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The screening of congenital heart disease by cardiac auscultation and 12-lead electrocardiogram among Indonesian elementary school students

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Abstract

Background: Screening for congenital heart disease (CHD) in school students is well-established in high-income countries; however, data from low-to-middle-income countries including Indonesia are limited. *Aim:* This study aimed to evaluate CHD screening methods by cardiac auscultation and 12-lead electrocardiogram to obtain the prevalence of CHD, confirmed by transthoracic echocardiography, among Indonesian school students. *Methods:* We conducted a screening programme in elementary school students in the Province of Special Region of Yogyakarta, Indonesia. The CHD screening was integrated into the annual health screening. The trained general practitioners and nurses participated in the screening. The primary screening was by cardiac auscultation and 12-lead electrocardiogram. The secondary screening was by transthoracic echocardiography performed on school students with abnormal findings in the primary screening. *Results:* A total of 6116 school students were screened within a 2-year period. As many as 329 (5.38%) school students were detected with abnormalities. Of those, 278 students (84.49%) had an abnormal electrocardiogram, 45 students (13.68%) had heart murmurs, and 6 students (1.82%) had both abnormalities. The primary screening programme was successfully implemented. The secondary screening was accomplished for 260 school students, and 18 students (6.9%) had heart abnormalities with 7 (2.7%) who were confirmed with septal defects and 11 (4.2%) had valve abnormalities. The overall prevalence was 0.29% (18 out of 6116). *Conclusions:* The primary screening by cardiac auscultation and 12-lead electrocardiogram was feasible and yielded 5.38% of elementary school students who were suspected with CHD. The secondary screening resulted in 6.9% confirmed cardiac abnormalities. The cardiac abnormality prevalence was 0.29%.

The importance of early detection of congenital heart disease (CHD) has been emphasised in many high-income countries. In those countries, most CHD can be detected during pregnancy and childhood, and therefore, early management such as corrective devices and surgery could be done thoroughly.[1,2] In low-to-middle-income countries several attempts to screen and early-detect CHD in their communities have been increasingly performed and established.[3,4] The challenging factors in low-to-middle countries are limitations of health infrastructure, deficiency in human resources and facilities, lack of properly trained health personnel, and low understanding concerning heart disease in children among society members.[5,6]

Left uncorrected, CHD with increased pulmonary blood flow could induce excessive circulation inside pulmonary vessels and increase the right heart volume load. Increased pulmonary vascular pressure and resistance, which results from histopathology changes of the pulmonary artery, lead to pulmonary arterial hypertension.[7] Finding of such late cases would cause many health problems, which include high cost of treatment and medication, low quality of life, reduced productivity, and disability of the patients.[8] Therefore, early detection is an important factor in preventing CHD complications.

In Indonesia, screening for heart abnormalities in children has not yet been systematically established. This situation affects the number of undiagnosed and uncorrected CHD in adulthood and also the outcome of corrective management in late finding cases.[9–11] Our hospital registry of adult patients indicated that almost 80% of patients with CHD had experienced pulmonary arterial hypertension and even Eisenmenger syndrome at a relatively young age.[12] One of the reasons for the high prevalence of adult undiagnosed CHD patients is that currently there

are no screening programmes for heart defects in Indonesia for children. As a result, most of them with mild symptoms would be under-diagnosed. Until today, the annual health screening programme in Indonesian children does not specifically detect heart abnormalities.

In 2015, we conducted a pilot project for CHD screening of 200 fourth-grade elementary school students in Yogyakarta city, Indonesia using cardiac auscultation and 12-lead electrocardiogram to assess the feasibility and acceptability of the method among school students, teachers, and parents. The results showed that the screening method by using cardiac auscultation and 12-lead electrocardiogram was well-received by the students, teachers, and parents, and also considerably uncomplicated to execute.[13] Therefore, the main aim of this study was to evaluate the ability of the CHD screening method by cardiac auscultation and 12-lead electrocardiogram as a primary screening method, which was simple, feasible, and acceptable, to obtain the prevalence of CHD among Indonesian school students. The subsequent screening by transthoracic echocardiography was performed as the secondary screening method to confirm the prevalence of CHD.

Materials and methods

Study design

The CHD screening programme was performed among first-grade elementary school students. The screening programme was conducted in 2018 and 2019. While our previous pilot project of screening was for fourth-grade elementary school students,[13] the first-grade elementary school students were the targets for the current screening due to several reasons such as the screening programme was intended to be executed at an earlier age; the first-grade elementary school students can obediently accept the procedure; and they have a mandatory annual health screening by the community health centres (Puskesmas) as a national government-sponsored annual programme. The CHD screening programme was incorporated into the annual health screening by the Puskesmas. The CHD screening programme protocol was approved by the Medical and Health Research Ethics Committee of Faculty of Medicine, Public Health and Nursing Universitas Gadjah Mada and authorised by the Provincial Government of the Province of Special Region of Yogyakarta via the Provincial Health Office and Provincial Education, Youth, and Sports Office. Every school principal was informed and gave their approval. The school principals informed the parents, teachers, and school students regarding the CHD screening and asked for their consent.

