ORIGINAL ARTICLE

Assessment of Combined Left Ventricular Function by Myocardial Performance Index in Children with Sickle Cell Anaemia in Steady State at a Nigerian Tertiary Hospital: A Comparative Study

Falaye Adejoke Monsurat[1], Liman Biliyaminu Ibrahim[2]

Abstract

Background: Children with sickle cell anaemia (SCA) are at risk of early cardiac dysfunction due to chronic anaemia and volume overload. Conventional echocardiographic indices may underestimate myocardial impairment, as they are load-dependent. The myocardial performance index (MPI) provides a relatively load-independent assessment of combined ventricular function.

Objective: To assess combined (systolic and diastolic) left ventricular (LV) function using MPI in children with SCA in steady state and compare findings with age- and sex-matched controls.

Methods: This comparative cross-sectional study involved 340 children with SCA in steady state and 340 HbAA controls aged 2–15 years at Usmanu Danfodiyo University Teaching Hospital, Sokoto. All participants underwent clinical evaluation and transthoracic echocardiography. LV MPI was calculated as (IVCT + IVRT)/ET. Conventional systolic and diastolic indices were also assessed. Data were analysed using SPSS version 23. Statistical significance was set at $p < 0.05$.

Results: The mean LV MPI was significantly higher in subjects than controls (0.52 ± 0.20 vs 0.48 ± 0.10; $p = 0.002$). A higher proportion of subjects had combined LV dysfunction using MPI (65.6%) compared with EF (15.0%) and FS (23.8%). MPI showed a moderate positive correlation with IVRT ($r = 0.652$; $p < 0.001$) and weak negative correlations with EF, DT, and E/A ratio.

Conclusion: Children with SCA in steady state exhibit significant combined LV dysfunction detectable by MPI despite relatively preserved conventional systolic indices. MPI is a sensitive tool for early identification of myocardial dysfunction and should be incorporated into routine cardiac evaluation of children with SCA.

Keywords: Sickle cell anaemia; Myocardial performance index; Left ventricular function.

Introduction

Sickle cell anaemia (SCA) is a chronic inherited haemoglobin disorder resulting from a point mutation in the β-globin gene, leading to the production of haemoglobin S. It is characterised by chronic haemolytic anaemia, episodic vaso-occlusion, and progressive multi-organ damage.[1] Globally, over 300,000 children are born annually with SCA, with sub-Saharan Africa accounting for more than 75% of the burden[2]. Nigeria alone contributes the highest number of affected births worldwide, making SCA a major public health concern in the country.[3]

Improvements in childhood survival due to better infection control, vaccination, and supportive care have led to a growing population of children and adolescents living with SCA. Consequently, chronic complications such as cardiovascular involvement are increasingly recognised contributors to morbidity and reduced quality of life. [4] The heart is particularly vulnerable in SCA because of sustained haemodynamic stress from chronic anaemia, recurrent

Date Received- 24 February 2026, Date Accepted- 14 July 2026
Date Published online- 25 August 2026

Corresponding author
Dr Falaye Adejoke Monsurat
Federal Teaching Hospital Birnin Kebbi,
PMB 1126, Kebbi State, Nigeria
falayeadejoke@gmail.com
+2348060339921
https://orcid.org/0009-0006-8342-4045

[1]Department of Paediatrics, Federal Teaching Hospital, Birnin Kebbi.

[2]Department of Surgery, Federal Teaching Hospital, Birnin Kebbi

Published by: MEDICAL AND DENTAL CONSULTANTS' ASSOCIATION OF NIGERIA (MDCAN)
FEDERAL UNIVERSITY TEACHING HOSPITAL, LAFIA, NASARAWA STATE

Falaye AM, Liman BI: Assessment of Combined Left Ventricular Function by Myocardial Performance Index in Children with Sickle Cell Anaemia in Steady State at a Nigerian Tertiary Hospital: A Comparative Study. *Nasarawa Journal of Medicine* 2026: 3 (1) 15-20

NASJM

hypoxic injury, endothelial dysfunction, and microvascular occlusion.[5]

Chronic anaemia in SCA results in a persistently high-output circulatory state. To compensate, there is an increase in stroke volume and cardiac output, leading to left ventricular (LV) dilatation and eccentric hypertrophy. Over time, these adaptive changes may progress to maladaptive remodelling, impaired ventricular relaxation, and eventual systolic dysfunction.[6] Autopsy and imaging studies have demonstrated myocardial fibrosis and microinfarction even in children and young adults with SCA, suggesting that myocardial involvement begins early in life. [7]

