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Prevalence of trachoma in Yemen: results of population-based prevalence surveys of 42 evaluation units in nine governorates

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ABSTRACT
Purpose: In suspected trachoma-endemic areas of Yemen, we sought to determine the prevalence of the sign trachomatous inflammation—follicular (TF) in children aged 1–9 years, and the potential individual and household risk factors for TF in that age group. We also sought to determine the prevalence of trichiasis in adults aged ≥15 years.
Methods: We conducted a cluster-sampled survey in each of 42 evaluation units (EUs) comprising 166 rural districts of nine Governorates (Adh Dhale'a, Al Hodeihah, Al Jawf, Hadramoot, Hajjah, Ibb, Lahj, Ma'rib, Taiz) using the Global Trachoma Mapping Project systems and methodologies. Fieldwork was undertaken from September 2013 to March 2015. Risk factors for TF in children aged 1–9 years were evaluated using multilevel random effects logistic regression.
Results: The TF prevalence in children aged 1–9 years was ≥10% in two EUs (7 districts) and 5–9.9% in six EUs (24 districts). In adults aged ≥15 years, trichiasis prevalence was ≥0.2% in five EUs (19 districts). Being older (within the 1–9-year age bracket), being male, living in a household with higher numbers of children, and living in a household that reported the use of open defecation, were each independently associated with higher odds of TF.
Conclusions: These surveys provided baseline data to enable planning for trachoma elimination. The World Health Organization Alliance for the Global Elimination of Trachoma by 2020 stands ready to assist Yemen once security considerations permit further surveys and implementation of control activities.

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Introduction

Trachoma, caused by repeated ocular *Chlamydia trachomatis* infection,[1] is or has recently been endemic in 11 of 22 countries in the World Health Organization (WHO)-defined Eastern Mediterranean Region.[2] A major international effort to eliminate trachoma as a public health problem[3] is currently underway, orchestrated by the WHO Alliance for the Global Elimination of Trachoma by 2020 (GET2020).[4] To achieve this goal, WHO recommends the SAFE strategy (surgery, antibiotics, facial cleanliness, and environmental improvement)[5] in all areas where trachoma prevalence exceeds elimination thresholds, based on population-based surveys.[6–8] Data on the prevalence of trichiasis in adults, the blinding stage of disease, are used to plan surgical interventions; data on the prevalence of trachomatous inflammation—follicular (TF) in 1–9-year-olds are used for planning antibiotic, facial cleanliness, and environmental improvement interventions.[9,10]

The Republic of Yemen is located on the Arabian Peninsula, bordered on the north and east by Saudi Arabia and Oman respectively, and on the south and west by the Arabian Sea, the Gulf of Aden, and the Red Sea. There are 22 Governorates in addition to the capital Sana'a. Though previous trachoma rapid assessments[11] identified a number of areas as being potentially trachoma-endemic, prior to this study, population-based

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*See Appendix.
Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/iope.

prevalence data were lacking. Preliminary analyses of some of the prevalence data presented here have been published elsewhere[12]; this article presents the final data and explores associations of TF in 1–9-year-olds at individual and household levels.

Materials and methods

The National Prevention of Blindness Program in the Ministry of Public Health & Population was responsible for planning and coordination, field team training, data gathering, data upload and data approval. Training of field teams was undertaken in September 2013 in and near Sana'a and Mareb City, Yemen. We used version 2 of the Global Trachoma Mapping Project (GTMP) training system,[13] following principles that have been previously published.[14]

We divided the suspected trachoma-endemic population into 42 unique evaluation units (EUs). By governorate, there were 2 EUs in Adh Dhale'a, 6 in Al Hodeihah, two in Al Jawf, 4 in Hadramoot, 7 in Hajjah, 6 in Ibb, 3 in Lahj, 1 in Ma'rib, and 11 in Taiz. In each EU, teams consisting of a grader, a recorder, a local facilitator, and a driver visited 24 clusters, which (after exclusion of urban areas) were selected with probability proportional to cluster population size. In each cluster, the protocol was explained to the village chief and local health care workers, and 30 households were selected from a village household list using systematic sampling. The examination protocol was explained to each eligible adult in their preferred language, and verbal consent for enrollment and examination was obtained. For eligible children, verbal consent was also obtained from parents or appropriate guardians. Eligible household members were those aged 1 year or above who, at the time of the survey, had lived for at least 6 months in the village or neighborhood. Consenting individuals were examined for signs of trachoma, graded according to the WHO simplified grading system,[9] using a flashlight or direct sunlight plus a 2.5× binocular loupe. In addition to demographic data and examination findings, teams recorded responses to household-level questions on access to water and sanitation, supplementing information received about access to sanitation facilities through direct observation. All data were recorded in the GTMP-LINKS app running on Android smartphones. Full details are given elsewhere.[14]