Target population

The CHD screening programme aimed to conduct cardiac examinations on first-year elementary school students. The Indonesian Ministry of Health has a priority programme concerning child health and welfare. One of its programmes is the annual health screening which is done on first-grade elementary school students. The examinations on eye, ear, nose, mouth, and throat are routinely performed as well as the measurement of height and weight during the annual health screening. The health personnel and non-health trained personnel conduct these examinations. The health personnel are general practitioners, nurses, or other clinical staffs from Puskesmas. The non-health trained personnel are teachers and volunteers who are trained as members of the healthy school programme (Unit Kesehatan Sekolah). Therefore, this CHD screening programme was performed on first-grade elementary school students and was integrated into the annual health screening programme.

Study area and sampling frame

A purposive multi-stage sampling was done to choose the elementary schools and Puskesmas to participate in the programme. In the Province of Special Region of Yogyakarta, there are five districts (four regencies: Sleman, Bantul, Gunung Kidul, and Kulon Progo and one municipality: Kota Yogyakarta) with 78 sub-districts and populated by 3,631,015 people. Among this population, 738,700 are school-age children. Based on 2017 data from Provincial Education, Youth, and Sports Office, there were 46,929 first-grade elementary school students of 1840 elementary schools. Each of the 78 sub-districts usually has 1 or 2 Puskesmas in the area which is/are in charge of more than 3 elementary schools.

The number of schools selected per district was based on 2017 data of the total number of school students, while Puskesmas selection was based on the performance, equipment, and recommendation by the District Health Office which supervises each Puskesmas. For the first year of this study in 2018, we selected 45 elementary schools from 19 Puskesmas with approximately 2788 first-grade elementary school students. In the second year, in 2019, 85 elementary schools were selected from 53 Puskesmas with 3579 first-grade elementary school students. The number of schools and Puskesmas were doubled by the second year in order to train more health personnel and extend this programme to more schools and increase the students' participation.

Screening procedure

The CHD screening programme consisted of two stages, which were the primary and secondary screening. The primary screening methods were a combination of heart examinations focusing on cardiac auscultation using a stethoscope and a 12-lead electrocardiogram examination. The 12-lead electrocardiogram was made up of 3 standard limb leads (I, II, and III), 3 augmented limb leads (aVR, aVL, and aVF), and 6 precordial leads (V1, V2, V3, V4, V5, and V6). The secondary screening was examination on school students that showed abnormal cardiac auscultation and/or electrocardiogram interpretation from the primary screening. At this stage, physical cardiac examination (inspection, percussion, palpation, and auscultation), confirmatory 12-lead electrocardiography, and transthoracic echocardiography were performed.

In the primary screening, cardiac auscultation and the 12-lead electrocardiogram were conducted by certified general practitioners and nurses from Puskesmas who had been trained. They were trained by our team, cardiologists (L.K.D., A.B.H., D.W.A.), and paediatric cardiologist (I.K.M.), assisted by trained general practitioners (V.C.D., A.P., and M.R.H.), to detect heart sounds and murmurs by cardiac auscultation using a stethoscope. The training programme was performed each year before the primary screening was conducted. It consisted of two standardised modules, namely the electrocardiogram module and cardiac auscultation module. The real patients (adults) with CHD participated in this training programme. The general practitioners and nurses reported whether there was a heart murmur positive or heart murmur negative. They sent the written report form of the results of cardiac auscultation to our team. The general practitioners and nurses were trained to perform the 12-lead electrocardiogram and interpret the electrocardiogram as normal and abnormal. Normal electrocardiogram reading was defined as normal sinus
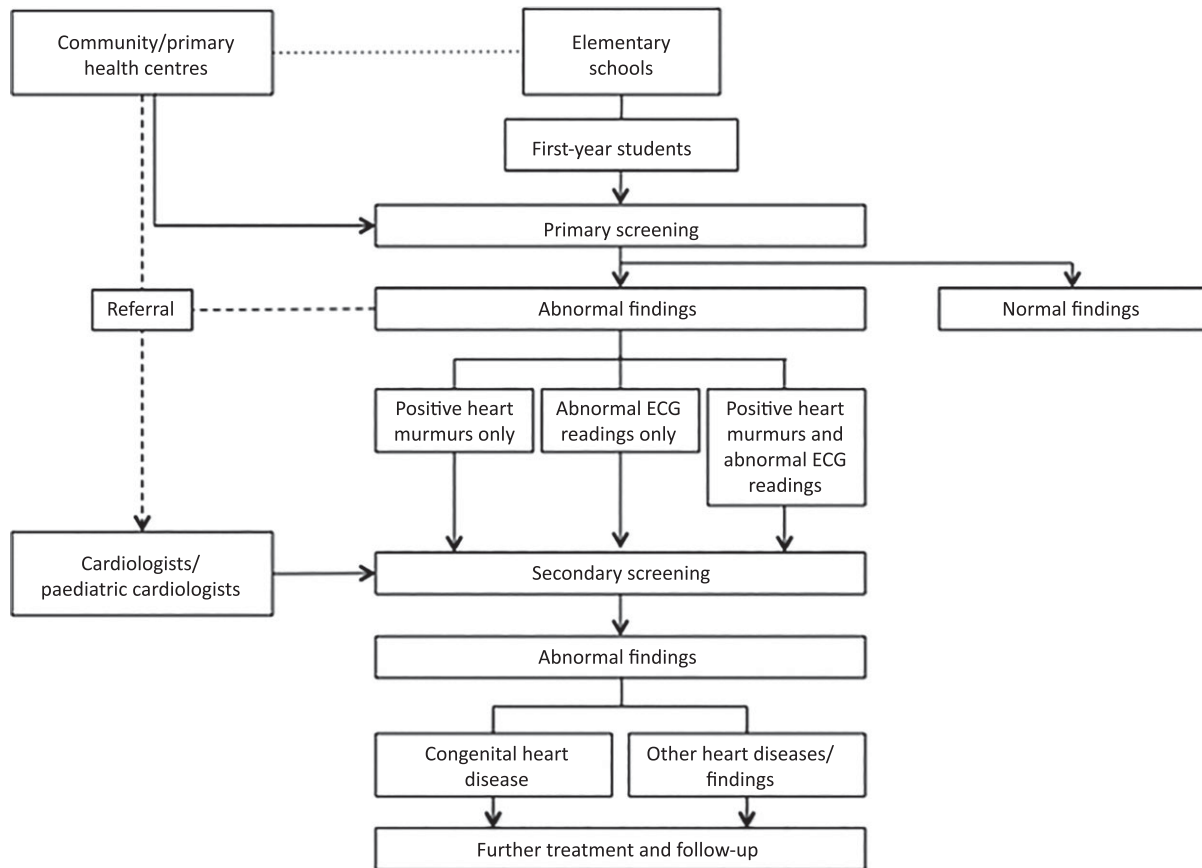
Figure 1. The workflow diagram of the CHD screening programme depicts primary and secondary screenings.

