BG Pulse Journal USA
ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg
BG PULSE JOURNAL

EARLY DETECTION OF CARDIOVASCULAR DISEASES IN CHILDREN: CLINICAL SCREENING, MODERN INSTRUMENTAL DIAGNOSTICS, AND ASSESSMENT OF RISK FACTORS

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doi:https://doi.org/10.5281/zenodo.22922330

Abstract. Cardiovascular disorders in childhood include congenital malformations, rhythm and conduction abnormalities, cardiomyopathies, arterial hypertension, and early metabolic risk states that may remain clinically silent for long periods. The aim of this review was to systematize evidence relevant to early cardiovascular detection in children, with emphasis on primary-care clinical screening, targeted instrumental diagnostics, and age-appropriate assessment of modifiable and hereditary risk factors. A structured narrative synthesis of 15 sources was performed, including 11 publications or educational materials from Uzbekistan and four international pediatric recommendations. The analysis shows that the most efficient strategy is a staged model: standardized history and family-history questions; physical examination with growth, body mass index, pulse quality, auscultation, and blood pressure measurement; neonatal pulse-oximetry screening; and selective use of electrocardiography, echocardiography, ambulatory blood-pressure monitoring, Holter monitoring, exercise testing, cardiac magnetic resonance/computed tomography, and genetic testing according to clinical indications. Particular attention should be paid to exertional syncope, chest pain, palpitations, abnormal murmurs, hypertension, obesity, dyslipidemia, diabetes risk, and a family history of premature cardiovascular disease or sudden death. Integration of these elements into routine pediatric care can increase diagnostic yield while limiting unnecessary instrumental testing (1,2,6,12-15).
Keywords: children; cardiovascular disease; screening; blood pressure; electrocardiography; echocardiography; risk factors; early diagnosis.

Annotatsiya. Bolalarda yurak-qon tomir patologiyasi tug‘ma yurak nuqsonlari, ritm va o‘tkazuvchanlik buzilishlari, kardiomiopatiyalar, arterial gipertenziya hamda erta metabolik xavf holatlarini qamrab oladi. Ushbu maqolaning maqsadi bolalarda yurak-qon tomir kasalliklarini erta aniqlashga doir dalillarni klinik skrining, zamonaviy instrumental diagnostika va xavf omillarini yoshga mos baholash nuqtai nazaridan tizimlashtirishdir. Tahlilga 15 ta manba, jumladan O‘zbekiston mualliflari va mahalliy ta’lim-ilmiy manbalaridan 11 tasi kiritildi. Eng maqbul yondashuv bosqichma-bosqich skrining bo‘lib, anamnez va oilaviy tarix, fizik ko‘rik, arterial bosim, neonatal pulsoksimetriya hamda ko‘rsatmaga ko‘ra EKG, ExoKG, sutkalik arterial bosim monitoringi, Holter, yuklama sinovi, MRT/KT va genetik tekshiruvlarni birlashtiradi.
Kalit so‘zlar: bolalar; yurak-qon tomir kasalliklari; skrining; arterial bosim; EKG; exokardiografiya; xavf omillari; erta tashxis.

Аннотация. Сердечно-сосудистая патология у детей включает врождённые пороки сердца, нарушения ритма и проводимости, кардиомиопатии, артериальную гипертензию и ранние метаболические факторы риска. Цель обзора — систематизировать данные по раннему выявлению сердечно-сосудистых заболеваний у детей с акцентом на клинический скрининг, современные инструментальные методы и оценку наследственных и

модифицируемых факторов риска. В анализ включено 15 источников, из них 11 — публикации и учебные материалы авторов Узбекистана. Наиболее рациональной является ступенчатая модель: стандартизированный анамнез и семейный анамнез, физикальное обследование, измерение артериального давления, неонатальная пульсоксиметрия и целевое применение ЭКГ, эхокардиографии, суточного мониторирования АД, Холтеровского мониторирования, нагрузочных тестов, МРТ/КТ и генетической диагностики.

Ключевые слова: дети; сердечно-сосудистые заболевания; скрининг; артериальное давление; ЭКГ; эхокардиография; факторы риска; ранняя диагностика.

