МОНГОЛ УЛСЫН ЗАСГИЙН ГАЗАР MINISTRY OF HEALTH

Prevalence and Associated Factors of Group A Streptococcal Throat Infection among Children

Ulaanbaatar, Mongolia

2025

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EXECUTIVE SUMMARY

This study aimed to generate baseline evidence on the prevalence of Group A streptococcal (GAS) throat infection among children aged 6–15 years in Mongolia and to identify multilevel factors associated with GAS infection through a complementary case–control analysis.

Prevalence was estimated using data from a nationwide, school-based screening programme implemented during 2024–2025, which targeted school-attending children. Screening data extracted from the electronic information system of the General Authority for Health Insurance indicated that 396,194 children aged 6–15 years were screened using throat swab specimens and rapid antigen detection tests, representing 52.7% of the total registered population in this age group in Mongolia (751,807 children). Of those screened, 52.3% resided in urban areas and 47.7% in rural areas.

The overall prevalence of GAS throat infection among children aged 6–15 years was 5.78% (22,911 children; 95% CI: 5.6–5.8). Among children with detected infection, 54.6% were boys and 45.4% were girls, while 52.8% lived in urban areas and 47.2% in rural areas. Infection prevalence was higher in urban than rural settings (urban 5.8%, 95% CI: 5.7–5.9; rural 5.6%, 95% CI: 5.5–5.7) and higher among boys (6.3%, 95% CI: 6.2–6.4) than girls (5.3%, 95% CI: 5.2–5.4).

Geographically, the prevalence of GAS throat infection was highest in the Central region (8.6%, 95% CI: 5.3–8.9) and the Khangai region (6.8%, 95% CI: 6.5–7.2), compared with the Gobi (3.1%, 95% CI: 2.8–3.3), Eastern (4.7%, 95% CI: 4.5–4.9), and Western (4.8%, 95% CI: 4.5–4.9) regions. At the subnational level, the highest prevalence was observed in Tuv, Gobi-Altai, Selenge, Darkhan-Uul, and Arkhangai aimags, as well as Baganuur District of Ulaanbaatar, while the lowest prevalence was recorded in Bayan-Ulgii, Dornogobi, Gobisumber, Dundgovi, and Umnugobi aimags.

To examine factors associated with GAS infection, a case–control study was conducted among school-aged children using multilevel modelling, incorporating individual, household, school, and health service–related variables. A total of 781 children were included, with equal numbers in the case and control groups.

At the individual level, pharyngeal mucosal injury (adjusted OR [aOR] 2.25; 95% CI: 1.27–3.98), tonsillar hypertrophy (25–50%: aOR 1.57; 50–75%: aOR 2.94), and clinically active tonsillar inflammation (aOR 1.69; p=0.008) were strongly associated with GAS infection. Although overall dental caries did not differ significantly between groups, among 6-year-old children the median

number of decayed teeth was substantially higher in cases than in controls (10 vs 3 teeth; p<0.001), suggesting a potential contribution of poor oral hygiene to susceptibility in younger children.

At the household level, the strongest associations were observed. Exposure to second-hand tobacco smoke increased the odds of GAS infection more than sixfold (aOR 6.30; 95% CI: 2.42–16.41), while household dampness and mould were associated with a nearly sixfold increase in risk (aOR 5.89; 95% CI: 1.27–27.24). Lower paternal educational attainment (aOR 5.62) and limited parental knowledge regarding throat infection complications were also associated with increased risk.

At the school level, not washing hands with soap at school was associated with a higher risk of GAS infection (aOR 1.85; p<0.001), whereas sanitation infrastructure quality was not significantly associated. Parental dissatisfaction with health services showed an association in unadjusted analyses but was attenuated in multivariable models.

Population attributable fraction analysis of modifiable risk factors indicated that the greatest potential reduction in GAS infection could be achieved by addressing household environmental risks (second-hand smoke exposure, dampness and mould: approximately 45–55%), followed by child biological vulnerability (approximately 30–40%), school hygiene practices (approximately 20–25%), and parental health knowledge gaps..

Conclusion

Approximately 5.78% (95% CI: 5.6–5.8) of children aged 6–15 years in Mongolia were identified with Group A streptococcal (GAS) throat infection through school-based screening. The prevalence was higher among boys than girls, in urban compared with rural areas, and in the Central and Khangai regions compared with other regions.

This study demonstrates that GAS throat infection among school-aged children is the result of the combined effects of multilevel risk factors, including individual biological vulnerability, household environmental hygiene, school contact and hygiene conditions, and insufficient parental health literacy. The highest population attributable fractions were observed at the household level (second-hand tobacco smoke exposure and household dampness/mould), followed by child-level biological factors (pharyngeal mucosal injury and tonsillar inflammation), school hygiene practices (handwashing with soap at school), and limited health-related knowledge.

As these risk factors are largely modifiable, the findings underscore the need for a multilevel, integrated prevention strategy to reduce the burden of Group A streptococcal throat infection among school-aged children.

Recommendations

Regular school-based screening for asymptomatic Group A streptococcal (GAS) throat infection should be institutionalized to enable early identification of carriers and prompt interruption of transmission at the community level. Sustained screening, combined with timely referral and appropriate management, has the potential to prevent serious complications, including acute rheumatic fever and rheumatic heart disease. Further in-depth research is also warranted to better elucidate the relationship between asymptomatic carriage and clinically apparent disease.

At the individual level, several factors were found to substantially increase the risk of GAS throat infection, including pharyngeal and tonsillar inflammatory activity, mucosal injury, and poor oral hygiene, particularly among younger children with a high burden of dental caries in primary (deciduous) teeth. These findings underscore the importance of promoting oral health from early childhood, ensuring regular dental check-ups, and providing parents with clear guidance on the care of primary teeth. In addition, during periods of increased seasonal respiratory infections, early identification of throat-related symptoms should be consistently implemented at the school, household, and primary health care levels.

At the household and family level, second-hand tobacco smoke exposure and household dampness and mould were identified as the most influential risk factors. The study findings indicate that reducing these environmental risks could potentially prevent up to half of GAS infections. Therefore, practical support should be provided to households to establish smoke-free home environments, routinely assess and mitigate children's exposure to second-hand smoke, and address the underlying causes of dampness and mould. Given that these environmental risks are closely linked to information access, financial capacity, and housing conditions, targeted support for vulnerable households is essential.

The study also demonstrated a statistically significant association between household educational level, particularly lower paternal education, and increased risk of GAS infection. This

finding highlights how educational disparities influence access to health information, timely decision-making, and early care-seeking behavior. Reducing inequalities in access to health services and health education related to educational attainment should therefore be considered a key strategy for preventing respiratory infections among children. Specifically, health information should be delivered to all parents—regardless of educational background—in clear, simple language, through regular and multiple communication channels. Primary health care facilities can play a central role by providing systematic, age-appropriate counseling on recognizing childhood illness symptoms, appropriate home care, rational antibiotic use, and prevention of complications, through both individual and group-based education sessions.

Because households with lower educational attainment often face greater barriers to accessing health information, the quality and consistency of counseling provided during home visits and preventive check-ups should be strengthened, alongside the introduction of enhanced models for early risk identification among children. As health care–seeking decisions may be delayed due to educational and informational constraints, strengthening information exchange between schools and primary health care facilities is recommended. Standardized processes for providing clear guidance to parents following early identification and facilitating timely referral to appropriate care should also be established. In parallel, the routine dissemination of targeted health education through mass media, school settings, and parent meetings can make an important contribution to reducing health inequities.

Educational attainment should be understood not as an individual attribute, but as a marker of socioeconomic conditions and disparities in access to information. Accordingly, policies and interventions to ensure equitable, inclusive, and accessible health education for all parents are essential and represent a foundational strategy for reducing the burden of childhood respiratory infections.

Within the school environment, the availability of handwashing facilities, access to soap, and institutional support for daily hygiene practices were key determinants of GAS transmission risk. The higher risk observed among children who did not wash their hands with soap at school highlights the need to promote and normalize hygiene practices, ensure adequate provision of sinks and soap, and strengthen environmental support for healthy behaviors in schools.

At the health service level, limited parental knowledge regarding complications of throat infections and rheumatic disease may delay timely diagnosis and appropriate treatment. Strengthening routine education at primary health care facilities on recognizing throat infection symptoms, preventing complications, and appropriate antibiotic use is therefore critical. In addition, improving integrated communication channels within the health system and facilitating timely information exchange between school health providers and primary care physicians will enhance early detection, continuity of care, and effective referral.

Abbreviations

GAS – Group A β-hemolytic Streptococcus

ARF – Acute Rheumatic Fever

RHD – Rheumatic Heart Disease

RADT – Rapid Antigen Detection Test for Group A Streptococcus

aOR – Adjusted Odds Ratio

All-OR – Fully Adjusted Odds Ratio

VIF – Variance Inflation Factor

PAF – Population Attributable Fraction

Modi-PAF – Modifiable Population Attributable Fraction

HI – Health Insurance

BMI – Body Mass Index

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INTRODUCTION

1. Background and Rationale

Group A streptococcal (GAS) throat infection is common among children aged 5–15 years worldwide. When GAS pharyngeal infection is not diagnosed in a timely manner and appropriately treated with antibiotics, it may lead to serious complications, including acute rheumatic fever (ARF) and rheumatic heart disease (RHD).

The distribution and burden of GAS infection are influenced by a range of factors, including environmental conditions (such as extreme cold climates and air pollution), socioeconomic determinants (population density and limited access to health care services), and behavioral factors (inappropriate antibiotic use and delayed health-care seeking). In the context of Mongolia, the harsh continental climate and high levels of air pollution, particularly during winter months, may increase susceptibility to GAS throat infection among children.

Studies conducted in the Asia–Pacific region and other low- and middle-income countries have demonstrated that environmental exposures and constrained health-care access play a significant role in the occurrence of GAS infection and its complications. However, country-specific evidence from Mongolia remains limited, particularly with respect to the prevalence of GAS infection and the contribution of multilevel risk factors. Therefore, this study was designed to generate evidence on the prevalence of GAS throat infection and to examine associated individual, household, school, and health-system-related risk factors among children in Mongolia.

2. Research Problem

Despite a relatively high burden of GAS throat infection and rheumatic heart disease in Mongolia, there is insufficient evidence on how environmental, socioeconomic, and behavioral factors interact to influence infection transmission and disease outcomes. In addition, access to early detection, diagnosis, and appropriate treatment remains limited in rural and remote areas. Addressing these gaps is essential for informing effective prevention and control strategies. This study seeks to respond to these challenges by providing a detailed analysis of GAS throat infection among school-aged children in Mongolia.

3. Study Objective

To determine the prevalence of Group A streptococcal (GAS) throat infection and to identify associated risk factors among children aged 6–15 years in Mongolia.

Specific Objectives:

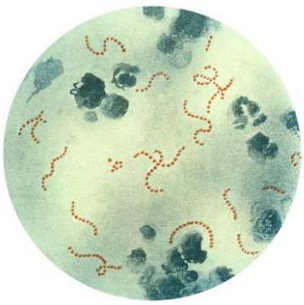
1. To estimate the prevalence of GAS throat infection among children aged 6–15 years in Mongolia;
2. To examine selected risk factors associated with GAS throat infection among school-aged children.

4. Research Questions

1. Does the prevalence of GAS throat infection among children aged 6–15 years in Mongolia differ by age, sex, and place of residence?
2. What are the key risk factors associated with GAS throat infection among children aged 6–15 years in Mongolia?

LITERATURE REVIEW

Characteristics of the Pathogen



Streptococcus pyogenes is a Gram-positive, catalase-negative, oxidase-negative, β-hemolytic streptococcus and a facultative anaerobic bacterial pathogen that is classified as Group A Streptococcus (GAS) under the Lancefield system. The Group A antigen of *S. pyogenes* is a cell wall polysaccharide composed of rhamnose and N-acetylglucosamine polymers, which serves as a key taxonomic and immunological marker.

Based on their association with post-infectious immune-mediated sequelae, strains of S. pyogenes are commonly categorized as rheumatogenic strains, which are associated with acute rheumatic fever, and nephritogenic strains, which are linked to acute post-streptococcal glomerulonephritis.

As a human pathogen, S. pyogenes primarily colonizes the oropharyngeal mucosa, but may also be present in the perianal region and genital mucosa. Infections caused by this pathogen are highly transmissible and are spread mainly through respiratory droplets, contact with contaminated surfaces, direct contact through disrupted skin barriers, and, less commonly, via contaminated food products.[1] Transmission is particularly efficient in crowded and closed settings, including schools, military barracks, and residential care facilities, where this pathogen can spread rapidly and may lead to localized outbreaks.

Pathogenesis and Immunological Mechanisms of Group A Streptococcal–Associated Rheumatic Heart Disease

Group A β-hemolytic Streptococcus (Streptococcus pyogenes; GAS)–associated throat infection is common in childhood. When GAS pharyngeal infection is not promptly diagnosed and adequately treated with antibiotics, dysregulated immune responses may lead to acute rheumatic fever (ARF) and, subsequently, progression to rheumatic heart disease (RHD). Globally, RHD remains one of the leading causes of acquired valvular heart disease, particularly in low- and middle-income settings.[1,2] The pathogenesis of ARF and RHD is immune-mediated rather than the result of direct bacterial tissue

injury. A central mechanism is molecular mimicry involving the streptococcal M protein, which shares structural and amino-acid sequence similarities with host proteins, including cardiac myosin, valvular laminin, and other connective tissue components.[3,4] Consequently, antibodies and $CD4^+$ T lymphocytes generated against streptococcal antigens may cross-react with host tissues, triggering autoimmune-mediated inflammatory injury.[5]

As a result of this cross-reactivity, B-cell–derived antibodies (including anti-streptolysin O, anti-DNase B, and anti-M protein antibodies) bind to endothelial cells of the cardiac valves and myocardial proteins, leading to complement activation, amplification of inflammatory cascades, tissue injury, and cellular necrosis.[6] In parallel, T-cell–mediated immune responses are characterized by the predominance of Th1 and Th17 subsets, with increased production of pro-inflammatory cytokines such as interferon-γ (IFN-γ), tumor necrosis factor-α (TNF-α), and interleukin-17 (IL-17), resulting in widespread inflammatory damage to cardiac tissues.[7] These multistep immune processes culminate in pancarditis involving all layers of the heart. Histologically, the acute phase of ARF is marked by the presence of Aschoff bodies, granulomatous inflammatory lesions that are pathognomonic of rheumatic carditis and provide compelling evidence of the disease's immune-mediated pathogenesis.