rhythm or sinus tachycardia. Any deviation from that standard was marked as an abnormal electrocardiogram. They recorded the electrocardiogram papers and sent them to our team for confirmation of the abnormal electrocardiogram reading. The cardiologists (L.K.D., A.B.H., and D.W.A.) and paediatric cardiologist (I.K.M.) confirmed that the abnormal electrocardiogram readings were reported.

In the secondary screening, the transthoracic echocardiography was performed on school students with abnormal findings in the electrocardiogram, and/or cardiac auscultations during primary screening. The school students with abnormal findings in the primary screening were invited to come to district hospitals or Pusat Jantung Terpadu (Integrated Heart Center) Dr Sardjito Hospital, to be examined using transthoracic echocardiography. The cardiologists (L.K.D., A.B.H., and D.W.A.) and paediatric cardiologist (I.K.M.) performed the transthoracic echocardiography and confirmed its results by standard procedure. The workflow of the study is depicted in Figure 1.

Statistics analysis

Data analysis was performed using SPSS Statistics version 22 (IBM Corp., Armonk, NY, United States of America). Data were presented as mean and standard deviation (SD) or median and interquartile ranges (IQR) or proportions, as appropriate. The prevalence was calculated based on abnormal findings in each category (abnormal electrocardiogram only, positive heart murmurs only, and both abnormalities present) from all school students of the CHD primary screening. The prevalence of abnormal findings

from each year was calculated based on abnormal findings in each category per year and divided by school students of the same year. The overall prevalence was calculated in 2-year period of screening per-100 school students. A chi-squared test or Fisher exact test was performed to compare the categorical data between the two groups. p values < 0.05 were considered significant.

Results

For this CHD screening, the collaborations with provincial and district governments were established. We worked with the Provincial and District/Municipal Health Offices, Provincial Education, Youth, and Sports Office, Puskesmas, and elementary schools. The training programme was performed before each screening programme with satisfactory results. The Puskesmas personnel consisted of at least one trained general practitioner to conduct the primary screening program.

A total of 130 elementary schools and 60 Puskesmas from 5 districts were selected in the 2-year period of this screening. Twelve Puskesmas participated during both the first- and second-year period. In 2018, the total school students predicted to participate was 2788 and in 2019 was 3579. The total for 2 years was 6367 first-grade school students targeted for this screening.

From primary screenings in 2018 and 2019, a total of 6116 first-grade elementary school students completed the screening procedure. This number was 96.06% of the targeted school students. The characteristics of school students who participated in the CHD screening are shown in Table 1.

Table 1. The characteristics of elementary school students who participated in the primary CHD screening

Characteristics	Description
Sex, n (%)	
Male	3088 (50.5)
Female	3028 (49.5)
Age (years), mean ± SD	6.7 ± 0.6
Body weight (kg), mean ± SD	21.9 ± 5.6
Body height (m), mean ± SD	1.2 ± 0.1
Pulse rate (beat/min), mean ± SD	103.0 ± 16.0

SD = standard deviation
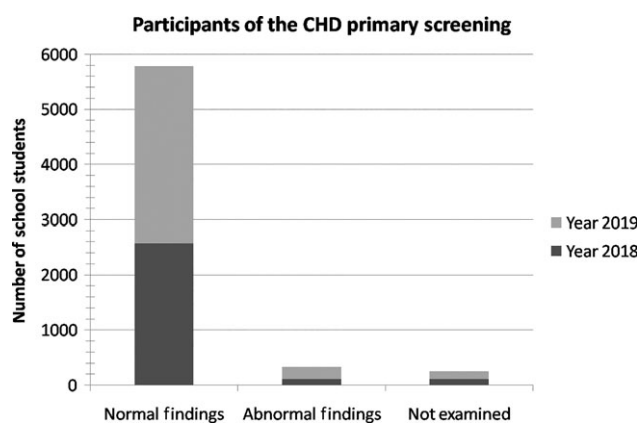
Figure 2. The school students of CHD primary screening (2682 school students in 2018 and 3434 school students in 2019 with a total of 6116 school students) and the distribution of findings (abnormal finding in 2018 was 112 school students and in 2019 was 217 school students, with a total of 329 school students). There were 106 school students in 2018 and 145 school students in 2019 who could not complete the screening (not examined).

