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Prevalence of rheumatic heart disease in children and young adults in Botswana

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Background. Rheumatic heart disease (RHD) primarily affects children and young adults in low-income countries, and marginalised groups in high-income countries. It results from acute rheumatic fever, leading to valvular lesions that may become clinically apparent several years later. Early echocardiograms enable prompt intervention and minimise the risks of progression. However, data on echocardiographic findings in Botswana are lacking.
Objective. To assess the prevalence of RHD in individuals aged 6 - 35 years.
Methods. This cross-sectional study, conducted from 2018 to 2023, screened schoolchildren and young adults in rural and urban districts of Botswana. Participants aged 6 - 35 years were randomly selected from primary schools, secondary schools and the community. Based on the 2012 World Heart Federation echocardiographic guidelines for RHD, they were classified as having one of normal findings, borderline RHD, or definite RHD.
Results. We included 4 786 participants, with a median (interquartile range) age of 17 (12 - 25) years; 64.8% were female. There were 19 cases of either borderline (n=7) or definite (n=12) RHD, resulting in a prevalence of 4 cases/1 000 population (95% confidence interval 2.5 - 6.2). The number of RHD cases varied by geographical location, with the highest being in the Northwest district. We also detected several asymptomatic congenital and non-RHD-acquired heart diseases.
Conclusion. RHD affected 4 cases per 1 000 population, representing a significant proportion of children and young adults in Botswana. The study also identified undiagnosed congenital cardiovascular diseases among the participants. The findings emphasise the need for a screening programme and a registry for children and young adults. Identifying those with mild conditions who could benefit from secondary antibiotic prophylaxis is essential.

Keywords: rheumatic heart disease, Botswana, children and young adults

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Rheumatic heart disease (RHD) is a significant health issue in Africa, particularly among children and young adults, with substantial associated economic costs, morbidity and mortality.[1-5] While auscultation has been used for screening, echocardiography is 3 - 10 times more sensitive, and supports early diagnosis and timely penicillin prophylaxis.[6] This led to the establishment of standardised criteria for epidemiological screening and echocardiographic reporting by the World Heart Federation (WHF) in 2012.[7] Several echocardiographic screenings for RHD have since been conducted worldwide, particularly in Africa, targeting schoolchildren aged 5 - 15 years and young adults (Table 1).[8-22] A systematic review and meta-analysis of studies conducted from 2015 to 2021 utilising the 2012 WHF criteria revealed a pooled prevalence of RHD of 25.5 per 1 000, highlighting the endemic nature of RHD across Africa.[22] The prevalence of RHD varies across African countries, and within communities in each country, owing to differences in socioeconomic and environmental factors, including inadequate housing, undernutrition, overcrowding, access to healthcare and poverty.[23,24] The high prevalence of RHD in Africa emphasises the need for policies and interventions that prioritise continuous,

Table 1. Summary of echocardiographic RHD screening studies in Africa*

Study	Country	Target population (*n*)	Reported RHD prevalence rate (per 1 000)
Engel *et al.* (2015)[8]	South Africa and Ethiopia	Schoolchildren (4 720)	20.2 (definite: 5.3, borderline: 14.9)
Ngaïdé *et al.* (2015)[9]	Senegal	Schoolchildren (2 019)	16.5 (definite: 4.95, borderline: 11.5)
Kwok *et al.* (2015)[10]	Angola	Urban and rural children (1 180)	32.0 (definite: 11.0, borderline: 21.0)
Godown *et al.* (2015)[11]	Uganda	Schoolchildren (4 773)	40.0 (definite: 11.0, borderline: 29.0)
Yadeta *et al.* (2016)[12]	Ethiopia	Schoolchildren (4 773)	37.0 (definite: 11.0, borderline: 26.0)
Gemechu *et al.* (2020)[13]	Ethiopia	Rural community (987)	56.7 (definite: 37.5, borderline: 19.2)
Musuku *et al.* (2018)[14]	Zambia	Schoolchildren (3 000)	36.0 (definite: 13.0, borderline: 23.0)
Mucumbitsi *et al.* (2017)[15]	Rwanda	Schoolchildren (2 525)	22.9 (definite: 6.7, borderline: 16.2)
Ali S *et al.* (2018)[16]	Sudan	Schoolchildren (4 515)	19.0 (Nyala)/0.3 (Khartoum)
Kazahura *et al.* (2021)[17]	Tanzania	Primary schoolchildren (1 061)	34.0 (definite: 10.4, borderline: 23.6)
Bimerew *et al.* (2021)[18]	East Africa (meta-analysis)	Schoolchildren (37 215)	17.9 (pooled prevalence)
Chillo *et al.* (2023)[19]	Tanzania	Schoolchildren (2 126)	17.4 (definite: 5.6, borderline: 11.8)
Ali A *et al.* (2023)[20]	Egypt	Schoolchildren (3 000)	33.3 (definite: 13.3, borderline: 20.0)
Ekure *et al.* (2019)[21]	Nigeria	Schoolchildren (4 107)	14.9 (definite: 2.7, borderline: 12.2)
Morais *et al.* (2024)[22]	Africa (meta-analysis)	Systematic review (84 321)	25.5 (pooled prevalence)

