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Risk factors of diphtheria outbreak in damt district of Al Dhalea Governorate, 2023 -Yemen: a case–control study

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Abstract

Background In Yemen, diphtheria has become an important health problem since 2017 when diphtheria re-emergence as a consequence of war and the collapse of the health system. In 2023, there has been a 57% increase in diphtheria cases compared to 2021 and 2022. Damt district of Al Dhalea Governorate had the highest reported cases for year 2023. The study aims to determine the risk factors associated with diphtheria outbreak in Damt District.

Methods A retrospective matched case–control (1:2) was used. All confirmed cases based on the WHO case definition reported from Damt district during 2023 were considered cases. Two age-matched (±5years) neighborhood controls were recruited per case. A pretested questionnaire was used for collecting data during household interviews including demographic and household characteristics, knowledge of diphtheria, vaccination status, contact with a case of diphtheria, and travel history. Frequency and proportion for quantitative and median with interquartile range (IQR) for quantitative variables. Chi-square and Mann–Whitney tests to compare the distribution of categorical and numerical variables between cases and controls. Univariate and multivariate conditional binary logistic regression, and Adjusted Odds ratio (AOR) with a 95% confidence interval at $P < 0.05$ were used to identify risk factors.

Results A total of 118 cases and 236 controls were enrolled, 56% were females (63% of cases vs. 53% of controls). The median (IQR) age was 14 (9,22) years for cases vs 12(7,23) of control, it was significantly higher for females than males in the case group: (16(10,29) Vs 10(6,18), $P < 0.001$) and control group: (15(8,25) vs 12(7,18), p-value = 0.022). Partial vaccination status AOR = 13.7(6.1–31.1), P-value < 0.001), contacts with a case of diphtheria AOR = 8.5(2.3–31.0), P value < 0.001) and Female gender, AOR = 3.3(CI; 1.1–9.5, P value = 0.029), were the main risk factors.

Conclusions Poor vaccination and contact with a case of diphtheria were the main contributors to diphtheria in the Damt district particularly among adult females. Increasing the vaccination coverage with a diphtheria-containing vaccine through routine immunization as well as tetanus-diphtheria vaccine for childbearing age females along with community awareness regarding protection measures during home care of diphtheria cases. Vaccination services as well as gender barriers related to Td vaccination should be investigated.

Keywords Risk Factors, Diphtheria outbreak, Damt district, Yemen

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Background

Diphtheria is an acute disease caused by toxin-producing strains of Corynebacterium diphtheriae mainly affects the upper respiratory tract (tonsils, pharynx, larynx, nose) [1]. Diphtheria is a vaccine-preventable disease but multiple doses and booster doses are necessary to establish and maintain immunity [1, 2].

Thus, young children and those who are not immunized or under-immunized are at risk of the disease which spreads from person to person directly through respiratory droplets, within 2–3 days of infection, a thick, grey coating pseudo-membrane covers the affected area of the respiratory system and could lead to airway obstruction [2]. The released toxin also can reach other organs and can cause myocarditis, paralytic symptoms, and nephritis death could occur if proper treatment is delayed and severe cases have a mortality rate of 5–10% [1–3].

Despite the availability of a safe and effective vaccine, recent outbreaks have occurred due to under-vaccination, particularly in developing countries [1].

In Yemen, diphtheria has become an important health problem since 2017 when the diphtheria epidemic occurred as a consequence of war, the health system collapsed, and low vaccination coverage [4, 5]. Between July 2017 and August 2018, 2243 cases were reported with an incidence rate of 8 cases per 100,000 population [6]. As a response, many efforts focused on: the clinical management of cases, referral pathways, and isolation units have been made along with three vaccination campaigns conducted in 2018 and 2019 and targeting children between the ages of 6 weeks and 15 years [7].

The widespread political instability, displacement of populations, and damaged infrastructure along with nearly half of the non-functional health facilities are the main challenges of vaccine delivery in Yemen that increased the risk of a diphtheria outbreak [8]. Furthermore, the insecurity and the destruction of transportation networks disrupted supply chains, particularly in remote areas, extremely challenging [9].

Recently, diphtheria cases have risen gradually since 2021, with a significant increase noted from June to September 2023 which indicates a 57% increase in diphtheria cases compared to 2021 and 2022. From January up to September 2023, a total of 1671 suspected diphtheria cases with 109 associated deaths have been reported from the whole country compared to 1283 cases reported in the whole of 2022 [10]. Furthermore, this increase marks a change from the usual winter seasonal pattern [11, 12].