From 6116 school students, the total number of students consisted of 2682 school students in 2018 and 3434 school students in 2019. In 2018, the abnormal findings were detected in 112 school students (4.18% of screened school students in the same year) and in 2019, we found 217 school students (6.32% of screened school students in the same year), with a total of 329 school students in the 2 years (5.38% of all screened school students). There was a significant difference in the prevalence of the abnormal findings between 2018 and 2019 (4.18 and 6.32%, p value < 0.001). Figure 2 and Table 2 indicate the distribution of primary school screening within the 2 years.

Among the 329 school students with abnormal findings, 278 (84.49%) had abnormal electrocardiogram readings only, 45 students (13.68%) had heart murmurs positive only, and 6 students (1.82%) had both abnormal electrocardiogram readings and heart murmurs positive. Abnormal electrocardiogram reading only was found in 79 school students in 2018 (2.94% of screened school students in the same year) and 199 school students in 2019 (5.79% of screened school students in the same year). The difference of the prevalence was statistically significant (p value < 0.001). Heart murmur positive only was found in 31 school students in 2018 (1.16% of screened school students in the same year) and in 14 school students in 2019 (0.40% of screened school students in

the same year). The difference of the prevalence was statistically significant (p value = 0.001). Both abnormal findings were detected in two school students in 2018 (0.07% of screened school students in the same year) and four school students in 2019 (0.12% of screened school students in the same year), with no statistically significant differences in the prevalence. In general, the prevalence of total abnormal findings was significantly higher in the year 2019 (6.32 versus 4.21%, p value < 0.001). Table 3 shows the comparison of the prevalence of each year and total abnormal findings in both years. Two school students had significant arrhythmias, namely total atrioventricular block and Wolff-Parkinson-White (WPW) pattern electrocardiogram. Figure 3 shows the findings of the primary screening.

For secondary screening, of the 329 school students, 22 students refused to come to district hospitals or our heart centre. Until February, 2020, 260 school students were able to participate in the secondary screening. We could not perform the secondary screening in 47 students, due to the unexpected pandemic situation and restrictions of social movement imposed by the National and Provincial Governments at the scheduled time (from March, 2020 until yet undetermined time). Figure 4 indicates the school students who participated in both the primary and secondary screenings. Among 260 school students, 18 students (6.9%) had an abnormality detected by transthoracic echocardiography. Seven students (2.7%) were confirmed with congenital septal defects, namely one student with atrial and ventricular septal defects, five students with atrial septal defects and one student with patent foramen ovale. Eleven students (4.2%) had valve abnormalities, namely one student had severe mitral regurgitation, six students had trivial-to-mild tricuspid regurgitation and four students have mild pulmonal regurgitation. Table 4 describes the school students with abnormal transthoracic echocardiogram results. The overall prevalence of cardiac abnormality from transthoracic echocardiogram findings was 0.29% (18 out of 6116).

Among the 36 school students with heart murmurs positive and normal electrocardiogram who underwent secondary screening, 29 students had normal echocardiograms and 3 students had trivial-to-mild tricuspid regurgitation or pulmonal regurgitation without enlargement of the right-sided heart chambers and obstruction of the right ventricle outflow tract. Four students with heart murmurs positive and normal electrocardiogram had CHD (Table 4). Two students with significant arrhythmias had normal echocardiograms.

Based on sex differences, male students had a significantly higher prevalence of an abnormal electrocardiogram findings (60.1%) compared to female students (39.9%), p = 0.001. Male students had a tendency of higher prevalence of both abnormalities compared to female students. The heart murmur findings did not significantly differ between sexes. The prevalence of congenital septal defects and valve abnormalities did not significantly differ between sexes, 57.1 versus 42.9%, p > 0.05 in congenital septal defects and 45.5 versus 54.5%, p > 0.05 in valve abnormalities respectively between female versus male students. Table 5 indicates the analysis based on sexes.

The primary CHD screening took approximately 5–8 minutes per school student, without combining other routine health examinations. The majority of the school students examined were cooperative. Nevertheless, a few of them still refused and were frightened by the 12-lead electrocardiogram examination. The primary CHD screening is feasible to be performed yearly in the

Table 2. The comparison between the characteristics of normal and abnormal finding in the primary CHD screening

Characteristics	Normal n = 5786	Abnormal ECG n = 278	Heart murmurs (+) n = 45	Both n = 6
Sex, n (%)				
Male	2892 (49.9)	167 (60.1)	23 (51.1)	5 (83.3)
Female	2894 (50.1)	111 (39.9)	22 (48.9)	1 (16.7)
Age (years), mean ± SD	6.7 ± 0.6	6.7 ± 0.5	6.6 ± 0.6	6.2 ± 3.5
Body weight (kg), mean ± SD	22.0 ± 5.7	21.1 ± 4.6	21.6 ± 5.2	25.8 ± 6.5
Body height (m), mean ± SD	1.2 ± 0.1	1.2 ± 0.1	1.2 ± 0.1	1.2 ± 0.1
Pulse rate (beat/min), mean ± SD	103.0 ± 16.0	104.0 ± 16.0	104.0 ± 18.0	95.0 ± 18.0