As for other trachoma mapping work conducted with the support of the GTMP, data cleaning and analysis was undertaken by a dedicated data manager (RW), then reviewed and approved by the national health ministry. For each cluster, the proportion of 1–9-year-olds with TF was adjusted by age in 1-year bands, using age distribution data from the 2004 census of Yemen[15] as a reference. The EU-level TF prevalence was estimated as the arithmetic mean of the adjusted cluster-level proportions. Similarly, for each cluster, the proportion of ≥15-year-olds with trichiasis was adjusted by sex and age in 5-year bands, and the arithmetic mean of the adjusted cluster-level proportions used as the EU-level trichiasis prevalence in adults. We did not record the presence or absence of trachomatous conjunctival scarring and are therefore unable to confirm that trichiasis seen was due to trachoma,[16] so refer here to the prevalence of trichiasis rather than the prevalence of "trachomatous trichiasis."

Random effects logistic regression models were used to characterize clustering in the data, accounting for a three-tier hierarchy (at district, cluster, and household levels). Null models were used to estimate the effect of cluster variables on the outcome TF in children aged 1–9 years, and the strength of possible models compared using the likelihood ratio test. A multilevel random effects logistic regression model was used to evaluate variables associated with TF in children aged 1–9 years. A null model with age and sex variables was run, accounting for clustering in TF at district, cluster, and household level.

Ethical considerations

The protocol received approval from the ethics committees of the Ministry of Public Health & Population of Yemen (238L) and the London School of Hygiene & Tropical Medicine (6319). Individuals with active trachoma were treated with 1% topical tetracycline ointment. Individuals with trichiasis were offered surgery.

Results

Surveys were implemented from September 2013–March 2015, with teams visiting 24,321 households in 975 clusters across the 42 EUs. A total of 139,228 people (71,366 males, 67,862 females) were enumerated, and 123,468 (89%; 66,076 males, 57,392 females) were examined. Among the 61,274 residents (28,659 men, 32,615 women) aged ≥15 years, 47,021 (77%; 24,045 men, 22,976 women) were examined.

The EU-level prevalence of TF in children aged 1–9 years ranged from 0–12.6% (Table 1). There were two EUs (7 districts) that had TF prevalences ≥10%, and there were six EUs (24 districts) with TF prevalences of 5–9.9% (Table 1, Figure 1).

The prevalence of trichiasis was above the WHO elimination threshold of 0.2% in adults aged ≥15 years[17] in 5 EUs (19 districts; Table 1 and Figure 2).

TF risk factors

Clustering of TF was strongest at household level: the random effects parameter estimate was 3.25 (standard error [SE] 1.16) at district level; 3.49 (SE 1.06) at cluster level; and 4.30 (SE 1.07) at household level. The model, accounting for clustering at both household and cluster levels, was a better fit to the data than the model accounting for clustering at household level alone (likelihood ratio test, $p < 0.0001$). All subsequent models accounted for clustering at both household and cluster levels.

The results of univariable analyses against the outcome, TF in children aged 1–9 years, are shown in

Table 1. Prevalence of trachomatous inflammation—follicular (TF) in children aged 1–9 years and trichiasis in those aged ≥15 years in 42 evaluation units (EUs) of Yemen, global trachoma mapping project, 2013–2015.