Damage to the valvular endothelium during inflammation promotes fibrin deposition and infiltration of inflammatory cells, followed by progressive fibrosis, thickening, and scarring of valve leaflets. Initially manifesting as valvulitis, repeated episodes of ARF over time lead to chronic structural deformities, most commonly mitral valve stenosis, regurgitation, or mixed lesions, with subsequent involvement of the aortic valve. These changes constitute the pathological basis of chronic rheumatic heart disease and its long-term clinical sequelae.[8] In addition to cardiac involvement, cross-reactive antibodies directed against streptococcal antigens may also bind to neuronal surface proteins within the central nervous system, particularly in the basal ganglia. This immune cross-reactivity underlies Sydenham chorea, characterized by involuntary movements and impaired motor coordination, underscoring that ARF is a multisystem immune-mediated inflammatory disease, not confined to the heart.[9]

Collectively, these mechanisms explain the risk of developing rheumatic disease following GAS throat infection in susceptible children. International evidence consistently demonstrates that early diagnosis and complete antibiotic treatment of GAS throat infection, together with long-term

secondary prophylaxis using intramuscular benzathine penicillin to prevent recurrent ARF episodes, remain the most effective strategies for preventing progression to chronic rheumatic heart disease.[10]

Prevalence and Risk Factors

The prevalence of *Streptococcus pyogenes* infection varies considerably across world regions and differs according to clinical manifestations. Although the overall burden declined from the mid-20th century, a resurgence was observed from the late 1980s onward. Over the past two decades, changes in pathogen virulence and the emergence of antibiotic resistance have contributed to an increased disease burden.[11,12]

In low- and middle-income countries, rheumatic heart disease (RHD) remains highly prevalent and is associated with substantial mortality, whereas in high-income countries, mortality is more often linked to severe invasive *S. pyogenes* infections. Globally, it is estimated that each year there are approximately 1.78 million cases of severe *S. pyogenes* infection, 282,000 new cases of RHD, and 616 million new episodes of streptococcal pharyngitis, resulting in around 163,000 deaths from severe infection and 233,000 deaths from RHD.[13] In the United States, *S. pyogenes* accounts for 15–30% of pharyngitis cases in children and 5–20% in adults.[14]

Risk factors for Group A β-hemolytic streptococcal infection are broadly categorized into demographic, behavioral, environmental and living conditions, public health and health-system factors, and transmission-related factors.[15]

GAS throat infection is particularly common among school-aged children, and patterns of clinical presentation, complications, and transmission are closely linked to specific combinations of these risk factors.[16] From a demographic perspective, children aged 5–15 years are more susceptible due to heightened activity of pharyngeal lymphoid tissue and incomplete maturation of protective immunity. Higher risk has also been reported among individuals with chronic underlying conditions, children under 15 years of age,[17] older adults,[18] pregnant and postpartum women,[19] and persons experiencing malnutrition, substance use, or excessive alcohol consumption. Several studies have shown that boys and males have a higher likelihood of acquiring infection compared with girls and females.[20]

At the behavioral level, inadequate hand and oral hygiene, frequent close contact with infected individuals, and conditions that reduce host resistance—such as sleep deprivation, psychological stress, and nutritional deficiencies—significantly increase the risk of infection.[21] Transmission occurs primarily via respiratory droplets and direct contact with infected persons or contaminated surfaces.[22,23] with occasional reports of foodborne transmission.[24]

Environmental and living conditions are also critical determinants of GAS infection risk.[25] Poor ventilation, overcrowded indoor spaces, and multiple household members sharing a single room facilitate transmission. During colder seasons, reduced humidity can lead to drying of the nasal and pharyngeal mucosa, creating favorable conditions for bacterial proliferation. High-risk settings characterized by prolonged close contact—regardless of income level—include schools, childcare centers, daycare facilities, residential care institutions[26–29] hospitals,[30] homeless shelters,[31] and military training camps.[32] Additional environmental and socioeconomic risk factors include homelessness, household overcrowding[33], limited household resources (e.g., sharing personal items),[34] and living in cold, damp, and poorly ventilated environments. Other contributors include low household income, exposure to second-hand tobacco smoke, insect bites, skin injuries, and pre-existing skin conditions, all of which compromise skin integrity and increase susceptibility to infection.[30]

GAS infection is reported to be more prevalent in developing countries[35,36], and disproportionately affects Indigenous populations in high-income countries.[34,37,38] The infection is often endemic among socioeconomically disadvantaged populations, reflecting persistent inequities in living conditions and access to health services.[39,40]

High disease burden is further associated with the circulation of antibiotic-susceptible yet highly virulent GAS strains, inadequate public health response, and frequent treatment interruptions, highlighting the strong interaction between biological factors and health-system capacity.[35]

Limited access to treatment, incomplete antibiotic courses, and weak surveillance systems not only facilitate ongoing transmission but also increase the risk of complications such as acute rheumatic fever and chronic rheumatic heart disease.[41]

Seasonal variation has also been documented. GAS throat infection occurs more frequently in temperate climates, with incidence peaking in late winter and early spring, whereas impetigo is more common among children living in humid climates. Severe skin infections tend to increase between January and April.[42]

International evidence consistently demonstrates that GAS infection clusters in socially vulnerable populations and areas with poor hygiene and adverse environmental conditions.[43] Systematic identification of these risk factors and targeted public health responses remain central to reducing transmission and strengthening prevention strategies.

MATERIALS AND METHODS

Prevalence of GAS throat infection among children aged 6–15 years in Mongolia

Study Design

The prevalence of Group A streptococcal (GAS) throat infection among school-aged children was estimated using data from a nationwide, school-based screening programme implemented during 2024–2025. The screening targeted children attending school and was conducted without requiring the presence of clinically apparent throat disease.

In accordance with Order No. A/436 of the Minister of Health, issued on 12 December 2023, a national Clinical Guideline on the early detection, diagnosis, differential diagnosis, treatment, and follow-up of streptococcal throat infection was approved for implementation in routine clinical practice. As stipulated in this guideline, rapid antigen detection tests (RADTs) were introduced for the identification of GAS throat infection, and nationwide screening among children aged 6–15 years commenced in 2023.

This component of the study employed a school-based census (population-based) study design, in which all eligible children within participating schools were offered screening using RADTs. In alignment with the study objectives, an overview of the study implementation framework and workflow is presented below.

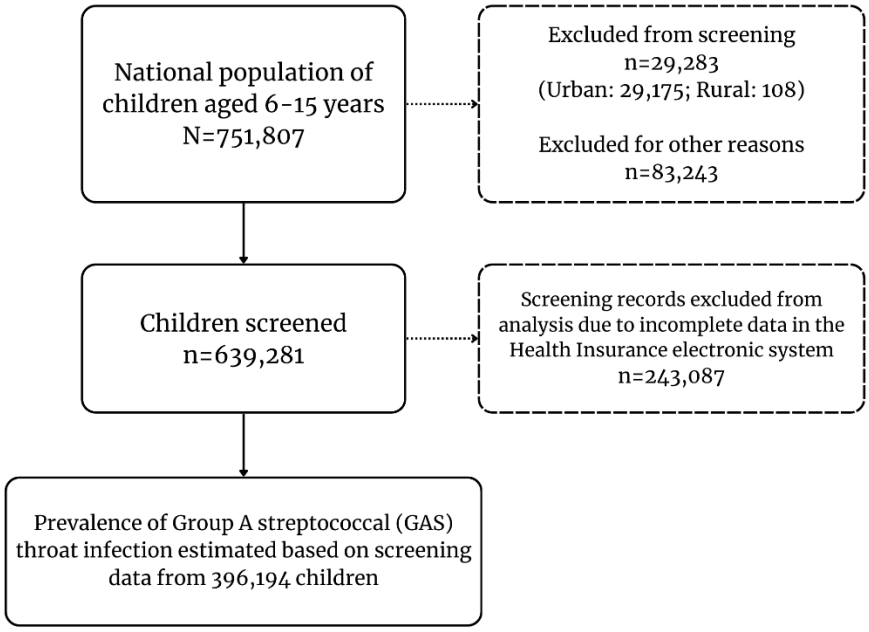


Figure 1. Study flow diagram for estimating the prevalence of Group A streptococcal (GAS) throat infection among school-aged children

Study Population and Screening Data

A total of 751,807 children aged 6–15 years were registered nationwide during the study period, of whom 639,281 children participated in the screening programme. Data from 29,283 children who declined screening or were not screened in urban and rural areas, as well as 83,243 children who did not participate for other reasons, were excluded from data processing.

During screening implementation, records for 243,087 children were registered at the point of service but were not entered into the Health Insurance electronic information system. These records were excluded following data quality checks. Consequently, complete and validated screening data from 396,194 children were included in the final analysis.

Outcome Definition and Prevalence Estimation

The prevalence of Group A streptococcal (GAS) throat infection among screened children was estimated based on screening data. A case detected was defined as a child with a positive rapid antigen detection test (RADT) for GAS performed by trained health-care professionals.

Prevalence was expressed as a percentage (%), calculated by dividing the number of children with detected GAS throat infection by the total number of children screened within each analytic category. Estimates were generated at the national level and stratified by region, aimag/district, place of residence (urban/rural), sex, and age group.

As the screening programme covered the entire eligible population within defined categories, no sampling procedures were applied. All prevalence estimates were therefore derived from the complete screening dataset, rather than from a sample. Statistical analyses were conducted using SPSS version 26.

Regional Classification

Geographic stratification followed the classification set out in Resolution No. 64 (2024) of the State Great Khural of Mongolia, *Concept of Regional Development of Mongolia*, Section 2.1. Accordingly, Mongolia was divided into the following regions:

- Khangai Region: Arkhangai, Bayankhongor, Övörkhangai aimags
- Western Region: Bayan-Ulgii, Govi-Altai, Zavkhan, Uvs, Khovd aimags
- Northern Region: Bulgan, Orkhon, Khuvsgul aimags
- Central Region: Darkhan-Uul, Selenge, Tuv aimags
- Eastern Region: Dornod, Sukhbaatar, Khentii aimags
- Gobi Region: Govisumber, Dornogovi, Dundgovi, Umnugovi aimags
- Ulaanbaatar Region: Ulaanbaatar city and its satellite cities

Risk factors associated with GAS throat infection among school-aged children

Study Design and Population

For Objective 2, a school-based case–control study design was employed to identify factors associated with Group A streptococcal (GAS) throat infection among children aged 6–15 years in Mongolia, based on results from the national screening programme.

Planned Sample Size

The study was designed to include 400 cases (children aged 6–15 years with detected GAS throat infection) and 400 matched controls, selected based on place of residence, age, and sex.

Using screening data from 639,281 children, those with a positive rapid antigen detection test (RADT) for GAS (n = 49,195) and those with a negative RADT result (n = 500,086) were identified. From these groups, 1,012 children attending eight general education schools in Khovd and Khentii aimags and two districts of Ulaanbaatar city were invited to participate in the case–control study.

During the screening and enrolment process, 212 children were excluded due to failure to meet eligibility criteria, unclear residence information, inconsistencies in age or sex data, or refusal to participate. As a result, 800 children were enrolled in the second phase of the study. After excluding 19 children with incomplete data, the final analytic sample comprised 394 children with positive RADT secults for GAS throat infection (cases). For the control group, 387 children with negative RADT results were selected and matched to cases by aimag/district, school, age group (6–15 years), sex, and comparable environmental conditions. This matching ensured comparable distributions of age, sex, and geographic location between cases and controls, thereby minimizing selection bias.

Eligibility Criteria

Inclusion Criteria – Case Group

- Children aged 6–15 years
- Laboratory-confirmed GAS throat infection identified through screening
- Attendance at selected health facilities, family health centers, or schools included in the study
- Written informed consent provided by a parent or legal guardian

Inclusion Criteria – Control Group

- Children aged 6–15 years, residing in the same geographic area
- No evidence of GAS throat infection
- No respiratory tract infection (e.g., common cold or influenza) within the preceding two weeks
- Matched to cases by age, sex, geographic location, and socioeconomic context

- Written informed consent provided by a parent or legal guardian

Exclusion Criteria (Applied to Both Groups)

- Antibiotic use within the previous two weeks
- Immunosuppressive conditions, including immunodeficiency or ongoing cancer treatment
- Diagnosed respiratory tract infections (e.g., influenza, adenovirus, Chlamydia, Mycoplasma)
- More than one child recruited from the same household
- Parental or guardian refusal to participate

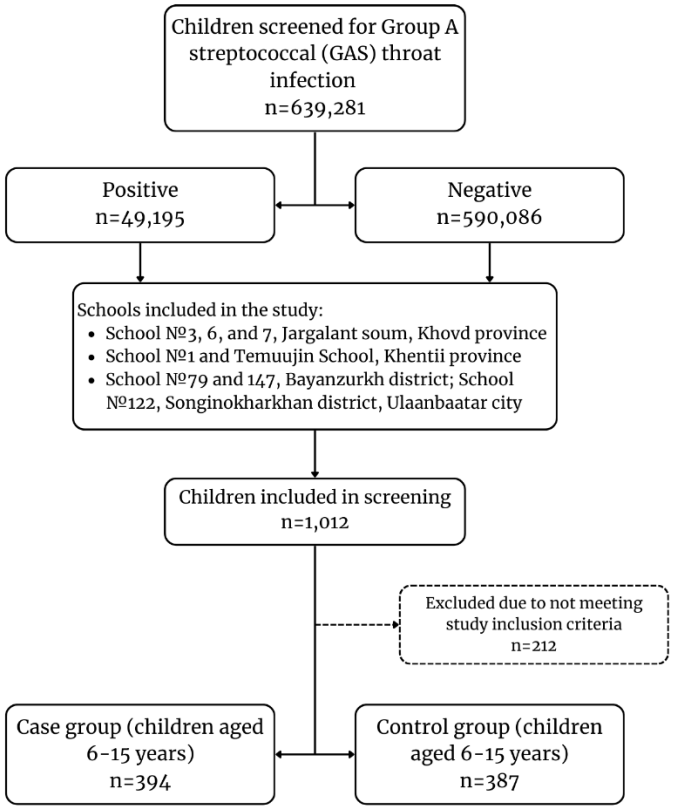


Figure 2 Study flow diagram for risk factors for of Group A streptococcal (GAS) throat infection among school-aged children

Conceptual Framework

The causal pathway linking GAS throat infection to acute rheumatic fever and rheumatic heart disease is illustrated in Figure 2. This pathway reflects the interaction of multiple risk domains, including environmental and climatic conditions, socioeconomic factors, access to health services (e.g., delayed

care-seeking and limited health literacy), general and oral health status, nutritional factors, and host susceptibility, including potential genetic influences.[44]

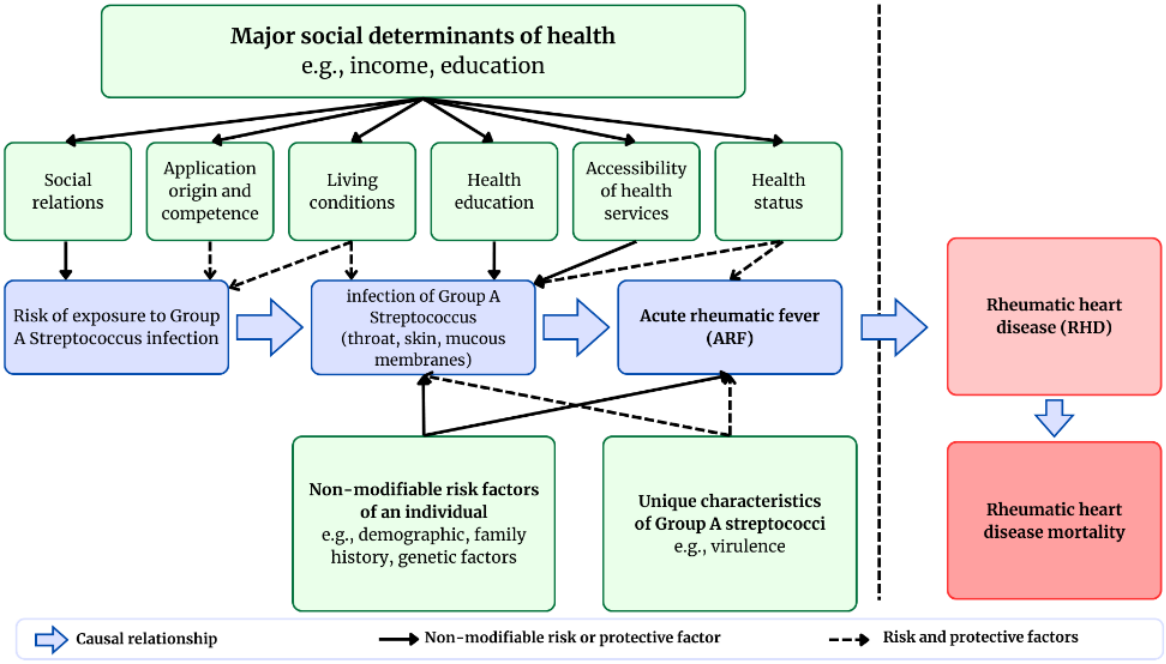


Figure 3 Multilevel risk factors and pathophysiological pathway from Group A streptococcal infection to rheumatic heart disease

Ecological framework of risk factors

The risk factors for Group A streptococcal (GAS) throat infection were conceptualized using Urie Bronfenbrenner's ecological model, illustrating the multilevel interactions of risk and protective factors across different social and environmental contexts. This framework is presented in Figure 3.