ECG = electrocardiogram, SD = standard deviation

Table 3. The comparison of prevalence of abnormal findings in each year

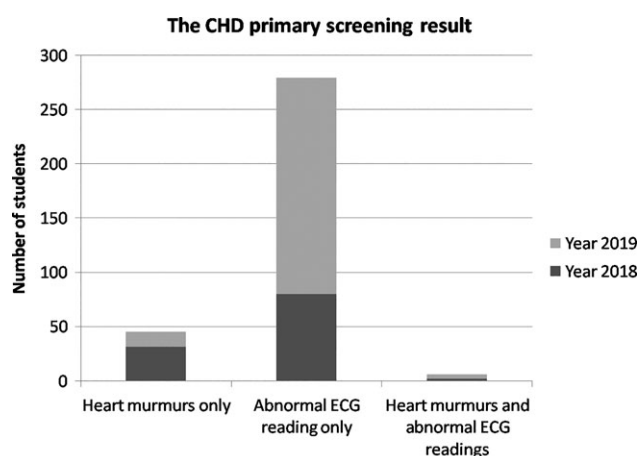| Abnormal findings	Year 2018 n = 2682	Year 2019 n = 3434	2 years n = 6116	p value
Abnormal ECG, n (%)	79 (2.94)	199 (5.79)	278 (4.54)	<0.001
Heart murmurs (+), n (%)	31 (1.16)	14 (0.40)	45 (0.74)	0.001
Both, n (%)	2 (0.07)	4 (0.12)	6 (0.09)	0.701
Total, n (%)	112 (4.21)	217 (6.32)	329 (5.38)	<0.001

ECG=electrocardiogram

Figure 3. The result of CHD primary screening among first elementary school students indicated 329 school students with abnormal findings. Heart murmurs positive was found only in 31 school students in 2018 and in 14 school students in 2019 (a total of 45 school students). Abnormal ECG reading was found only in 79 school students in 2018 and 199 school students in 2019 (a total of 278 school students). Both findings were detected in two school students in 2018 and four school students in 2019 (a total of six school students).

first-grade elementary school students and able to be integrated as a single activity with the mandatory annual health screening programme. The secondary screening by transthoracic echocardiography was easily accepted by the school students. The transthoracic echocardiography was performed without any difficulties. However, the willingness of school students and parents to get secondary screening required some motivation because it needed extra time for them to come to the district hospital or our heart centre.

Discussion

The screening programme was the first CHD screening in Indonesia which was intended to develop the most feasible screening system for CHD in children in the country. The system worked well by collaborating with stakeholders from the Provincial and District Health Offices which are in charge of the Puskesmas and the Provincial Education, Youth, and Sports Office which is in charge of the elementary schools. The support from the Provincial Government is also of paramount importance for the screening system to be conducted smoothly. This CHD screening among first-grade elementary school students resulted in the finding of 5.38% with abnormal findings from cardiac auscultation and 12-lead electrocardiogram examinations. The confirmation by the secondary screening revealed 18 out of 260 (6.9%) school students have abnormalities detected by transthoracic echocardiography, namely congenital septal defects (2.7%) and valve abnormalities (4.2%). The overall prevalence of cardiac abnormality confirmed with transthoracic echocardiogram was 0.29% (18 out of 6116).

Birth prevalence of CHD is similar worldwide, which is currently estimated at 10–12 per 1000 live births.[14] However, there is an increasing trend reported in the total CHD birth prevalence over time, especially in low-to-middle-income countries, due to alteration in diagnostic and screening modalities.[15,16] According to the worldwide burden of disease in 2010, 28% of major congenital anomalies are CHD and 96% of these occurred in low-to-middle-income countries.[5] The report in 2017 indicated that the highest rate of CHD was observed in low-to-middle-income countries in Africa and central and southeast Asia.[17] Most CHD involves septal defects, which are acyanotic type CHD.[15] The fatal and non-fatal burdens of CHD are serious concerns in infants less than 1 year, while the CHD in adulthood is associated with disability burden.[17] Early detection or screening is emphasised not only to

Table 4. The abnormal transthoracal echocardiogram findings in secondary screening

No.	Sex	Age (years)	Height (m)	Weight (kg)	Pulse (bpm)	SpO$_2$ (%)	Heart murmur	ECG findings	TTE result
1	Female	7	1.16	20	103	98	No	RAD, RVH	ASD
2	Female	6	1.15	23	124	99	Yes	RBBB	ASD
3	Male	6	1.23	25.5	82	97	No	RBBB	ASD
4	Female	6	1.22	17	110	97	Yes	Normal	ASD
5	Female	7	1.15	17	79	99	No	RBBB	ASD
6	Male	7	1.11	15	80	80	Yes	Normal	ASD, VSD
7	Male	7	1.24	31	80	99	Yes	normal	PFO, Mild TR
8	Male	7	1.12	23	112	98	No	RAD, RVH	Mild TR
9	Male	7	1.21	20	118	98	Yes	Normal	Mild TR
10	Female	7	1.20	19	123	97	No	RVH	Mild TR
11	Male	6	1.23	24	90	98	No	RBBB	Mild TR
12	Female	7	1.12	18.5	103	99	Yes	Normal	Trivial TR
13	Female	7	1.18	19	115	98	No	RVH	Trivial TR
14	Male	7	1.29	29	92	98	No	RVH, VES	Mild PR
15	Male	6	1.18	23	77	99	Yes	Normal	Mild PR
16	Female	5	1.04	17.9	131	96	No	RBBB	Mild PR
17	Male	7	1.17	21	100	95	No	RBBB	Mild PR
18	Female	6	1.13	20.5	109	98	Yes	Normal	Severe MR
19	Female	6	1.19	22	68	99	No	Total AV block	Normal
20	Male	7	1.20	22	114	98	No	WPW pattern	Normal