*All studies listed used 2012 World Heart Federation criteria.[7]

population-based active surveillance for early detection and management, especially in children and adolescents.[25] Owing to insufficient RHD data in Botswana, we conducted a nationwide study to assess the prevalence of RHD in the country.

Methods

Study design and setting

This cross-sectional study was conducted in Botswana, an upper-middle-income nation in southern Africa, from June 2018 to June 2023. It included primary and secondary schools as well as community settings.[26] It encompassed urban and rural populations in eight selected administrative districts of Botswana (Fig. 1). The country has 10 districts: Central, Chobe, Gantsi, Kgalagadi, Kgatleng, Kweneng, Northeast, Southeast, Northwest and Southern. Central is the largest in area and population, whereas Southeast, Kweneng and Northeast are smaller but more populous. The Kgalagadi is vast but sparsely populated, with the Kalahari Desert covering approximately one-third of its area. Northwest is one of the largest districts and is home to the second-largest village, Maun. Chobe is a small district in the north, previously part of the Northwest district. The Southern district is home to the largest beef farms, private ranches and government farms. Chobe was excluded from the study because its similarities to the Northwest district suggested that findings from Maun would be sufficient to represent it. Similarly, Kgatleng was excluded due to its small size, proximity to and shared characteristics with Gaborone. The study sites included Gaborone and the nearby rural Southeast District, Kanye Village and its surroundings (Southern District), Molepolole Village (Kweneng District), Tshabong Village (Kgalagadi District), Serowe Village (Central District), Ghanzi (Ghanzi District), Francistown and surrounding areas (Northeast) and Maun Village (Northwest). In 2018, these districts had a combined population of 1 659 893, accounting for 1.8% of the country's total population of 2 304 238.[27]

Study participants

Eligible participants were aged 6 - 35 years. We used a prevalence of 20 cases per 1 000 schoolchildren, as reported in South Africa and Ethiopia, for our sample size calculations.[8] To estimate a prevalence rate of 4 cases per 1 000 with 95% confidence, the minimum required sample size was 4 786.[8]

Sampling procedure

We used a multistage sampling method. Using a random number list for the first stage, we selected eight administrative districts for the study. A single study site was designated for each district. The overall population across these selected sites was 643 776. Using proportional sampling, we randomly selected primary and secondary schools, as well as enumeration areas, for the second-stage sampling. An enumeration area in Botswana is a small geographic zone used for censuses and surveys, covered by a single enumerator. It typically contains 75 - 150 dwellings (~300 - 600 people) in rural areas, and 110 - 220 dwellings (~440 - 880 people) in urban areas.[28,29] We selected 19 primary schools and 20 junior and senior secondary schools. We contacted the heads of education departments, community leaders, and all selected schools to obtain permission to conduct the study in their respective areas or schools. We then visited schools and communities to explain the study objectives and procedures. In each school, we randomly selected classes from the available list. Information sheets and consent forms were sent home to parents or guardians of students selected to sign. Their respective class teachers collected the signed informed consent forms the following day, and participants signed the informed assent forms before taking part in the study. Parents and guardians who required further clarification were provided with it by phone. We invited young adults from the communities, via their community leaders, to selected study sites. A consecutive enrolment process was used for eligible young adults from the designated area. Adults who consented to participate were enrolled consecutively in the study.