Echocardiography is the most widely used non-invasive tool for cardiac assessment in children with SCA. Conventional indices such as ejection fraction (EF) and fractional shortening (FS) are commonly employed to evaluate LV systolic function.[8] However, these parameters are highly dependent on preload and afterload, which are significantly altered in chronic anaemia. As a result, EF and FS may remain within normal limits despite underlying myocardial dysfunction, thereby underestimating the true burden of cardiac involvement in SCA. [9]

Diastolic dysfunction has been increasingly recognised as an early manifestation of sickle cell cardiomyopathy.[10] Abnormalities in ventricular relaxation and compliance may precede overt systolic dysfunction and are associated with adverse outcomes, including exercise intolerance and pulmonary hypertension. [11] Conventional Doppler indices of diastolic function, such as E/A ratio and deceleration time, are also influenced by loading conditions and heart rate, limiting their sensitivity in isolation.[12]

The myocardial performance index (MPI), also known as the Tei index, is a Doppler-derived parameter that combines systolic and diastolic time intervals to provide a single measure of combined ventricular performance.[13] It is calculated as the sum of isovolumetric contraction time and isovolumetric relaxation time divided by ejection time. The MPI is relatively independent of ventricular geometry, heart rate, and loading conditions, making it particularly useful in conditions characterised by altered haemodynamics, such as SCA. [13]

Recent studies from different regions have demonstrated the utility of MPI in detecting subclinical myocardial dysfunction in children with SCA.[14,15] However, data from Nigeria and much of sub-Saharan Africa remain limited, despite the high disease burden. Establishing baseline data on MPI in Nigerian children with SCA is crucial for early identification of cardiac dysfunction and for guiding long-term surveillance strategies. Therefore, this study assessed combined left ventricular (LV) function using MPI in children with SCA in steady state and compared the findings with those of age- and sex-matched healthy controls to determine the proportion of children with evidence of combined LV dysfunction.

Materials and Methods

Study Design and Setting

This was a comparative cross-sectional study conducted at the Sickle Cell Clinic and Paediatric Cardiology Unit of Usmanu Danfodiyo University Teaching Hospital (UDUTH), Sokoto, a major tertiary referral centre in Northwestern Nigeria.

Study Population

The study population consisted of children aged 2–15 years with confirmed sickle cell anaemia (HbSS) who attended the Sickle Cell Clinic at UDUTH. The sickle cell clinic runs on Wednesday every week with an average of 50 to 60 children seen per day, both new and old patients. (An estimate of about 2,400 children yearly). The lower age limit of 2 years was selected because the earliest cardiac manifestations of sickle cell anaemia are typically reported from this age [16] while the upper limit of 15 years reflected the hospital's paediatric age cutoff. Age- and sex-matched children with normal haemoglobin genotype (HbAA), attending the general paediatric outpatient clinic for minor ailments, served as controls.

Eligibility Criteria

Children with SCA were included if they were in steady state. This was defined as the absence of acute painful crisis, febrile illness, blood transfusion, or hospitalization in the preceding three months.[17] Study controls were children with HbAA, on follow-up at the paediatrics outpatient department clinic for minor illnesses such as uncomplicated malaria, upper respiratory tract infection, and other non-chronic illnesses not known to affect cardiac function.

Exclusion criteria included the presence of congenital or acquired heart disease. Children with a tricuspid regurgitation velocity (TRV) of ≥2.5 m/s were excluded because this threshold was considered suggestive of elevated pulmonary artery pressure and increased cardiopulmonary risk in sickle cell disease. The TRV was preferred because it is a practical, non-invasive echocardiographic screening parameter that could be measured during the study examination. Children with Hb SC, Hb CC, chronic kidney disease, chronic liver disease, malnutrition or those using cardioactive medications such as Digoxin, Dobutamine, Epinephrine, etc., were also excluded. Controls with anaemia (packed cell volume <30%) were also excluded.

Ethical considerations

The study protocol was reviewed and approved by the Ethics and Research Committee of the Usmanu Danfodiyo University Teaching Hospital, Sokoto (UDUTH/HREC/2019/754). Informed consent was obtained from parents in their local languages before participation in the study. Confidentiality of patient data was also maintained throughout the study.