Governorate (EU code)	Districts included in EU	Estimated EU population	Number of 1–9-year-olds examined	TF prevalence in 1–9-year-olds, %[a] (95% CI)[c]	Number of ≥15-year-olds examined	Trichiasis prevalence in ≥15-year-olds, %[b] (95% CI)[c]
Adh Dhale'a (569)	Adh Dhale'a, Al Azareq, Al Hosha, Al Husain, Al Shoaeeb	350,966	1399	1.0 (0.5–1.4)	1276	0.0 (0.0–0.0)
Adh Dhale'a (570)	Damt, Jahaf, Joban, Qatabah	301,565	1520	1.3 (0.5–2.1)	1329	0.1 (0.0–0.2)
Al Hodeidah (82)	Al Garrahi, Al Khawkhah, Hays, Jabal Ra's	23,351	1384	0.8 (0.3–1.6)	1120	0.0 (0.0–0.0)
Al Hodeidah (83)	Al Mansuriyah, At Tuhayat, Bayt al-Faqih, Zabid	141,770	1283	1.4 (0.6–2.6)	837	0.0 (0.0–0.0)
Al Hodeidah (84)	Ad Durayhimi, Al Hali, Al Hawak, As Sukhnah	404,001	1258	0.1 (0.0–0.3)	1008	0.1 (0.0–0.3)
Al Hodeidah (85)	Ad Dahi Al Hajjaylah, Al Marawi'ah, Bajil, Bura	92,040	1401	2.6 (0.9–4.5)	1725	0.3 (0.1–0.6)
Al Hodeidah (86)	Al Mighlaf, Al Munirah, As Salif, Az Zaydiyah	54,279	1330	6.3 (4.3–8.7)	1880	0.1 (0.0–0.1)
Al Hodeidah (87)	Al Qanawis, Alluheyah, Az Zuhrah	43,695	1389	10.3 (6.8–15.1)	1234	0.1 (0.0–0.2)
Al Jawf (88)	Al Humaydat, Az Zahir, Bart Al Anan, Khabb wa ash Sha'af, Kharab Al Marashi, Rajuzah	293,882	907	5.4 (2.7–8.4)	785	0.2 (0.0–0.5)
Al Jawf (89)	Al Ghayl, Al Hazm, Al Khalq, Al Maslub, Al Matammah, Al Maton	65,151	783	8.9 (4.1–12.5)	565	0.0 (0.0–0.0)
Hadramoot (583)	Aldulaiah, Alqaten, Amd, Dawaan, Hajer, Haredah	264,941	1434	1.9 (0.8–3.6)	881	0.0 (0.0–0.1)
Hadramoot (584)	Sayuon, Shebam, Wadi Alaeen,	249,235	1423	0.3 (0.1–0.7)	1250	0.0 (0.0–0.1)
Hadramoot (585)	Alsoom, Khail Ben, Yameen, Sa'ah Tareem	229,593	1491	1.0 (0.4–2.1)	978	0.1 (0.0–0.3)
Hadramoot (586)	Aldees, Alriada Wa Qusiaaer, AlShaher, Broom Mafae, Khail Ba Wazeer	298,644	1338	3.6 (2.0–5.9)	1199	0.1 (0.0–0.2)
Hajjah (587)	Abs	185,595	1429	6.8 (4.5–9.9)	1309	0.1 (0.0–0.3)
Hajjah (588)	Hairan, Haradh, Midi, Mostaba	233,198	1687	4.8 (3.1–6.7)	1065	0.1 (0.0–0.2)
Hajjah (589)	Aslam, Khairan Al Muharaq, Kushar, Qarah, Wash Hah	395,764	1714	3.6 (2.4–5.1)	974	0.0 (0.0–0.1)
Hajjah (590)	Ash Shaghaderah, Bani Qais At Tur, Hajjah, Najrah, Sharis	311,056	1456	2.3 (1.2–3.6)	1134	0.1 (0.0–0.3)
Hajjah (591)	Aflah Alyemen, Aflah Ash Sham, Al Mahabeshah, Kohlan Ash Sharaf	261,495	1610	5.7 (3.1–8.9)	978	0.0 (0.0–0.0)