Within the case–control study, factors associated with GAS throat infection were identified across multiple ecological levels:

- Individual level: behavioral factors, nutritional status, oral health, and skin health;
- Family and interpersonal level: household socioeconomic status, housing conditions, and parental health-seeking behaviors;
- Community level: access to health-care services, availability of safe water and sanitation facilities, and classroom crowding;

– Societal and environmental level: quality and accessibility of school-based health services and the broader school environment.

This multilevel framework highlights that GAS throat infection among school-aged children is not the result of isolated individual factors, but rather emerges from the dynamic interaction between biological vulnerability, household conditions, community infrastructure, and institutional health-system factors (Figure 4).

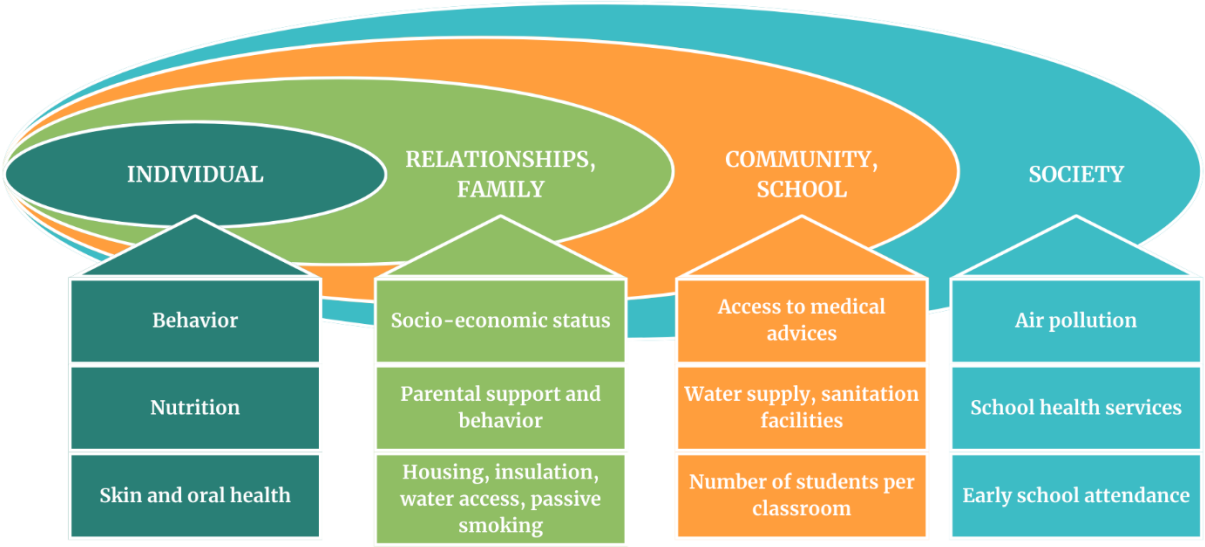


Figure 4 Ecological model of multilevel risk and protective factors associated with Group A streptococcal (GAS) throat infection

Table 1 Multilevel risk factors and data collection methods

Risk level	Factors	Examples	Data collection methods
Individual	Personal hygiene practices	Handwashing, face washing, toothbrushing	Structured questionnaire
	Nutritional status	Underweight, micronutrient deficiency	Anthropometric measurements (weight, height), growth charts, clinical signs (skin, nails), health examination
	Oral health	Dental caries, gingivitis	Oral examination
	Skin condition	Impetigo, pruritic skin lesions	Skin examination (clinical assessment)
Household (Interpersonal level)	Family history of illness	History of throat infection among parents or siblings	Questionnaire (family health history)
	Caregiver health-seeking behavior	Knowledge, attitudes, and practices related to seeking medical care	Questionnaire (caregiver health-seeking behavior)
	Second-hand smoke exposure	Child exposure to household tobacco smoke	Questionnaire (number of smokers in the household)
	Household size	Overcrowded living conditions	Questionnaire
	Housing conditions	Insulation, dampness, water supply, sanitation facilities	Questionnaire
Community / School	Classroom environment	Number of students per classroom	Questionnaire
	School water supply and sanitation	Availability of handwashing and toilet facilities	Questionnaire
	Access to health-care services	Distance to facilities, cost barriers, dissatisfaction with services	Questionnaire (caregiver report on health-care access)

Statistical Analysis

Statistical analyses were conducted using SPSS version 26.0.

Demographic characteristics of the study population were summarized using frequencies, percentages, medians, and means with 95% confidence intervals (95% CI), as appropriate. Differences in continuous variables across sex, urban/rural residence, and age groups were initially assessed using one-way analysis of variance (ANOVA).

The prevalence of GAS throat infection was calculated as the proportion of children with a positive rapid antigen detection test (RADT) among all children screened within a given category.

To assess factors associated with GAS throat infection, a case–control study design was applied. Risk factors were categorized into four ecological domains based on the conceptual framework:

(I) individual level,
(II) household/interpersonal level,
(III) community level, and
(IV) societal/environmental level.

The distribution of variables within each domain was described.

Normality of continuous variables was evaluated using the Shapiro–Wilk test, with $p<0.05$ indicating non-normal distribution. Variable distributions were further assessed using histograms and Q–Q plots.

Continuous variables were summarized as medians and interquartile ranges (IQR) or means ± standard deviation (SD), as appropriate. Differences between case and control groups were assessed using the Mann–Whitney U test, while comparisons across more than two groups were conducted using the Kruskal–Wallis one-way ANOVA. Differences in categorical variables were evaluated using the chi-square (χ^2) test.

Associations between individual risk factors and GAS throat infection were first examined using univariate logistic regression. Variables with $p < 0.20$ in univariate analyses were included in multivariable logistic regression models. Adjusted odds ratios (aORs) and fully adjusted odds ratios (all-ORs) were estimated to quantify associations between risk factors and GAS throat infection.

Model fit was assessed using the Hosmer–Lemeshow goodness-of-fit test, and multicollinearity was evaluated using the Variance Inflation Factor (VIF). As the proportion of missing data was ≤5%, a complete-case analysis approach was applied. Statistical significance was defined as $p < 0.05$.

Population Attributable Fraction (PAF) Analysis

Risk factors were further classified as modifiable or non-modifiable. To estimate the potential impact of modifiable risk factors on GAS throat infection, the Population Attributable Fraction (PAF) was calculated. PAF represents the theoretical proportion of cases that could be prevented if a given risk factor were eliminated.

For the case–control design, PAF was calculated based on adjusted odds ratios (aORs) using the following formula:

$$\text{PAF} = \frac{P_e(aOR - 1)}{P_e(aOR - 1) + 1}$$

where:

- P_e= prevalence of the risk factor among cases
- aOR= adjusted odds ratio for the risk factor

To compare the relative contribution of each modifiable risk factor, the sum of PAFs for all modifiable factors was standardized to 100%, and the relative contribution (%) of each factor was calculated accordingly. This approach allowed identification of the proportion of the potentially preventable burden of GAS throat infection attributable to each modifiable risk factor.

RESULTS

Prevalence of Group A streptococcal (GAS) throat infection among children aged 6–15 years

General characteristics of the participants

Analysis of screening data recorded in the electronic information system of the General Authority for Health Insurance showed that, among 404,972 children aged 6–15 years who were eligible for screening, a total of 396,194 children had valid test results for Group A streptococcal (GAS) throat infection. This corresponds to 52.7% of the total registered population of children aged 6–15 years in Mongolia (n = 751,807).

Among the children included in the analysis, 52.3% resided in urban areas, while 47.7% were from rural areas.

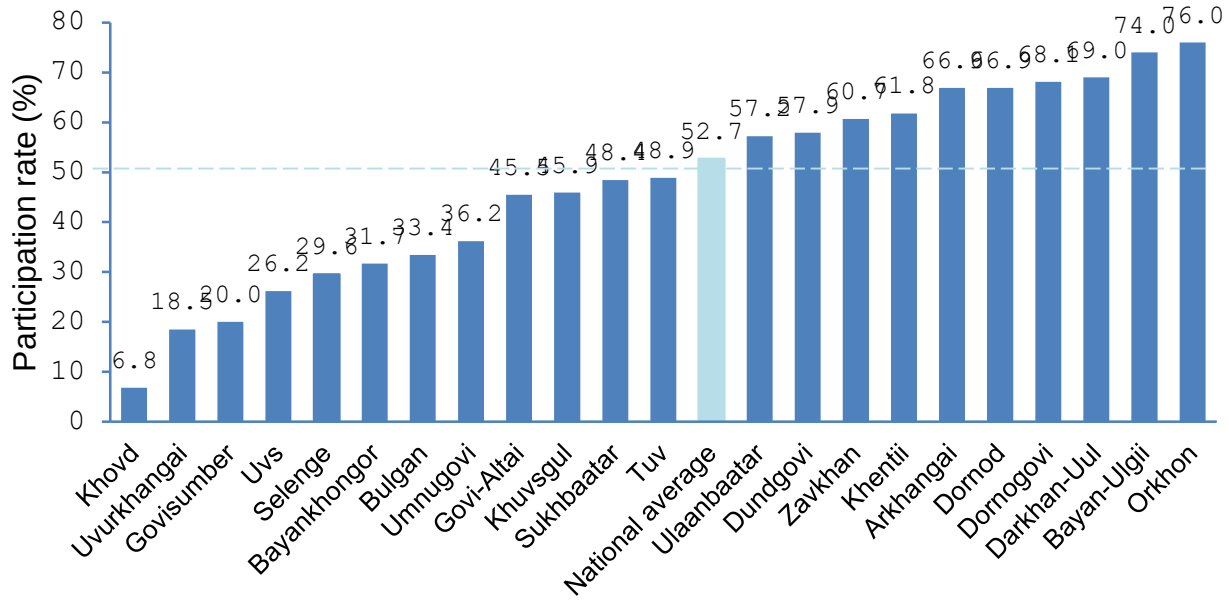


Figure 5 Provincial distribution of screening coverage for Group A streptococcal (GAS) throat infection among school-aged children (6–15 years)

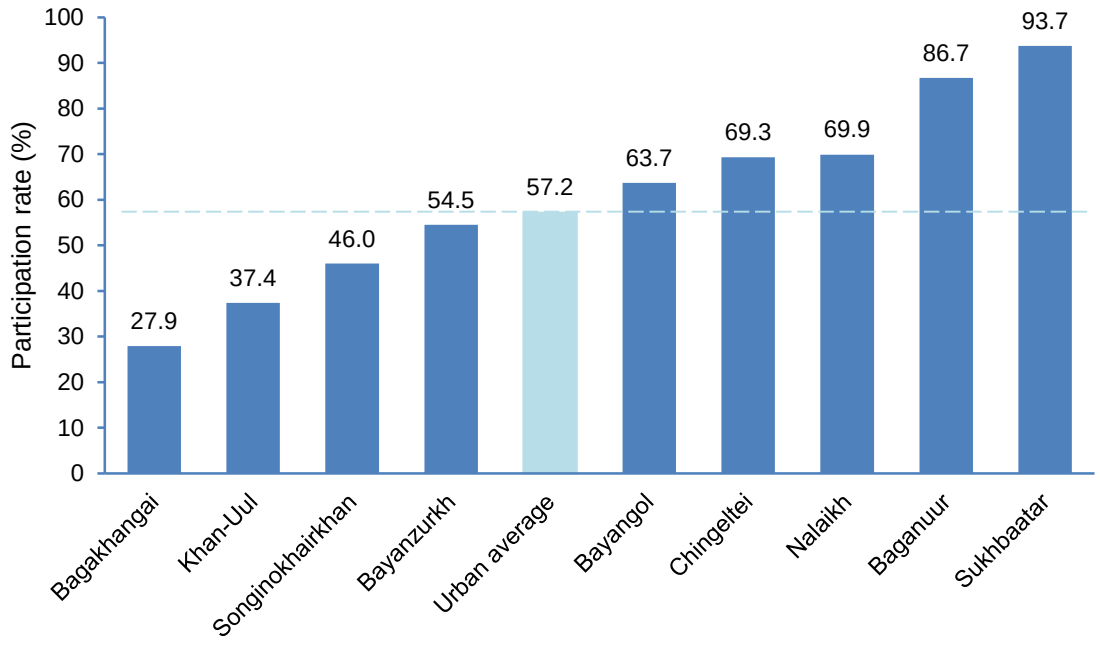


Figure 6 District-wise distribution of screening coverage for Group A streptococcal (GAS) throat infection among school-aged children (6–15 years) in Ulaanbaatar

Source: General authority for health insurance

Screening coverage for Group A streptococcal (GAS) throat infection among children aged 6–15 years was highest in Orkhon, Bayan-Ölgii, and Darkhan-Uul aimags, as well as in Sükhbaatar and Baganuur districts, while Khovd aimag had the lowest screening coverage (Figures 5 and 6).

Table 2 Distribution of children aged 6–15 years participating in screening for Group A streptococcal (GAS) throat infection, by age and sex

Age (years)	Female		Male		Total	
	n	%	n	%	n	%
6	20,505	49.0	21,365	51.0	41,870	10.9
7	20,258	48.8	21,221	51.2	41,479	10.8
8	20,597	49.2	21,247	50.8	41,844	10.9
9	20,977	49.3	21,551	50.7	42,528	11.1
10	21,251	49.4	21,807	50.6	43,058	11.3
11	19,875	49.9	19,987	50.1	39,862	10.4
12	18,685	50.1	18,642	49.9	37,327	9.8
13	17,074	50.6	16,648	49.4	33,722	8.8
14	17,156	50.8	16,633	49.2	33,789	8.8
15	14,203	52.1	13,045	47.9	27,248	7.1
Total	190,581	49.8	185,231	50.2	382,727	100.0

Among children aged 6–15 years who participated in screening for Group A streptococcal (GAS) throat infection, 49.8% were male and 50.2% were female (Table 2).

Prevalence of Group A streptococcal (GAS) throat infection among children aged 6–15 years

Overall, 5.78% of children aged 6–15 years (n = 22,911; 95% CI: 5.6–5.8) tested positive for GAS throat infection. Among children with detected infection, 54.6% were male and 45.4% were female. In terms of place of residence, 52.8% lived in urban areas, while 47.2% resided in rural areas.

