GLOBAL HEART

Cluster-Sampled Survey on the Prevalence, Distribution, and Types of Congenital Heart Disease among School-Aged Children in a District of Kathmandu, Nepal

ORIGINAL RESEARCH

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ABSTRACT

Background: Congenital heart disease (CHD) is a leading cause of childhood morbidity and mortality, accounting for one-third of all congenital birth defects. Despite its global significance, population-based data on CHD among school-aged children in Nepal remain limited.

Methods: A district-level, cross-sectional, school-based cluster survey was conducted in Bhaktapur Municipality in Kathmandu Valley from 22 to 26 December 2025, with the school as the primary sampling unit (cluster); no second-stage sampling was performed within schools. Total 90 registered schools (97.8%) participated. All enrolled children aged 3–18 years in the participating schools (N = 34,775; 95.2% of all enrolled children) underwent cardiac auscultation by trained physicians. Suspected cases were referred for echocardiography examination by pediatric cardiologists. CHD was classified according to the American Heart Association guidelines. Data were collected using standardized forms and analyzed using SPSS and R software.

Result: Out of 34,775 screened, 104 cases of CHD were detected, yielding the prevalence of 2.99 per 1,000 (95% CI: 2.44–3.62). Prevalence was higher in boys (3.80 per 1,000) than in girls (2.34 per 1,000). The prevalence of CHD requiring treatment was 0.92 per 1,000, with a marked male predominance (2.56 vs. 0.47 per 1,000 in girls). The most common defects were atrial septal defect (34, 32.6%), ventricular septal defect (14, 13.5%), patent foramen ovale (12, 11.5%), and complex CHD (4, 3.8%).

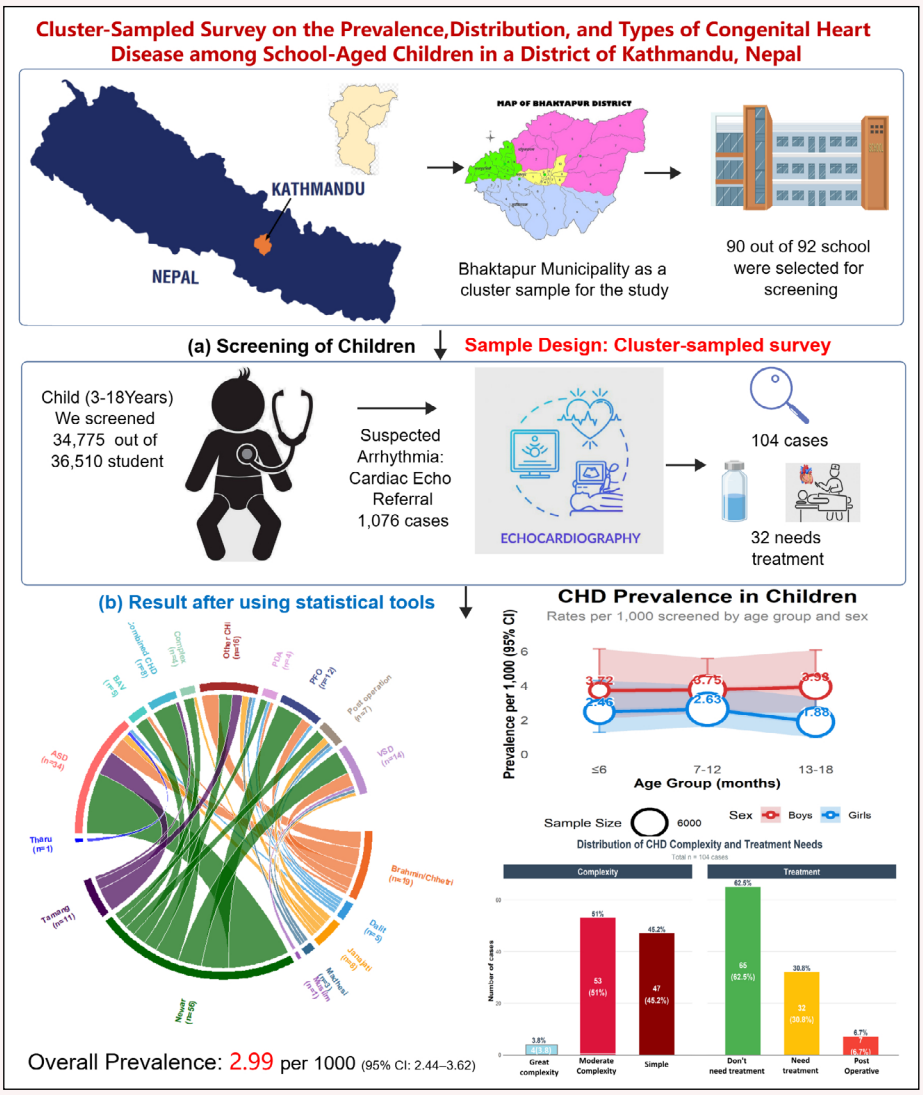
Conclusion: This study provides the first district-level, population-based prevalence estimate of CHD among school-aged children in Nepal, with ASD as the predominant lesion and a marked adolescent male predominance among treatment-requiring cases. The findings indicate a burden of CHD detectable through school-based cardiac screening and support further evaluation of such screening for early detection.