Data collection

The research team, in collaboration with a school or community staff member, organised RHD screening in private rooms at schools and public health facilities. We used portable machines (Sonosite M-Turbo Portable Ultrasound, FUJIFILM Sonosite Inc., USA) with a P21X cardiac probe with a 1 - 5 MHz frequency range, and a Mindray Portable echocardiographic machine (Mindray Medical International, China). We performed two-dimensional echocardiography with a 2-MHz linear transducer, focusing on the aortic and mitral valves through parasternal long-axis and four-chamber views. We chose to use the 2012 WHF echocardiographic criteria for the diagnosis of RHD. These criteria are evidence-based and were the standard until

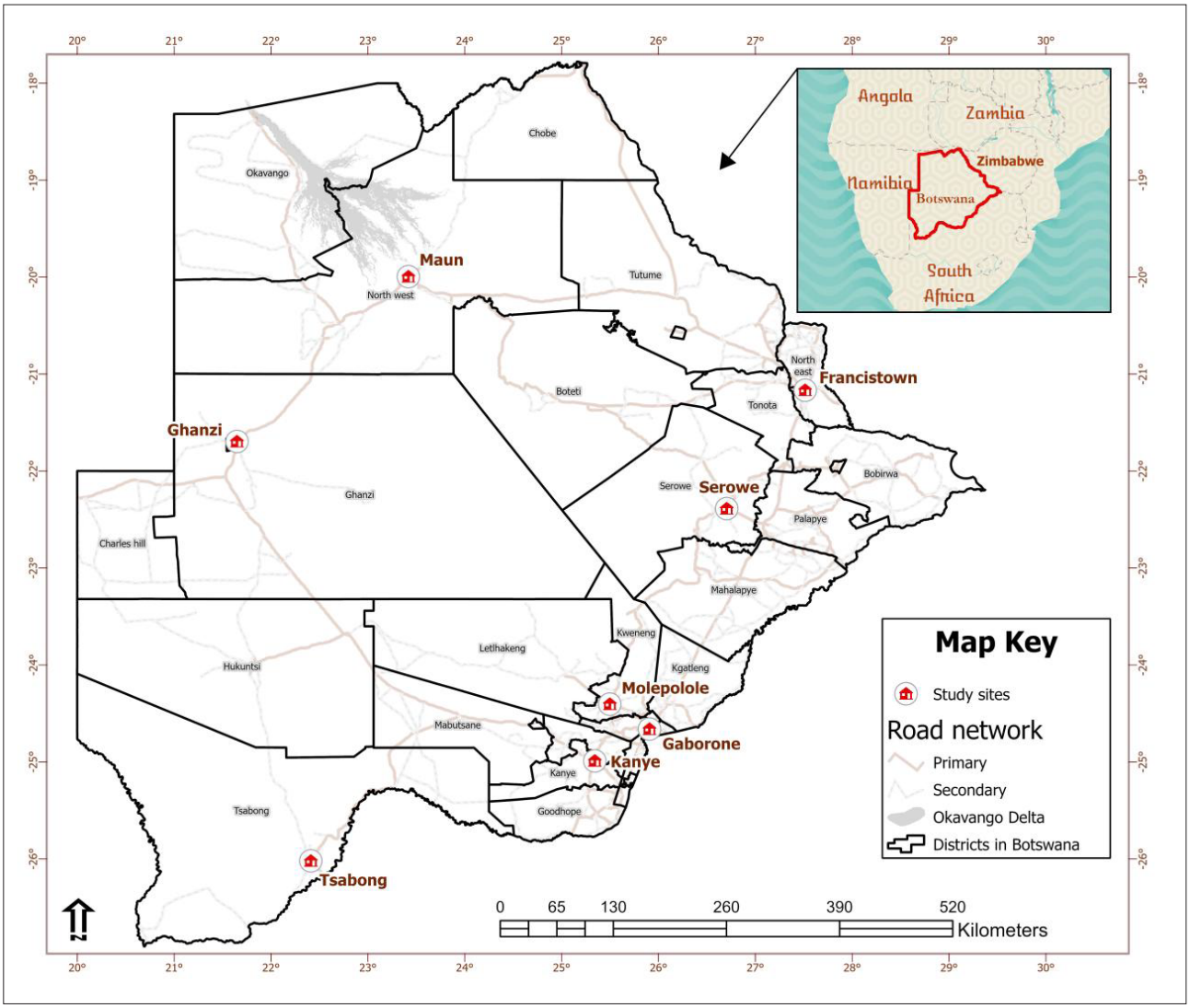

Fig. 1. Study area map.