Regional distribution of GAS throat infection showed variation across the country, with prevalence highest in the Central region (12.8%), followed by the Northern (9.4%), Western (8.4%), and Khangai (7.4%) regions, and lower prevalence observed in the Eastern (6.3%) and Gobi (3.0%) regions.

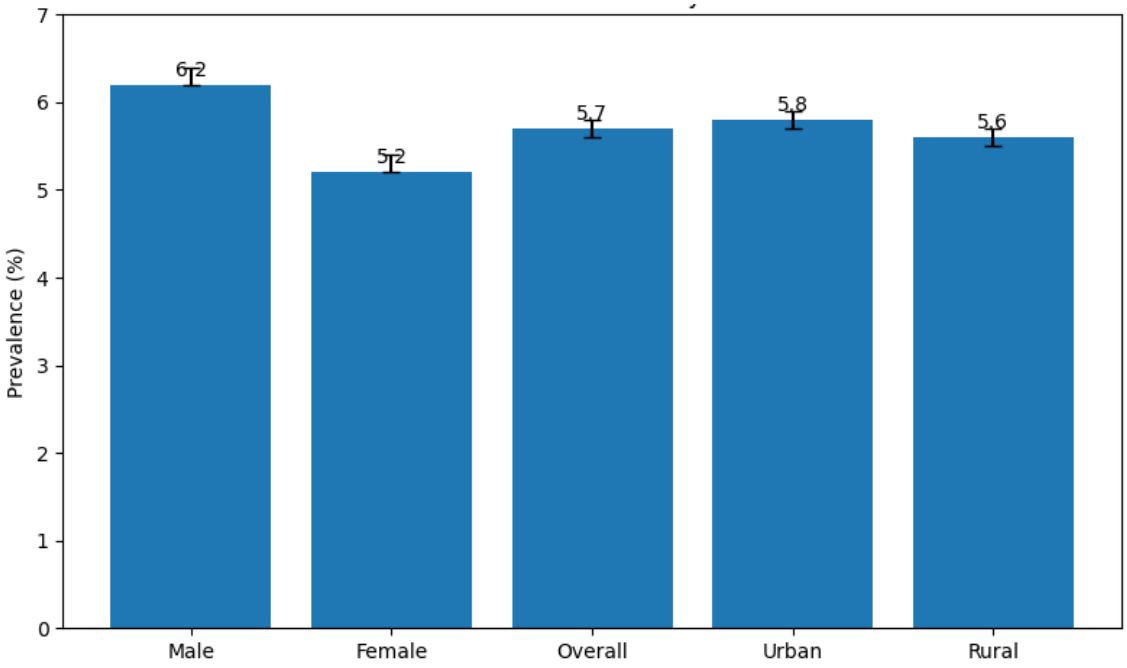


Figure 7 Figure 7. Prevalence of Group A streptococcal (GAS) throat infection among school-aged children (6–15 years), stratified by sex and place of residence (urban/rural)

Source: General authority for health insurance

The prevalence of Group A streptococcal (GAS) throat infection among children aged 6–15 years was higher in urban areas than in rural areas (urban: 5.8%, 95% CI: 5.7–5.9; rural: 5.6%, 95% CI: 5.5–5.7). In addition, prevalence was higher among boys (6.3%, 95% CI: 6.2–6.4) compared with girls (5.3%, 95% CI: 5.2–5.4) (Figure 7).

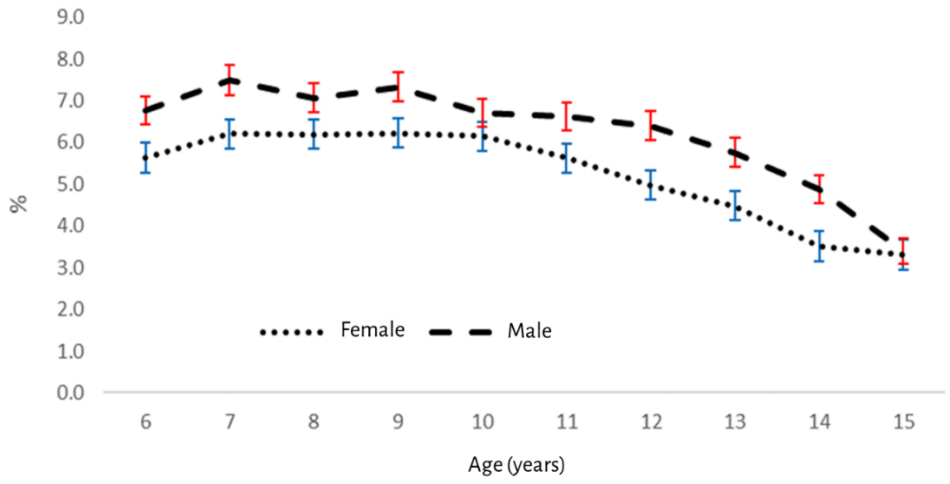


Figure 8 Prevalence of Group A streptococcal (GAS) throat infection among children aged 6–15 years, by single-year age group and sex

Source: General authority for health insurance

The prevalence of Group A streptococcal (GAS) throat infection was consistently higher among boys than girls across all age groups. In both sexes, the prevalence of GAS throat infection decreased with increasing age, demonstrating a significant inverse association between age and infection prevalence (p = 0.001) (Figure 8).

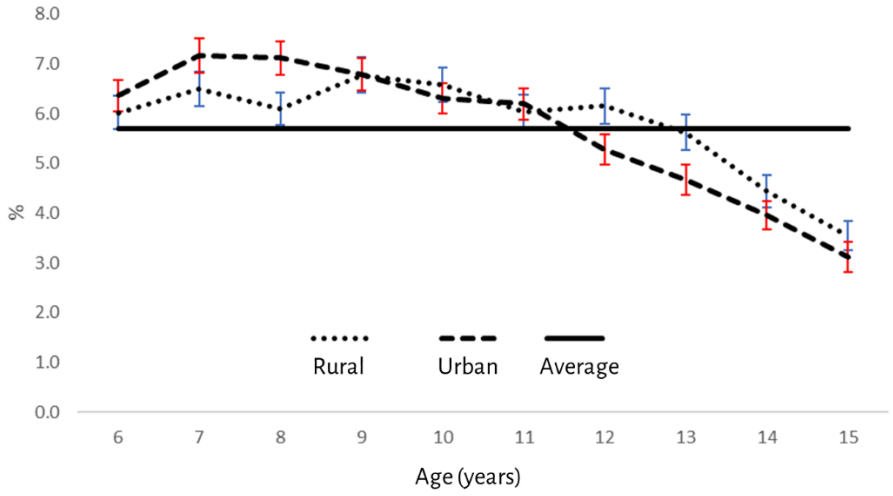


Figure 9 Prevalence of Group A streptococcal (GAS) throat infection among children aged 6–15 years, by single-year age group and place of residence

Source: General authority for health insurance

The age-specific prevalence of Group A streptococcal (GAS) throat infection differed by place of residence. In urban areas, the prevalence peaked among children aged 7–9 years, whereas in rural areas the highest prevalence was observed among those aged 9–10 years. A declining trend was noted from 10 years of age in urban settings and from 12 years of age in rural settings, with the difference being statistically significant (p = 0.001) (Figure 9).

The prevalence of asymptomatic GAS throat infection among children aged 6–15 years was further analyzed by region. Regional classification followed the "Regional Development Concept of Mongolia" (Article 2.1), whereby the country is divided into seven regions.

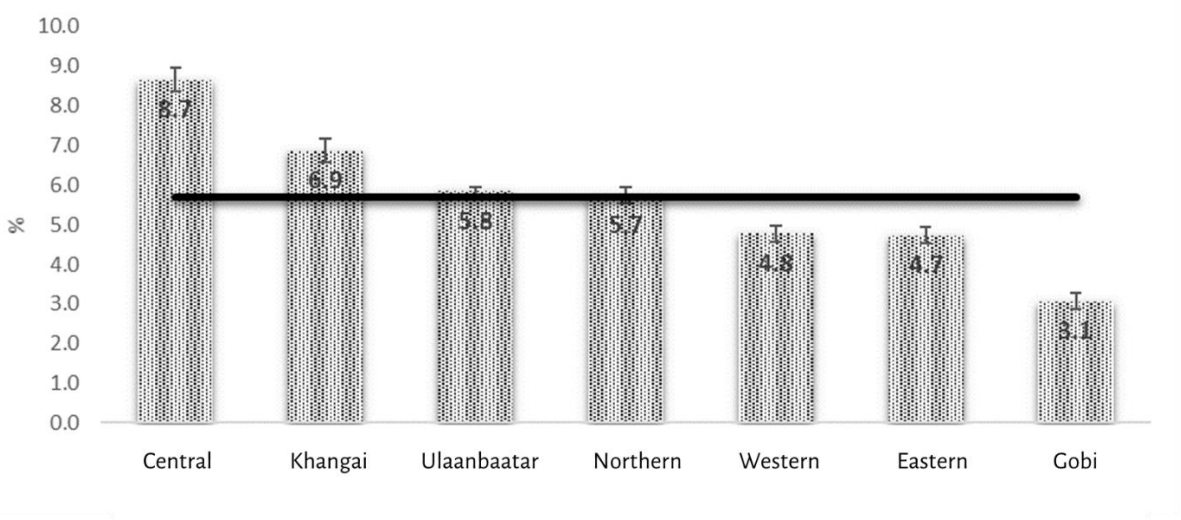


Figure 10 Regional distribution of Group A streptococcal (GAS) throat infection among children aged 6–15 years

Source: General authority for health insurance

The prevalence of Group A streptococcal (GAS) throat infection among children aged 6–15 years was higher in the Central region (8.6%, 95% CI 5.3–8.9) and the Khangai region (6.8%, 95% CI 6.5–7.2) compared with other regions, including the Gobi region (3.1%, 95% CI 2.8–3.3), Eastern region (4.7%, 95% CI 4.5–4.9), and Western region (4.8%, 95% CI 4.5–4.9) (Figure 10).

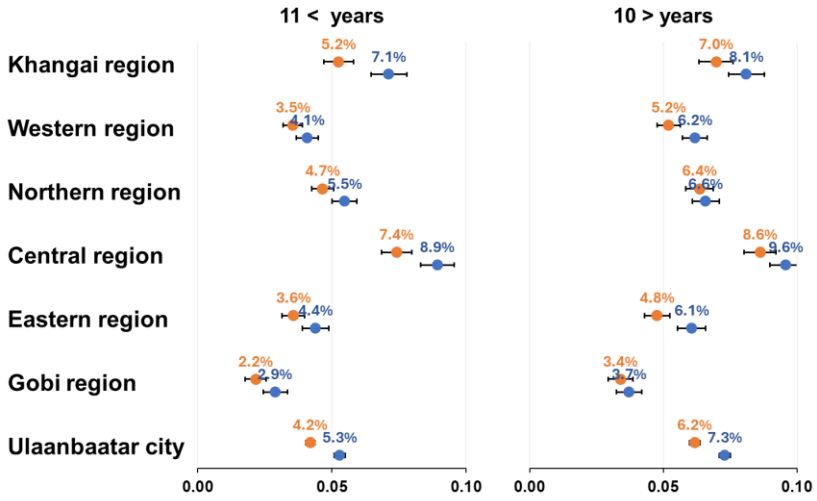


Figure 11 Regional-, sex-, and age-specific prevalence of Group A streptococcal (GAS) throat infection among children aged 6–15 years

Source: General authority for health insurance

Across all regions, the prevalence of Group A streptococcal (GAS) throat infection among children aged 6–15 years was consistently higher in boys than in girls. Among children aged 6–10 years, boys exhibited a 1.03–1.27-fold higher prevalence, while among those aged 10–15 years, the prevalence was 1.17–1.35 times higher in boys compared with girls ($p < 0.001$) (Figure 11).

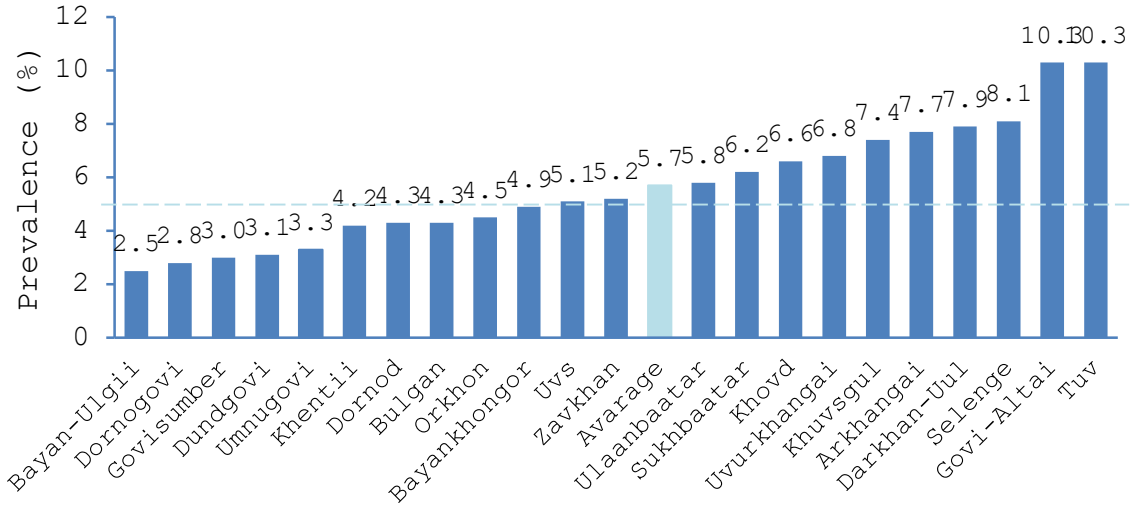


Figure 12 Distribution of Group A streptococcal (GAS) throat infection prevalence among children aged 6–15 years across provinces

Source: General authority for health insurance

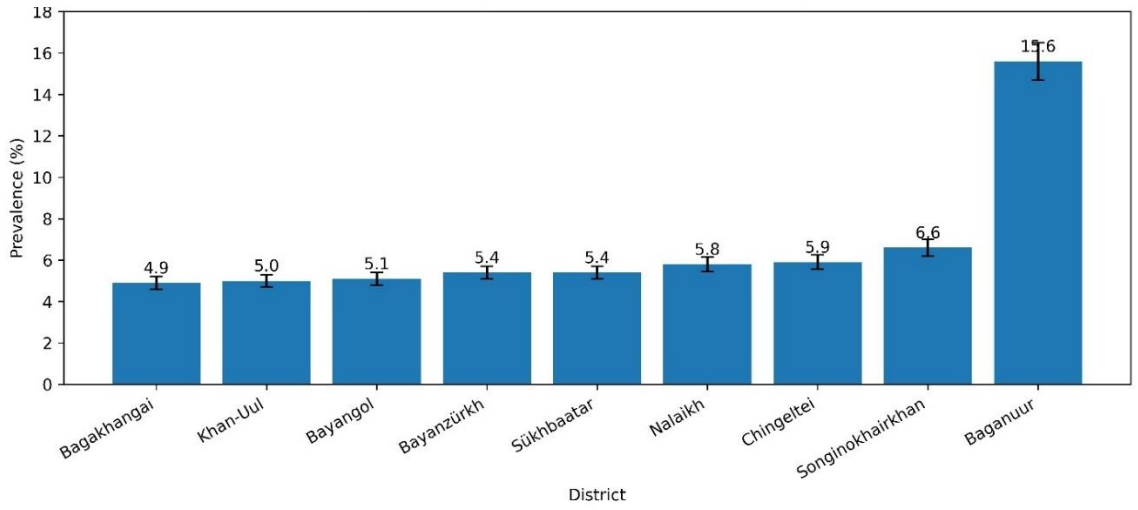


Figure 13 Prevalence of Group A streptococcal (GAS) throat infection among children aged 6–15 years in Ulaanbaatar, by district.