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GRAPHICAL ABSTRACT



BACKGROUND

Congenital heart disease (CHD) represented one of the most common birth defects globally (1) and continued to be a leading cause of health impact and mortality, particularly in low- and middle-income countries (LMICs) (2–4). Globally, the prevalence of cases of CHD was 15,774,456, and the age-standardized prevalence rate was 2.1 per 1,000 population in 2021 (5). Globally, the prevalence of CHD has been increasing among the school-aged children (6–8). In the United States, 2.4 million individuals are currently living with CHD (9, 10).

In Africa, the population-based prevalence was 5.12 per 1,000 children with ventricular septal defect (VSD), which was the most common type of CHD, followed by atrial septal defect (ASD) (11). The high CHD prevalence was also documented in the world's two most populous countries that share the border with Nepal (5). Tibet, China, reported the prevalence of CHD among children was significantly higher at 9.7 per 1,000 population, with ASD and patent ductus arteriosus (PDA) being the most common subtypes (12). In India, the prevalence of CHD among children was estimated at 2.25–5.2 per 1,000, and the most common CHD observed was VSD, followed by PDA and ASD (5, 13).

Actually, low and low-middle Socio-demographic Index (SDI) regions experienced the highest prevalence, and South Asia had the highest number of CHD cases (3, 5, 14). However, the epidemiological reported estimates of CHD prevalence in Nepal vary. A school-based echocardiographic screening of 6,573 children (aged 5–16 years) in the Sunsari district reported congenital defects accounted for 3.3 per 1,000 (15). An earlier study conducted in Kathmandu Valley among 9,420 school children found a CHD prevalence of 1.3 per 1,000. Respectively, both studies identify ASD as the most common lesion (17). More recent hospital-based studies from

two different tertiary centers indicated that among 218 and 249 children clinically suspected of cardiac disease and referred for echocardiography, 66.05% and 30.5% were detected as CHD, respectively (18). In 2023, a meta-analysis synthesizing data from nine studies across Nepal estimated the overall prevalence of CHD in the pediatric age group to be approximately 7 per 1,000 population, with a male predominance and ASD as the most common type overall (19).

Despite the above contributions, existing studies in Nepal were constrained by several limitations, including relatively small sample sizes, recruitment from single healthcare facilities, or focus on specific subgroups such as hospital-referred cases. There was a notable lack of designed population-representative data obtained through more reliable methods specifically targeting school-aged children. This study therefore aimed to conduct a district-level, school-based cluster survey, in which each registered school constituted a cluster, to determine the current prevalence and different CHD treatment statuses, as well as types and size of the CHD defects among school-aged children in Bhaktapur, Nepal. The findings could provide updated epidemiological evidence to guide public health planning, resource allocation, and early detection strategies for LMICs to improve outcomes for children with CHD (20), aligning with Sustainable Development Goal 3.2 to reduce the infant and under-five mortality by ≤12 and ≤25 per thousand live births, respectively (21).

METHODOLOGY

STUDY DESIGN AND PARTICIPANTS

We conducted a district-level, cross-sectional, cluster-sampled school-based survey to estimate the prevalence, distribution, and clinical types of CHD among children aged 3 to 18 years in Bhaktapur Municipality, located in the Kathmandu Valley, Nepal. The school was defined as the cluster (primary sampling unit): one cluster corresponded to one registered school within Bhaktapur Municipality. Schools, rather than classes or grades, were used as clusters because the municipal register of schools provided a complete and verifiable sampling frame and because examining all eligible children within each school on site was feasible within the five-day screening period. A one-stage, 'take-all' cluster design was used, and no second-stage sampling was performed at the class, grade, or individual level. The study was carried out over a five-day period from December 22 to 26, 2025, as part of the 'Love Heart Journey' initiative, a collaborative cardiac screening project between Chinese and Nepalese medical institutions. All 92 registered schools (both public and private) within Bhaktapur Municipality constituted the sampling frame and were invited to participate. Of these, 90 schools (97.8%) agreed to take part in the screening; the remaining two schools had completed routine health examinations within the preceding six months, and their principals therefore considered a repeat examination unnecessary at that time. All enrolled children aged 3–18 years were eligible for inclusion and were offered screening; of the 36,510 children enrolled in the participating schools, 34,775 (95.2%) were screened. All children aged 3–18 years enrolled in the participating schools were eligible for inclusion; the only exclusion criteria were refusal of informed consent by a parent or guardian and absence from school on the days of screening. No child was excluded on the basis of symptoms or clinical findings, and children with previously recognized or operated cardiac disease were included. Because all registered schools in the municipality were invited and every eligible child was included, the survey was a complete enumeration of the target population rather than a sample, and no a priori sample-size calculation was performed; the numbers of children who were absent and of those whose parents declined consent are shown in Figure 1. Field screening was completed over five consecutive days (22–26 December 2025); the subsequent phase of data collation, verification, coding, and analysis continued for a further month, from 27 December 2025 to 27 January 2026, as described below.