Many studies have been conducted to describe the impact of war and ongoing conflicts such as health system collapse and low vaccination coverage as the root causes of a diphtheria outbreak in Yemen [4, 5]. The epidemiology, clinical, and microbiological features also have been described and investigated by many studies [6, 12, 13].

As for the risk factors of diphtheria transmission at the level of the individual, a study conducted in Sana'a city in 2019 indicated Sharing a bedroom with at least two people, contact with a diphtheria case, and Non-vaccination as the main risk factors for diphtheria in Sana'a city [14].

There is still a gap in the information related to the risk factors of diphtheria transmission in rural areas such as Damt district which is the district of Al Dhalea Governorate that reported 204 diphtheria cases and 14 associated deaths. So, it is considered the first district to report diphtheria cases and related deaths for 2023. The study aims to determine the risk factors associated with diphtheria infection in Damt District.

Methods

Study design

A matched case–control study with a ratio of (1:2) cases to controls matched by age ± 5 years and residency was performed in Damt District, Al Dhalea Governorate.

Study area

The study was conducted in Damt District of Al Dhalea Governorate, which has a total of nine districts. Three districts are under the authority of the northern government (Damt, Jaban, and Al-Hasha) and five districts are under the authority of the southern government (Al-Shuaib, Al-Husayn, Al-Dhalea, Jahaf and Al-Azaraq). The last one (Qa'taba district) is divided between the two authorities. Damt district is located and far away from the south of the capital Sana'a by 198 km^2, has an area of 371 km^2 with (10) sub-districts shown in Fig. 1. The population density is 284 people/km^2 and the majority of the population works in agriculture. There are 4 Medical Health Centres and 12 health units, where immunization services are provided. According to the electronic Integrated Diseases Early Warning System (eIDEWS), Damt district is the first district in Al Dhalea Governorate and Yemen that reported diphtheria cases and assoiled deaths for the year 2023.

Definition of cases and controls

The WHO case definition for diphtheria was used as any persons at any age who have lived in one of the Damt subdistricts, Al Dhalea Governorate, stuffed from inflammation of the tonsils, pharynx, or larynx, with a membrane attached and difficult to remove from the tonsils, pharynx, or nose and reported by eIDEWS during the year 2023.