INTRODUCTION

Cardiovascular disease is commonly perceived as a problem of adulthood, yet many clinically important cardiac disorders begin in fetal life, infancy, childhood, or adolescence. Congenital heart defects may be present at birth, inherited electrical disorders can manifest with syncope or sudden cardiac arrest in otherwise healthy children, and acquired risk factors such as obesity, elevated blood pressure, dyslipidemia, insulin resistance, physical inactivity, and tobacco exposure may initiate vascular injury years before overt disease appears. Local pediatric literature from Uzbekistan likewise emphasizes congenital heart disease, childhood rhythm and conduction disorders, metabolic syndrome, and adolescent hypertension as important targets for early recognition (1-11).

The challenge for pediatric practice is not simply to perform more tests, but to identify which children need further investigation and at what stage. Routine echocardiography or electrocardiography for every asymptomatic child is neither necessary nor feasible. By contrast, a structured screening pathway can identify warning symptoms, abnormal examination findings, high-risk family history, and modifiable risk factors before irreversible myocardial or vascular changes develop. International guidance supports annual blood-pressure measurement from three years of age and targeted evaluation of children with obesity, renal disease, diabetes, or aortic arch pathology; modern recommendations also stress routine questioning about exertional syncope, exercise-related chest pain, unexplained seizures, and sudden death in relatives (12,14).

Early detection is particularly relevant in Uzbekistan, where pediatric services increasingly use echocardiography, electrocardiography, Holter monitoring, and other non-invasive techniques. Regional research has highlighted the value of local echocardiographic reference data, early recognition of congenital anomalies, and attention to adolescent hypertension and metabolic risk (3-10). Therefore, a clinically integrated framework is needed to connect primary screening with modern instrumental diagnostics rather than treating these as separate activities.

The aim of this article is to synthesize national and international evidence on the early detection of cardiovascular diseases in children and to formulate a practical age- and risk-oriented approach that combines clinical screening, modern instrumental diagnostics, and systematic assessment of cardiovascular risk factors.

MATERIALS AND METHODS

A structured narrative review was performed. Fifteen sources published between 2011 and 2025 were selected for their direct relevance to pediatric cardiovascular screening, congenital heart disease, rhythm disorders, childhood hypertension, metabolic risk, echocardiography, and prevention of sudden cardiac death. Eleven sources originated from Uzbekistan or were authored by specialists working in Uzbek medical institutions, representing 73.3% of the bibliography. Four international sources were selected because they provide widely used pediatric recommendations

for high blood pressure, integrated cardiovascular risk reduction, sudden cardiac death screening, and critical congenital heart disease screening (12-15).

The evidence was organized into three analytical domains: (1) clinical screening and red-flag symptoms; (2) instrumental diagnostics, including electrocardiography, echocardiography, ambulatory monitoring, pulse oximetry, exercise testing, and advanced imaging; and (3) assessment of hereditary, anthropometric, metabolic, behavioral, and perinatal risk factors. Because no primary patient dataset was provided, the Results section represents an evidence synthesis rather than original clinical outcome data. Diagnostic methods were assessed according to their practical role in primary, secondary, or specialist-level evaluation.

RESULTS

The reviewed evidence supports a staged screening model. The first stage is clinical and should be incorporated into routine pediatric visits. History taking should identify poor feeding or diaphoresis in infancy, exercise intolerance, dyspnea, chest pain, palpitations, syncope, cyanosis, unexplained seizures, recurrent dizziness, and reduced school or sports performance. Family history is equally important and should include congenital heart disease, cardiomyopathy, inherited arrhythmia syndromes, pacemaker or implantable defibrillator use at a young age, and sudden or unexplained death before approximately 50 years of age (1,2,14).

Physical examination should include age-appropriate heart rate and respiratory rate, precordial inspection and palpation, auscultation, assessment of femoral and peripheral pulses, upper- and lower-extremity blood pressure when coarctation is suspected, oxygen saturation when clinically indicated, and evaluation of growth and nutritional status. A pathologic murmur, persistent tachycardia or bradycardia, pulse asymmetry, cyanosis, hepatomegaly, edema, or signs of heart failure should trigger targeted cardiologic assessment. Uzbek studies on minor cardiac anomalies and congenital heart defects reinforce the value of careful clinical examination followed by echocardiographic confirmation when structural disease is suspected (2,4,5,10,11).