SCREENING AND DATA COLLECTION

Screening was conducted by two teams comprising a total of 28 medical doctors from Nepal and China, all registered with the Nepal Medical Council. Before the survey, all physicians completed a standardized pre-service training program delivered in three stages by qualified instructors: theoretical teaching (at least 8 hours), simulation practice on heart-sound recordings (at least 4 hours), and supervised on-site practice, with senior trainers working alongside the physicians throughout. The syllabus covered normal heart sounds and innocent murmurs in children, the standardized five-area auscultation sequence, Levine grading, the murmur patterns of the common lesions, and the positivity rules applied in this survey (any systolic murmur of grade

2/6 or more, any diastolic or continuous murmur, or any abnormal second heart sound). Before screening independently, each physician completed at least 200 supervised auscultations and achieved a personal sensitivity of at least 90% against echocardiography over at least 50 paired comparisons; the training and calibration protocol is provided as Supplementary File S2. Each child underwent cardiac auscultation by a single physician to detect pathological murmurs or other clinical signs such as growth retardation, cyanosis, or arrhythmia; because each child was examined once by a single examiner, a two-examiner kappa could not be computed, and reliability was instead addressed through this criterion-based calibration of all physicians before fieldwork. Children with abnormal findings were classified as suspected CHD cases and referred for echocardiography, which was performed on-site by a pediatric cardiologist and an ultrasound doctor using portable ultrasound systems (Mindray M9T and Philips CX50).

Demographic and clinical data forms were adapted from published SCI journals (22) and included age, sex, ethnicity, auscultatory findings, echocardiographic diagnosis, and treatment recommendations as need treatment (including need follow-up), post-operation, and don't need treatment. CHD types were recorded according to ICD-10-CM (International Classification of Diseases, 10th Revision) (23); specific ICD-10-CM information is provided in the supplementary material. The severity classification (simple, moderate complexity, great complexity) according to 2018 AHA/ACC anatomic complexity classification (24). Simple: Defects with no anticipated need for intervention; routine follow-up in primary care. Moderate Complexity: Defects amenable to a single corrective procedure (surgical or transcatheter). Great Complexity: Defects requiring multiple staged procedures or lifelong palliative care; follow-up at specialized adult CHD centers recommended.

After the field survey had closed, a team of eight researchers—Nepali physicians, postgraduate students, and nurses drawn from the study team—assembled and verified all study data over a period of approximately one month, from 27 December 2025 to 27 January 2026. Completed data forms and echocardiography reports were checked for completeness and internal consistency; all records were entered into a Microsoft Excel database using double data entry, with each record entered independently by two researchers, and any discrepancies between the two entries were resolved against the source documents and, where necessary, with the examining physician. Diagnoses were then coded according to ICD-10-CM and the 2018 AHA/ACC anatomic complexity classification before statistical analysis.

Ethical approval and the procedures for parental consent and child assent are described under 'Ethics approval and consent to participate'.