Table 2. 2012 World Heart Federation criteria for echocardiographic diagnosis of RHD[7]

Individuals aged ≤20 years		Individuals aged >20 years
Definite RHD (either A, B, C, or D)	**Borderline RHD (either A, B, or C)**	**Definite RHD (either A, B, C, or D)**
A. Pathological MR and at least two morphological features of RHD of MV	A. At least two morphological features of RHD of MV without pathological MR or MS	A. Pathological MR and at least two morphological features of RHD of MV
B. MS mean gradient ≥4 mmHg	B. Pathological MR	B. MS mean gradient ≥4 mmHg
C. Pathological AR and at least two morphological features of RHD of AV	C. Pathological AR	C. Pathological AR and at least two morphological features of RHD of AV, only in individuals aged <35 years
D. Borderline disease of both AV and MV		D. Pathological AR and at least two morphological features of RHD of MV

RHD = rheumatic heart disease; MR = mitral regurgitation; MV = mitral valve; MS = mitral stenosis; AR = aortic regurgitation; AV = aortic valve.

the recent 2023 update.[30] The 2012 WHF criteria are more specific and reproducible for confirmed cases compared with the 2005 standards set by the World Health Organization and the National Institutes of Health, which relied on expert consensus.[31] Our analysis of RHD included two-dimensional, colour and spectral Doppler assessments, focusing on the valve and chordal thickening, leaflet mobility, coaptation abnormalities and prolapse. We also evaluated Doppler features for mitral and aortic regurgitation. Participants with abnormalities in the apical four-chamber or parasternal long-axis views were referred to Princess Marina Hospital, a tertiary hospital in Botswana, for confirmatory echocardiograms by two cardiologists (JCM, ET) using a VIVID Q machine (GE HealthCare, USA) with a frequency range of 2.5 - 5 MHz. Findings were categorised using the 2012 WHF guidelines (Table 2) as 'normal', 'borderline RHD', or 'definite RHD'.[7] Disagreement between the two cardiologists was settled through discussion and agreement. Patients with other

abnormalities, such as congenital heart disease, were also referred to Princess Marina Hospital for confirmatory echocardiograms.

Data analysis

Data entry and analysis were performed using SPSS software version 27 (IBM, USA). Numerical variables were displayed as means and standard deviations (SDs), or medians and interquartile ranges (IQRs). Categorical variables were expressed as proportions and percentages. The prevalence of RHD was estimated for the total population, study sites, and age groups (≤20 years and >20 years).

Ethical considerations

This research was approved by the institutional review boards of the University of Botswana and the Health Research and Development Committee of the Botswana Ministry of Health (ref. no. HPDME 13/18/1). Approval was obtained from the districts and schools involved in the study. Children were given consent forms to take home for their parents or guardians to sign and instructed to return them. Every parent or guardian provided written informed consent for their children to participate in the study. Before participating, children also provided informed assent by signing consent forms. All adult participants provided written informed consent before participating in the study, and the study was conducted in accordance with the principles outlined in the Declaration of Helsinki. Participants and their families were not compensated for their involvement, but they were notified of their results. Those confirmed to have RHD were referred to the appropriate care facility for further management, which included secondary antibiotic prophylaxis for acute rheumatic fever.