Source: General authority for health insurance

Among children aged 6–15 years in Ulaanbaatar, the prevalence of Group A streptococcal (GAS) throat infection was 5.8% (95% CI: 5.7–5.9), with the highest prevalence observed in Baganuur District (Figure 8).

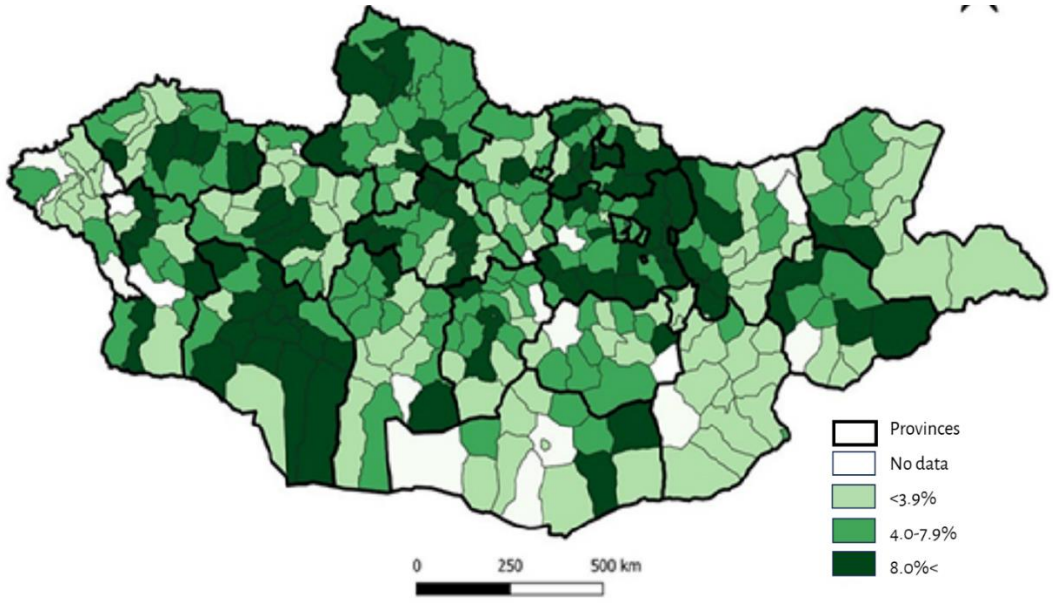


Figure 14 Prevalence of Group A streptococcal (GAS) pharyngeal infection among children aged 6–15 years, by soum

Source: General authority for health insurance

At the soum level, the highest prevalence of Group A streptococcal (GAS) throat infection among children aged 6–15 years was observed in Khyargas soum of Uvs aimag (35.3%), Tsetserleg soum of Khövsgöl aimag (26.2%), Guchin-Us soum of Uvurkhangai aimag (24.0%), Buyant soum of Khovd aimag (21.9%), Jargalant soum of Arkhangai aimag (21.4%), and Tünel soum of Khuvsgul aimag (20.8%). In these soums, approximately one in every three to five children was identified with GAS throat infection.

Factors associated with Group A streptococcal (GAS) throat infection

Individual-level factors

Assessment of personal hygiene practices and history of previous illness showed similar patterns between the case and control groups, with no statistically significant differences observed.

Regarding hand hygiene practices, the median reported handwashing frequency among all participating children was three times per day (median = 3, IQR: 2–4), with comparable responses between the case and control groups (p = 0.648). Overall, 33.3% of children (n = 260) reported washing their hands 1–2 times per day, including 33.5% in the case group (n = 132) and 33.1% in the control group (n = 128). Reporting handwashing three times per day accounted for 32.7% of all children (n = 255), with 33.5% in the case group (n = 132) and 31.8% in the control group (n = 123). Children who reported washing their hands four or more times per day comprised 34.1% of the total sample (n = 266), including 33.0% in the case group (n = 130) and 35.1% in the control group (n = 136). These differences were not statistically significant (p = 0.798).

When asked whether they washed their hands every time their hands became dirty, 67.9% of children overall (n = 529) responded "yes," including 69.5% of the case group (n = 273) and 66.3% of the control group (n = 256) (p = 0.462). A response of "sometimes" was reported by 28.1% of children (n = 219), while 4.0% (n = 31) reported that they did not wash their hands when their hands were dirty. Differences between the case and control groups for these responses were likewise not statistically significant.

Table 3 Factors related to children's hygiene practices

Variable	Total (N=781)		Cases (n=394)		Controls (n=387)		*p* value
	n	%	n	%	n	%	
Handwashing frequency per day, median (IQR)	3	(2–4)	3	(2–4)	3	(2–4)	0.648
1–2 times/day	260	33.3	132	33.5	128	33.1	
3 times/day	255	32.7	132	33.5	123	31.8	
≥4 times/day	266	34.1	130	33.0	136	35.1	
Washes hands whenever visibly dirty							0.462
Yes	529	67.9	273	69.5	256	66.3	
Sometimes	219	28.1	103	26.2	116	30.1	
No	31	4.0	9	2.3	10	2.6	
Toothbrushing ≥2 times/day	546	69.9	279	70.8	267	69.0	0.849
Shares toothbrush	22	2.8	4	1.0	0	0.0	0.071
Hospitalized in the past 12 months							0.330
Yes	71	9.1	32	8.1	39	10.2	
No	710	90.9	362	91.9	348	89.8	

Oral hygiene behaviors, including toothbrushing frequency and sharing of toothbrushes, did not differ significantly between the case and control groups. Overall, 69.9% of children (n = 546) reported brushing their teeth two or more times per day, with similar proportions observed among cases (70.8%, n = 279) and controls (69.0%, n = 267) (p = 0.849). The risky practice of sharing a toothbrush was identified in 2.8% of participants (n = 22), with no statistically significant difference between the two groups (p = 0.071). These findings indicate that oral hygiene practices were relatively stable and comparable between cases and controls among the school-aged children included in the study.

Table 4 History of previous illnesses among children aged 6–15 years, by case–control status

Variable	Total (N=781)		Cases (n=394)		Controls (n=387)		*p* value
	n	%	n	%	n	%	
History of febrile illness	640	81.9	325	82.5	315	81.4	
Management during fever							0.628
Self-medication	508	66.8	254	65.6	254	67.9	
No treatment	2	0.3	1	0.3	1	0.3	
History of seizure							0.987
Yes	6	0.8	3	0.8	3	0.8	
No	704	91.1	353	90.7	351	91.4	
History of dental or gingival disease							0.138
Yes	524	67.4	255	64.9	269	69.9	
No	751	96.3	378	96.2	373	96.4	
Hospitalization within the past 12 months							0.330
Yes	71	9.1	32	8.1	39	10.2	
Annual frequency of healthcare visits due to illness, median (IQR)	1	(1–1)	1	(1–1)	1	(1–1)	0.535

With regard to prior morbidity, 81.9% of all children (n = 640) reported having previously experienced sore throat, with no difference observed between the case group (82.5%, n = 325) and the control group (81.4%, n = 315) (p = 0.692).

Parental actions taken when the child had fever were also similar between the two groups. Overall, 66.8% of respondents (n = 508) reported practicing self-treatment, while 27.3% (n = 208) reported seeking treatment based on a physician's advice. These proportions were comparable between the case and control groups (p = 0.628).

Several child health–related indicators—including a history of inflammatory skin conditions such as rash and purulent skin lesions, scabies, underlying allergic conditions (eczema, diathesis), and dental and gingival morbidity—were similarly distributed between the two groups, with no statistically significant differences observed. For example, a history of purulent skin infection was reported by 13.7% of all children (n = 107), including 12.8% (n = 50) in the case group and 14.7% (n = 57) in the control

group (p = 0.424). Although toothache and gingival inflammation were common, the differences between the groups did not reach statistical significance (p = 0.138).

Overall, individual-level factors, including oral hygiene practices, prior morbidity, and dermatological conditions, were insufficient to explain differences between the case and control groups with respect to streptococcal throat and pharyngeal infection.

Household and family factors

In response to the question regarding place of residence during the academic year, 97.8% of participating children (n = 763) reported living at home, while a small proportion (2.2%, n = 17) reported living with relatives or others. Living away from home was reported by 2.2% of children in the case group and 0.8% in the control group, and this difference was statistically significant (p = 0.008).

At the household and family level, evaluation of the home environment, living conditions, and daily household practices indicated that the living environments of children affected by streptococcal infection were generally similar to those of the control group, although some indicators had the potential to increase infection risk.

The median number of household members among all participating children was five (IQR: 4–6). This distribution was similar between the case group (58.9%, n = 232) and the control group (59.7%, n = 231), indicating that household size did not differentiate risk for streptococcal infection (p = 0.819).

Regarding housing type, 44.2% of households (n = 345) lived in traditional gers, 34.6% (n = 270) in detached houses, and 20.7% (n = 162) in apartments. The distribution of housing types was comparable between the case and control groups, and no statistically significant difference was observed (p = 0.749). This finding suggests that the risk of streptococcal infection was not directly associated with housing type (for example, living in a ger as a colder or dustier environment).

Household sanitation conditions were also similar between groups. Overall, 68.2% of households (n = 533) reported using unimproved sanitation facilities, while 31.8% (n = 248) reported using improved sanitation facilities, with no significant difference between the groups (p = 0.632). Access to a functional handwashing sink was reported by 74.3% of households (n = 580), including 74.9% in the case group (n = 295) and 73.6% in the control group (n = 285), with no statistically significant difference observed (p = 0.694).

With respect to access to hot water for daily bathing, 29.7% of households (n = 232) reported having adequate access, 50.6% (n = 395) reported no access, and 19.7% (n = 154) reported limited access. This indicator also did not differ significantly between the case and control groups (p = 0.079).

Table 5 Household and domestic factors

	Total		Case group		Control group		*P value*
	n	%	n	%	n	%	
Place of residence							0.008
Own household	763	97.8	380	96.4	383	99.	
Living with relatives	17	2.2	14	3.6	3	0.8	
Household size							
Median (IQR)	5	(4-6)	5	(4-6)	5	(4-6)	0.580
≤5 members	463	59.3	232	58.9	231	59.7	0.819
≥6 members	318	40.7	162	41.1	156	40.3	
Type of housing							0.749
Apartment	162	20.7	85	21.6	77	19.9	
Private house	270	34.6	129	32.7	141	36.4	
Ger	345	44.2	178	45.2	167	43.2	
Number of rooms, Median (IQR)	2	(2 - 3)	2	(2 - 3)	2	(2 - 3)	0.974
Floor area (m^2)	60	(48 - 70)	57	(47 - 70)	60	(48 - 73.5)	0.349
Living space per person (m^2)	11.3	(9.14 - 15.0)	10.7	(8.75 - 14.0)	11.7	(9.7 - 16)	0.164
Average monthly household income, Median (IQR)	2500000	(1600000 - 3500000)	2200000	(1500000 - 3100000)	2800000	(1800000 - 3500000)	0.147
Average monthly income per household member, Median (IQR)	500000	(300000- 750000)	500000	(333333- 750000)	500000	(300000- 707142)	0.142
Sanitation facilities							0.632
Unimproved	533	68.2	272	69.0	261	67.4	
Improved	248	31.8	122	31.0	126	32.6	
Presence of functional handwashing sink							0.694
No	201	25.7	99	25.1	102	26.4	
Yes	580	74.3	295	74.9	285	73.6	
Access to daily hot bathing							0.079
Not available	395	50.6	189	48.0	206	53.2	
Available	232	29.7	115	29.2	117	30.2	
Limited	154	19.7	90	22.8	64	16.5	
Household dampness							0.646
Yes	132	16.9	69	17.5	63	16.3	
No	649	83.1	325	82.5	324	83.7	
Presence of mold in any part of the dwelling							0.012
Yes	32	4.1	30	7.5	5	1.4	
No	749	95.9	364	92.5	382	98.6	
Household excessively cold in winter							0.874
Yes	143	18.3	73	18.5	70	18.1	
No	638	81.7	321	81.5	317	81.9	

Regarding access to hot water for daily bathing, 29.7% of households (n = 232) reported having adequate access, 50.6% (n = 395) reported no access, and 19.7% (n = 154) reported limited access. This indicator did not differ significantly between the case and control groups (p = 0.079). Taken together, these findings indicate that family environment, housing type, sanitation infrastructure, and availability of basic daily amenities did not differentiate streptococcal infection risk between the groups.

When specific characteristics of the home environment were examined, 17.3% of the case group and 16.3% of the control group reported that their homes were generally humid, a difference that was not statistically significant. In contrast, the presence of visible mold in at least one part of the home was reported at a significantly higher rate in the case group (7.5%, n = 30) compared with the control group (1.4%, n = 5), representing an approximately fivefold difference (p = 0.012). This finding suggests a potential association between household dampness-related conditions and increased risk of streptococcal infection.

Given Mongolia's climatic conditions and the widespread use of coal-based or centralized heating during the winter months, substantial heat loss in dwellings often leads to indoor condensation and moisture accumulation on walls and floors. Such conditions are conducive to mold growth and are also associated with increased levels of airborne particulates and allergens.

Elevated indoor humidity weakens the protective barrier of the upper respiratory mucosa, disrupts mucosal integrity, and enhances baseline inflammatory activity. As a result, bacterial adhesion and colonization on mucosal surfaces are facilitated, increasing children's susceptibility to respiratory tract infections. For pathogens such as streptococci, which are readily transmitted via respiratory droplets, impaired mucosal defense substantially lowers the threshold for infection.

Accordingly, household dampness and mold presence constitute plausible environmental risk factors that may increase children's vulnerability to streptococcal infection. This interpretation is consistent with the study findings and suggests that, within the Mongolian domestic context, the risk of Group A streptococcal infection may be partially influenced by indoor environmental quality.