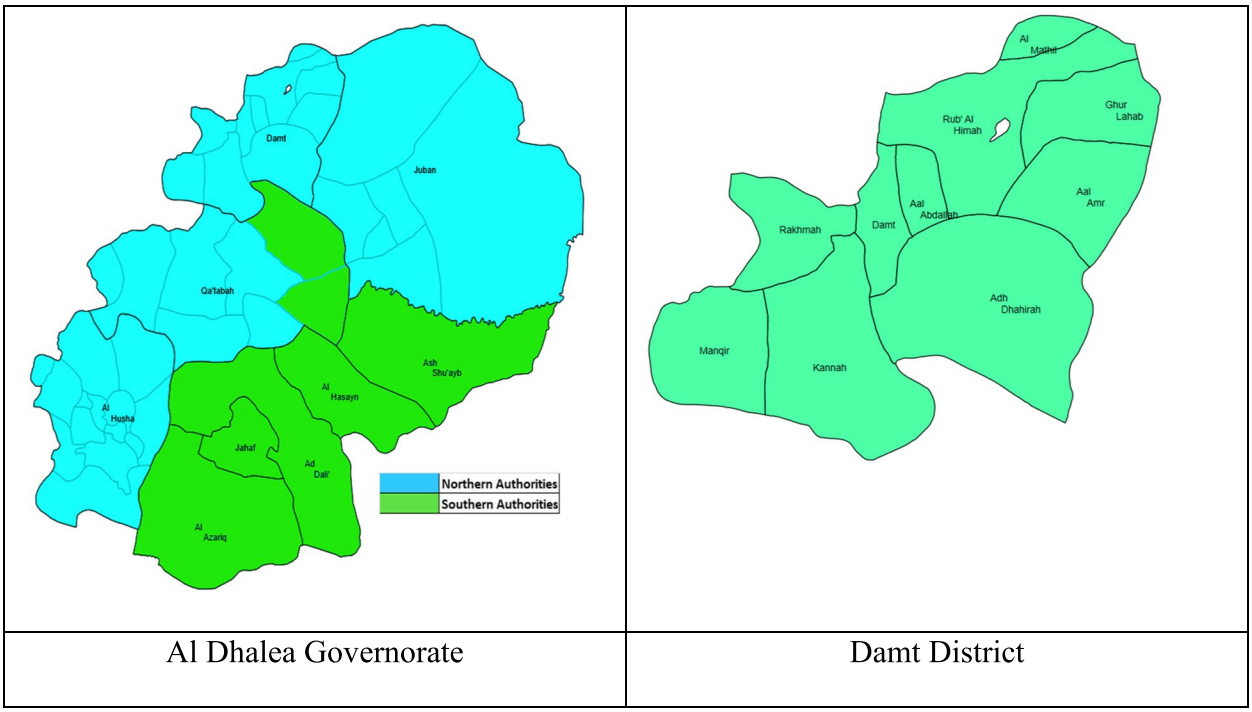

Fig. 1 Map of Al Dhalea Governorate and Damt District

Controls were defined as; any person who matched the case by age (± 5years) lived in the same neighborhood since January 2023 and did not suffer from any of the diphtheria symptoms.

Study sample and sampling procedure

All confirmed or probable cases of diphtheria reported by eIDEWS from January to December 2023 were considered cases. Two age-matched (± 5years) neighborhood controls were recruited per case, particularly from houses located on the right side of the case house, with one control per house. If no matched control in a house or the matched control refused to participate in the study, another control was recruited from the next house.

Inclusion and exclusion criteria

All confirmed or probable cases of diphtheria reported by eIDEWS from January to December 2023 were included. Cases were excluded if they lived outside of Damt district during the year 2023, refused to participate, died, were psychiatric patients, or moved from the district at the time of study conducting. Controls were excluded if they lived outside of Damt district during the year 2023, or refused to participate in the study or psychiatric patients at the time of study conducting.

Data collection tools and procedures

A pretested structured questionnaire was adopted from literature in English [14, 15]. It was translated into Arabic and tested through a pilot study among 14 participants who were not included in this study.

The questionnaire covered sociodemographic characteristics of cases and controls (age; sex; sub-district; education and occupation) travel history, vaccination status with diphtheria toxoid-containing vaccines diphtheria-pertussis and tetanus vaccine, and contact with diphtheria cases. The variables related to the head of household characteristics; (education, occupation), household type, number of rooms, family size, family income, availability, and number of handwashing and toilet facilities were collected, in addition to (Yes/No) answers to 5 questions related to diphtheria general information.

Data collected during household interviews and the line list of reported cases was used to identify the address of cases to be visited at their homes by well-trained interviewers, and face-to-face interviews either with participants ≥ 18 years or with the head of the household / parents of participants < 18 years who agree to participate in the study.

As for data quality, the questionnaires were reviewed each day and checked for any incomplete or missing data, and ten percent of questionnaires were selected randomly for validation which was performed through phone calls or home visits by supervisors.

Variables and operational definitions

The vaccination status was defined as follows: participants were considered fully vaccinated if they had received three or more doses of diphtheria toxoid-containing vaccines or partially vaccinated if they had received less than three doses of diphtheria toxoid-containing vaccines confirmed by vaccination card or verbally for older people who only vaccinated in the national campaigns.

For analysis purposes, the householders were categorized as the following. As for cases and controls, the education was further categorized as uneducated; illiterate individuals who could not read and write or were at pre-school age and educated; or individuals with a basic and secondary school or university education. The occupation was categorized as pre-school age for children at that age, students for people at schools, employed for those who had a job in private or public sector, and unemployed for individuals without a job. As for householders, illiterate individuals who could not read and write or with basic school education (attained 9 or fewer years of school education), were classified as having low-level education, whereas individuals with a secondary school or university or above were classified as high-level of education. Individuals who had a job and were working were classified as employed while those who had not a job and were not working as unemployed. The World Bank classification for low-income countries for the year (2022–2023), was used to classify monthly income of householder by Yemeni Rial (YR) equivalent to USD: low income (≤ 61,000 YR), moderate (> 61,000 YR and ≤ 273,500 YR), and high income (> 273,500 YR), For knowledge, the scoring system for answers to five questions: 1 for correct answer and 0 for wrong answers) the scores were summed and categorized according to the median as good ≥ median or poor < median scores.