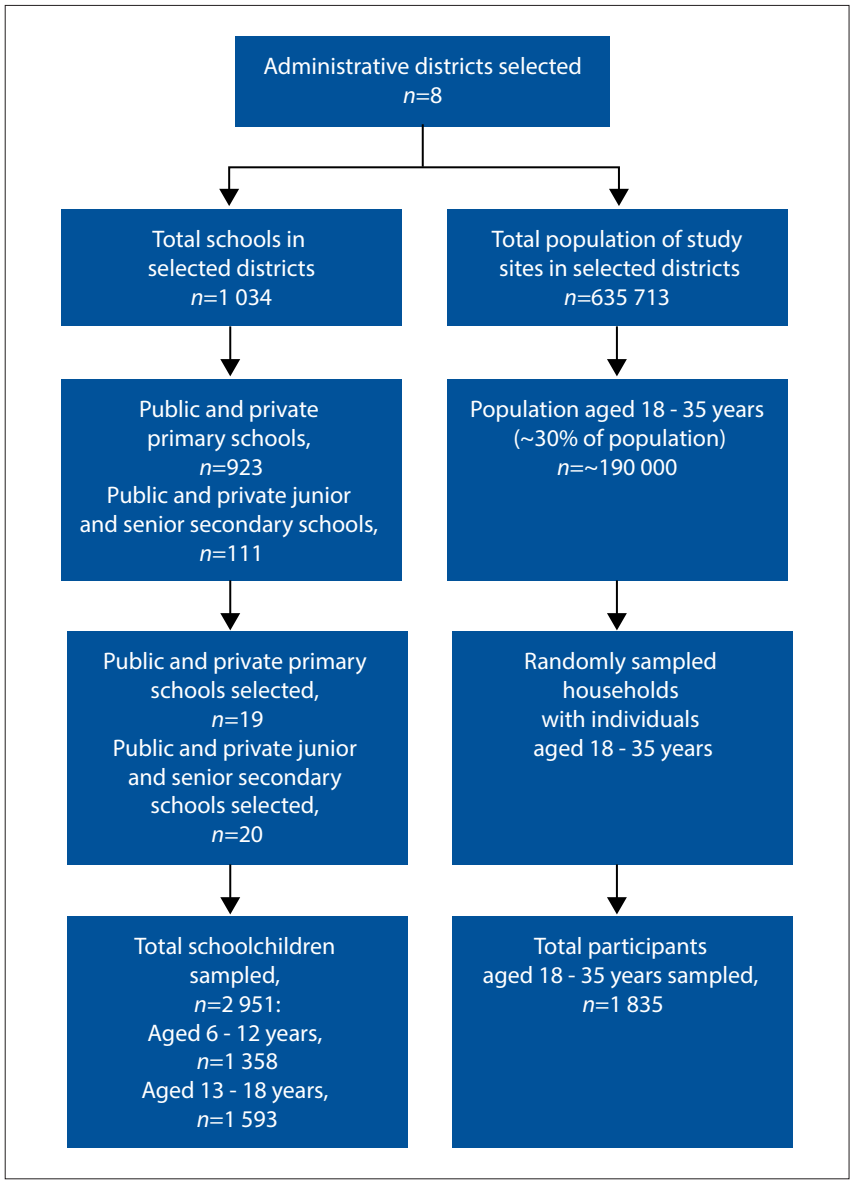

Fig. 2. Flowchart of sample selection (N=4 786).

Results

Sociodemographic characteristics

We screened 4 786 participants from the eight administrative districts (Fig. 2, Table 3). The median age was 17 years (IQR 12 - 25), with a minimum age of 6 years and a maximum of 35 years. The median age for individuals aged ≤20 years was 14 (10 - 17) years, whereas for those >20 years, it was 28 years (25- 32) years. A total of 3 101 (64.8%) were female, and 3 162 (66.1%) were aged ≤20 years. None of the participants had previously been informed by a healthcare professional of a heart condition. Out of all participants, systolic murmurs were detected in 109 (2.3%), while diastolic murmurs were found in 8 (0.2%) participants.

Results of echocardiographic screening

Table 4 presents abnormal echocardiographic findings among 4 786 screened individuals, stratified by age groups ≤20 years (*n*=3 162) and >20 years (*n*=1 624). Non-RHD (congenital/acquired) was identified in 11 cases overall (6 in ≤20 years, 5 in >20 years), while RHD (borderline/definite) affected 19 cases (11 in ≤20 years, 8 in >20 years).

Prevalence of RHD

Nineteen participants had RHD. The highest number of RHD cases was observed in the Northeast district. There were no cases of RHD in the Central District. Twelve were classified as definite, and seven were regarded as borderline RHD, yielding a prevalence of 4.0 cases per 1 000 (95% CI 2.5 - 6.2).

Four and eight cases of definite RHD were found among participants aged ≤20 years and >20 years, yielding prevalences of 3.5 cases per 1 000 (95% CI 1.9 - 6.3) and 4.9 cases per 1 000 (95% CI 2.5 - 9.8), respectively. All definite and borderline RHD lesions in participants aged ≤20 years involved the mitral valve. Among those aged >20 years, four participants had mitral valve involvement, and four had aortic valve involvement. There were no cases of mitral stenosis or aortic stenosis. None had involvement of more than one valve (Table 5).