Table 6 Selected family behavioral factors

	Total		Case group		Control group		*P value*
	n	%	n	%	n	%	
Presence of a smoker in the household							0.017
Yes	380	48.7	208	52.8	117	30.4	
No	401	51.3	185	47.2	269	69.6	
Number of smokers, median (iq)			1	(1 - 1)	1	(1 - 1)	0.468
Presence of a household member with recurrent throat pain							0.88
Yes	436	55.8	221	56.1	215	55.6	
No	345	44.2	173	43.9	172	44.4	
Number of individuals with throat pain, median (iq)			1	(0 - 1)	1	(0 - 1)	0.648
During early childhood, did any caregiver lick the child's spoon or pre-chew food before feeding?							0.714
Yes	453	58.0	226	57.4	227	58.7	
No	328	42.0	168	42.6	160	41.3	
Sharing of household items among family members							
Cup	352	45.1	166	42.1	186	48.1	0.096
Water bottle	156	20.0	77	19.5	79	20.4	0.761
Toothbrush, tongue scraper	50	6.4	25	6.3	25	6.5	0.948
Face/hand towel	361	46.2	184	46.7	177	45.7	0.787
Not shared at all	260	33.3	134	34.0	126	32.6	667
Father's educational level							<0.001
No formal education	19	2.5	17	4.4	2	0.5	
Primary education	94	12.3	75	19.2	19	5.1	
Incomplete secondary education	85	11.1	43	11.0	42	11.3	
Completed secondary education	370	48.5	170	43.6	200	53.6	
Technical/vocational education	40	5.2	15	3.8	25	6.7	
Higher education	133	17.4	58	14.9	75	20.1	
Father absent	22	2.9	12	3.1	10	2.7	
Mother's educational level							0.896
No formal education	2	0.3	1	0.3	1	0.3	
Primary education	20	2.6	9	2.4	11	2.9	
Incomplete secondary education	59	7.8	29	7.6	30	8.0	
Completed secondary education	350	46.1	180	47.1	170	45.1	
Technical/vocational education	39	5.1	16	4.2	23	6.1	
Higher education	278	36.6	140	36.6	138	36.6	
Father absent	4	0.5	3	0.8	1	0.3	

These findings suggest that lower paternal educational attainment may be associated with reduced access to health-related information at the household level, less appropriate health-seeking behavior during the early stages of illness, and poorer hygiene-related protective practices. When considered in the context of Mongolia's socioeconomic conditions and disparities in employment opportunities, the results indicate that children from households with lower paternal education may be at increased risk of infectious exposure, including streptococcal infection.

In contrast, maternal educational level did not differ significantly between the case and control groups ($p = 0.896$). Among participating mothers, those with completed secondary education (46.1%, n = 350)

and tertiary education (36.6%, n = 278) predominated, and the distribution was nearly identical in both groups. This finding suggests that maternal education level did not independently influence the risk of streptococcal infection in this study population.

This discrepancy may be interpreted as follows. In the Mongolian household context, mothers typically play a dominant role in children's daily care, nutrition, and health-related practices, which may result in relatively uniform caregiving behaviors regardless of differences in maternal education level. In contrast, lower paternal educational attainment may more strongly influence household income, lifestyle, and health-related risk behaviors, thereby exerting a greater indirect effect on children's susceptibility to infection.

Classroom and school environment

When evaluating several variables related to the school environment, baseline classroom conditions were largely similar between the case and control groups. The median class size was 40–41 students overall (IQR: 35–45). The proportion of children attending classrooms with 30 or more students was 93.4% (n = 368) in the case group and 94.6% (n = 366) in the control group, with no statistically significant difference observed between groups (p = 0.575).

The consistently high classroom density across schools suggests that large class size is a common structural characteristic of the school system and may mask potential differences in infection risk between groups, limiting its discriminatory value as an independent risk factor in this setting.

Table 7 Factors associated with children's social participation, school environment, and classroom conditions

	Total		Case group		Control group		*P value*
	N	%	N	%	N	%	
Number of students per classroom							
Median (iqr)	40	(35-45)	41	(35 - 45)	40	(35 - 45)	0.575
29≥	47	6.0	26	6.6	21	5.4	0.491
30≤	734	94.0	368	93.4	366	94.6	
Active participation in school and community activities							0.01
No	233	29.8	134	34.0	99	25.6	
Yes	548	70.2	260	66.0	288	74.4	
Sharing food and drinks with friends (mouth-to-mouth transmission)							0.514
No	332	42.5	172	43.7	160	41.3	
Yes	449	57.5	222	56.3	227	58.7	
Availability of a child-friendly handwashing environment at school							0.96
No	30	3.8	15	3.8	15	3.9	
Yes	751	96.2	379	96.2	372	96.1	
Practice of handwashing with soap at school							0.001
No	550	70.4	299	75.9	251	64.9	
Yes	231	29.6	95	24.1	136	35.1	
Type of sanitation facilities provided for children at school							0.205
Unimproved	15	1.9	10	2.5	5	1.3	
Improved	766	98.1	384	97.5	382	98.7	
Satisfaction with school sanitation facilities							0.353
Very poor	19	2.4	8	2.0	11	2.8	
Poor	93	11.9	47	11.9	46	11.9	
Average	228	29.2	127	32.2	101	26.1	
Good	415	53.1	201	51.0	214	55.3	
Very good	26	3.3	11	2.8	15	3.9	

Participation in school and community activities was reported by 74.4% (n = 288) of children in the control group and 66.0% (n = 260) in the case group. Contrary to the initial theoretical assumption, greater participation appeared to have a protective association against infection, with a statistically significant difference observed between groups (p = 0.01).

Sharing food or drinks mouth-to-mouth with friends is considered a potential transmission pathway for streptococcal infection. In this study, 56–59% of children reported engaging in this behavior (56.3%, n = 222 in the case group and 58.7%, n = 227 in the control group). However, no statistically significant difference was observed between the two groups (p = 0.514).

School hygiene infrastructure and access to sanitary facilities are considered essential baseline factors in reducing children's risk of infectious diseases. Among surveyed parents, 96.2% (n = 379) reported that appropriate handwashing facilities were available at school. Similar proportions were observed in

the case group (96.2%, n = 379) and the control group (96.1%, n = 372), with no statistically significant difference between groups (p = 0.96). This indicates that handwashing infrastructure was equally available to all students.

However, access to handwashing facilities does not necessarily equate to actual handwashing behavior using soap. A significant difference was observed for the indicator "handwashing with soap at school" (p = 0.001). In the case group, 75.9% (n = 251) reported not using soap, compared with 64.9% (n = 251) in the control group. Conversely, the proportion of students who reported using soap was 35.1% (n = 136) in the control group and 24.1% (n = 95) in the case group. These findings suggest that soap use during handwashing may confer a protective effect against infection. Despite similar infrastructure, differences in actual hygiene practices highlight the role of behavioral factors as protective determinants.

Regarding school sanitation facilities, 97.5% (n = 384) of students reported using improved toilets, with no significant difference between groups (p = 0.205). This finding reflects the generally adequate sanitation infrastructure in the schools included in the study.

Although sanitation facility quality, accessibility, and user satisfaction are often considered potential determinants of streptococcal infection risk, no statistically significant differences were observed between groups in this study (p = 0.353). Overall, 51.0% (n = 201) of parents rated school sanitation facilities as "good," with similar proportions in the case group (51.0%) and control group (55.3%). A "moderate" rating was reported by 32.2% (n = 127) of the case group and 26.1% (n = 101) of the control group. Ratings of "poor" or "very poor" ranged between 13–15% overall, consistent with the high proportion of schools equipped with improved sanitation facilities (97–99%).

These results indicate that subjective assessments of sanitation facility quality do not discriminate risk for streptococcal infection in this study population.

Health-Care Seeking Behavior of Parents and Caregivers and

Responses regarding challenges faced by families when accessing health-care services showed a similar pattern between the case and control groups, with no statistically significant differences observed. This indicates that these common barriers to health-care access do not exert a differential effect on the risk of exposure to group A streptococcal infection.

The most frequently reported difficulty was limited access to physicians and long waiting times. This issue was identified by 43.9% of the case group (n = 173) and 45.0% of the control group (n = 174), reflecting the real-world context of Mongolia's health-care system, where primary health-care facilities experience high workloads and waiting times increase further during periods of seasonal respiratory infections. As this factor represents a system-wide challenge affecting households broadly, no association was observed with group A streptococcal infection status.

High medication costs and limited access to prescriptions were also commonly reported barriers. These challenges were noted by 31.5% of the case group (n = 124) and 32.3% of the control group (n = 125), indicating that the financial burden of medications is perceived similarly at the household level in both groups. Medication use typically increases during episodes of respiratory illness, and this burden was experienced to a comparable extent among cases and controls.

Perceived high service fees were reported at similar levels in both groups (23.9% in the case group and 22.5% in the control group), suggesting that out-of-pocket health-care costs constitute a common household burden regardless of infection status.

Table 8 Accessibility and satisfaction with health services

	Total		Case group		Control group		P value
	N	%	N	%	N	%	
Seeking medical care when child is ill							0.483
No	22	2.8	13	3.3	9	2.3	
Rarely	98	12.5	48	12.2	50	12.9	
Sometimes	364	46.6	175	44.4	189	48.8	
Always	297	38.0	158	40.1	139	35.9	
Barriers to accessing health services							
Difficult to reach (road, transport, remote location)	183	23.4	99	25.1	84	21.7	0.259
Limited availability of doctors, long waiting times	347	44.4	173	43.9	174	45.0	0.767
High cost of medicines, lack of prescriptions	249	31.9	124	31.5	125	32.3	0.804
High service fees	181	23.2	94	23.9	87	22.5	0.648
No problems	226	28.9	109	27.7	117	30.2	0.429
Satisfaction with health services							0.034
Very dissatisfied	23	2.9	12	3.0	11	2.8	
Dissatisfied	354	45.3	197	50.0	157	40.6	
Satisfied	343	43.9	153	38.8	190	49.1	
Very satisfied	61	7.8	32	8.1	29	7.5	

In contrast, difficulties related to geographic access were reported less frequently. Transportation challenges and remote location were cited by 25.1% of the case group (n = 99) and 21.7% of the control group (n = 84). Compared with other barriers, this lower prevalence suggests that most children included in the study reside in areas with relatively good proximity to primary health-care services. While access challenges are more pronounced in some rural soums of Mongolia, the school-based design of this study and its concentration in urban and peri-urban settings may explain the relatively lower reporting of geographic barriers.

Conversely, 27.7–30.2% of households in both groups reported no difficulties in accessing health-care services, indicating similar perceptions of service availability and quality across groups and reinforcing the notion that reported barriers are systemic rather than group-specific.

Regarding satisfaction with health-care services, a statistically significant difference was observed between the two groups (p = 0.034). Parents of children in the case group expressed greater dissatisfaction with service quality, whereas a higher proportion of parents in the control group reported being satisfied.

Specifically, 50.0% of parents in the case group (n = 197) rated health-care services as “unsatisfactory,” compared with 40.6% in the control group (n = 157). Conversely, 49.1% of parents in the control group (n = 190) reported being “satisfied,” compared with 38.8% in the case group (n = 153). Ratings at the extremes (“very dissatisfied” and “very satisfied”) were similar in both groups (3.0–3.9% and 7.5–8.1%, respectively), indicating that differences in moderate satisfaction levels primarily accounted for the overall disparity.

Several factors may explain this difference. First, households with children affected by group A streptococcal infection typically interact more frequently with health-care services during illness episodes, leading to heightened awareness of challenges related to waiting times, diagnostic procedures, medication availability, and service coordination. In such contexts, expectations of care quality may be higher, and psychological stress may further amplify dissatisfaction.

Second, parents seeking care for an acutely ill child often experience increased anxiety and responsibility, making any perceived shortcomings in service delivery more salient and negatively influencing satisfaction. In contrast, households in the control group may have less frequent contact with health-care services and experience fewer stressful encounters, resulting in relatively fewer negative perceptions and higher overall satisfaction.

Collectively, these findings suggest that health-care satisfaction is shaped by a complex interaction of illness experience, psychological burden, and actual service accessibility. Therefore, observed differences in satisfaction are unlikely to reflect objective differences in service quality alone, but rather the accumulated experiences, expectations, and perceptions of households during episodes of illness.

Knowledge and Perceptions of Parents and Caregivers Regarding Sore Throat and Careseeking Behavior

Assessment of caregivers' prior experiences with sore throat, actions taken during episodes of throat pain, and their understanding of causes and potential complications revealed largely similar patterns between the case and control groups. Approximately three-quarters of respondents reported having previously experienced sore throat (80.7%, n = 318 in the case group; 81.1%, n = 314 in the control group; p = 0.88). This finding reflects the Mongolian climatic context—particularly during spring and autumn—when recurrent respiratory infections are common, making sore throat a frequent clinical complaint.

Actions taken during episodes of sore throat did not differ significantly between the two groups (p = 0.737). Approximately one-third of respondents reported self-medicating (35.0% vs. 33.8%), around 20% used herbal remedies or traditional treatments (20.1% vs. 20.5%), and 10–13% preferred gargling with warm salt water. The proportion seeking medical care was 28.7% in the case group and 31.2% in the control group, reinforcing the common perception among Mongolian households that sore throat is a mild, self-limiting condition that often does not require professional medical attention.

Similar patterns were observed regarding sources of information used to decide on medication use (p = 0.278). Between 43% and 47% of parents identified physicians' recommendations as their primary source of guidance; however, the continued influence of social media (approximately 12%) and advice from family members or acquaintances (approximately 5–8%) warrants attention. These influences may increase the risk of inappropriate medication use, particularly unnecessary antibiotic consumption. Although a correct understanding—that antibiotics should only be used under a physician's prescription—was reported at comparable levels in both groups (approximately 74%), further investigation is needed to determine how consistently this knowledge translates into actual practice.

Table 9 Measures taken by parents or caregivers when a child experiences sore throat

Knowledge and practices	Total		Case group		Control group		*P value*
	N	%	N	%	N	%	
History of sore throat (self or child)							0.88
Yes	632	80.9	318	80.7	314	81.1	
No	149	19.1	76	19.3	73	18.9	
Common measures taken during sore throat							0.737
No action taken	31	4.0	14	3.6	17	4.4	
Self-medication	268	34.4	138	35.0	130	33.8	
Use of herbal remedies	158	20.3	79	20.1	79	20.5	
Gargling with warm saline solution	89	11.4	50	12.7	39	10.1	
Consulting a physician	233	29.9	113	28.7	120	31.2	
Decision-making on medication use							0.278
Other	15	1.9	8	2.0	7	1.8	
Social media	98	12.6	49	12.4	49	12.7	
Close acquaintances	50	6.4	31	7.9	19	4.9	
Self	262	33.6	121	30.7	141	36.6	
Physician	354	45.4	185	47.0	169	43.9	

Parents' understanding of the causes of sore throat was generally limited. Only 3.8–3.9% of respondents correctly identified bacterial infection (Group A Streptococcus) as the cause, while the majority provided other explanations, indicating insufficient knowledge regarding the underlying etiology of pharyngitis and the appropriate indications for antibiotic treatment.

A very high proportion of households reported not knowing the potential complications that may arise from inadequately treated sore throat. This lack of awareness was significantly more common in the case group (80.7%, n = 318) than in the control group (74.4%, n = 288), and the difference was statistically significant (p = 0.003). These findings highlight substantial gaps in health education related to complications of childhood pharyngitis—particularly acute rheumatic fever (ARF) associated with Group A streptococcal infection.