Hajjah (592)	Al Jamemah, Al Meftah, Ash Shahil, Koaidenah, Qofl Shamr	312,348	1698	3.2 (1.7–4.6)	1067	0.0 (0.0–0.0)
Hajjah (593)	Al Maghrabah, Bani Al Awam, Kohlan Afar, Mabyan	288,087	1685	1.9 (0.7–3.3)	714	0.0 (0.0–0.0)
Ibb (76)	Al Qafr, Hazm Al Udayn, Hubaysh	141,160	1057	1.8 (0.9–2.7)	853	0.4 (0.1–0.8)
Ibb (77)	Al Udayn, Far Al Udayn, Mudhaykhirah	35,812	870	6.3 (1.7–11.2)	686	0.17 (0.0–0.5)
Ibb (78)	As Sabrah, As Sayyani, Dhi As Sufal	98,199	793	12.6 (5.9–19.8)	1359	0.1 (0.0–0.1)
Ibb (79)	Al Dhihar, Al Mashannah, Ba'dan, Jiblah	238,810	1020	0.7 (0.0–1.7)	1408	0.1 (0.0–0.3)
Ibb (80)	Al Makhadir, As Saddah, Yarim	78,439	1022	0.0 (0.0–0.0)	602	0.0 (0.0–0.0)
Ibb (81)	An Nadirah, Ar Radmah, Ash Sha'ir	28,778	838	3.3 (2.3–4.8)	945	1.3 (0.4–2.6)
Lahj (562)	Laboous, Al Haad, AlMaflahi	231,185	1469	2.8 (1.1–4.7)	722	0.0 (0.0–0.0)
Lahj (563)	Al Malah, Habeel Jaber, Halemeen, Radfan, Radfan Alhabeleen, Tuben, Yahar	362,167	1408	0.8 (0.2–1.5)	1179	0.0 (0.0–0.0)
Lahj (564)	Al Hawta, Al Maqaterah, Al Mathareba & Al Arah, Al Musaimeer, Al Qabiata, Tor Albaha	408,847	1352	0.2 (0.0–0.4)	1051	0.0 (0.0–0.0)
Ma'rib (73)	Al Abdiyah, Al Jubah, Bidbadah, Harib, Harib Al Qaramish, Jabal Murad, Mahliyah, Majzar, Ma'rib, Ma'rib City, Medghal, Raghwan, Rahabah, Sirwah	46,541	982	4.5 (2.7–6.3)	25	No estimate[d]
Taiz (571)	At Taiziah	274,832	1625	4.4 (2.4–6.5)	1267	0.0 (0.0–0.0)
Taiz (572)	As Selw, Hayfan, Khader, Same'e	387,262	1344	0.9 (0.1–2.1)	1699	0.0 (0.0–0.0)
Taiz (573)	Al Maafer, Al Mawaset, Ash Shamayatain	525,989	1754	2.1 (1.1–3.4)	1015	0.0 (0.0–0.1)
Taiz (574)	Al Mesrakh, Jabal Habashi	305,208	1294	2.2 (1.1–3.0)	2095	0.6 (0.4–0.9)
Taiz (575)	Al Qaherah	202,840	1176	0.5 (0.1–0.8)	1447	0.1 (0.0–0.2)
Taiz (576)	Al Mudhafar	237,589	1557	1.0 (0.3–1.6)	957	0.1 (0.0–0.2)
Taiz (577)	Sharab Ar Rawnah, Sharab As Salam	355,679	1247	0.9 (0.4–1.6)	1642	0.1 (0.0–0.2)
Taiz (578)	Al Makha, Al Wazieah, Dhubab, Mawza'a	148,914	1613	0.8 (0.5–1.2)	1040	0.0 (0.0–0.1)
Taiz (579)	Salah	207,050	1291	1.2 (0.6–1.8)	1405	0.0 (0.0–0.0)
Taiz (580)	Maweah, Saber Al Mawadem	331,872	1587	1.6 (0.9–2.7)	1022	0.0 (0.0–0.0)
Taiz (581)	Maqbanah, Mashrah, Wahdnan	293,319	1409	0.5 (0.1–0.9)	1294	0.0 (0.0–0.1)