Patients with confirmed RHD were advised to commence secondary antibiotic prophylaxis and continue their care at a specialist hospital. Additionally, three

Table 3. Distribution of participants by study district and age group (*N*=4 786)

	District, *n* (%)							
Age group	**Southeast**	**Southern**	**Northwest**	**Kweneng**	**Kgalagadi**	**Central**	**Ghanzi**	**Northeast**
≤20 years, *n*=3 162	522 (16.5)	657 (20.8)	425 (13.4)	589 (18.6)	425 (13.4)	431 (13.6)	127 (4.0)	281 (8.9)
>20 years, *n*=1 624	328 (20.2)	372 (22.9)	207 (12.7)	381 (23.5)	207 (12.7)	47 (2.9)	139 (8.6)	126 (7.8)
All, *n*= 4 786	850 (17.8)	1 029 (21.5)	632 (13.2)	970 (20.3)	154 (3.2)	478 (10.0)	266 (5.6)	407 (8.5)

Table 4. Results of echocardiographic screening (*N*=4 786)

Abnormal echocardiographic findings	≤20 years, *n*=3 162	>20 years, *n*=1 624	All, *n*=4 786
Non-RHD (congenital/acquired)	6	5	11
RHD (borderline/definite)	11	8	19

RHD = rheumatic heart disease.

Table 5. RHD prevalence by valve type (*N*=19)

	Age ≤20 years (*n*=3 162)		Age >20 years (*n*=1 624)	Total
Valve type, *n*	**Borderline**	**Definite**	**Definite**	
Mitral valve				
Pathological regurgitation	5	4	4	13
Morphological features of RHD	2	-		2
Aortic valve				
Pathological regurgitation	-	-	4	4
Overall	7	4	8	19
Cases per 1 000 population (95% CI)	3.5 (1.9 - 6.3)		4.9 (2.5 - 9.8)	4.0 (2.5 - 6.2)

RHD = rheumatic heart disease, CI = confidence interval.

patients were referred for surgery owing to severe mitral regurgitation and severe aortic regurgitation.

Fig. 3 illustrates the cases of RHD among different age groups: primary school children (6 - 12 years old), secondary school children (13 - 20 years old) and the adult population (>20 years old).

Non-RHD echocardiographic findings

We identified seven participants with congenital heart disease and four with non-RHD acquired heart disease during the study (Table 6). There were three adolescent participants with large atrial septal defects; one with a partial anomalous pulmonary venous connection (aged 16 years); one with a small patent ductus arteriosus (aged 6 years); one with an isolated cleft of the anterior mitral valve leaflet (aged 10 years); and one with isolated pulmonary stenosis (aged 12 years). Three participants had heart failure: two due to dilated cardiomyopathy, one caused by hypertension, and one with a moderate pericardial effusion. All were referred to Princess Marina Hospital for additional assessment and management. Apart from the patent ductus arteriosus, which was silent without the need for invasive intervention, the congenital lesions were surgically repaired.

Discussion

This is the first RHD screening study conducted in Botswana. The prevalence of RHD among children and young adults was 4 per 1 000, with rates of 3.5 per 1 000 in individuals aged ≤20 years and 4.9 per 1 000 in those aged >20 - 35 years. Additionally, our study identified several undiagnosed asymptomatic congenital heart conditions and cases of heart failure, which were subsequently managed.

The reported prevalence of RHD in Botswana (4.0 per 1 000 population) is lower than that reported in other echocardiographic screening studies in Africa.[5,8,14,18,19] Most studies report double-digit rates per thousand, leading to a pooled prevalence of RHD in Africa at 25.5 cases per 1 000 individuals.[22] A few studies indicate a single-digit prevalence, similar to ours. A study in Senegal reported a rate of 5.0 per 1 000 schoolchildren, whereas a study in Nigeria reported a lower prevalence of 2.7 per 1 000 individuals.[9,21] Our findings contribute to understanding the epidemiology of RHD in Africa, and are consistent with the considerable variation between African countries and between geographically adjacent communities. This variation arises from socioeconomic and environmental factors, such as poor housing, undernutrition, overcrowding, limited access to healthcare and poverty, which impact Group A *Streptococcus* pharyngitis exposure, diagnosis and treatment.[8,23-25,32] Botswana's upper-middle-income status and universal healthcare likely contribute to the low prevalence of RHD, thanks to improved living standards and access to treatment. While the lower prevalence compared with other African countries is encouraging, we must remain vigilant, as RHD remains endemic in Botswana.[26,33,34] As in many African countries, efforts to prevent RHD remain vital, as detailed in the Addis Ababa communiqué on eradicating the disease across the continent.[25]

