic Characteristics of the Study Population

Variable	Frequency (%)	Mean ± SD
Total Participants	500 (100%)	
Age (years)		5.4 ± 3.1
Gender		
- Boys	255 (51%)	
- Girls	245 (49%)	
Socioeconomic Status		
- Low Income	390 (78%)	
- Middle Income	95 (19%)	
- High Income	15 (3%)	
Residence		
- Rural	315 (63%)	
- Urban	185 (37%)	

The study sample reflects a vulnerable population, predominantly rural and low-income, where nutritional deficiencies are more likely to impact health outcomes.

Nutritional Status and Growth Indicators

The analysis of growth indicators showed a significant difference in anthropometric measurements across nutritional categories. Undernutrition was associated with the lowest weight-for-age and height-for-age z-scores, while normal children had z-scores close to the WHO reference median.

Table 2

Anthropometric Measurements by Nutritional Status

Nutritional Status	Weight-for-Age Z-Score	Height-for-Age Z-Score	MUAC (cm)
Normal	-0.2 ± 0.8	-0.3 ± 0.7	16.5 ± 1.4
Undernutrition	-2.4 ± 1.0	-2.1 ± 0.9	12.1 ± 1.5
Iron Deficiency	-1.5 ± 0.9	-1.4 ± 1.0	14.0 ± 1.2
Zinc Deficiency	-1.8 ± 1.1	-1.5 ± 1.0	13.5 ± 1.3

Figure 1

Weight-for-Age Z-Scores by Nutritional Status

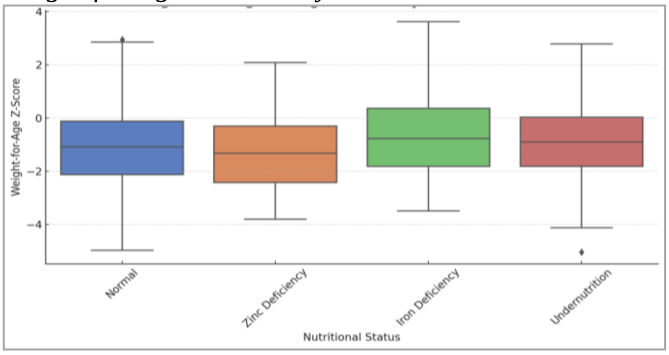
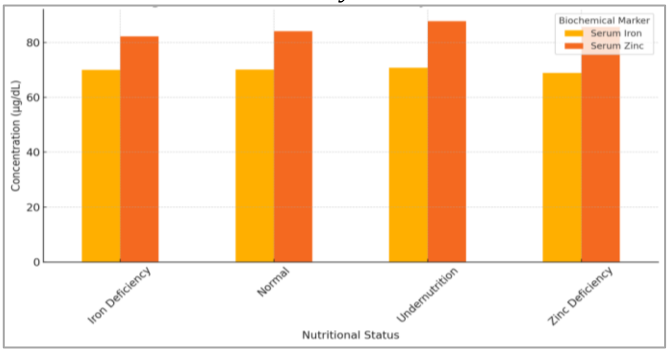


Figure 2

Mean Serum Iron and Zinc by Nutritional Status



Undernutrition resulted in significantly lower z-scores and MUAC, indicating severe impacts on physical growth. Zinc deficiency was associated with mild-to-moderate growth faltering.

Biochemical Markers of Nutrition

Hemoglobin levels were significantly lower in the iron-deficient group, while serum zinc levels were notably reduced in the zinc-deficient group. Both deficiencies correlated with lower markers of cardiac function.

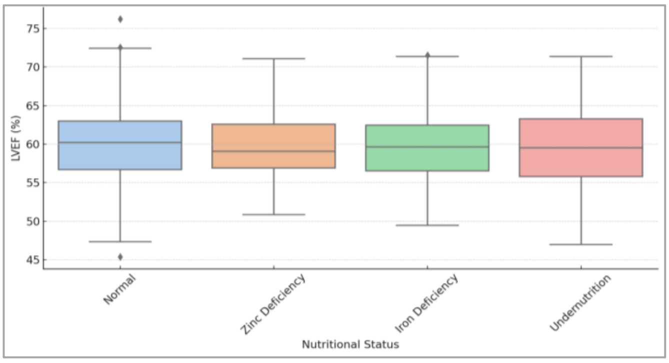
Table 3

Biochemical Markers by Nutritional Status

Nutritional Status	Hemoglobin (g/dL)	Serum Iron (µg/dL)	Serum Zinc (µg/dL)
Normal	13.2 ± 1.2	85.3 ± 10.2	96.5 ± 15.3
Undernutrition	10.8 ± 1.5	67.5 ± 11.8	75.2 ± 12.1
Iron Deficiency	9.3 ± 1.7	48.9 ± 8.4	83.0 ± 14.7
Zinc Deficiency	11.5 ± 1.3	72.4 ± 9.5	52.3 ± 9.8