Data analysis

Epi Info Version 7.2 was used for data analysis. Frequency and percentage were used to summarize qualitative variables, mean standard deviation for quantitative variables with normally distributed data, and otherwise median and interquartile range (IQR). Chi-square, and T/ANOVA otherwise the Mann–Whitney tests were used respectively to compare the distribution of categorical and numerical variables of cases and controls. Conditional logistic regression was used to allow for age and residency matching. Univariate analysis was used to calculate the cured odds ratio (COR), and all variables with $P < 0.25$ were included in multivariate analysis and the likelihood ratio test (LRT) was checked to ensure fitness. Adjusted Odds ratio (AOR) with a 95% confidence interval (CI) was used to report the strength of the association between the variables and diphtheria infection. $P < 0.05$ was considered to indicate statistical significance.

Results

A total of 118 cases and 236 controls were enrolled in the study with a median (IQR) age of 13(8,23) years;14 (9,22) years of cases compared to 12(7,25) of controls. In both groups, 47% of participants were from the Damt subdistrict. More than half (56%) were females (63% of cases vs. 53% of controls), and 59% had basic schools (64% of cases vs 57% of controls). Almost half (51%) of the participants were students (52% of cases vs. 51% of control) (Table 1).

For vaccination status against diphtheria; 60% (211/354) of all participants including 25% (30/118) of cases and 77% (181/236) of controls were fully vaccinated. The rest 40% (143/354) were partially vaccinated including 75% (88/118) of cases and 23% (55/236) of controls. Of all participants, 15% (52/354) had contacts with diphtheria cases accounting for 33%(39/118) and 6%(13/236) of cases and controls, respectively. only 6% (7/118) of cases compared to 1% (3/236) of controls had a travel history to areas affected by diphtheria (Table 2).

Only, 16% (19/118) of household heads of cases compared to 14% (33/236)of household heads of controls had a university education, the majority, 87% (103/118) compared to 93%(219/236) of household heads of cases and controls were unemployed. Low monthly income of 58% in both groups, 81% of cases compared to 73% of controls lived at houses, and both groups had a median (IQR) of 3(2,4) rooms, 5% of both groups had no toilet facility, and 49% of cases compared to 54% of controls had not handwashing facility at their dwellings. The health facilities are not far away and could be reached by both groups in a median (IQR) of 17(12,33) minutes (Table 3).

The univariate analysis by conditional binary logistic regression shows a significant association between diphtheria infection and various factors related to sociodemographic characteristics, household characteristics, vaccination status, and risks of contracting infection. As for sociodemographic factors, the COR of Gender females compared to males showed a higher likelihood of diphtheria infection COR = 1.9 (95% CI; 1.1–3.3, *P*-Value = 0.032) and individuals who were not engaged in work compared to pre-school age had a significantly higher risk COR = 11.7(95% CI;1.3–104.6, *P* value = 0.028). Individuals who lived in houses compared to those who lived in apartments had higher odds of infection COR = 3.6 (95% CI: 1.4–9.3, *P*-Value = 0.009). As for the potential risks of contracting diphtheria, partially vaccinated individuals compared to fully vaccinated individuals were at a significantly higher risk COR = 13.4 (95% CI; 6.7–27.9, *P*-Value < 0.001), having contact with a person who has diphtheria or traveling to an area affected

Table 1 Socio-demographic characteristics of diphtheria cases and controls, Damt District of Al Dhalea Governorate—Yemen, 2023

Characteristics			Total *N* = 354(%)	Cases *N* = 118 (%)	Controls N236(%)	*P* value
Subdistrict		Damt	165(47%)	55(47%)	110(47%)	1.00
		Al-Dhahirah	69(19%)	23(19%)	46(19%)	
		Al- Omar	36(10%)	12(10%)	24(10%)	
		Ruba al-Hamma	36(10%)	12(10%)	24(10%)	
		Al- Abdullah	18(5%)	6(5%)	12(5%)	
		Kanna	12(3%)	4(3%)	8(3%)	
		Manqir	12(3%)	4(3%)	8(3%)	
		Rakhma	3(1%)	1(1%)	2(1%)	
		Al Mathil	3(1%)	1(1%)	2(1%)	
Age (years) median (IQR)			13(8,23)	14(9,22)	12(7,23)	0.394
	Male age		11(7,18)	10(6,18)	12(7,18)	
	Female age		15(9,26)	16(10,29)	15(8,25)	
	P value		< 0.001*	< 0.001*	0.022*	
Gender		Female	198(56%)	74(63%)	124(53%)	0.069
		Male	156(44%)	44(37%)	112(47%)	
Education		Pre-school age	53(15%)	15(13%)	38(16%)	0.671
		Illiterate	28(8%)	7(6%)	21(9%)	
		Basic	209(59%)	75(64%)	134(57%)	
		Secondary	56(16%)	19(16%)	37(16%)	
		University	8(2%)	2(2%)	6(3%)	
Occupation		Pre-school age	53(15%)	15(13%)	38(16%)	0.668
		Student	180(51%)	61(52%)	119(50%)	
		Employed	38(11%)	11(9%)	27(11%)	
		Unemployed	83(23%)	31(26%)	52(22%)	