In accordance with prior observations, the prevalence of RHD in our study was shown to increase with age, with a greater number of cases per 1 000 population of definite RHD.[22] A meta-analysis of studies of schoolchildren in East Africa revealed a lower prevalence of 17.9 cases per 1 000, compared with 25.5 cases per 1 000 in studies involving children and young adults.[18,22] RHD results from cumulative valvular damage caused by carditis, which typically persists lifelong in most cases, thereby explaining the age-related increase in prevalence, a pattern observed in our study.[1]

Although the absolute figures in each district are insufficient for statistically meaningful comparisons, the number of RHD cases can be seen to vary across geographical regions. Similar patterns have

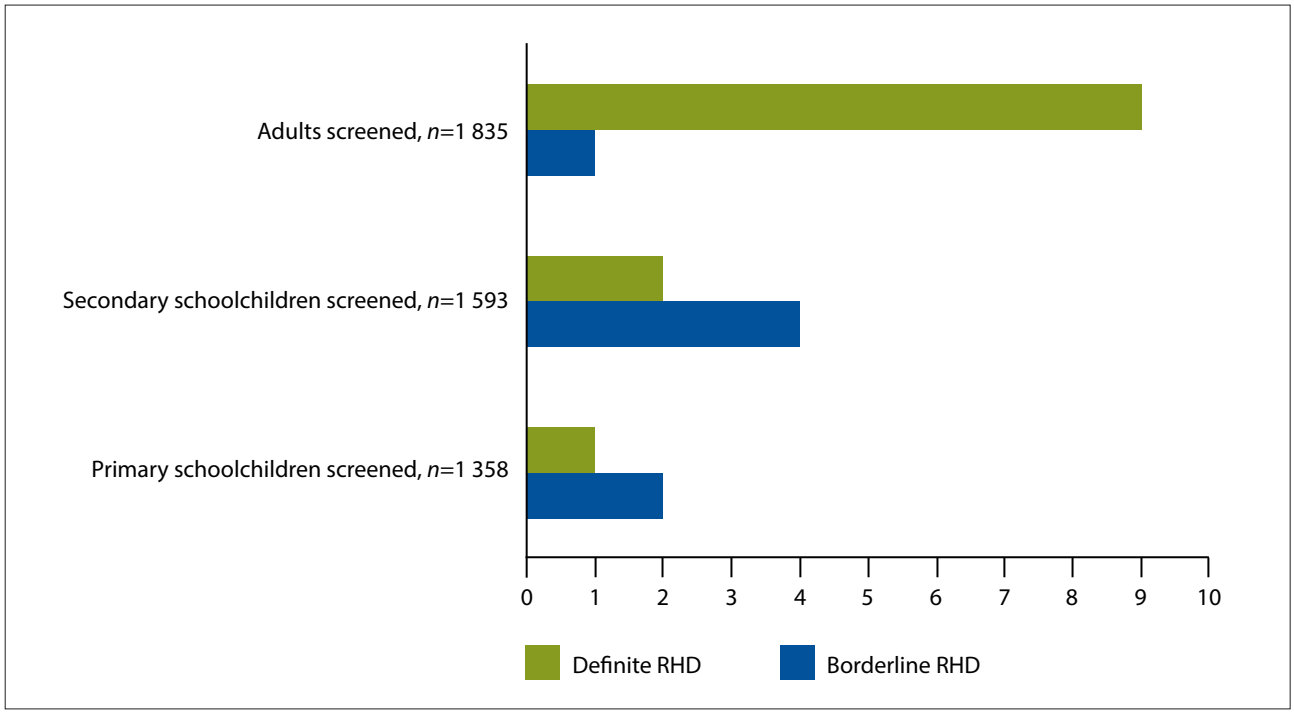

Fig. 3. Number of rheumatic heart disease (RHD) cases by population group screened.

