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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 problem3 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 assessments11 identified a number of areas as being potentially trachoma-endemic, prior to this study, population-based

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prevalence data were lacking. Preliminary analyses of some of the prevalence data presented here have been published elsewhere; 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 Marib City, Yemen. We used version 2 of the Global Trachoma Mapping Project (GTMP) training system, following principles that have been previously published.

We divided the suspected trachoma-endemic population into 42 unique evaluation units (EUs). By governorate, there were 2 EUs in Adh Dhala’ and 6 in Al Hodeiah, 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, 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.

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 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, 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 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, % (95% CI)\( ^{a} \) | Number of ≥15-year-olds examined | Trichiasis prevalence in ≥15-year-olds, % (95% CI)\( ^{a} \) |
|----------------------|--------------------------|-------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Adh Dhale’a (569)    | Adh Dhale’a, Al Azareq, Al Hosha, Al Hosain, Al Shoaeed | 350,966 | 1399 | 1.0 (0.5–1.4) | 1276 | 0.0 (0.0–0.0) |
| Adh Dhale’a (570)    | Damt, Jhaf, Jiban, Qatabah | 301,565 | 1520 | 1.3 (0.5–2.1) | 1329 | 0.1 (0.0–0.2) |
| Al Hodeidah (82)    | Al Garri, Al Khwakhah, Hays, Jabal Ra’s | 23,351 | 1384 | 0.8 (0.3–1.6) | 1120 | 0.0 (0.0–0.0) |
| Al Hodeidah (83)    | Al Mansuryah, 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)    | Al Darayhim, 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 Dalai Al Hajaylah, Al Marawi’, 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, As Zaydyi | 54,279 | 1330 | 6.3 (4.3–8.7) | 1880 | 0.1 (0.0–0.1) |
| Al Hodeidah (87)    | Al Qanawis, Alwheyyah, Al Zuhrah | 43,695 | 1389 | 10.3 (6.8–15.1) | 1234 | 0.1 (0.0–0.2) |
| Al Jawf (88)        | Al Humayan, Az Zair, Bait Al Anam, Khabb wa ash Shaaf, Karab al Marashi, Rajazah | 293,882 | 907 | 5.4 (2.7–8.4) | 785 | 0.2 (0.0–0.5) |
| Al Jawf (89)        | Al Ghayl, Al Haim, Al Khali, Al Maslub, Al Matamnah, Al Maton | 65,151 | 783 | 8.9 (4.1–12.5) | 565 | 0.0 (0.0–0.0) |
| Hadramoout (583)    | Al Dolialah, Alqaten, Arum, Dawaa, Hajar, Harehad | 264,941 | 1434 | 1.9 (0.8–3.6) | 881 | 0.0 (0.0–0.1) |
| Hadramoout (584)    | Sayuoon, Shebam, Wadi Alameen, | 249,235 | 1423 | 0.3 (0.0–1.0) | 1250 | 0.0 (0.0–0.0) |
| Hadramoout (585)    | Al Disoom, Khalil Ben Yameen, Sahh Tareem | 229,593 | 1491 | 1.0 (0.4–2.1) | 978 | 0.1 (0.0–0.3) |
| Hadramoout (586)    | Aldees, Aliwa Da Wusaiae, Alshaheer, Broom Mafae, Khalil Ba Wazeer | 298,644 | 1338 | 3.6 (2.0–5.9) | 1199 | 0.1 (0.0–0.2) |
| Hajjah (587)        | Alshal | 185,595 | 1429 | 6.8 (4.5–9.9) | 1399 | 0.1 (0.0–0.3) |
| Hajjah (588)        | Al Jamra, Haradh, Midi, Mostaba | 233,198 | 1687 | 4.8 (3.1–6.7) | 1065 | 0.1 (0.0–0.2) |
| Hajjah (589)        | Aljami, Khairan Al Muharaq, Khashar, Qarah, Wash Hah | 395,764 | 1714 | 3.6 (2.4–5.1) | 974 | 0.0 (0.0–0.1) |
| Hajjah (590)        | Ash Shaghadherah, Bani Qais At Tur, Hajjah, Najirah, Sharis | 311,056 | 1456 | 2.3 (1.2–3.6) | 1134 | 0.1 (0.0–0.3) |
| Hajjah (591)        | Aljaffal Ayemen, Absh Ash Sham, Al Mahabeshah, Kholan Ash Sharaf | 261,495 | 1610 | 5.7 (3.1–8.9) | 978 | 0.0 (0.0–0.0) |
| Hajjah (592)        | Al Jamermah, Al Meftaf, Ash Shaleel, Koadenah, Qofil | 312,348 | 1698 | 3.2 (1.7–4.6) | 1067 | 0.0 (0.0–0.0) |
| Ibb (76)            | Al Maghabrah, Bani Al Awam, Kholan Afar, Mabyan | 288,087 | 1685 | 1.9 (0.7–3.3) | 714 | 0.0 (0.0–0.0) |
| Ibb (77)            | Al Qafir, Hazm Al Udayn, Hubaysh | 141,160 | 1057 | 1.8 (0.9–2.7) | 853 | 0.4 (0.1–0.8) |
| Ibb (78)            | Al Udain, Far Al Udayn, Mudhaykhirah | 35,812 | 870 | 6.3 (1.7–11.2) | 686 | 0.17 (0.0–0.5) |
| Ibb (79)            | As Sabrah, As Sayyani, Dh Al Suffal | 98,199 | 793 | 12.6 (5.9–19.8) | 1359 | 0.1 (0.0–0.1) |
| Ibb (80)            | Al Dirhim, Al Mashannah, Baharijah, Jililah | 238,810 | 1020 | 0.7 (0.0–1.7) | 408 | 0.1 (0.0–0.3) |
| Ibb (81)            | Al Mahkadhir, As Saddah, Yamir | 78,439 | 1022 | 0.0 (0.0–0.0) | 602 | 0.0 (0.0–0.0) |
| Ibb (82)            | Al Nadirah, Ar Radmah, Ash Sha’ir | 28,788 | 838 | 3.3 (2.3–4.8) | 945 | 1.3 (0.4–2.6) |
| Lahj (562)          | Labousou, Al Haad, AlMaffali | 231,185 | 1469 | 2.1 (1.1–4.7) | 722 | 0.0 (0.0–0.0) |
| Lahj (563)          | Al Malah, Habeel Jaber, Haleemun, Radfan, Radfan | 362,167 | 1408 | 0.8 (0.2–1.5) | 1179 | 0.0 (0.0–0.0) |
| Lahj (564)          | Al Musameer, Al Qabiya, Tor Alalba | 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, Mahilyah, Majzar, Ma’rib, Ma’rib City, Midghal, Raghwah, Rababah, Sirwah | 46,541 | 982 | 4.5 (2.7–6.3) | 25 | No estimate\(^{d}\) |