STATISTICAL ANALYSIS

Analyses were performed with SPSS version 26.0 (SPSS, Chicago, Illinois) and RStudio version 2026.01.0 + 392 (https://www.r-project.org/). Categorical variables are summarized as frequencies and percentages. Age, the only continuous variable, was not normally distributed and is summarized by medians and interquartile ranges; comparisons of age between groups therefore used the Mann-Whitney U test (two groups) and the Kruskal-Wallis H test (three or more groups), and categorical variables were compared using the chi-square test or Fisher's exact test. Trends across ordered age groups were assessed using the Cochran-Armitage test. Prevalence estimates were expressed per 1,000 screened children with 95% confidence intervals (CI) computed by the exact (Clopper–Pearson) binomial method, the same method being applied to all subgroup estimates. As the study was a complete enumeration rather than a sample, the sample size was not determined by an a priori calculation; the precision achieved for the prevalence estimates is conveyed by the reported 95% confidence intervals. A two-tailed $P < 0.05$ was considered statistically significant. Because all registered schools within the municipality were enumerated (a take-all cluster design with the school as the primary sampling unit), no sampling weights were applied. School identifiers were not recorded in the analytical dataset, so the intracluster correlation and design effect could not be estimated, and the 95% confidence intervals were calculated under a binomial assumption without adjustment for intra-school correlation; as all schools were enumerated rather than sampled, this affects the precision of the estimates rather than the point estimates. To identify factors associated with treatment demand, a multivariable multinominal logistic regression model was fitted among the 104 children with CHD, with the treatment category as the outcome and age, sex, and ethnicity entered simultaneously as fixed effects; results are reported as exponentiated coefficients with 95% confidence intervals (Supplementary Table S1).

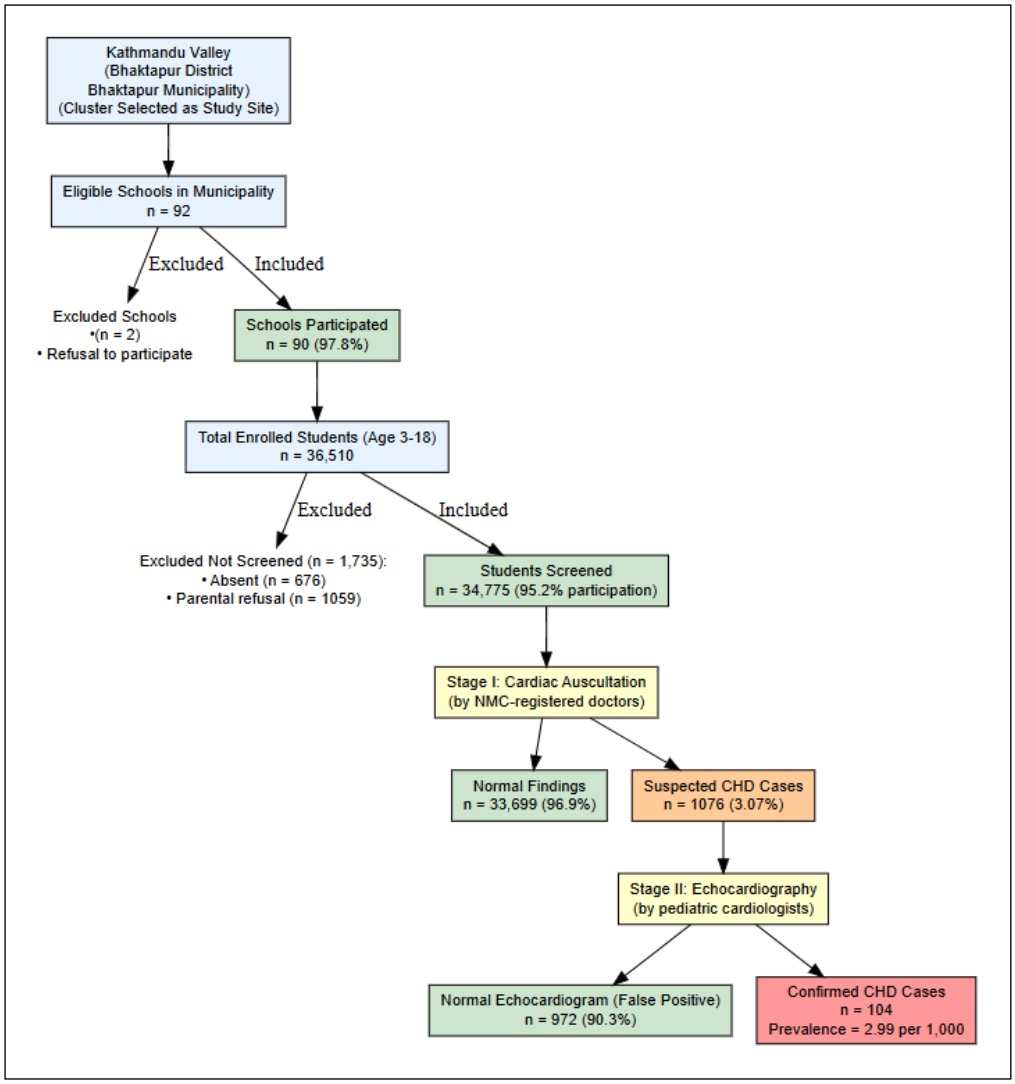


Figure 1 STROBE flow diagram of the study.