Blood pressure is a central screening variable because childhood hypertension may be silent and may track into adulthood. The AAP recommends annual blood-pressure measurement in all children from three years of age, with measurement at every relevant encounter in children with obesity, renal disease, diabetes, a history of aortic arch obstruction, or medications known to increase blood pressure (12). Local observations in Tashkent adolescents and Uzbek pediatric reports on secondary hypertension show the practical relevance of repeated, standardized measurement and the need to search for renal, endocrine, vascular, or cardiac causes when hypertension is confirmed (6,7).

Table 1. Age- and risk-oriented clinical cardiovascular screening in children

Age / setting	Core screening elements	Red flags requiring escalation	Suggested next step
Newborn period	Prenatal history, physical examination, femoral pulses, pre/post-ductal pulse oximetry	Cyanosis, SpO_2 screen failure, weak femoral pulse, shock, pathologic murmur	Urgent echocardiography and pediatric cardiology assessment
Infancy–2 years	Growth, feeding tolerance, sweating, respiratory symptoms, auscultation,	Failure to thrive, tachypnea, recurrent cyanosis, persistent	ECG and echocardiography according to clinical

Age / setting	Core screening elements	Red flags requiring escalation	Suggested next step
	pulses	tachycardia, hepatomegaly	findings
≥3 years	Annual BP, BMI, family history, activity tolerance, auscultation	BP ≥95th percentile on repeated visits, abnormal murmur, pulse asymmetry	Repeat auscultatory BP, consider ABPM; ECG/echo if indicated
School age / adolescence	BP, BMI, lifestyle, lipids/glucose when risk is elevated, syncope/chest pain/palpitations questions	Exertional syncope, exercise chest pain, sustained palpitations, family sudden death	12-lead ECG first; cardiology referral; Holter/exercise test/echo as indicated
High-risk child	Disease-specific surveillance for obesity, diabetes, renal disease, congenital heart disease, inherited syndromes	Progressive symptoms, abnormal ECG, ventricular dysfunction, uncontrolled hypertension	Specialist follow-up, advanced imaging/genetic testing when clinically justified

This table emphasizes that age alone is not sufficient to determine screening intensity. A healthy child without symptoms may require only routine history, examination, and age-appropriate blood-pressure assessment, whereas the same-age child with exertional syncope or a strong family history requires immediate escalation to electrocardiography and specialist evaluation. This risk-adapted approach reduces unnecessary testing while preserving sensitivity for potentially life-threatening disease (12,14).

Instrumental diagnostics should be selected according to the suspected mechanism. Twelve-lead electrocardiography is the preferred first-line test when there is concern for electrical disease, arrhythmia, conduction disturbance, myocarditis, ventricular hypertrophy, or sudden-death risk. Local pediatric data from Tashkent describe clinically meaningful conduction abnormalities in children and support integration of ECG with symptom assessment and echocardiography rather than interpretation in isolation (3). Holter monitoring is particularly useful when palpitations, intermittent syncope, episodic bradycardia/tachycardia, or suspected rhythm disturbances are not captured on resting ECG.

Echocardiography is the key non-invasive method for evaluating structural heart disease, chamber dimensions, ventricular function, valve pathology, shunts, and hemodynamics. Uzbek research has emphasized both the need for pediatric and regional reference values and the utility of echocardiography for congenital and minor cardiac anomalies (2,4,5,9-11). However, echocardiography should follow a clinical question: pathologic murmur, abnormal ECG, cyanosis, heart failure signs, abnormal pulses, suspected cardiomyopathy, or a defined family/genetic risk. Advanced cardiac magnetic resonance and computed tomography provide additional anatomical and tissue characterization when echocardiography is insufficient, particularly in complex congenital heart disease, coronary anomalies, myocarditis, cardiomyopathy, or preoperative planning.