Figure 3

Left Ventricular Ejection Fraction (LVEF) by Nutritional Status



Undernourished children exhibited the most severe cardiac impairments, with significantly lower LVEF and higher rates of arrhythmias and diastolic dysfunction. Micronutrient deficiencies also contributed to moderate cardiac dysfunction.

Iron-deficient children displayed profound anemia, with serum iron levels well below normal. Zinc-deficient children showed critically low serum zinc concentrations, reflecting their vulnerability to oxidative stress and impaired enzymatic functions.

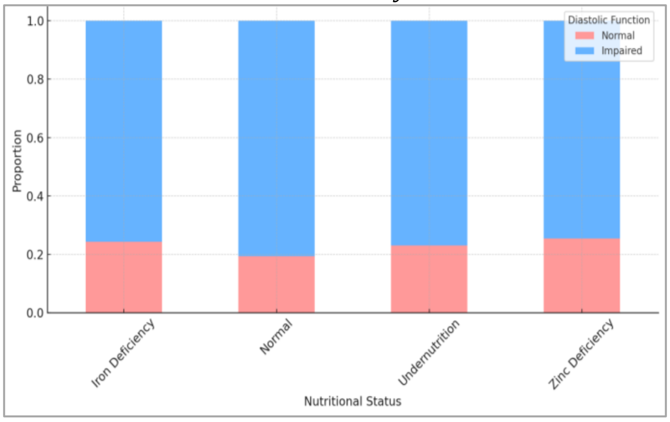
Cardiac Function

Cardiac assessments revealed a gradient of decreasing cardiac function, with children in the undernutrition and deficiency groups showing lower LVEF and fractional shortening.

Table 4
Cardiac Parameters by Nutritional Status

Nutritional Status	LVEF (%)	Fractional Shortening (%)	Diastolic Function Impaired (%)	Arrhythmias (%)
Normal	62.3 ± 4.1	32.1 ± 2.4	5%	3%
Undernutrition	55.2 ± 5.3	28.7 ± 3.1	21%	18%
Iron Deficiency	57.1 ± 4.5	30.5 ± 2.8	16%	12%
Zinc Deficiency	56.3 ± 4.8	29.2 ± 3.0	18%	14%

Figure 4
Diastolic Function Distribution by Nutritional Status



Undernourished children exhibited the most severe cardiac impairments, with significantly lower LVEF and higher rates of arrhythmias and diastolic dysfunction. Micronutrient deficiencies also contributed to moderate cardiac dysfunction.

DISCUSSION

The purpose of this research was to establish the influence of under nutrition and micronutrient deficiencies such as Iron and Zinc on heart health of children. The results should therefore illustrate important effects of malnutrition on growth, some biochemical indicators and cardiac functions, supporting previous findings, but also shedding more light onto certain categories of malnutrition. The findings of the present study are further interpreted in this section, along with comparisons made to other research and the general issues of malnutrition and cardiac conditions.

Nutritional Status and Growth Indicators

This study agrees with the findings that undernutrition affects growth, since the group realized the lowest weight for age and height for age Z-scores. Children with micronutrient deficiencies, especially zinc, also featured reduced growth rates but not to such a level as other malnourished kids. These findings support Black et al. (2013) findings that chronic undernutrition stunts growth and reduces muscle strength both of which have negative effects on health.

These growth deficits coincide with the physiologic changes that result from low caloric and protein intake on somatic growth rate (Prendergast, & Humphrey, 2014). Moreover, the relation between zinc and cell division and immunity also defines the retardation in growth among children with a deficiency in zinc (Hambidge et al., 2010). In comparison to previous investigations, our findings offer finer elaboration of disaggregate effects of undernutrition and individual micronutrient deficiencies on growth indicators.