RESULT

PARTICIPANTS CHARACTERISTICS

A total of 34,775 school-aged children from the 90 participating schools underwent cardiac auscultation; their median age was 10 years (interquartile range [IQR] 6–13 years). Abnormal auscultatory findings were identified in 1,076 children (3.1%), all of whom underwent confirmatory echocardiography. CHD was confirmed in 104 children, an overall prevalence of 2.99 per 1,000 screened children (95% CI 2.44–3.62) (Figure 1).

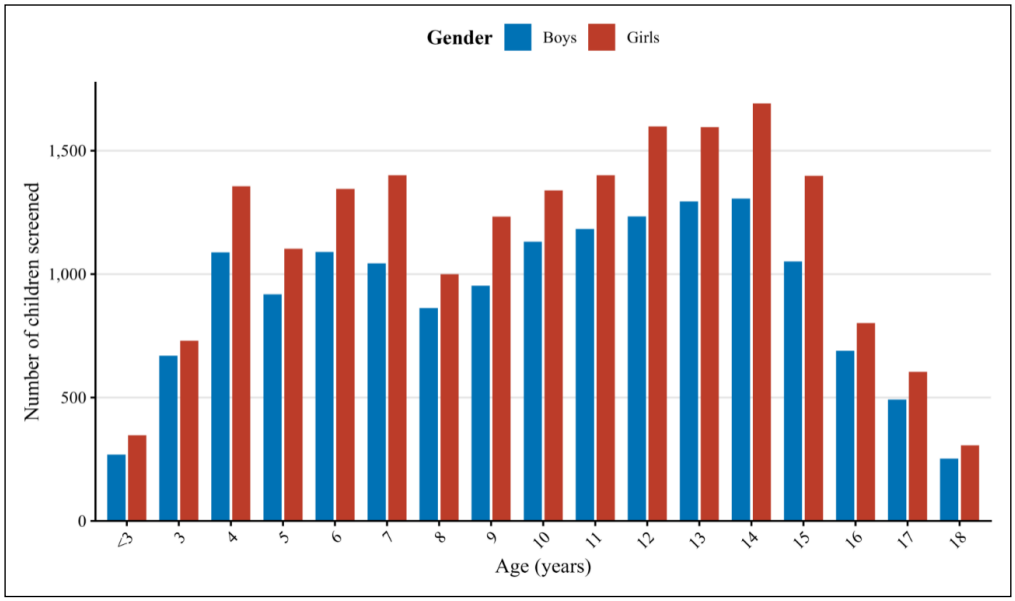


Figure 2 Age-sex distribution in community-based congenital heart disease screening.

PREVALENCE DISTRIBUTION AND TREATMENT REQUIRED DISTRIBUTION

The prevalence of CHD was higher in boys than in girls (3.80 versus 2.34 per 1,000; Table 1). Overall prevalence showed no significant trend across age groups (P = 0.880). The prevalence of treatment-requiring CHD, by contrast, rose significantly with age (P for trend = 0.016). This increase was driven almost entirely by boys: no significant age trend was observed in girls (P = 0.907), whereas in boys the rise was statistically significant (P < 0.001). The sex difference was therefore concentrated in adolescence, where the prevalence of treatment-requiring CHD in boys was more than five times that in girls (2.56 versus 0.47 per 1,000); in the younger age groups the two sexes were similar. Total CHD prevalence, in contrast, remained stable across age groups in both sexes (all P > 0.05) (Table 1) (Figure 2).

AGE	NUMBER OF CHILDREN SCREENED	CHD	PER 1,000 (95% CI)	*P*	REQUIRING TREATMENT CHD	PER 1,000 (95% CI)	*P*
Boys				0.982#			**<0.001**
≤6	4034	15	3.72 2.08, 6.13)		1	0.25 (0.01, 1.38)	
7–12	6407	24	3.75 (2.40, 5.57)		5	0.78 (0.25, 1.82)	
13–18	5084	20	3.93 (2.41, 6.07)		13	2.56 (1.36, 4.37)	
Total	15525	59	3.80 (2.89, 4.90)		19	1.22 (0.74, 1.91)	
Girls				0.633#			0.907
≤6	4881	12	2.46 (1.27, 4.29)		4	0.82 (0.22, 2.10)	
7–12	7972	21	2.63 (1.63, 4.02)		6	0.75 (0.28, 1.64)	
13–18	6397	12	1.88 (0.97, 3.27)		3	0.47 (0.10, 1.37)	
Total	19250	45	2.34 (1.71, 3.13)		13	0.68 (0.36, 1.15)	
Both				0.880#			**0.016**#
≤6	8915	27	3.03 (2.00, 4.40)		5	0.56 (0.18, 1.31)	
7–12	14379	45	3.13 (2.28, 4.19)		11	0.77 (0.38, 1.37)	
13–18	11481	32	2.79 (1.91, 3.93)		16	1.39 (0.80, 2.26)	
Total	34775	104	2.99 (2.44, 3.62)		32	0.92 (0.63, 1.30)	

Table 1 Distribution of congenital heart disease prevalence and requiring treatment CHD cases, stratified by sex and age in Kathmandu, Nepal.