ASD = atrial septal defect; AV = atrioventricular; ECG = electrocardiogram; PFO = patent foramen ovale; PR = pulmonal regurgitation; RAD = right axis deviation; RBBB = right bundle branch block; RVH = right ventricle hypertrophy; TE = tricuspid regurgitation; TTE = transthoracal echocardiography; VES = ventricular extrasystole, VSD = ventricle septal defect; WPW = Wolff-Parkinson-White
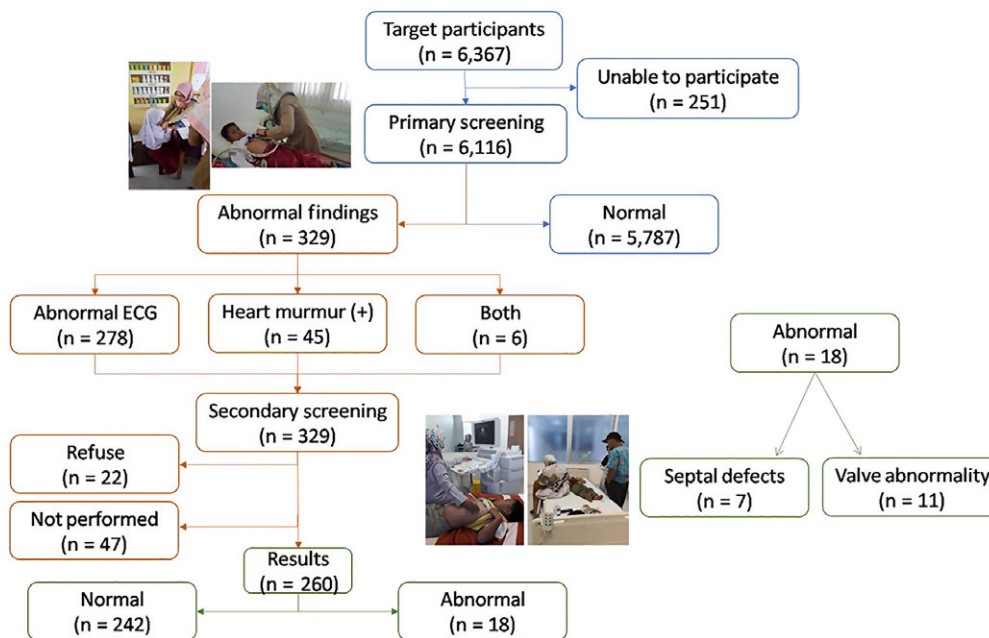

Figure 4. The school students' participation in the CHD primary and secondary screenings.

provide an early referral, appropriate management, and timely correction before the complication, but also to prevent further irreversible sequelae and disability.[5,16,17,18] Cyanotic CHD can be easily detected since birth and childhood, while non-cyanotic CHD can be asymptomatic or with minimal symptoms which can be undetected until complications manifest.[19] Our findings indicated that school students with suspected CHD by primary screening were those without cyanotic CHD.

Table 5. The comparison of abnormal findings between sexes

	All sexes, n (%)	Male, n (%)	Female, n (%)	p value
Heart murmurs (+), n (%)	45 (100)	23 (51.1)	22 (48.9)	1.00
Abnormal ECG, n (%)	278 (100)	167 (60.1)	111 (39.9)	0.001
Both, n (%)	6 (100)	5 (83.3)	1 (16.7)	0.219*
Abnormal echocardiogram, n (%)				
Septal defects	7 (100)	3 (42.9)	4 (57.1)	1.00*
Valve abnormalities	11 (100)	6 (54.5)	5 (45.5)	1.00*

ECG = electrocardiogram
*Comparison by Fisher's exact test

In high-income countries, many methods of heart disease screening have been established which are conducted during various stages of children's growth, with the direction towards the earliest screening programme in prenatal and infancy periods.[2,20–23] In low-to-middle-income countries, the CHD screening had taken place mostly in the later life during childhood and adolescence. After 2010, the CHD screening in school children was mostly performed in middle-income and low-income countries which was carried out in conjunction with screening for rheumatic heart disease which was prevalent in these countries.[3,4,24–29] Table 6 shows the current results of the CHD screening in schoolchildren among countries. Most current screening methods were conducted by structured anamnesis, questionnaire, physical examination focusing on cardiac auscultation, and confirmatory examination by transthoracic echocardiography. The utility of a 12-lead electrocardiogram was conducted and confirmed by Liu et al and our current screening.[25] We also included data from high-income countries for comparison by using the Global Burden Disease (GBD) dataset.[16] Compared with other results, the prevalence of CHD in our screening programme was lower.