[a]Adjusted for age in 1-year age bands.
[b]Adjusted for gender and age in 5-year age bands.
[c]95% confidence intervals from bootstrapped adjusted-cluster-level proportions over 10,000 replicates; upper bound of confidence level for zero count EUs estimated from the exact binomial approximation.
[d]Only 25 adults examined: too few for a reliable trichiasis prevalence estimate.
CI, confidence interval

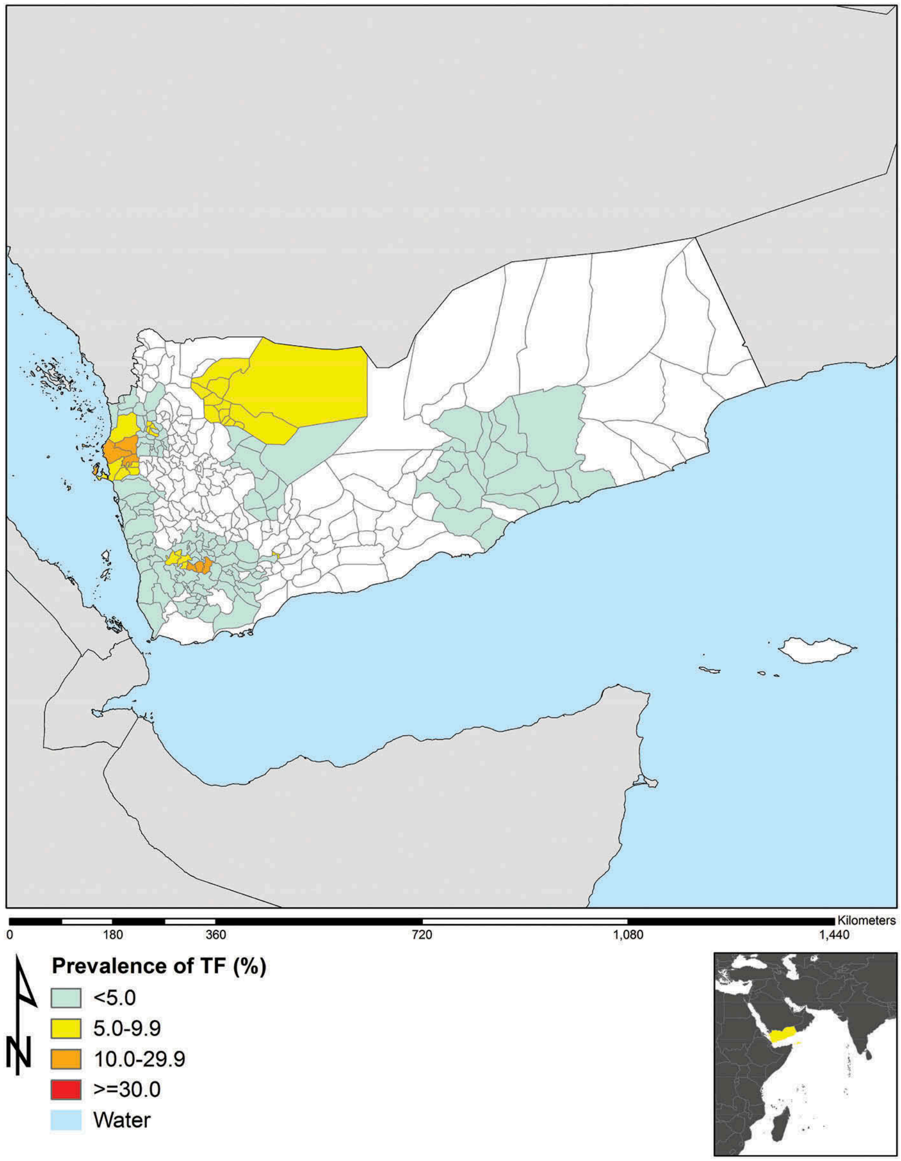

Figure 1. Evaluation unit-level prevalence of trachomatous inflammation—follicular (TF) in 1–9-year-olds, global trachoma mapping project, Yemen, 2013–2015. Internal boundaries represent districts.

Table 2. In the full multivariable model (Table 3), being a younger child, and being female were independently associated with lower odds of TF. Living in a household with higher numbers of children, and living in a household in which adults reported the use of open defecation, were independently associated with higher odds of TF.

Discussion

We believe this to be the largest collection of trachoma prevalence surveys ever reported from the Arabian Peninsula. Our field teams were able to generate high participation rates in communities selected for inclusion, with 89% of those living in sampled households consenting to and being examined for trachoma, resulting in the inclusion of more than 120,000 people. This, together with the robust nature of the GTMP approach to mapping,[18] generates confidence that the findings are generally representative of the true trachoma prevalence in each of the 42 EUs at the time of fieldwork. The exception to this is the trichiasis prevalence estimate for Ma'rib, which we have not reported here because (due to the fact that an unexpectedly large proportion of adults were working outside the governorate) only 25 adults were examined in the EU as a whole. In the remainder, relatively low prevalences of TF (compared to those recorded in many parts of Ethiopia,[19–21] for example) were matched