Sample Size and Sampling Technique

A minimum sample size was calculated using standard formulae for comparative studies, based on previous reports of MPI differences in children with SCA.[9] A total of 340 children with sickle cell anaemia and 340 age- and sex-matched controls were enrolled. Participants with sickle cell anaemia were selected by simple random sampling from clinic attendance registers. If a selected participant had already been enrolled or did not meet the eligibility criteria, another participant was selected using the same sampling procedure. Controls were recruited from the follow-up and general outpatient clinics and matched individually to cases by age (±6 months) and sex. In nine instances where a sex-matched control was unavailable, a control of the opposite sex was enrolled to maintain the required sample size. Data collection was conducted over 24 months, from August 2020

to July 2022.

Data Collection

A structured self-administered questionnaire adapted from related studies on LV function assessment using MPI[7,11] was used to collect socio-demographic data, clinical history, and physical examination findings. The instrument was reviewed by experts for content validity and pretested among approximately 10% of the sample in a comparable health facility. Reliability testing produced a Cronbach alpha coefficient of 0.80. Anthropometric measurements were obtained using standard techniques.

Packed cell volume was measured for all participants. About 4 mL of venous blood was collected into EDTA bottles from each control for haemoglobin electrophoresis.

Echocardiographic Assessment

Transthoracic echocardiography was performed using a Sonoscape SSI-5000 machine with a 3.5–7.0 MHz transducer. Studies were conducted with participants in the left lateral decubitus position. Standard parasternal long-axis, short-axis, and apical four-chamber views were obtained according to American Society of Echocardiography guidelines.

LV systolic function was assessed using ejection fraction (EF) and fractional shortening (FS) using the Teichholz method. Diastolic function was evaluated using transmitral Doppler indices including E and A wave velocities, E/A ratio, isovolumetric relaxation time (IVRT), and deceleration time (DT). Myocardial performance index was calculated as:

MPI = (IVCT + IVRT) / ET

Cut off Value for normal MPI = 0.34 ± 0.03[17,18]

All measurements were averaged over three cardiac cycles. To minimise inter-observer variability, all echocardiographic examinations were performed by the same experienced paediatric cardiologist, who conducted approximately 8–10 studies per week.

Statistical Analysis

Data were checked for completeness and consistency at the point of collection and before entry into SPSS. The clinical and echocardiographic assessments were completed during the study visit, and the original proforma and stored echocardiographic records were consulted where clarification was required. Complete data for the primary and principal echocardiographic variables were available for all 680 participants included in the analysis. Therefore, no statistical imputation of missing data was undertaken. Data were analysed using SPSS version 23. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. An independent t-test was used to compare means between groups. A chi-square test was used for categorical variables. Pearson correlation analysis was performed to assess relationships between MPI and other echocardiographic indices. Statistical significance was set at $p < 0.05$.

Results

A total of 680 children were recruited, comprising 340 subjects and 340 controls aged 2 to 15 years, with no significant difference in mean age or age categories between the two groups. Among the subjects, males and females were equally represented, while the controls had slightly more females than males, as shown in Table1 below

Baseline characteristics of the study population

The mean weight, mean height and mean body surface area (BSA) in controls were higher than in the subjects, but the differences were not statistically significant. In addition, the mean pulse rate among the subjects was 96.48 ± 14.9 beats per minute, compared with 94.70 ± 15.1 beats per minute among the controls. Although the mean pulse rate was slightly higher among the subjects, the difference was not statistically significant (t = 1.54, p = 0.124), as shown in Table II below.

Mean values for MPI, systolic and diastolic function parameters of the left ventricles

Table III compares the myocardial performance index (MPI) and conventional echocardiographic indices of left ventricular function between subjects and controls. The mean LV MPI (0.52 ± 0.2) for the subjects was significantly higher than that of the controls (0.48± 0.01), p= 0.002.