The CHD screening does not need sophisticated tools, and by utilising simple equipment, it is an accurate way to find suspected CHD patients. One of the most effective methods at the earliest period is by using a foetal echocardiography. This device is able to visualise foetal heart during pregnancy, thus very early detection of congenital heart anomaly can be made.[7,21] In developed countries, screening of critical CHD has been performed in neonates by using pulse oximetry.[22,23] Pulse oximetry screening is important for the screening of CHD especially in neonates in order to avoid missing those with critical CHD.[22,30] In the United States of America, a screening toolkit has been developed to detect critical CHD during the newborn period. This screening method recommends the use of pulse oximetry in newborns to identify critical CHD, a more serious form of CHD which requires intervention in the first year of life.[23] Detection of heart defects during the postnatal period, which is currently done based on symptoms and physical examination within the first 24 hours of life, was proven to effectively find only 50% of infants with a heart defect.[21] Previous studies in China have proven pulse oximetry examination combined with heart auscultation increased the detection rate of major CHD in the early neonatal stage.[30] Nevertheless, pulse oximetry could help identify newborns or infants with low levels of oxygen and be faster in diagnosing patients with critical CHD.[22,23,30–32] In Indonesia, mass screenings in the prenatal and postnatal periods have not yet been implemented.

The screening and early detections for CHD have been performed in stages, starting from during prenatal, then continued during newborn, infant, and childhood and at adolescent stages. From this type of screening programme, CHD can be identified as early as possible before severe symptoms and irreversible complications manifest, and corrective treatment can be performed. By screening in stages, it also can capture the escaped CHD undetected from previous screenings in the timeline. In Japan, the success of this screening in stages could drastically decrease the number of CHD incidence in adulthood.[2] Several methods have been developed in the screening programme such as cardiac auscultation examination with stethoscope, 12-lead electrocardiogram, peripheral oxygen saturation examination using pulse oximetry while resting and after activities, heart exercise examination, and portable echocardiography.[2] We adopted two simple examinations for this screening, namely cardiac auscultation and 12-lead electrocardiogram.

Our findings indicated that male students had a significantly higher prevalence of abnormal electrocardiogram findings in the primary screening compared to female students. However, confirmation at the secondary screening by transthoracic echocardiography showed that the prevalence of CHD did not significantly differ between sexes. In our screening, female students tended to have a higher prevalence of congenital septal defect. Similar data were reported in the United States of America among children aged 6–12 years old that showed there was a slight predominance of female to male children with CHD estimated by assumption methods.[33] Data from the Germany Registry also showed that the prevalence of simple CHD was significantly higher in female children, whereas a predominance of males was found in complex CHD.[34] The predominance of female children with CHD from several population studies was also recorded in China, Nigeria, and Malaysia.[3,25,28,35] However, the online database from the GBD 2017 showed that the incidence rate of all types of CHD was slightly higher in males as compared with females.[36]

In Indonesia, the children's health has been one of the top priorities of the Ministry of Health. Programmes at the school-age level are school health programmes for elementary school and adolescence health care. According to the Ministry of Health, school-age children are a strategic target for health programmes implementation, because they are large in number and also accessible because they are well-organised. For younger children, mainly first-year elementary students, health screening or medical examination is done every year, usually at the beginning of the new school term. However, the current screening does not involve the examination of students' cardiac health. Our primary CHD

Table 6. The prevalence of CHD from the screening of CHD among school children in low-to-middle-income countries and the current data from high-income countries based on Global Disease Burden database.

City, country	Year(s)	Prevalence per 1000	Age range	Sex difference	Methods	Publication
Uganda	2010	3.59	5–16 years old	Not stated	Physical exam (cardiac murmurs) followed by TTE	Beaton et al (2012)[24]
Xinjiang, China	2010–2012	10.54 (for 7–12 years old)	0–18 years old	Female preponderance	Physical exam (cardiac murmurs) and 12-lead ECG followed by TTE	Liu et al (2015)[25]
Andhra Pradesh, India	2011	10.4	5–18 years old	Not stated	Physical exam (cardiac murmurs) followed by TTE	Rama Kumari et al (2013)[4]
Dakar, Senegal	2011	8.9	5–18 years old	Not stated	Physical exam (cardiac murmurs) followed by TTE	Bodian et al (2015)[26]
Dongguan City, China	2011–2012	2.14	6–13 years old	Similar	Physical exam (cardiac murmurs) followed by TTE	Kang et al (2016)[27]
Port Harcourt, Nigeria	2014	18.1	5–14 years old	Female preponderance	Physical exam (cardiac murmurs) followed by TTE	Susan et al (2019)[28]
Arequipa, Peru	2014–2015	20.5	5–16 years old	Not stated	Physical exam (cardiac murmurs) followed by TTE	Spitzer et al (2015)[29]
Lagos, Nigeria	2016–2017	6.57	5–16 years old	Female preponderance	Physical exam (cardiac murmurs) followed by TTE	Ekure et al (2020)[3]
Yogyakarta, Indonesia	2018–2019	2.94	6–8 years old	Similar	Physical exam (cardiac murmurs) and 12-lead ECG followed by TTE	This publication
Global	2017	3.25	5–9 years old	Not stated	GBD Input Data Sources Tool of the Global Health Data Exchange	GBD 2017 Congenital Heart Disease Collaborators (2020)[16]
High-income North America	2017	3.63	5–9 years old	Not stated	GBD Input Data Sources Tool of the Global Health Data Exchange	GBD 2017 Congenital Heart Disease Collaborators (2020)[16]
Western Europe	2017	3.43	5–9 years old	Not stated	GBD Input Data Sources Tool of the Global Health Data Exchange	GBD 2017 Congenital Heart Disease Collaborators (2020)[16]
Eastern Europe	2017	3.76	5–9 years old	Not stated	GBD Input Data Sources Tool of the Global Health Data Exchange	GBD 2017 Congenital Heart Disease Collaborators (2020)[16]
High-income Asia Pacific	2017	5.95	5–9 years old	Not stated	GBD Input Data Sources Tool of the Global Health Data Exchange	GBD 2017 Congenital Heart Disease Collaborators (2020)[16]