Cochran–Armitage trend test across age groups. 95% CIs computed by the exact (Clopper–Pearson) binomial method.

CHD AND ETHNICITY

Of the 104 children with CHD, 19 (18.3%) were from the ethnic majority group and 85 (81.7%) from minority groups, with no significant age difference between them (P = 0.206; Table 2). Simple and moderate-complexity lesions together predominated in both groups, and the proportion recommended for treatment was similar across ethnicities. A difference was seen only in postoperative status: all seven children who had undergone cardiac surgery belonged to minority groups, and none belonged to the majority group (Table 2).

FACTORS M (P_{25}, P_{75})/N (%)	TOTAL	ETHNICITY		*P*
		MAJORITY	MINORITY	
Age	10 (6,13)	12 (7,14)	10 (6,13)	0.206[a]
Gender				
Boys	59 (56.7)	10 (52.6)	49 (57.6)	0.690[b]
Girls	45 (43.3)	9 (47.3)	36 (42.3)	
CHD Anatomy				
Simple	47 (45.2)	9 (47.3)	38 (44.7)	0.628[b]
Moderate Complexity	53 (51.0)	10 (52.6)	43 (50.5)	
Great Complexity	4 (3.8)	0 (0)	4 (4.7)	
Echocardiography Recommendations				0.606[c]
Requiring Treatment	32 (30.8)	6 (31.6)	26 (30.6)	
No treatment required	65 (62.5)	13 (68.4)	52 (61.2)	
Postoperative	7 (6.7)	0 (0)	7 (8.2)	

Table 2 Baseline characteristics of school-aged children with screen-detected CHD in Bhaktapur (Nepal), stratified by ethnicity.

a: Mann-Whitney U test; b: Chi-square test; c: Fisher test.

TYPES OF CHD AND ETHNICITY

The Newar ethnic group carried the highest overall burden of CHD and accounted for the largest share of cases across several diagnostic categories (Figure 3). ASD was the leading lesion in this group, followed by patent foramen ovale, ventricular septal defect, and combined CHD. Among Brahmin/Chhetri children, ASD and other CHD were the most frequently observed lesions. No cases of combined CHD, complex CHD, or post-operative status were recorded in the Brahmin/Chhetri group (Figure 3).