IQR Interquartile range

* Statistically significant

Table 2 Vaccination status and risks of contracting diphtheria infection among cases and controls, Damt District of Al Dhalea Governorate—Yemen, 2023

Factors			Total *N* = 354	Cases *N* = 118	Controls *N* = 236	*P* value
Vaccination status						< 0.001
Fully vaccination			211(60%)	30(25%)	181(77%)	
		Three doses	118(51%)	22(59%)	159(67%)	
		Four doses	22(8%)	7(59%)	22(9%)	
Partially vaccination			143(40%)	88(75%)	55(23%)	
		One dose	111(31%)	82(59%)	29(12%)	
		Two doses	33(9%)	7(59%)	26(11%)	
Risk of contracting infection						
Contact with a case	Yes		52(15%)	39(33%)	13(6%)	0.012
	NO		302(85%)	79(77%)	223(94%)	
Travel history	Yes		10(3%)	7(6%)	3(1%)	< 0.001
	NO		344(97%)	111(94%)	233(99%)	

by diphtheria increases the odds of infection COR = 13.5 (95% CI; 5.3–34.4, *P*-Value < 0.001), COR = 4.7 (95% CI; 1.2–18.0, *P*-Value = 0.026), respectively. The result of univariate analysis for all variables is presented in Supplement 1. All variables with a *P* value < 0.25 in the univariate analysis were included for multivariate analysis by conditional logistic regression, and after adjusting for other variables, only three variables including; gender,

Table 3 Household characteristics of diphtheria cases and controls, Damt District of Al Dhalea Governorate—Yemen, 2023

		Total *N* = 354(%)	Cases *N* = 118 (%)	Controls *N* = 236(%)	*P* value
Head of household					
Education	Illiterate	93(26%)	29(25%)	64(27%)	0.294
	Basic	105(30%)	29(25%)	76(32%)	
	Secondary	104(29%)	41(35%)	63(27%)	
	University	52(15%)	19(16%)	33(14%)	
Occupation	Employed	32(9%)	15(13%)	17(7%)	0.088
	Un-employed	322(91%)	103(87%)	219(93%)	
Monthly income (YR)	Low	206(58%)	67(57%)	139(59%)	0.292
	Moderate	115(32%)	36(31%)	79(33%)	
	High	33(9%)	15(13%)	18(8%)	
Knowledge related to diphtheria	Median (IQR) score	3(1,5)	4(1,5)	3(1,5)	0.060
	Poor	168(47%)	52(44%)	116(49%)	0.329
	Good	186(53%)	66(56%)	120(51%)	
Household characteristics					
Dwelling type	House	269(76%)	96(81%)	173(73%)	0.094
	Apartment	85(24%)	22(19%)	63(27%)	
Family members	Median (IQR)	7(5,10)	7(5,9)	7(5,10)	0.494
Room number	Median (IQR)	3(2,4)	3(2,4)	3(2,4)	
Toilet	No	17(5%)	6(5%)	11(5%)	0.860
	Yes	337(95%)	112(95%)	225(95%)	
Hand Washing	No	186(53%)	58(49%)	128(54%)	0.366
	Yes	168(47%)	60(51%)	108(46%)	
Time to reach health facility (Minutes)	Median (IQR)	17(12,33)	17(12,33)	17(12,33)	1.00

vaccination status, and contacts with diphtheria cases, remained associated with diphtheria infection. Female gender compared to males had three times the odds of contracting diphtheria AOR = 3.3(95%CI; 1.1–9.5, *P* value = 0.029), individuals with partial vaccination status had 13.7 times the odds of diphtheria infection of those fully vaccinated AOR = 13.7(95%CI: 6.1–31.1, *P*-value < 0.001), people who contacted with a case of diphtheria have eight times the odds of infection of those who not contacted a case of diphtheria AOR = 8.5(95%CI; 2.3–31.0, *P* value < 0.001) (Table 4).