Ambulatory blood-pressure monitoring (ABPM) has an important role in distinguishing sustained hypertension from white-coat hypertension and in detecting masked hypertension. When elevated office blood pressure is persistent, confirmation with standardized repeated auscultatory

measurements and, where available, ABPM prevents both overdiagnosis and underdiagnosis. In children with confirmed hypertension, evaluation should consider renal disease, endocrine disorders, coarctation of the aorta, medications, obesity, and sleep-disordered breathing (6,7,12).

Pulse oximetry represents a special case of population-level instrumental screening. Updated AAP recommendations for critical congenital heart disease endorse pre- and post-ductal measurements and a passing saturation of at least 95% in both measurements, with only one repeat for an indeterminate result. The method complements, but does not replace, prenatal ultrasound and newborn physical examination (15). Local fetal ultrasound research also demonstrates the importance of prenatal detection pathways for congenital heart disease (9).

Table 2. Modern instrumental methods and their targeted role in pediatric cardiovascular diagnostics

Method	Best clinical use	Main strengths	Important limitations
12-lead ECG	Syncope, palpitations, conduction/rhythm disorders, hypertrophy, myocarditis suspicion	Fast, widely available, detects electrical abnormalities	Normal ECG does not exclude structural or intermittent disease
Echocardiography + Doppler	Murmur, CHD, cardiomyopathy, ventricular function, pulmonary pressure	Non-invasive structural and hemodynamic assessment	Operator dependent; indiscriminate screening may increase incidental findings
Holter / event monitor	Intermittent palpitations, syncope, episodic tachy- or bradyarrhythmia	Captures transient rhythm abnormalities in daily life	Diagnostic yield depends on symptom frequency and recording duration
ABPM	Persistent elevated BP, suspected white-coat or masked hypertension	Better characterization of BP phenotype and circadian profile	Requires pediatric cuff/device validation and patient cooperation
Exercise testing	Exertional symptoms, exercise-induced arrhythmia, functional capacity	Links symptoms and ECG/hemodynamic response to exertion	Not appropriate in unstable disease; interpretation is age dependent
Cardiac MRI / CT	Complex anatomy, coronary anomalies, tissue characterization, surgical planning	High-detail anatomy; MRI provides tissue and functional data without ionizing radiation	Availability, cost; CT radiation; MRI time/sedation in younger children
Genetic testing	Inherited arrhythmia, cardiomyopathy, syndromic CHD, strong family history	Can identify familial disease and guide cascade screening	Variants of uncertain significance; requires counseling

The diagnostic sequence should therefore be question-driven rather than technology-driven. A child with an innocent-sounding murmur and no other abnormal findings may need observation, whereas a child with a pathologic murmur, exertional symptoms, abnormal pulses, or an abnormal ECG requires echocardiographic assessment. Similarly, advanced imaging is most useful after a structural or functional problem has been identified or strongly suspected.

Risk-factor assessment is the third pillar of early cardiovascular detection. In childhood, risk is cumulative and multidimensional. Non-modifiable factors include congenital heart disease, inherited cardiomyopathies and channelopathies, family history of premature atherosclerotic cardiovascular disease, genetic syndromes, and certain perinatal exposures. Modifiable factors include excess adiposity, elevated blood pressure, dyslipidemia, hyperglycemia or insulin resistance, poor diet, insufficient physical activity, tobacco or nicotine exposure, and sleep disorders. Uzbek studies on metabolic syndrome and obesity underline the clustering of obesity, hypertension, glucose dysregulation, and dyslipoproteinemia in children and adolescents (8,10).

Anthropometric screening should include weight, height, body mass index percentile, and, where clinically useful, waist assessment. Children with obesity or a strong family history should receive focused metabolic evaluation based on age and clinical context. Lipid testing is particularly relevant in children with familial hypercholesterolemia risk, obesity, diabetes, hypertension, chronic kidney disease, or a family history of premature cardiovascular disease. The integrated cardiovascular-risk approach recommended in pediatric preventive guidance treats these variables as interacting rather than isolated abnormalities (13).

Importantly, cardiovascular screening must include psychosocial and behavioral context. Sedentary lifestyle, low physical fitness, high intake of ultra-processed foods, sleep deprivation, and exposure to cigarettes or electronic nicotine products may amplify metabolic risk. Counseling should be family-centered, because diet, activity, sleep, and tobacco exposure are frequently shared within the household. Early identification of risk should therefore lead not only to laboratory testing but also to structured preventive intervention.