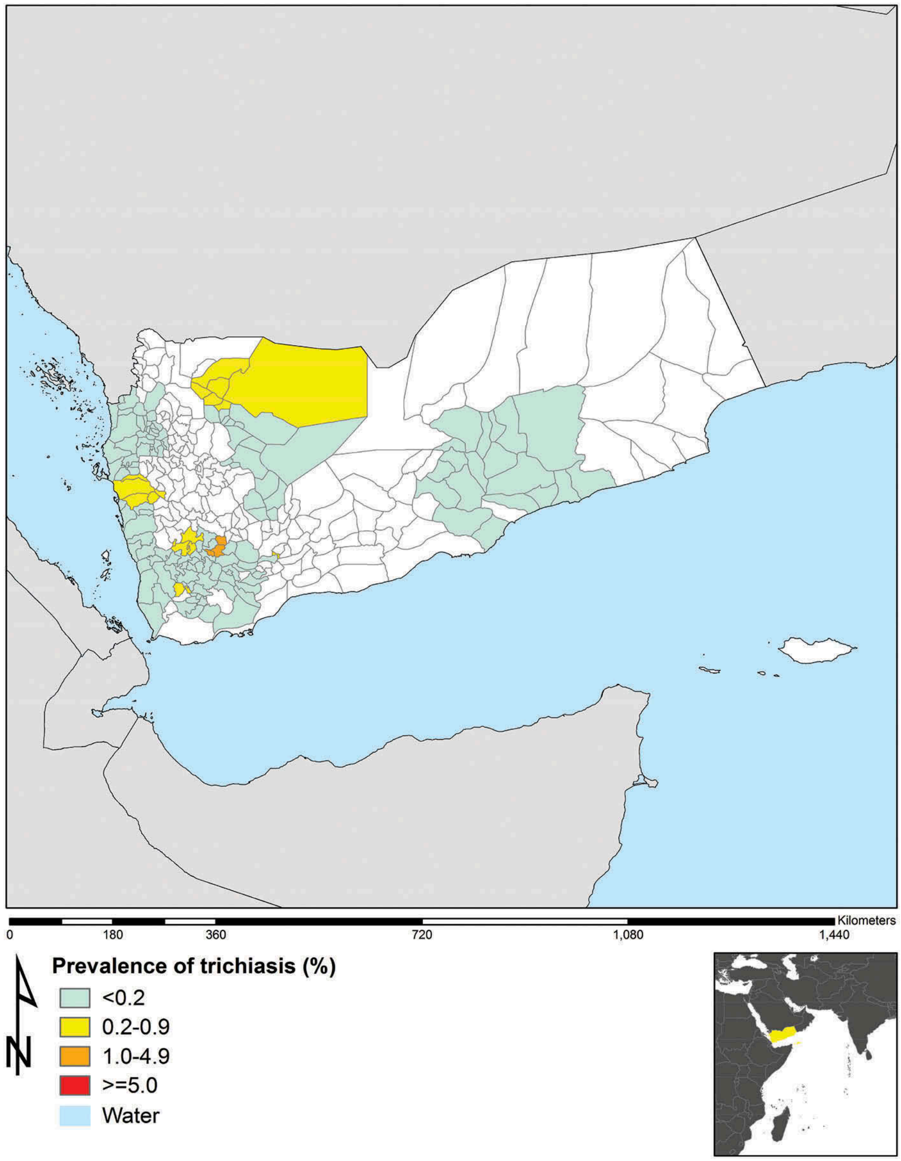

Figure 2. Evaluation unit-level prevalence of trichiasis in ≥15-year-olds, global trachoma mapping project, Yemen, 2013–2015. Internal boundaries represent districts.

by low prevalences of trichiasis. Only eight EUs had TF prevalences in 1–9-year-olds ≥5%, and only five had trichiasis prevalence in ≥15-year-olds ≥0.2%, indicating a need for public health-level action. One EU (Al Jawf, 88) had prevalence estimates above the respective elimination thresholds for both TF and trichiasis.

Only one EU had a trichiasis prevalence in adults of ≥1% (Ibb 81: 1.3%, 95%CI 0.4–2.6), suggesting that the number of surgeries needed to reach the elimination target would, in general, have been relatively small at the time of these surveys, and that trachoma is not a significant cause of blindness in Yemen. This is consistent with other recent observations. A 2002 community-based survey of 707 individuals in rural areas of Taiz governorate found 7.9% of those aged ≥50 years had bilateral blindness, with cataract and age-related macular degeneration accounting for 86% of cases.[22] Similar estimates of blindness prevalence were reported from rapid assessments of avoidable blindness conducted in 2009 in ≥50-year-olds in Amran (9.3%) and Lahj (10.8%) governorates.[23] These previous studies did not identify any people with corneal blindness due to trachoma.