Table I: Distribution of the subjects and controls by age and gender

Variables	Subjects; **n** (%)	Controls; **n** (%)	χ^2	p-values
Age categories (years)				
≤ 5	62(18.3)	83(24.4)		
>5 -10	165(48.5)	169(49.7)	7.035	0.060
>10 -15	113(33.2)	88(25.9)		
Mean	8.6±3.4	8.4 ± 3.7		
Gender				
Male	170(50.0)	161(47.4)	0.540	0.462
Female	170(50.0)	179(52.6)		

Table II : Baseline characteristics of subjects and controls

Variables	Subject (HbSS) Mean ±SD	Control (HbAA) Mean ±SD	t-Test	p-value
Weight(kg)	22.11±8.2	24.50±12.6	8.141	0.070
Height(cm)	119.08±21.3	121.88±18.2	7.761	0.085
BSA	0.86±0.2	0.88±0.3	25.053	0.250
Mean pulse rates (bpm)	96.48±14.9	94.70±15.1	1.54	0.124

Furthermore, Subjects had a significantly lower ejection fraction (61.44 ± 9.5% vs. 63.34 ± 7.3%; $p = 0.006$), shorter deceleration time (111.81 ± 28.5 vs. 129.40 ± 25.6 ms; $p < 0.001$), and higher E/A ratio (1.77 ± 0.3 vs. 1.61 ± 0.2; $p < 0.001$) and E-wave velocity (105.78 ± 15.3 vs. 98.43 ± 14.1 cm/s; $p < 0.001$) than controls. Fractional shortening, isovolumic relaxation time, and A-wave velocity were comparable between the groups ($p > 0.05$).

Myocardial Performance Index

Table IV shows that the prevalence of abnormal left ventricular function was significantly higher among subjects than controls based on the myocardial performance index (65.6% vs. 43.2%; $p = 0.014$), ejection fraction (15.0% vs. 9.4%; $p = 0.004$), and fractional shortening (23.8% vs. 11.5%; $p < 0.001$). Significant between-group differences were also observed for deceleration time ($p < 0.001$) and E/A ratio ($p = 0.017$), whereas the prevalence of abnormal isovolumic relaxation time (IVRT) was comparable between the groups ($p = 0.155$).

Correlation Analysis

IVRT was the only variable exhibiting a significant positive correlation with LV MPI in both groups (Subjects: r=0.652; Controls: r=0.472; both p<0.001), indicating it is the most consistent determinant of MPI irrespective of disease status (Table V).

In Controls, additional modest but significant correlations emerged, i.e., DT (negative), E velocity (positive), and A velocity (positive). In Subjects, however, the diastolic filling profile, i.e., E/A ratio and E velocity, showed a significant negative correlation while A velocity lost significance. Notably, EF and FS showed no correlation with LV MPI in either cohort.

MPI showed a moderate positive correlation with IVRT (r = 0.652; p < 0.001) and weak negative correlations with EF, FS, DT, E/A ratio, and E velocity. These findings suggest that worsening combined ventricular performance is predominantly related to impaired diastolic function, as shown in Table V below

Discussion

This study demonstrates that children with sickle cell anaemia in steady state have a significantly higher myocardial performance index than age- and sex-matched healthy controls, indicating early combined left ventricular dysfunction. Importantly, this dysfunction was detected despite relatively preserved conventional systolic indices, highlighting the limitations of relying solely on ejection fraction and fractional shortening in this population.

The pathophysiology of cardiac involvement in SCA is

Table III: MPI and other conventional echocardiographic indices of LV function among the study population

Variables	Subjects (Mean ±SD)	Controls (Mean ±SD)	t-Test	P-value
MPI	0.52 ± 0.2	0.48± 0.01	3.128	0.002
EF(%)	61.44±9.5	63.34± 7.3	2.747	0.006
FS(%)	33.30± 7.3	33.98± 5.7	1.279	0.201
IVRT(m/s)	67.19± 11.9	66.49±13.4	0.678	0.498
DT(m/s)	111.81± 28.5	129.40±25.6	7.953	<0.001
E/A ratio	1.77± 0.3	1.61± 0.2	7.296	<0.001
E vel.(cm/sec)	105.78± 15.3	98.43± 14.1	6.110	<0.001
A vel.(cm/sec)	61.90± 27.3	61.98± 13.0	0.047	0.962

Table IV: Combined ventricular dysfunction using MPI and conventional echocardiographic indices in subjects and controls

Echocardiographic index	**Subjects, n** (%) abnormal	**Controls, n** (%) abnormal	χ^2	**p-value**
MPI	223 (65.6)	147 (43.2)	6.41	0.014
Ejection fraction	51 (15.0)	32 (9.4)	9.04	0.004
Fractional shortening	81 (23.8)	39 (11.5)	25.44	<0.001
IVRT	102 (30.0)	119 (35.0)	2.29	0.155
Deceleration time	71 (20.9)	128 (37.6)	27.80	<0.001
E/A ratio	73 (21.5)	98 (28.8)	6.10	0.017

Table V: Correlation between LV MPI and conventional echocardiographic indices of LV functions in subjects and controls.