\(^{a}\)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 limit for zero count EU estimated from the exact binomial approximation.

\(^{d}\)Only 25 adults examined: too few for a reliable trichiasis prevalence estimate.

CI, confidence interval.
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,\textsuperscript{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’tirib, 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,\textsuperscript{19–21} for example) were matched.
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. 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. 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. This is thought to relate to the fact that eye-seeking Musca sp. flies lay their eggs on surface-exposed

Figure 2. Evaluation unit-level prevalence of trichiasis in ≥15-year-olds, global trachoma mapping project, Yemen, 2013–2015. Internal boundaries represent districts.
Table 2. Univariable analysis of factors associated with trachomatous inflammation—follicular (TF) in 1–9-year-olds, global trachoma mapping project, Yemen, 2013–2015.

| Individual | OR± | 95% CI |
|------------|-----|--------|
| Age group 1–4 years (vs. 5–9 years) | 0.86 | 0.76–0.97 |
| Female sex | 0.83 | 0.74–0.93 |
| ≥8 people resident in the household | 1.16 | 0.97–1.39 |
| ≥5 children aged 1–9 years resident in the household | 1.62 | 1.34–1.97 |
| Latrine type observed at household | 1.0 | 1.0 |
| Improved | 1.0 | 1.0 |
| Unimproved | 1.0 | 1.0 |
| Open defecation, bush or field | 2.8 | 2.14–3.66 |
| Household-reported use of open defecation, bush or field | 2.5 | 1.94–3.21 |
| Unimproved source of drinking water | 2.2 | 1.96–1.57 |
| Time to source of drinking water ≥30 minutes | 1.54 | 1.21–1.98 |

±Univariable odds ratio from multilevel random effects logistic regression accounting for clustering at household- and cluster-level.

| Household | OR± | 95% CI |
|-----------|-----|--------|
| ≥8 people resident in the household | 1.16 | 0.97–1.39 |
| ≥5 children aged 1–9 years resident in the household | 1.62 | 1.34–1.97 |
| Latrine type observed at household | 1.0 | 1.0 |
| Improved | 1.0 | 1.0 |
| Unimproved | 1.0 | 1.0 |
| Open defecation, bush or field | 2.8 | 2.14–3.66 |
| Household-reported use of open defecation, bush or field | 2.5 | 1.94–3.21 |
| Unimproved source of drinking water | 2.2 | 1.96–1.57 |
| Time to source of drinking water ≥30 minutes | 1.54 | 1.21–1.98 |

±Univariable odds ratio from multilevel random effects logistic regression accounting for clustering at household- and cluster-level.

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± | 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 |

±Odds ratio from multilevel hierarchical logistic regression accounting for clustering at household- and cluster-level.

| bLikelihood ratio test for inclusion of variable in/exclusion of variable from the final model. OR, odds ratio}

It has been suggested that provision of improved latrines could reduce the fecundity of these flies,24–25 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 wholesale 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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