DISCUSSION

The central finding of this review is that effective pediatric cardiovascular screening depends on integration rather than expansion of testing. A small number of carefully selected clinical questions and measurements can identify the majority of children who merit additional evaluation. The screening pathway should begin with a symptom and family-history filter, continue with physical examination and blood-pressure assessment, and then branch to targeted instrumental studies. This model is consistent with both local pediatric experience and international guidance (1-15).

In primary care, four clinical scenarios deserve especially high priority. First, the newborn with possible critical congenital heart disease requires coordinated prenatal information, physical examination, and pulse-oximetry screening, followed by echocardiography if screening is abnormal. Second, the child with a murmur requires distinction between innocent and pathologic features, with echocardiography reserved for suspected structural disease. Third, the school-age child or adolescent with hypertension, obesity, or metabolic abnormalities requires confirmation, risk stratification, and longitudinal prevention. Fourth, any child with exertional syncope, exercise-associated chest pain, sustained palpitations, unexplained seizure-like events, or a family history of premature sudden death requires prompt evaluation for electrical or structural disease (2,6-10,12,14,15).

The role of ECG deserves balanced interpretation. Universal ECG screening of all children remains debated because of false-positive findings, cost, interpretation requirements, and uncertain

population-level benefit. Nevertheless, ECG is strongly justified when clinical screening raises concern. Modern pediatric ECG interpretation should account for age-specific normal variants, athletic adaptation, conduction intervals, repolarization patterns, and ventricular hypertrophy criteria. When the resting ECG is nondiagnostic but symptoms are intermittent, Holter or event monitoring becomes more appropriate (3,14).

Echocardiography is similarly most valuable when applied selectively. The availability of regional echocardiographic reference data is important because cardiac dimensions change with body size and age. Studies from Uzbekistan on echocardiographic norms and minor cardiac anomalies reinforce the need to index measurements appropriately and to avoid labeling physiological variation as disease (4,5). The same principle applies to blood pressure: cuff size, measurement technique, repeated confirmation, age/sex/height percentiles, and ABPM can substantially alter classification (6,7,12).

For O‘zbekiston pediatric practice, a pragmatic pathway could be implemented at three levels. At family-polyclinic level, routine visits should capture growth, BMI, blood pressure from age three, pulse quality, auscultation, exertional symptoms, family history, and lifestyle risk. At district or regional pediatric level, ECG, targeted laboratory testing, ABPM or Holter monitoring, and echocardiography can resolve common abnormalities. Specialized pediatric cardiology centers should manage complex CHD, cardiomyopathies, inherited arrhythmia syndromes, advanced imaging, and genetic diagnostics. Such tiering can improve referral quality and reduce the burden of low-yield testing.

The evidence base also has limitations. Much of the Uzbek literature consists of single-center studies, conference materials, narrative reviews, or relatively small cohorts, and standardized national pediatric thresholds are not uniformly available for every diagnostic domain. Therefore, local evidence should be combined with internationally validated pediatric guidelines while further multicenter research develops age- and population-specific reference standards. Future priorities include standardized pediatric BP surveillance, broader use of validated pediatric devices, electronic risk flags, longitudinal registries for congenital and inherited heart disease, and outcome-based evaluation of screening pathways.

CONCLUSION

Early detection of cardiovascular disease in children should be organized as a staged, risk-oriented process rather than a universal technology-based screening program. Clinical history, family history, physical examination, growth assessment, and blood-pressure measurement form the foundation. Neonatal pulse oximetry is an important population-screening tool for critical congenital heart disease, while ECG, echocardiography, ABPM, Holter monitoring, exercise testing, advanced imaging, and genetic testing should be selected according to specific clinical indications (12-15).

In Uzbek pediatric practice, particular attention is warranted for congenital heart disease, adolescent hypertension, rhythm and conduction abnormalities, obesity, and metabolic syndrome. Combining local evidence with international pediatric recommendations can strengthen early referral, prevent delayed diagnosis, and create opportunities for cardiovascular prevention before adult disease becomes established (1-11).

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