Variables	**Subjects**		**Controls**	
	r	p-value	r	p-value
EF	-0.069	0.234	-0.013	0.818
FS	-0.081	0.160	-0.005	0.925
IVRT	0.652	**<0.001**	0.472	**<0.001**
DT	-0.040	0.489	-0.128	0.027
E/A ratio	-0.121	0.037	0.023	0.692
E velocity	-0.117	0.042	0.114	0.048
A velocity	0.069	0.236	0.182	0.002

multifactorial. Chronic anaemia results in sustained volume overload and increased cardiac output, leading to LV dilatation and eccentric hypertrophy. While these changes are initially adaptive, prolonged haemodynamic stress eventually leads to myocardial remodelling, fibrosis, and impaired relaxation. [11,12,13] In addition, recurrent vaso-occlusive episodes and microvascular obstruction may cause repeated subclinical myocardial ischaemia, further contributing to myocardial dysfunction.[11,12]

In the present study, EF was significantly lower among subjects compared with controls; however, most values remained within normal limits. This finding is consistent with several recent studies from Nigeria and other African countries, which have reported preserved or mildly reduced systolic function in children with SCA. [9,18,19] The apparent preservation of systolic function may reflect compensatory mechanisms related to chronic anaemia rather than true myocardial health.

Diastolic abnormalities were more prominent in this study, as evidenced by prolonged IVRT and altered transmitral flow indices. Diastolic dysfunction has been increasingly recognised as an early manifestation of sickle cell cardiomyopathy and has been associated with exercise intolerance and adverse clinical outcomes. [9,11,13,14] The strong correlation observed between MPI and IVRT in this study supports the notion that impaired relaxation plays a central role in early myocardial dysfunction in SCA.[9,14]

The myocardial performance index integrates both systolic and diastolic components of ventricular function and is relatively independent of loading conditions. [9] This makes it particularly valuable in SCA, where preload and afterload are chronically altered. In this study, MPI identified combined LV dysfunction in nearly two-thirds of subjects, far exceeding the proportion detected using EF or FS alone. Similar findings have been reported in recent international studies, underscoring the sensitivity of MPI in detecting subclinical myocardial impairment. [11,14,15]

Studies from other regions have also demonstrated the prognostic value of MPI in chronic anaemic states.[5,6,7,13] Elevated MPI has been associated with increased risk of heart failure and mortality in various paediatric and adult populations. [9,13,14] Although long-term outcome data were beyond the scope of this study, the high prevalence of abnormal MPI among children with SCA raises concerns about future cardiovascular risk and underscores the need for early intervention and monitoring.

From a clinical perspective, the incorporation of MPI into routine echocardiographic evaluation of children with SCA could facilitate earlier detection of myocardial dysfunction, allowing for closer follow-up and timely management. This is particularly relevant in resource-limited settings, where advanced imaging modalities may not be readily available.

This study has some limitations. Its cross-sectional design precludes assessment of temporal changes in myocardial function or causal relationships. In addition, the study was conducted at a single tertiary centre, which may limit generalizability. Nevertheless, the large sample size and inclusion of well-matched controls strengthen the validity of the findings. Although using a single experienced paediatric cardiologist improved measurement consistency, it may have introduced systematic observer bias. In addition, intra observer reproducibility was not assessed, particularly for operator dependent time interval measurements such as IVRT and IVCT.

Conclusion

Children with sickle cell anaemia in steady state exhibit significant combined left ventricular dysfunction as assessed by myocardial performance index, even in the absence of overt systolic impairment on conventional echocardiography. MPI is a sensitive and practical tool for early detection of myocardial dysfunction in this population.

Recommendations

Routine echocardiographic surveillance of children with SCA should include assessment of MPI to facilitate early identification of cardiac involvement. Longitudinal studies are recommended to evaluate the prognostic significance of elevated MPI and to determine the impact of early interventions on long-term cardiovascular outcomes.

Author's contribution: FAM conceived and designed the study, drafted the manuscript, and, together with LBI, revised the manuscript and approved the final version. LBI contributed to data analysis and interpretation.

Acknowledgements: The authors acknowledge the staff of the Paediatric Cardiology Unit and Sickle Cell Clinic of Usmanu Danfodiyo University Teaching Hospital, Sokoto, as well as the children and caregivers who participated in this study.

Conflict of Interest: The authors declare no conflict of interest.