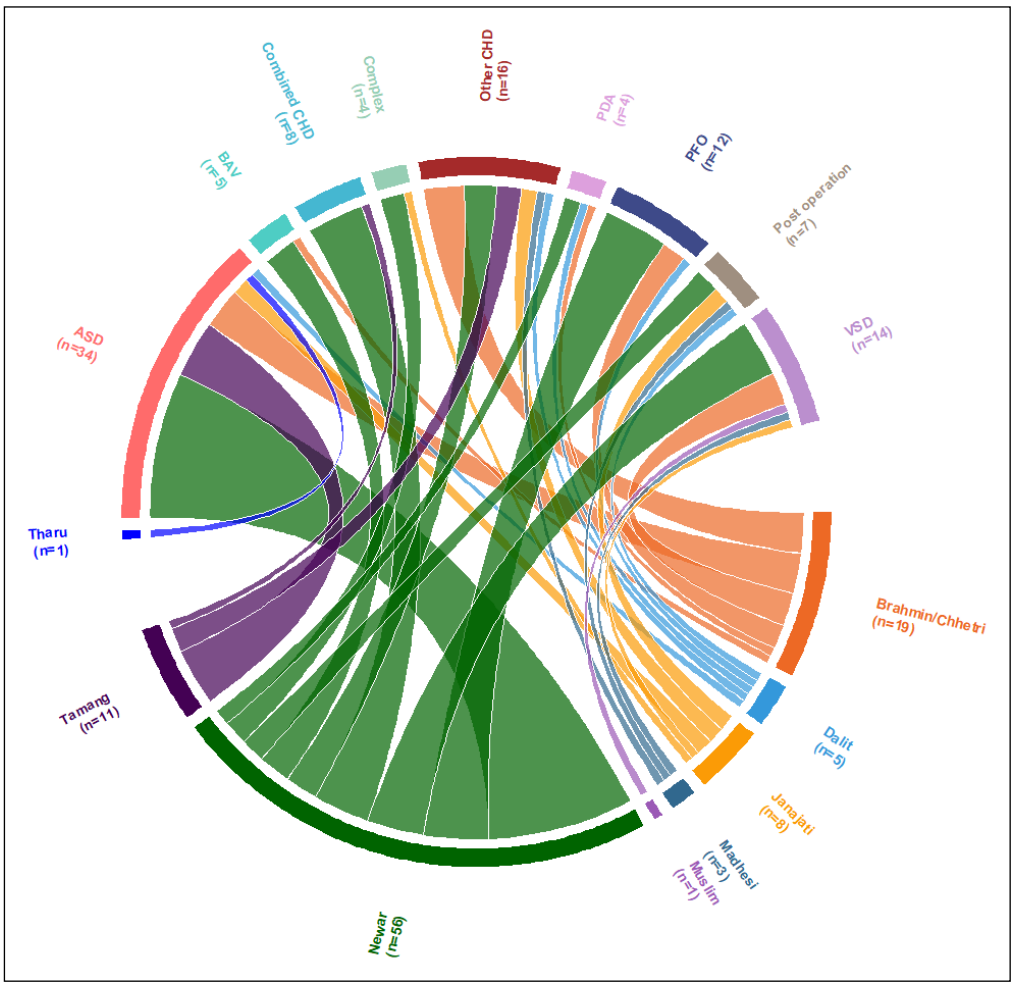


Figure 3 Chord diagram of associations between congenital heart disease types and ethnic groups in Nepal.

DISCUSSION

This school-based cluster survey, in which each registered school constituted a cluster and all registered schools of the municipality were enumerated, provides the most complete population-based estimate to date of CHD prevalence among school-aged children in one district of Nepal. The key findings are a substantial burden of CHD, a marked sex disparity in disease severity during adolescence, and a distinctive CHD lesion distribution. These findings are relevant to the design of targeted screening in Nepal and other LMICs.

The observed prevalence sits at the lower end of estimates from population-based studies in other LMICs (6, 15); a systematic review of unrepaired CHD in LMICs reported a pooled prevalence of 3.84 per 1,000 (95% CI 3.016–4.765) (6). It is substantially lower than estimates from hospital-based studies in Sub-Saharan Africa, where rates of 8–10 per 1,000 have been documented in Dakar, Senegal (25), but it aligns closely with the population-based subset of the Shrestha analysis, which reported a mean prevalence of 3.3 per 1,000 (15).

The higher figure in the meta-analysis probably reflects the inclusion of hospital-based studies, which are biased toward more symptomatic and complex cases, whereas a community survey captures a larger reservoir of mild, asymptomatic lesions; most confirmed cases in this study required no treatment (Table 2). The 2.3-fold higher prevalence than in earlier community studies in Kathmandu (16, 17) is unlikely to indicate a true rise; it more plausibly reflects the

greater diagnostic sensitivity of the two-tiered approach (systematic auscultation followed by echocardiography), underscoring the role of portable ultrasound in detecting the community burden of CHD.

A novel and clinically relevant finding was the age-related divergence in treatment-requiring CHD between the sexes: overall CHD prevalence was stable across age groups, whereas the prevalence of treatment-requiring CHD rose with age in boys but not in girls, producing a widening sex difference in adolescence. This finding is consistent with global patterns of male predominance in CHD (26), and the observed sex ratio is comparable to the 1.5:1 reported by Sherzad et al. (27) and Bodian et al. (25). The reasons for this divergence cannot be determined from these data and would require longitudinal or health-service evidence.

The predominance of ASD over VSD in this study departs from the global epidemiological pattern, in which VSD is typically the most common defect (6, 8), and appears instead to be a characteristic signature of community-based screening in a school-aged population. Hospital-based studies, such as those from Nepal (28, 29) and Nigeria (30), capture VSD more frequently because these patients often present with symptoms in infancy or early childhood, whereas ASDs rarely close spontaneously and often remain asymptomatic until later in life, accumulating to become the most prevalent detectable lesion in this age group. This pattern is consistent with other school-based studies in China (31) and India (32), and it indicates that, for school-based screening in an LMIC, ASD is the primary target lesion, a finding that should inform resource allocation and training. This lesion distribution must also be read in the light of the auscultation-first design, in which defects producing an audible and persistent murmur were preferentially detected; it reinforces the case for adding pulse oximetry, and where feasible targeted echocardiography, to school-based screening in low- and middle-income settings.

The distribution of CHD anatomical complexity was similar across ethnic lines, with simple and moderate-complexity lesions together accounting for the vast majority of cases in both groups (Table 2). The few great-complexity lesions occurred exclusively in the minority group; because the absolute numbers were small, this difference did not reach statistical significance and cannot be interpreted further with these data.