Table 6. Non-rheumatic heart disease echocardiographic findings (*N*=11)

Condition type	Specific diagnosis	*n*
Congenital heart defect	Atrial septal defects	3
	Partial anomalous pulmonary venous connection	1
	Patent ductus arteriosus	1
	Isolated cleft of the anterior mitral valve leaflet	1
	Isolated pulmonary stenosis	1
Non-RHD acquired heart disease	Heart failure due to dilated cardiomyopathy	2
	Heart failure due to hypertension	1
	Moderate pericardial effusion	1

been reported elsewhere, with different countries and even regions within the same country exhibiting varying rates of RHD.[8] In Botswana, although access to healthcare services is consistent across districts, socioeconomic disparities persist. Since RHD is associated with low socioeconomic status, the disease burden also varies among districts. The Northwest District showed a higher number of cases and has the highest rates of multidimensional poverty and deprivation.[28] While the national average for severe multidimensional poverty is 3.4%, this figure rises to 15.9% in the Northwest District, which is predominantly rural.[28,29] The connection between individual or community socioeconomic status and rural residency on the incidence of RHD has been well-documented, especially in rural Africa and among indigenous communities in developed countries such as Australia, New Zealand, Canada and American Samoa.[8,35-37]

In our study, mitral regurgitation was the most common valvular lesion, followed by aortic regurgitation. While there are slight differences from our study findings, a comparable pattern of predominant mitral regurgitation was also documented in a prior study, in which mitral regurgitation was observed in 73% of cases.[38] The mitral valve is more susceptible to RHD than the aortic valve owing to its anatomical features and inflammatory response. Its larger and more complex structure, combined with a delicate apparatus, renders it vulnerable to scarring. The left-sided mitral valve is subject to prolonged *Streptococcus*-induced inflammation and haemodynamic stresses, leading to damage such as commissural fusion, scarring and structural changes (thickening, restriction, calcification) from recurrent rheumatic fever.[39-41]

Although we did not record involvement of more than one valve, previous studies indicate that combined aortic and mitral valve regurgitation occurs in ~8% of cases.[40] The absence of two-valve involvement and of mitral and aortic stenosis in our study is unusual.

As in other screening studies, we identified asymptomatic, undiagnosed non-RHD structural abnormalities. Incidental discovery of non-RHD abnormalities is a spin-off benefit of a screening program.

Study limitations

Most screening activities were conducted during the work week, which posed challenges for working adults to participate. To address this issue, we extended the screening period to include weekends. Owing to funding constraints, we were unable to cover all the districts in Botswana. Chobe is small, has the fewest inhabitants, and was part of the Northwest District until recently. In contrast to the current Northwest District, Chobe remains the least populated district, and is among those without any recorded cases of severe multidimensional poverty. Likewise, Kgatleng was excluded owing to its small size, proximity and shared characteristics with Gaborone, including its low level of severe multidimensional poverty. Therefore, it is unlikely that excluding these districts would have resulted in overlooking many RHD cases.

Conclusion

Using the diagnostic criteria established by the WHF, this research identified RHD among 4 per 1 000 individuals aged 6 - 35 years in Botswana – a condition that had previously gone unquantified. Considering that this age cohort comprises 1 421 590 residents in

the country, an estimated 5 687 individuals are affected by RHD, and require penicillin prophylaxis and long-term clinical follow-up. Some of these individuals may need anti-failure therapy, whereas others might require valve repair or replacement, with ongoing resource implications. Since early detection of mild RHD cases via echocardiographic screening facilitates prompt initiation of secondary antibiotic prophylaxis to prevent disease progression, these findings underscore the importance of establishing a national screening programme and registry. The disease poses a substantial health burden to young populations. The study also identified cases of undiagnosed congenital cardiovascular diseases among the participants.

Data availability. The datasets analysed during the current study are available from the corresponding author upon reasonable request and permission from the Development Committee of the Botswana Ministry of Health.

Declaration. None.

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Author contributions. ET and JCM conceived the study, supervised data collection, performed echocardiograms, collected and analysed data, and drafted the initial manuscript. GL, OJM and LG provided valuable suggestions for the study design. MZP, MG, TD, KM, LM, WS, EB, MP, RR, EG, LS and BR collected the data. All authors revised successive drafts of the manuscript and approved its final version.

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Conflicts of interest. None.

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