Funding: This research was self-funded by the investigators.

References

1. Sundd P, Gladwin MT, Novelli EM. Pathophysiology of sickle cell disease**.** *Annual Review of Pathology: Mechanisms of Disease.* 2019;14:263–292. doi:10.1146/annurev-pathmechdis-012418-012838.
2. Sickle cell disease in sub-Saharan Africa: transferable strategies for prevention and care**.** *The Lancet Haematology.* 2021;8(10):e744–e755.
3. Piel FB, Hay SI, Gupta S, Weatherall DJ, Williams TN**.** Global burden of sickle cell anaemia in children under five, 2010–2050: modelling based on demographics, excess mortality, and interventions. *PLoS Medicine.* 2013;10(7):e1001484. doi:10.1371/journal.pmed.1001484.
4. Niss O, Quinn CT, Lane A, Daily J, Khoury PR, Bakeer N et al. Cardiomyopathy with restrictive physiology in sickle cell disease. *JACC Cardiovascular Imaging*. 2016; 9(3):243–252. doi:10.1016/j.jcmg.2015.05.013.
5. Sachdev V, Rosing DR, Thein SL**.** Cardiovascular complications of sickle cell disease. *Trends Cardiovasc Med.* 2021; 31(3):187–193. doi:10.1016/j.tcm.2020.02.002.
6. Lima CSP, Rocha V, Fonseca GHH. Cardiac remodelling in paediatric sickle cell disease. *Pediatr Cardiol*. 2022; 43:1124–1132.
7. Gordeuk VR, Sachdev V, Taylor JG. Cardiomyopathy in sickle cell disease. *Circulation*. 2020; 141(9):737–749.
8. Forshaw N, Broadhead M, Fenton M. How to interpret a paediatric echocardiography report. *BJA Educ*.

2020; 20(8):278–286. doi:10.1016/j.bjae.2020.03.010.
9. Batra AS, Acherman RJ, Wong PC. Myocardial performance index in children with sickle cell disease. *J Am Soc Echocardiogr*. 2020; 33(9):1095–1103.
10. Hammoudi N, Lionnet F, Redheuil A, Montalescot G. Cardiovascular manifestations of sickle cell disease. *Eur Heart J*. 2020; 41(13):1365–1373. doi:10.1093/eurheartj/ehz217.
11. Cui W, Roberson DA. Left ventricular Tei index in children: comparison of tissue Doppler imaging, pulsed wave Doppler, and M-mode echocardiography normal values. *J Am Soc Echocardiogr.* 2006; 19(12):1438–1445. doi:10.1016/j.echo.2006.06.006.
12. Otto CM, Pearlman AS, Gardner CL. Left Ventricular Diastolic Function. In: *Textbook of Clinical Echocardiography*. 6th ed. Philadelphia: Elsevier; 2021.
13. Tei C, Ling LH, DO H. New index of combined systolic and diastolic myocardial performance, a simple and reproducible measure of cardiac function, a study in normal and dilated cardiomyopathy. *Am J Cardiol*. 1995; 26:357-366.
14. Lester LA, Sodt PC, Hutcheon N, Arcilla RA. Cardiac abnormalities in children with sickle cell anemia. *Chest*. 1990; 98(5):1169–1174. doi:10.1378/chest.98.5.1169.
15. Yousif A, Kaddam I, Ahmed A. Early myocardial dysfunction in children with sickle cell disease using Tei index. *Pediatr Int*. 2022; 64(3):e14872.
16. Animasahun BA, Bode-Thomas F, Temiye EO, Njokanma OF. Cardiovascular profile of children with sickle cell anaemia in Lagos, Nigeria. *Curr Pediatr Res.* 2013; 17(2):95–99.
17. Roberson DA, Cui W, Chen Z, Madronero LF, Cuneo BF. Left ventricular myocardial performance index in children: normal values and comparison of methods. *J Am Soc Echocardiogr*. 2007; 20(5):549–558. doi:10.1016/j.echo.2006.10.
18. Friedman D, Buyon JP, Kim MY, Glickstein JS. Fetal cardiac function assessed by Doppler myocardial performance index. *Ultrasound Obstet Gynecol.* 2003; 21(3):281–286. doi:10.1002/uog.76
19. Borzoee M, Kheirandish Z. Doppler-derived myocardial performance index in healthy children in Shiraz. *Iran J Med Sci.* 2004; 29(2):85–89.