Discussion

Diphtheria is still an important health problem, particularly in conflict countries such as Yemen where diphtheria cases have risen gradually since 2021 to reach a significant increase in 2023 [10]. Damt District of Al Dhalea Governorate is one of the affected areas, where this matched case–control study has been conducted to identify the related risk factors for such an increase.

The result of univariate analysis in this study indicated an association between diphtheria infection and female gender. Even after adjusting with other variables, the AOR suggests a potentially increased risk of diphtheria among females compared to males. While there is no specific trend in the occurrence of respiratory diphtheria by gender [16]. A slightly higher proportion of males was reported in a study conducted in the Sadah governorate of Yemen, and another study conducted in Nigeria [13, 17]. The explanation of this result could be attributed to many factors including; the incomplete vaccination status of females [18], women might be more exposed to household contacts since they are the caregivers for patients at home. As well as even vaccinated women, are more susceptible to diphtheria infection after 10 years of vaccination [19].

The unexpected result of our study is that more than half of the female cases (based on median age) of childbearing age are supposed to be prevented as they have received the tetanus-diphtheria (Td) vaccine. Thus, the result highlighted the absence of Td administration for females of childbearing age. It might be due to the gender barrier that could be attributed to the traditional conservative customs in Yemen. The cultural and social norms often restrict women's access to healthcare, particularly in rural and conflict-affected areas. Women may face obstacles like needing male permission to seek medical care, limited mobility due to safety concerns, and a shortage of female healthcare workers, which can be particularly significant in conservative communities

Table 4 Univariate and Multivariate analysis for the risk factors of diphtheria in Damt District of Al Dhalea Governorate—Yemen, 2023

Factors	Univariate		Multivariate	
	COR (95%CI)	*P*-Value	AOR (95%CI)	*P*-Value
Individual factors				
Gender (Female/Male)	1.9(1.1–3.3)	0.032*	3.3(1.1–9.5)	0.029*
Uneducated /Educated)	0.4(0.2–1.0)	0.054	0.7(0.1–6.0)	0.716
Occupation				
Student/pre-school-age	2.2(0.7–6.7)	0.165	1.1(0.1–23.3)	0.933
Employed/pre-school-age	4.6(0.6–36.2)	0.151	4.8(0.1–319.2)	0.465
Unemployed /pre-school-age	11.7(1.3–104.6)	0.028*	6.7(0.1–333.4)	0.341
Household factors				
Householder Education (low/high)	0.7(0.5–1.2)	0.186	0.8(0.3–1.8)	0.514
Occupation (unemployed/employed)	2.1(0.9–4.6)	0.077	4.0(1.0–16.2)	0.056
Householder knowledge (Poor/good)	0.7(0.3–1.2)	0.196	0.8(0.3–2.0)	0.619
Family Income (Low/High)	0.5(0.2–1.2)	0.120	2.0(0.5–8.3)	0.339
Family income (Moderate/High)	0.5(0.2–1.2)	0.105	0.6(0.1–2.4)	0.458
Dwelling type (house /apartment)	3.6(1.4–9.3)	0.009	2.4(0.7–8.6)	0.165
Risk of contracting infection				
Vaccination (Partial/Full)	13.4(6.7–27.9)	< 0.001*	13.7(6.1–31.1)	< 0.001*
Contact (Yes/No)	13.5(5.3–34.4)	< 0.001*	8.5(2.3–31.0)	0.001*
Traveling (Yes/No)	4.7(1.2–18.0)	0.026*	0.8(0.05–13.2)	0.887

COR Crude odds ratio, *AOR* Adjusted odds ratio

* Statistically significant

where women prefer or are only allowed to be treated by female providers [20]. These barriers may lead to lower vaccination coverage among women, especially those of childbearing age, who are more likely to be isolated during pregnancy or after childbirth [21]. Additionally, the healthcare infrastructure's collapse due to ongoing conflict further exacerbates these issues, as disrupted supply chains and damaged facilities make it difficult to maintain routine immunization programs [8].