In our data, reported open defecation by adults was associated with higher odds of active trachoma in children in the same household, as also seen in previous studies.[19,21] This is thought to relate to the fact that eye-seeking *Musca* sp. flies lay their eggs on surface-exposed

Table 2. Univariable analysis of factors associated with trachomatous inflammation—follicular (TF) in 1–9-year-olds, global trachoma mapping project, Yemen, 2013–2015.

	Examined, n	TF cases, n (%)	OR[a]	95%CI[b]
Individual				
Age group 1–4 years (vs. 5–9 years)	23,656	675 (2.9)	0.86	0.76–0.97
Female sex	26,450	758 (2.9)	0.83	0.74–0.93
Household				
≥8 people resident in the household	10,403	337 (3.2)	1.16	0.97–1.39
≥5 children aged 1–9 years resident in the household	7,448	336 (4.5)	1.62	1.34–1.97
Latrine type observed at household [c]				
Improved	43,269	1024 (2.4)	1	
Unimproved	6,966	335 (4.8)	2.04	1.58–2.63
Open defecation, bush or field	6,155	393 (6.4)	2.8	2.14–3.66
Household-reported use of open defecation, bush or field	7,698	461 (6.0)	2.5	1.94–3.21
Unimproved source of drinking water	21,808	730 (3.4)	1.22	0.96–1.57
Time to source of drinking water ≥30 minutes	14,440	610 (4.2)	1.54	1.21–1.98

[a]Univariate odds ratio from multilevel random effects logistic regression accounting for clustering at household- and cluster-level.
[b]95% confidence interval; Wald's test.
[c]Observed by data recorders previously trained to identify latrine types linked to the WHO/UNICEF Joint monitoring program definitions
CI, confidence interval; OR, odds ratio

Table 3. Multivariable analysis of factors associated with trachomatous inflammation—follicular (TF) in 1–9-year-olds, global trachoma mapping project, Yemen, 2013–2015.

Variable	OR[a]	*p*-value[b]
Age 1–4 years (vs. 5–9 years)	0.86	0.012
Female sex	0.83	0.002
≥5 children aged 1–9 years in household	1.67	<0.0001
Household-reported use of open defecation, bush or field	2.47	<0.0001

[a]Odds ratio from multilevel hierarchical logistic regression accounting for clustering at household- and cluster-level.
[b]Likelihood ratio test for inclusion of variable in/exclusion of variable from the final model.
OR, odds ratio

human faeces.[24,25] It has been suggested that provision of improved latrines could reduce the fecundity of these flies,[24] and thereby limit transmission of ocular *C. trachomatis* infection in areas where flies are an important vector. However, the extent to which latrine use directly influences force of infection is unclear, insofar as latrine use could also represent a surrogate for other health-influencing parameters, such as education or economic opportunity.

We found that younger children had lower odds of TF. This finding contrasts with that of many other studies,[19,21,26,27] where the burden of TF is typically found in pre-school children – the age group shown to harbor the bulk of the ocular *C. trachomatis* reservoir in environments in which this has been studied in detail.[28,29] A shift of the burden of TF to higher age groups has been noted in areas where trachoma has lower overall prevalence, presumably because intensity of transmission (and age of first exposure) is lower in these areas. However, it has been suggested that clinical signs of active trachoma and *C. trachomatis* infection become decoupled at low prevalences,[30] and we did not collect data on infection, so we will forgo further conjecture based on this finding.

In this article, we identify areas where, at the time of the surveys, trachoma was a public health problem as defined by WHO – albeit mostly at a relatively moderate level. A national trachoma action plan was subsequently developed and adopted by the Ministry of Public Health & Population. Unfortunately, to date its implementation has been impossible due to insecurity, which also prevented survey fieldwork in several further EUs: in Shabwah and Amran governorates, and in areas adjacent to EUs established here as requiring interventions. The catastrophic consequences of the war, which include loss of infrastructure, widespread famine, and wholescale internal displacement,[31,32] may consign our data to be of historical interest only, since it could be some time before local health services can again prioritize trachoma elimination,[33] and in the meantime, the populations of the EUs surveyed are likely to have changed both quantitatively and qualitatively. We hope fervently for a speedy end to the current conflict.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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