The proportion of children recommended for treatment was likewise comparable between the majority and minority groups (Table 2), and most children in both groups had lesions that did not require treatment, consistent with the predominantly mild nature of screen-detected CHD. A difference emerged only in postoperative status: all children who had undergone cardiac surgery belonged to minority groups, the Newar—the predominant minority in Bhaktapur—contributing most of these cases. Whether this reflects differential access to intervention cannot be determined from the present data.

LIMITATION OF THIS STUDY

While providing the most complete enumeration to date within the Kathmandu Valley, this study had limitations. First, the generalizability of the findings to Nepal's diverse, often rural, geographic and ethnic landscape is limited: the higher altitude, different ethnic compositions, and variable healthcare access in other regions could yield different prevalence estimates. Second, the school-based design inherently excluded out-of-school children, a population that may face higher socioeconomic barriers and potentially a higher risk of undiagnosed or more severe CHD; this could lead to a conservative underestimate of the true population prevalence. Third, the screening strategy was auscultation-first: all children underwent clinical examination, and only those with pathological murmurs or other abnormal findings were referred for echocardiography, so silent or near-silent lesions, such as small secundum atrial septal defects, small patent ductus arteriosus, and mild pulmonary stenosis, may have been missed, and the reported prevalence is best interpreted as a minimum estimate of the true burden of CHD in this population; because echocardiography was not performed in children with normal auscultation, the sensitivity of the screening strategy could not be quantified. Fourth, although the school served as the sampling unit (cluster), school identifiers were not recorded in the analytical dataset, so the intracluster correlation and design effect could not be estimated, and the 95% confidence intervals were calculated under a binomial assumption without adjustment for intra-school clustering; as all registered schools in Bhaktapur

Municipality were enumerated and invited to participate, this affects the precision of the estimates rather than the point estimates, and the intervals may be slightly narrower than those that would have been obtained had a design effect been applied. Fifth, the multivariable analysis identifies factors associated with treatment demand but, given the cross-sectional design and the limited number of cases across outcome categories, establishes associations rather than causal effects.

CONCLUSION

This study provides the first robust, district-level, population-based prevalence estimate of CHD among school-aged children in Nepal and reveals a substantial, previously underappreciated burden of disease with ASD as the predominant lesion. The emergence of a sex-based disparity in disease severity during adolescence is a notable finding. These findings document the burden and distribution of CHD in this population and could inform the design and evaluation of school-based screening; they support the case for assessing such a program in comparable settings, rather than establishing its effectiveness.

ABBREVIATIONS

AHA/ACC	American Heart Association/American College of Cardiology
ASD	Atrial Septal Defect
BAV	Bicuspid Aortic Valve
CHD	Congenital Heart Disease
ICD	International Classification of Disease
IQR	Inter Quartile Range
LMICs	Low- and Middle-Income Countries
NCDs	Non-Communicable Disease
NHRC	Nepal Health Research Council
PDA	Patent Ductus Arteriosus
PFO	Patent Foramen Ovale
SCI	Science Citation Index
SDI	Socio Demographic Index
SDG	Sustainable Development Goal
SPSS	Statistical Packages of Social Sciences
VSD	Ventricular Septal Defect
WHO	World Health Organization

DATA ACCESSIBILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ADDITIONAL FILES

The additional files for this article can be found as follows:

- **Supplementary File S1.** Child Assent Form. DOI: https://doi.org/10.5334/gh.1598.s1
- **Supplementary File S2.** Written Parental Consent Form. DOI: https://doi.org/10.5334/gh.1595.s2
- **Supplementary File S3.** Standard Operating Procedure for Cardiac auscultation in the Children with Congenital heart disease. DOI: https://doi.org/10.5334/gh.1595.s3

ETHICS AND CONSENT

Ethical approval was obtained from the Ethical Review Committee of the Nepal Health Research Council (Ref. No. 466). The study protocol conformed to the ethical principles of the Declaration of Helsinki. Informed consent was obtained in two stages: before the heart-sound screening, which was non-invasive and carried no expected risk, verbal consent was obtained from the parent or guardian together with verbal assent from the child; for children whose screening indicated possible congenital heart disease, written consent was obtained from the parent or guardian before the health questionnaire was administered and before confirmatory echocardiography. Assent was obtained from each child in a form appropriate to age, namely written assent for children aged 12–18 years and verbal assent, recorded on the form, for younger children; a signature or thumbprint was accepted where a parent or child was unable to write. The consent and assent forms are provided as Supplementary File S3. Children diagnosed with CHD were referred for appropriate clinical management at Shahid Gangalal National Heart Center, Nepal.

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COMPETING INTERESTS

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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