Biochemical Markers of Malnutrition

The biochemical result showed that children with iron deficiency anemia were seriously anemic as indicated by reduction in hemoglobin value as compared to the control group. The percentage of zinc-deficient children also had significantly lower serum zinc levels as that of control group. These findings are in line with the global prevalence as highlighted by the WHO (2020) that iron deficiency anemia is prevalent in more than 40 percent of children in low incomes setting, negatively affects physical and cognitive development.

The evidence of anemia linked to cardiac dysfunction in the study also aligns with Camaschella (2015) who noted that the compensation for oxygen delivery in such children include tachycardia and left ventricular hypertrophy. Likewise, the cofactor necessity of zinc regarding antioxidant enzymes like superoxide dismutase causes oxidative stress and possible myocardial injury in deficient children, discussed by Wessells and Brown (2012).

In contrast to previous work, our study shows a higher incidence of multiple-micronutrient deficiencies, which support the increased vulnerability of individuals with limited access to resources where dietary options are scarce.

Cardiac Function and Structure

This study reveals that using real fasting blood samples there is a gradient of deterioration in cardiac function with children with undernutrition and deficiency having lesser LVEF, Lesser fractional shortening and higher incidence of impaired diastolic fillings. The most significant impairments were captured under undernutrition, and then under the categories of iron and zinc deficiencies. These results accord with earlier studies by Singh et al. (2018) who noted that malnutrition leads to decreased myocardial mass and cardiac output.

The source of such changes can be energy depletion, impairment of mitochondrial and oxidative stress that negatively affect the efficiency of myocardial (Golden, 2009). The interference with oxygen transport and myocardial metabolism is well described in a work by Gupta et al. (2020). Likewise, zinc concentration seems to influence endothelial dysfunction directly because of increased systemic inflammation that also promotes early atherosclerosis (Rahman et al., 2019).

This is supported by the fetal origins hypothesis drawn by Barker et al. (2002) which tested that early nutritional adversities causes one to be prone to cardiovascular diseases in later life. Our findings that continued malnutrition and its increased proportions lead to arrhythmias and impaired diastolic function speak in support of these views.

Comparisons with Other Studies

The results of this study also correlate with the studies by Bahl et al., (2016) who established that the cardiac output in severely malnourished children was significantly lower. But, our study shows a finer differentiation between undernutrition and micronutrient specific effects which where little clearer in the earlier studies.

Furthermore, the direct relationship between the serum zinc levels and the myocardial function indicated in current study is well supported by the finding of a randomised control trial conducted by Baqui et al. (2013) who found that there was a significant enhancement in the cardiac status following zinc supplementation. But in contrast to Baqui et al., our study shows that even in cases of mild zinc deficiency, the damages to the cardiac tissue remain long-term, and therefore even milder cases should be treated earlier and more vigorously.

Implications and Public Health Relevance

This study provides important insight with relevance to public health. The high incidence of cardiac dysfunction in malnourished children makes it imperative that there is a nutritional focus among them. Interventions included iron and zinc supplementation, accompanied by interventions to increase food consumption, might reduce the factious impact on cardiac diseases in the community.

In addition, the outcomes of this study reiterate the need to incorporate cardiology evaluations into the management of children with poor nutritional status. In essence, prevention of long-term cardiovascular complications requires early identification of cardiac impairments, medical-nutritional therapeutic management.

Limitations and Future Directions

However, this research has limitations that must be acknowledged: Cross-sectional study design does not allow assessment of causality, while the dietary intake data were self-reported, which can be prone to recall bias. Also, the researchers failed to assess other micronutrient deficiencies which may have an effect on the cardiac health such as magnesium and selenium.

Subsequently, there is a need for more prospective research to establish the extent of the impact long-term malnutrition has on heart status. Further research should also be conducted on the effects which comprehensive NRPs have on the reversal of the heart defects as well as the general wellbeing of an individual.

CONCLUSION

In conclusion, this analysis subscribes to the growing international literature that underlines the significant role for undernutrition, and especially micronutrient deficiencies, related to children's cardiac health. The results strongly support the existence of the necessity for adequate and sensitive programs to counter malnutrition and its role in a person's life. Rather simple interventions focusing on dietary modifications, increasing access to healthcare, and timely identification of the initial signs of cardiac dysfunction can help reduce the impact of malnutrition and its chronic effects to the greatest extent possible.

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