The findings of this study showed no significant association between diphtheria infection and the education level and occupation of participant or household factors: education of household head, knowledge about diphtheria, dwelling type, family size, or number of rooms. This result was similar to the findings of a previous study conducted in Yemen and a study conducted in India [14, 22]. However, our result was contrary to the result of a study reviewing factors affecting diphtheria which revealed educational level, physical conditions of the home, and level of knowledge [23]. The discrepancy in the results might be due to the difference in study design and study populations.

The results of this study indicated that full vaccination against diphtheria could reduce the likelihood of diphtheria infection by 13.7 times as compared to partial vaccination. These findings were in line with the findings reported by a previous study in Yemen [14], and many studies conducted elsewhere [23–25].

As for the source of infection; contact with a case of diphtheria was found to be associated with contracting diphtheria infection which increased the likelihood of infection by 8 times as compared to the absence of contacts. This finding was in line with the findings reported by a previous study in Yemen [14], and the result of the systematic review until January 2023 [21]. Similar to the result of previous studies, travel history was not found associated with diphtheria infection [14, 24].

There were some limitations in this study, it was conducted in a small district and the majority of participants were females and the results may not be generalizable for all Yemeni governorates. Furthermore, however, this study was a matched case control, the match was for age and residency since it was difficult to find the matched gender for some cases that were from very remote areas or located in the front area of the war, and the immunization status might be affected by recall bias, particularly for older people who were lived at those areas. Nevertheless, this study provides information health programmers and policymakers could use to formulate vaccination policies as well as for further related research.

In conclusion, poor vaccination and contact with a case of diphtheria were the main identified factors that contributed to the occurrence of diphtheria outbreak in the

Damt district particularly among females who are mostly the caregivers for patients at home and are at higher risk of household contact. Increasing the vaccination coverage against diphtheria either by DPT in general or Td for females of childbearing age. Moreover, increasing community awareness regarding home care protection measures and isolation of diphtheria cases could reduce the spread of the disease. Underline factors such as cold chain, vaccine delivery and other factors related to the vaccination services as well as gender barriers related to Td vaccination should be investigated.

The unexpected finding that females, particularly of childbearing age, are at higher risk of diphtheria despite being expected to have received the Td vaccination underscores significant gender-related disparities in healthcare access. These disparities, driven by cultural norms, limited mobility, and ongoing conflict in Yemen, highlight the critical need for targeted public health interventions that address the unique challenges women face in accessing healthcare.

For public health practice, this finding emphasizes the importance of integrating gender-sensitive approaches into vaccination programs. Ensuring that women have equal access to vaccinations, addressing vaccine hesitancy, and providing education tailored to their needs are essential steps to prevent future outbreaks and improve overall health outcomes. Public health strategies must also consider the broader social determinants of health, such as literacy and mobility, to effectively reduce the disease burden among vulnerable populations, particularly women in conflict zones.

Abbreviations

AOR	Adjusted Odds Ratio
COR	Crude Odds Ratio
CI	Confidence Interval
DPT	Diphtheria-Tetanus-Pertussis Vaccine
eIDEWS	Electronic Integrated Diseases Early Warning System
IQR	Interquartile Range
LRT	Likelihood Ratio Test
Td	Tetanus-Diphtheria Vaccine
WHO	World Health Organization
YR	Yemeni Rial

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12879-024-09932-7.

Supplementary Material 1.

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Authors' contributions

SS contributed to the conception, design of the study, and methodology, supervised the data collection, analyzed the data, wrote the study report, and participated in manuscript writing. HA contributed to the conception and participated in data analysis and review of the study report. LA made significant conception in reviewing the overall study, finalizing the study report, and reviewing the manuscript. MA revised the analysis of data, wrote the draft manuscript, and finalized the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

All relevant data are presented in this paper, and more information can be provided upon reasonable request from the corresponding author.

Declarations

Ethics approval and consent to participate

This study followed the Declaration of Helsinki guidelines and was approved by the research ethical committee of the Ministry of Public Health and Population, Sana'a, Yemen (Letter no152 date 8/8/2023. An official approval from health authorities in the governorate was obtained. Informed consent was obtained from all subjects and/or their legal guardian(s). The authors confirm that all methods were performed based on the relevant guidelines and regulations in the county. The study did not involve experiments on human subjects or human participants. No human studies are presented in this manuscript.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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