Table 10. Parents' and caregivers' knowledge regarding sore throat

	Total		Case group		Control group		*P value*
	N	%	N	%	N	%	
Knowledge score on pharyngitis among parents, median (iqr)	3	(2 - 5)	3	(2 - 5)	3	(2 - 5)	0.297
Perceived main cause of sore throat							0.453
Bacteria	30	3.8	15	3.8	15	3.9	
Virus	152	19.5	73	18.5	79	20.4	
Environmental pollution	81	10.4	43	10.9	38	9.8	
Other	248	31.8	119	30.2	129	33.3	
Cold exposure	201	25.7	113	28.7	88	22.7	
Do not know	69	8.8	31	7.9	38	9.8	
Awareness of possible complications if sore throat is not properly treated							0.003
Aware	175	22.4	76	19.3	99	25.6	
Not aware	606	77.6	318	80.7	288	74.4	
Awareness of rheumatic fever caused by angina							<0.001
No	576	73.8	293	74.4	283	73.1	
Yes	205	26.2	101	25.6	104	26.9	
Belief: sore throat can lead to rheumatic fever							0.495
Incorrect	413	52.9	216	54.8	197	50.9	
Correct	368	47.1	178	45.2	190	49.1	
Belief: proper treatment of sore throat prevents heart disease							0.287
Incorrect	383	49.0	203	51.5	180	46.5	
Correct	398	51.0	191	48.5	207	53.5	
Belief: antibiotics should only be used under physician's guidance							0.749
Incorrect	204	26.1	101	25.7	103	26.6	
Correct	577	73.9	293	74.4	284	73.4	

Awareness that rheumatic fever can develop as a consequence of tonsillitis (pharyngitis) was generally very low. Only 25.6% of respondents in the case group and 26.9% in the control group reported having heard of this association, with no significant difference between groups. Similarly, knowledge regarding whether sore throat can cause rheumatic fever was comparable between the two groups (approximately 45–49%, p = 0.495), indicating that more than half of the population has incorrect or unclear understanding of this relationship. Awareness that appropriate and complete treatment of sore throat can prevent heart disease was also limited, with only about 50% of respondents in both groups recognizing this link (p = 0.287), highlighting persistent gaps in health education.

Findings from Skin, Oral, and Pharyngeal Examinations

Comparative clinical assessment of skin, oral cavity, and pharyngeal findings among participating children revealed that some signs were clearly associated with streptococcal infection risk, whereas others did not demonstrate statistically significant differences between groups.

Impetigo, a common manifestation of streptococcal skin infection, was observed in 14.5% (n = 56) of children in the case group and 10.4% (n = 41) in the control group; however, this difference did not reach statistical significance (p = 0.085). Although impetigo represents a frequent cutaneous presentation of streptococcal infection and skin colonization may coexist with respiratory carriage, the observed trend—while biologically plausible—did not establish impetigo as a strong risk marker in this study. Other skin conditions, including rash, eczema, and scabies, were similarly distributed between the two groups.

Among oral and pharyngeal findings, signs of pharyngeal and tonsillar inflammation showed the most pronounced differences. Pharyngeal mucosal damage and erythema were detected in 10.2% (n = 40) of children in the case group compared with 4.9% (n = 19) in the control group, consistent with physiological mechanisms whereby Group A Streptococcus colonization compromises mucosal barrier integrity (p = 0.006). In addition, tonsillar hypertrophy involving 25–50% and 50–75% enlargement was more frequently identified in the case group, reflecting active inflammatory processes.

On pharyngeal examination, tonsillitis was diagnosed in 20.3% (n = 80) of children in the case group compared with 13.2% (n = 51) in the control group, representing a statistically significant difference (p = 0.008).

Table 11 Findings from examination of skin, oral cavity, and pharynx

		Total		Case group		Control group		*P value*
		N	%	n	%	n	%	
Skin Disorders								
	Impetigo	97	12.4	41	10.4	56	14.5	0.085
	Rash	71	9.1	36	9.1	35	9.0	0.964
	Eczema	8	1.0	4	1.0	4	1.0	0.98
	Scabies	1	0.1	0	0.0	1	0.3	0.313
Dental Caries								0.541
	Present	668	85.5	340	86.3	328	84.8	
	Absent	113	14.5	54	13.7	59	15.2	
Number of Decayed Teeth (total)	Median (IQR)	3	(1-6)	4	1.-6	3	1.-6	0.226
	at age 6	7	(3-10)	10	(7-12)	3	(2-10)	<0.001
Gingivitis (redness, swelling, bleeding)	Present	33	4.2	21	5.3	12	3.1	0.122
Condition of Oral Mucosa (lesions, ulcers, redness)	Present	59	7.60	40	10.2	19	4.9	0.006
Condition of Posterior Pharyngeal Mucosa								0.41
	Normal	612	78.4	304	77.2	308	79.6	
	Edematous and erythematous	169	21.6	90	22.8	79	20.4	
Tonsillar Appearance								0.036
	Not visible	207	26.5	90	22.8	117	30.2	
	<25%	380	48.7	193	49.0	187	48.3	
	25-50%	152	19.5	83	21.1	69	17.8	
	50-75%	36	4.6	25	6.3	11	2.8	
	>75%	6	0.8	3	0.8	3	0.8	
Presence of Tonsillitis								0.008
	Yes	131	16.8	80	20.3	51	13.2	
	No	650	83.2	314	79.7	336	86.8	
Type of Tonsillitis								0.938
	Catarrhal	122	93.1	74	92.5	48	94.1	
	Follicular	6	4.6	4	5.0	2	3.9	
	Lacunar	3	2.3	2	2.5	1	2.0	

In addition, dental caries were highly prevalent among the study population (approximately 85%). The median number of decayed teeth did not differ significantly between the case and control groups (4 vs. 3 teeth, respectively; $p = 0.226$). However, when the median number of decayed teeth was analyzed by age, a statistically significant difference was identified among six-year-old children. In this age group, the median number of decayed teeth was 10 (IQR: 7–12) in the case group compared with 3 (IQR: 2–10) in the control group ($p < 0.001$).

This finding suggests that insufficient parental attention to primary (deciduous) tooth hygiene, along with limited access to regular dental check-ups, may adversely affect the oral microenvironment of younger children. A commonly held perception that primary teeth are "temporary and destined to fall out" often results in reduced preventive care at the household level. Such attitudes may create a favorable environment for bacterial proliferation, compromise oral protective barriers, and thereby increase susceptibility to recurrent upper respiratory tract infections, including streptococcal infections.

Overall, findings from the skin, oral, and pharyngeal examinations indicate that mucosal damage, tonsillar hypertrophy, and tonsillitis are the clinical features most directly associated with an increased risk of streptococcal infection. In contrast, skin conditions and general indicators of oral health, such as caries in permanent teeth, were not identified as significant risk factors. However, poor oral hygiene of primary teeth in younger children appears to contribute to increased vulnerability to streptococcal infection, as demonstrated by the study results.

Growth and Nutrition Related Factors

Comparisons of body weight, height, and nutritional status indicators among the participating children showed no statistically significant differences between the case and control groups. The mean height of children in the case group was 142 cm (95% CI: 130–155), compared with 143 cm (95% CI: 130–156) in the control group. The median body weight was identical in both groups at 36 kg ($p = 0.940$). Similarly, age- and sex-adjusted Z-scores for weight, height, and body mass index (BMI) demonstrated comparable patterns between the two groups, with no statistically significant differences observed for any indicator ($p > 0.8$ for all measures). These findings indicate that nutritional status and growth trajectories did not differ between children with and without group A streptococcal pharyngeal infection in this study population.

Table 12 Selected indicators of children's growth and nutritional status.

	Total		Case group		Control group		*P value*
	Median	IQR	Median	IQR	Median	IQR	
Child's height (cm)	142	(130 – 155)	142	(130 - 155)	143	(130 - 156)	0.877
Child's weight (kg)	36	(28 – 46.6)	36	(28 - 46.5)	36	(28 - 47)	0.940
Weight-for-age Z-score	0.4	(-0.26 – 1.28)	0.4	(-0.24 - 1.18)	0.5	(-0.275 - 1.31)	0.990
Height-for-age Z-score	0.3	(-0.45 – 0.98)	0.3	(-0.48 - 0.95)	0.2	(-0.44 - 0.98)	0.818
BMI-for-age Z-score	0.2	(-0.44 – 1.05)	0.2	(-0.42 - 1.06)	0.2	(-0.44 - 1.04)	0.942

Multivariable Analysis of Risk Factors for Group A Streptococcal Throat Infection

The results of the multivariable logistic regression analysis identified several factors that were independently associated with an increased risk of group A streptococcal (GAS) pharyngeal infection among children aged 6–15 years.

Table 12. Odds ratios, adjusted odds ratios and 95% confidence intervals for risk factors associated with pharyngitis and tonsillitis caused by Group A streptococcal infection among children aged 6–15 years

Variable	Total N (%)	Case group n(%)	Control group n(%)	p value	Crude OR (95% CI)	p value	Adjusted OR (95% CI)	p value	All OR (95% CI)	p value
Place of residence				0.008						
Own household	763 (97.8)	380 (96.4)	383 (99.2)	—	1 (ref)	—	1 (ref)	—	1 (ref)	—
Living with relatives	17 (2.2)	14 (3.6)	3 (0.8)	—	4.70 (1.34–16.50)	0.016	4.83 (1.36–17.06)	0.015	3.66 (1.00–13.39)	0.050
Presence of mold in the dwelling				0.012						
Yes	32 (4.1)	30 (7.5)	5 (1.4)	—	5.70 (1.24–26.20)	0.025	5.89 (1.27–27.24)	0.023	—	—
No	749 (95.9)	364 (92.5)	382 (98.6)	—	1 (ref)	—	1 (ref)	—	—	—
Smoking inside the household				0.017						
Yes	380 (48.7)	208 (52.8)	117 (30.4)	—	6.30 (2.42–16.41)	<0.001	6.30 (2.42–16.41)	<0.001	—	—
No	401 (51.3)	185 (47.2)	269 (69.6)	—	1 (ref)	—	1 (ref)	—	—	—
Father's education level				<0.001						
Low/none	113 (14.8)	21 (5.6)	92 (23.6)	—	5.17 (3.14–8.52)	<0.001	5.62 (3.37–9.38)	<0.001	3.88 (2.24–6.71)	<0.001
Secondary or higher	650 (85.2)	352 (94.4)	298 (76.4)	—	1 (ref)	—	1 (ref)	—	1 (ref)	—
Participation in community activities				0.010						
No	233 (29.8)	134 (34.0)	99 (25.6)	—	1.50 (1.10–2.04)	0.010	1.53 (1.11–2.12)	0.010	1.60 (1.12–2.30)	0.010
Yes	548 (70.2)	260 (66.0)	288 (74.4)	—	1 (ref)	—	1 (ref)	—	1 (ref)	—
Handwashing with soap at school				0.001						
No	550 (70.4)	299 (75.9)	251 (64.9)	—	1.71 (1.25–2.33)	0.001	1.85 (1.31–2.60)	<0.001	1.91 (1.32–2.77)	0.001
Yes	231 (29.6)	95 (24.1)	136 (35.1)	—	1 (ref)	—	1 (ref)	—	1 (ref)	—
Satisfaction with primary health care services				0.007						
Dissatisfied	377 (48.3)	168 (43.4)	209 (53.0)	—	1.47 (1.11–1.95)	0.007	1.53 (1.14–2.07)	0.005	1.19 (0.86–1.66)	0.288
Satisfied	404 (51.7)	219 (56.6)	185 (47.0)	—	1 (ref)	—	1 (ref)	—	1 (ref)	—
Knowledge of complications of throat infection				0.035						
Does not know	606 (77.6)	318 (80.7)	288 (74.4)	—	1.44 (1.03–2.02)	0.035	1.45 (1.03–2.04)	0.036	1.32 (0.89–1.95)	0.165
Knows	175 (22.4)	76 (19.3)	99 (25.6)	—	1 (ref)	—	1 (ref)	—	1 (ref)	—
Awareness of rheumatic disease				<0.001						
No	576 (73.8)	293 (74.4)	283 (73.1)	—	11.85 (3.59–39.09)	<0.001	12.87 (3.72–44.52)	<0.001	5.93 (1.65–21.23)	0.006
Yes	205 (26.2)	101 (25.6)	104 (26.9)	—	1 (ref)	—	1 (ref)	—	1 (ref)	—
Mucosal damage/redness				0.006						
Present	59 (7.6)	40 (10.2)	19 (4.9)	—	2.19 (1.24–3.85)	0.007	2.25 (1.27–3.98)	0.005	2.46 (1.34–4.51)	0.004
Not present	722 (92.4)	354 (89.8)	368 (95.1)	—	1 (ref)	—	1 (ref)	—	—	—
Size of tonsils				0.036						
Not visible	207 (26.5)	90 (22.8)	117 (30.2)	—	1 (ref)	—	1 (ref)	—	—	—
<25%	380 (48.7)	193 (49.0)	187 (48.3)	—	1.34 (0.96–1.89)	0.089	1.34 (0.96–1.89)	0.089	—	—
25–50%	152 (19.5)	83 (21.1)	69 (17.8)	—	1.57 (1.03–2.40)	0.037	1.57 (1.03–2.40)	0.037	—	—
50–75%	36 (4.6)	25 (6.3)	11 (2.8)	—	2.94 (1.37–6.29)	0.006	2.94 (1.37–6.29)	0.006	—	—
>75%	6 (0.8)	3 (0.8)	3 (0.8)	—	1.27 (0.25–6.49)	0.772	1.27 (0.25–6.49)	0.772	—	—
Presence of tonsillitis				0.008						
Yes	131 (16.8)	80 (20.3)	51 (13.2)	—	1.68 (1.14–2.46)	0.008	1.69 (1.15–2.50)	0.008	1.92 (1.27–2.91)	0.002
No	650 (83.2)	314 (79.7)	336 (86.8)	—	1 (ref)	—	1 (ref)	—	1 (ref)	—
Dental caries detected on examination				0.541						

Not detected	113 (14.5)	54 (13.7)	59 (15.2)	—	1 (ref)	—	1 (ref)	—	1 (ref)	—
Detected	668 (85.5)	340 (86.3)	328 (84.8)	—	1.13 (0.76-1.69)	0.541	1.12 (0.75-1.68)	0.580	1.13 (0.72-1.78)	0.585

Living with non-parental caregivers (living with relatives or other households) was associated with a markedly increased risk of infection. Compared with children living in their own homes, children living with other families had a 4.8-fold higher likelihood of group A streptococcal (GAS) infection (aOR = 4.83; 95% CI: 1.36–17.06).

Household environmental conditions also played a significant role. Presence of visible household mold was strongly associated with infection risk, with children living in such environments having a 5.9-fold increased odds of GAS infection (aOR = 5.89; 95% CI: 1.27–27.24). This finding is biologically plausible, as damp and mold-contaminated indoor environments may impair upper respiratory mucosal defense mechanisms and facilitate bacterial colonization.

Among household behavioral factors, exposure to secondhand tobacco smoke emerged as the strongest risk factor. Children living in households where at least one family member smoked indoors had a 6.3-fold higher risk of infection (aOR = 6.30; 95% CI: 2.42–16.41).

Socio-demographic characteristics were also significant. Lower paternal educational attainment was independently associated with an increased risk of infection, with children whose fathers had low education levels experiencing a 5.6-fold higher odds of GAS infection (aOR = 5.62; 95% CI: 3.37–9.38).

With respect to the school environment, lack of regular participation in community or extracurricular activities was associated with a 1.53-fold increased risk of infection (aOR = 1.53; 95% CI: 1.11–2.12). In addition, not washing hands with soap at school significantly increased the risk of GAS infection by 1.85 times (aOR = 1.85; 95% CI: 1.31–2.60). These findings indicate that even when handwashing facilities are available, inadequate hygiene practices in school settings may substantially increase transmission risk.

Parental knowledge and attitudes were also significantly associated with infection risk. Lack of awareness regarding complications of sore throat increased the likelihood of infection by 1.45 times (aOR = 1.45; 95% CI: 1.03–2.04), while lack of knowledge about rheumatic fever was associated with a markedly elevated risk (aOR = 12.87; 95% CI: 3.72–44.52).