screening programme was integrated into this annual programme, in such a way that it can save both resources and time. The additional time needed to perform the CHD screening items was 5–8 minutes per student, therefore it did not add significantly more time to the routine programme.

Before the screening programme was performed, our team had several discussions with the Provincial Government and Health Authority representatives regarding the management and follow-up for school students with cardiac abnormalities found during screening. It was agreed that for school students with cardiac abnormalities found during screening, our team would discuss what their treatment or care options will be. Our team made a protocol for follow-up for school students with cardiac anomalies detected during screening by incorporating them into the health care system of district and national health insurance system by referral to District Hospital for further management. Five district hospitals in the Special Province of Yogyakarta have been equipped with resources to care for school students with detected cardiac anomalies. If needed, the referral to our heart centre will be performed if advanced procedures are needed.

We demonstrated the feasibility of primary screening of CHD among first-year elementary school students using a 12-lead electrocardiogram in the Province of the Special Region of Yogyakarta, Indonesia. This message could inform policy makers to formulate an effective screening programme for the detection of CHD in children. We found about 5% of first-year elementary school students undergoing primary screening by cardiac auscultation and 12-lead electrocardiogram were suspected with CHD and 7% of those suspected had confirmed cardiac anomalies. Accordingly, we reported the results to the Provincial Government. In 2020, we are currently in the process of making an Academic and Legislation Draft with the Yogyakarta Provincial Government for the implementation of routine CHD screening for first-year elementary school children (based on our experience during the past 2 years (2018–2019)), including the management and follow-up for those affected by the screening programmes.

These findings highlight the feasibility and ability to perform and integrate the CHD screening of school students in Indonesia with the current health screening and to determine

the prevalence of CHD by using cardiac auscultation and 12-lead electrocardiogram. The team from Puskesmas successfully performed examinations of the primary screening after being trained to refresh their technique to perform cardiac auscultation and 12-lead electrocardiogram and to recognise heart murmurs and the normal pattern of electrocardiogram reading. The primary CHD screening was performed concomitant with annual health examinations for first-grade elementary school so that resources and time can be saved, given the many programmes that should be executed by Puskesmas yearly. We observed that not all Puskesmas are equipped with sufficient human resources (lack of general practitioners) or logistics (lack of well-functioning electrocardiogram machines and medical-standard stethoscopes). Nevertheless, the primary CHD screening was feasible and considerably uncomplicated to perform and was able to detect school students with suspected heart abnormalities.

Here, we should address several limitations regarding the primary CHD screening. There are possibilities of bias and subjectivity that can affect the outcomes of this study. A previous study on primary physicians or general practitioners' skills in paediatric cardiac auscultation showed low performances and lack of training levels. Therefore, possibilities of under- or over-diagnosis of heart murmurs could happen during the primary screening. Trainings on heart auscultation prior to primary screening for primary health care general practitioners who would perform heart murmur examinations are needed to improve their performance. In some countries, the use of a digital stethoscope and Internet Cloud has been considered in areas with a shortage of medical personnel or heart and paediatric specialists. An initial study showed that this system was able to collect and then transmit phonocardiogram and heart sounds from rural areas to a board-certified paediatric cardiologist in far places.[37] This method may reduce misdiagnoses by general practitioners and increase the accuracy of findings in primary screening.

The 12-lead electrocardiogram examination is generally acceptable by first-grade elementary school students, however, a few students needed extra time before successfully undergoing the procedure. The patience of health personnel and the involvement of teachers may be necessary to persuade the school students during the primary screening. The secondary screening by transthoracic echocardiography was challenging because the school students and parents needed to be motivated to visit the district hospital and heart centre for further examination. Despite the simple procedure (all the school students underwent transthoracic echocardiography without any difficulties), the willingness of school students and parents to get secondary screening required some additional motivation.

Conclusions

This study shows that the primary CHD screening by cardiac auscultation and 12-lead electrocardiogram is feasible to execute and is capable to screen and identify 5.38% suspected CHD. The subsequent secondary screening was challenging and resulted in 6.9% confirmed cardiac abnormalities. Overall, the prevalence of cardiac abnormality was 0.29%. We demonstrated the feasibility of primary screening of CHD among first-year elementary school students using a 12-lead electrocardiogram in the Province of the Special Region of Yogyakarta, Indonesia. This message could inform policy makers to formulate an effective screening programme for the detection of CHD in children. The improvements of human resources and logistics availability are among aspects

that need to be solved in order for the government to perform primary CHD screening on elementary school students independently. Further follow-up by secondary screening and subsequent care for school students affected by the screening findings are also mandatory to be incorporated in the screening programme.

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