Clinical examination findings further supported these associations. Children with oral mucosal damage had a 2.25-fold higher risk of GAS infection (aOR = 2.25; 95% CI: 1.27–3.98), consistent with the role of mucosal barrier disruption in facilitating bacterial adherence and colonization.

Similarly, tonsillar hypertrophy was strongly associated with infection risk. Children with 25–50% tonsillar enlargement had a 1.57-fold increased risk (aOR = 1.57; 95% CI: 1.03–2.40), while those with 50–75% enlargement exhibited an even higher risk (aOR = 2.94; 95% CI: 1.37–6.29). In addition, clinically diagnosed tonsillitis was associated with a 1.69-fold increased odds of infection (aOR = 1.69; 95% CI: 1.15–2.50), confirming the strong link between GAS infection and upper respiratory inflammatory pathology.

Overall, these findings demonstrate that GAS pharyngeal infection is driven by a complex interaction of individual, household, school, and knowledge-related factors. Infection risk is influenced not only by clinical and biological susceptibility, but also by household living conditions, exposure to tobacco smoke, school hygiene practices, parental education, and awareness of disease complications, underscoring the need for multilevel prevention strategies.

Modifiable and Non-modifiable Risk Factors

Identified risk factors were classified as modifiable and non-modifiable to assess their relative contribution to the overall disease burden. To quantify the potential impact of each modifiable risk factor on disease occurrence, the Population Attributable Fraction (PAF) was calculated.

Given the methodological characteristics of the case–control study design, PAFs were estimated based on adjusted odds ratios (aORs) derived from multivariable logistic regression models. The PAF represents the theoretical proportion of disease cases that could be prevented if a specific risk factor were completely eliminated from the population, assuming a causal relationship.

This approach allows estimation of the potential reduction in the overall burden of group A streptococcal pharyngeal infection attributable to modifiable exposures, thereby supporting prioritization of preventive interventions and public health strategies.

Table 13 Adjusted odds ratios (aOR), population attributable fraction (PAF), and modifiable population attributable fraction (Modi-PAF) for risk factors associated with Group A streptococcal infection among children.

	Pe	aOR	PAF	PAF (%)	Modi. PAF (%)
Living with relatives/others	0.022	4.83	0.078	7.8	2.4
Presence of mold in any part of the dwelling	0.041	5.89	0.167	16.7	5.2
Exposure to secondhand smoke at home	0.487	6.3	0.721	72.1	22.2
Father with no or low education	0.148	5.62	0.406	40.6	12.5
Not participating in school or community activities	0.298	1.53	0.136	13.6	4.2
Not washing hands with soap at school	0.704	1.85	0.374	37.4	11.5
Parents dissatisfied with primary health care services	0.483	1.53	0.204	20.4	6.3
Lack of knowledge about complications of throat infection	0.776	1.45	0.259	25.9	8.0
Not aware of rheumatic disease as a sequela of tonsillitis	0.738	12.87	0.898	89.8	27.7

Notes: Pe – prevalence of exposure, PAF – population attributable fraction, Modi.PAF – - Modifiable population attributable fraction

The results indicate that factors directly related to the living environment and family context contributed the largest share of the overall burden of group A streptococcal infection. In particular, exposure to household tobacco smoke showed the greatest impact on disease burden, with a PAF of 72.1% and a modifiable PAF (modi-PAF) of 22.2%, identifying it as the single most influential modifiable risk factor.

Environmental conditions within the home also played an important role. Visible mold growth in any part of the dwelling (modi-PAF = 5.2%) and living outside the child's own home during the school year (modi-PAF = 2.4%) were associated with increased infection risk, highlighting the importance of indoor environmental hygiene and housing stability in reducing susceptibility to infection.

Among family demographic characteristics, low paternal educational attainment was strongly associated with infection risk (aOR = 5.62) and accounted for a substantial proportion of the disease burden (PAF = 40.6%, modi-PAF = 12.5%). This finding underscores the critical role of household educational level in shaping hygiene practices, early recognition of symptoms, and timely health-seeking behavior.

With respect to school-related factors, not washing hands with soap at school significantly increased the risk of group A streptococcal infection (aOR = 1.85), with a modi-PAF of 11.5%, emphasizing the preventive value of effective hand hygiene practices in the school environment.

Insufficient knowledge regarding complications of sore throat accounted for a relatively high theoretical contribution to disease burden (PAF = 25.9%); however, the modifiable fraction was lower (modi-PAF = 8.0%), reflecting limited feasibility of complete risk elimination. In contrast, lack of awareness of rheumatic fever showed a very strong association with infection risk (aOR = 12.87) and a high theoretical impact (PAF = 89.8%). Nevertheless, its modi-PAF was reduced to 27.7%, likely due to the lower prevalence of this knowledge gap and the influence of multiple concurrent causal pathways.

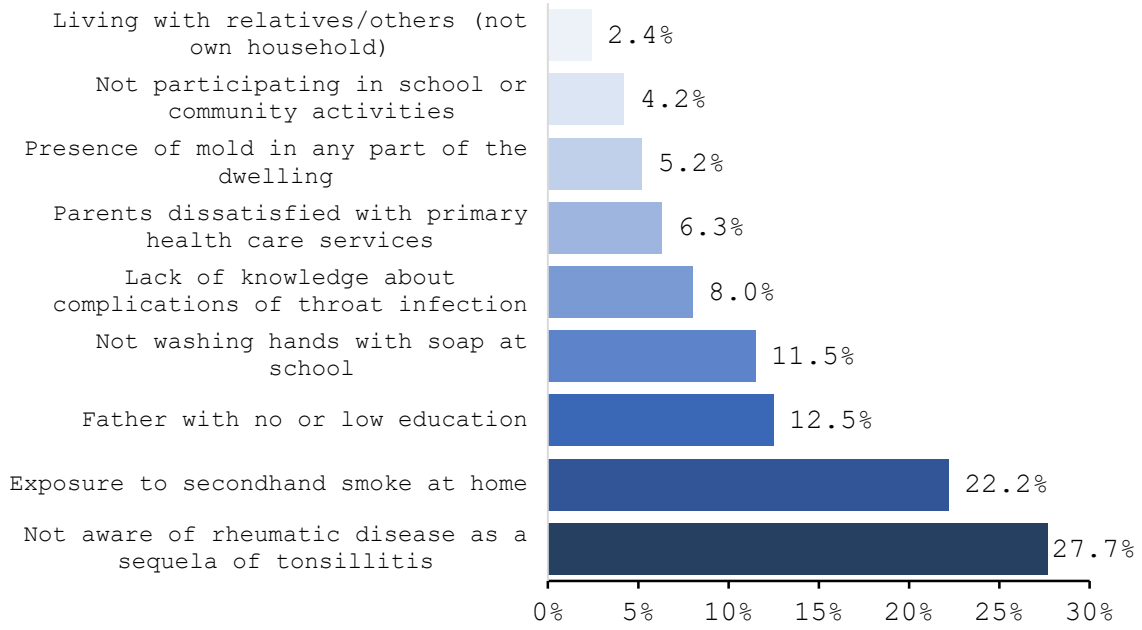


Figure 15 Relative contribution of modifiable risk factors to GAS throat infection

Taken together, these findings demonstrate that household environmental hygiene, caregiver educational level, school hygiene practices, and limited awareness of throat infections and their complications represent the most practically relevant contributors to group a streptococcal infection risk. The combined evaluation of paf and modi-paf provides critical insight into which risk factors should be prioritized for public health intervention, enabling more effective targeting of preventive strategies and resource allocation. The relative contributions of modifiable risk factors (modi-paf) are ranked and illustrated in the Figure 15.

DISCUSSION

Prevalence of Group A Streptococcal Infection

Most international studies have focused on estimating the prevalence of GAS pharyngitis among symptomatic children, while relatively few have assessed asymptomatic carriage. A large meta-analysis of 285 studies conducted between 1946 and 2017 reported that the prevalence of asymptomatic GAS carriage among children ranged from 6% to 11%.[45]

In Egypt, a case–control study among school-aged children found that 16% of healthy children aged 5–15 years in the control group were asymptomatic GAS carriers.[2] Similarly, a four-year cohort study conducted in the United States (1998–2002) reported an asymptomatic carriage rate of 15.5% among children aged 5–15 years.[46,47]

In contrast, our study found a lower prevalence of asymptomatic carriage (5.7%) among children aged 6–15 years. This difference may be explained by variations in study design, diagnostic approaches, environmental factors, and population characteristics. Notably, our study employed a large-scale, school-based, nationwide sampling strategy, covering a broader population than many previous studies conducted in more limited or clinical settings.

Sex and Age Differences in Infection

Numerous international studies have consistently reported a higher prevalence of GAS infection among boys. Lin et al. found that 56.3% of GAS pharyngitis cases occurred in boys,[48] while studies of post-streptococcal acute rheumatic fever reported that 54.8% of cases were male.[49] These differences may be partly explained by sex-related variations in immune responses, particularly Th1/Th2 immune activation influenced by sex hormones.[50]

Our findings align with this evidence, as 54.6% of GAS pharyngitis and tonsillopharyngitis cases occurred in boys.

Age-related trends observed in our study are also consistent with previous research, which demonstrates an inverse relationship between age and GAS infection risk.[51,52] Younger children are more susceptible due to incomplete immune maturation, limited prior exposure to Streptococcus pyogenes, and behavioral factors such as close contact, shared play, and poor hygiene practices that

facilitate transmission.[53] In our study, children aged 6–8 years exhibited the highest prevalence across both sexes, with rates declining progressively with increasing age.

Interpretation of Risk Factors

Our analysis showed that several individual-level behavioral factors—such as handwashing frequency and sharing of eating or drinking utensils—did not differ significantly between case and control groups. This likely reflects the widespread and relatively uniform distribution of these behaviors among school-aged children. International evidence suggests that hand hygiene is more strongly associated with viral respiratory infections, while its direct and consistent association with GAS pharyngitis is less robust.[54,55] GAS transmission primarily occurs via respiratory droplets and close contact.

In contrast, oral health indicators revealed notable findings. Although permanent tooth caries did not differ between groups overall, a striking difference was observed among 6-year-old children: the median number of decayed primary teeth was significantly higher in the case group (10 teeth) compared with controls (3 teeth; $p<0.001$). This suggests that poor oral hygiene in early childhood may alter the oral microbiome and compromise mucosal defenses, increasing susceptibility to GAS colonization. Recent microbiome studies support this mechanism, demonstrating that dysbiosis involving Streptococcus mutans and related species can weaken mucosal barriers and facilitate upper respiratory bacterial colonization.[56,57]

Findings from throat and tonsillar examinations showed the strongest associations with GAS infection. Pharyngeal mucosal damage, tonsillar hypertrophy, and tonsillitis were significantly more common in the case group. These findings are biologically plausible, as GAS colonization is facilitated by micro-injuries to the mucosa, and chronically inflamed tonsillar crypts may serve as bacterial reservoirs.[16,58,59]

Household and School Environment Factors

Several household-level factors were strongly associated with GAS infection. Exposure to secondhand tobacco smoke, indoor mold, and low paternal educational attainment emerged as significant risk factors. Secondhand smoke is known to damage upper respiratory mucosa and impair local immune defenses, increasing susceptibility to bacterial colonization.[60-62]

At the school level, failure to wash hands with soap was associated with a significantly increased risk of infection, consistent with WHO and UNICEF evidence that the availability of soap is critical for effective hand hygiene. In contrast, classroom crowding was not associated with infection risk in our study, likely because most participating schools had similarly high student density, limiting variability.

Knowledge, Attitudes, and Health System Factors

Parental knowledge regarding the complications of sore throat and its link to rheumatic fever was generally poor and significantly associated with increased infection risk. As noted by Carapetis et al., lack of awareness regarding the consequences of untreated GAS pharyngitis can lead to delayed healthcare seeking, inappropriate self-treatment, incomplete antibiotic courses, and ultimately increased risk of complications.[64]

Additionally, dissatisfaction with healthcare services was associated with higher infection risk. Limited access to physicians, long waiting times, restricted diagnostic services, and perceived poor quality of care may discourage timely care-seeking and contribute to untreated or inadequately treated infections.[65]

Taken together, these findings demonstrate that GAS infection among children is not driven solely by individual behaviors, but rather by a complex interaction of biological vulnerability, household environment, school hygiene practices, caregiver education and knowledge, and health system performance. Effective prevention strategies should therefore adopt a comprehensive, multi-level approach that integrates child health education, parental awareness, school-based hygiene interventions, and improvements in primary healthcare accessibility and quality.[66]

Study Limitations

Several limitations of this study should be acknowledged. Data used to describe the distribution of Group A Streptococcal (GAS) pharyngitis and tonsillopharyngitis among children aged 6–15 years were obtained from provincial Health Departments and represented aggregated summaries covering a total of 639,281 children nationwide. These data were available only at the provincial level and did not allow for detailed stratification by district, age, or sex.

In contrast, records from the National Health Insurance electronic database covered approximately half of the target population (n = 396,194) and permitted disaggregation by province, district, age, and

sex. However, because child-level data were not fully entered into the national electronic system and population denominators by age and sex were incomplete, it was not possible to calculate population-based prevalence rates. Consequently, some estimates reflect case-detection–based patterns rather than true population prevalence, which should be considered when interpreting the findings.

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ЭРҮҮЛ МЭНДИЙН ЯАМНЫ
АНАГААХ УХААНЫ ЁС ЗҮЙН ХЯНАЛТЫН
ХОРООНЫ ТОГТООЛ

2025 оны 07 сарын 04 өдөр Дугаар 25/042 Улаанбаатар хот

Судалгаа эхлүүлэх зөвшөөрөл олгох тухай

Анагаах ухааны ёс зүйн хяналтын хорооны 2025 оны 07 дугаар сарын 04-ний өдрийн 25/04 дүгээр хурлын протоколыг үндэслэн ТОГТООХ НЬ:

1."Хүүхдэд тохиолдох А бүлгийн стрептококкын шалтгаант залгиурын үрэвсэлд нөлөөлөх эрсдэлт хүчин зүйлсийн судалгаа" сэдэвт Нэгдсэн үндэстний байгууллагын Хүүхдийн сангийн санхүүжилттэй, судалгааны төслийг судлаач, Анагаах ухааны доктор Самбуу овогтой Цэгмэдийн удирдлаган дор 2025 онд багтаан хийж, гүйцэтгэхийг зөвшөөрсүгэй.

2.Судалгааны явцад тодорхой шалтгааны улмаас арга аргачлал өөрчлөгдөх, гадаад орон руу сорьц тээвэрлэх, Хельсинкийн тунхаглалд туссан ёс зүйн асуудал хөндөгдсөн тохиолдолд Анагаах ухааны ёс зүйн хяналтын хороонд мэдэгдэж, дахин хэлэлцүүлэхийг судалгааны удирдагч болон багийнханд үүрэг болгосугай.

3.Судалгааны явцын тайланг Эрдмийн зөвлөлөөр хэлэлцүүлэн, Анагаах ухааны ёс зүйн хяналтын хороонд ирүүлэхийг төслийн удирдагчид үүрэг болгосугай.

4.Судалгааны төгсгөлийн тайланг Эрдмийн зөвлөлөөр хэлэлцүүлэн, судалгаа дууссан хугацаанаас хойш 2 сарын дотор багтаан Анагаах ухааны ёс зүйн хяналтын хороонд ирүүлэхийг төслийн удирдагчид үүрэг болгосугай.

ДАРГА Ж.МӨНХЦЭЦЭГ