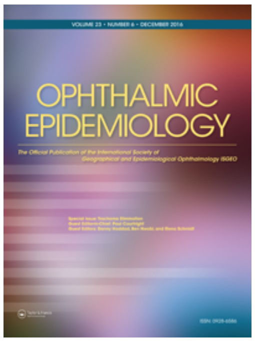

Ophthalmic Epidemiology

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ISSN: 0928-6586 (Print) 1744-5086 (Online) Journal homepage: https://www.tandfonline.com/loi/iope20

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OPHTHALMIC EPIDEMIOLOGY
2016, VOL. 23, NO. 6, 392–405
http://dx.doi.org/10.1080/09286586.2016.1243717

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ORIGINAL ARTICLE

OPEN ACCESS

Prevalence of and Risk Factors for Trachoma in Oromia Regional State of Ethiopia: Results of 79 Population-Based Prevalence Surveys Conducted with the Global Trachoma Mapping Project

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ABSTRACT

Purpose: To complete the baseline trachoma map in Oromia, Ethiopia, by determining prevalences of trichiasis and trachomatous inflammation – follicular (TF) at evaluation unit (EU) level, covering all districts (woredas) without current prevalence data or active control programs, and to identify factors associated with disease.

Methods: Using standardized methodologies and training developed for the Global Trachoma Mapping Project, we conducted cross-sectional community-based surveys from December 2012 to July 2014.

Results: Teams visited 46,244 households in 2037 clusters from 252 woredas (79 EUs). A total of 127,357 individuals were examined. The overall age- and sex-adjusted prevalence of trichiasis in adults was 0.82% (95% confidence interval, CI, 0.70–0.94%), with 72 EUs covering 240 woredas having trichiasis prevalences above the elimination threshold of 0.2% in those aged ≥15 years. The overall age-adjusted TF prevalence in 1–9-year-olds was 23.4%, with 56 EUs covering 218 woredas shown to need implementation of the A, F and E components of the SAFE strategy (surgery, antibiotics, facial cleanliness and environmental improvement) for 3 years before impact surveys. Younger age, female sex, increased time to the main source of water for face-washing, household use of open defecation, low mean precipitation, low mean annual temperature, and lower altitude, were independently associated with TF in children. The 232 woredas in 64 EUs in which TF prevalence was ≥5% require implementation of the F and E components of the SAFE strategy.

Conclusion: Both active trachoma and trichiasis are highly prevalent in much of Oromia, constituting a significant public health problem for the region.

ARTICLE HISTORY
Received 6 January 2016
Revised 15 September 2016
Accepted 24 September 2016

KEYWORDS
Ethiopia; Global Trachoma Mapping Project; Oromia; prevalence; risk factors; trachoma; trichiasis

Introduction

Trachoma is the leading infectious cause of blindness, and is caused by conjunctival infection with the bacterium *Chlamydia trachomatis*. Early infection manifests as redness and irritation, with follicles on the tarsal conjunctiva; this may meet the definition of trachomatous inflammation – follicular (TF) of the World Health Organization (WHO) simplified trachoma grading system. Repeated infections may result in scarring of the conjunctivae, and alteration in eyelid morphology and function such that in-turning of the eyelashes ensues; this condition is known as trachomatous trichiasis (TT). The in-turned eyelashes rub on the cornea and cause devastating pain at each blink.[1] With repeated rubbing, ulceration and subsequent opacification of the normally clear cornea can develop, which may result in visual impairment and blindness.[2,3]

WHO has targeted trachoma for elimination as a public health problem worldwide by 2020, advocating

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*See Appendix
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control using the SAFE strategy (surgery for trichiasis, antibiotics to clear infection, facial cleanliness, and environmental improvement), with the recommended intensity of interventions stratified by the prevalence of disease.[4]

Trachoma is a public health problem in more than 50 countries, with 232 million people estimated to be at risk of blindness from it in 2014. Significant progress in eliminating trachoma has been made in the past decade, with seven countries (Gambia, Ghana, Iran, Morocco, Myanmar, Oman, and Vietnam)[5] having reported achieving the goal of elimination. Ethiopia is estimated to be the most trachoma-affected country in the world.[5]

Oromia is the largest of the nine regions of Ethiopia by both landmass and number of residents, with the 2015 population estimated to be over 33 million.[6] It is divided into 12 town administration units and 18 rural zones; these are further divided into 304 woredas (districts), of which 265 are rural. The 2005–2006 national survey of blindness, low vision and trachoma estimated the region-level prevalence of TF among children 1–9 years of age to be 24.5%, and the TT prevalence in people aged 15 years and older to be 2.8%[7]. Despite these estimates, which were among the highest known, by 2012 only 23 of the 265 rural woredas had either started interventions against trachoma or had prevalence data to guide programmatic interventions (Table 1, Figure 1). For the purposes of the work presented here, existing district-level prevalence estimates were considered to be adequate if they were (1) designed to estimate the prevalence of TF in children aged 1–9 years, and (2) had taken place in the 10 years prior to 2012, when the project began.

Based on this assessment, over 230 woredas in Oromia were identified that did not have program-ready trachoma data, or had data that were considered to be outdated. WHO guidelines recommend that district-level estimates are used to make decisions on where to implement the SAFE strategy. However, a 2010 WHO recommendation allowed for mapping at larger scales in suspected highly trachoma-endemic areas, in order to expedite the start of much needed interventions.[8] To complete the map of trachoma in Oromia, we undertook a series of population-based prevalence surveys covering all remaining unmapped rural woredas in Oromia.

Table 1. Woredas surveyed for trachoma, or in which interventions against trachoma had commenced, prior to the Global Trachoma Mapping Project (GTMP), Oromia, Ethiopia, 2012.

Zone	Woreda	Year of most recent survey[a]	TF,[b] %	Trichiasis,[c] %	Remarks
Arsi	Ziway Dugda	2010	22.1	3	
	Dodota	2010	16.9	2.5	
East Shewa	Bora	2008	60	12	
	Dugda	2008	60	7	
	Adami Tullu, Jido Kombolcha	2008	23	7	
	Lomie	2013	12.53	1.68	
	Adama	2007	19	1.7	MDA stopped in 2011. An impact survey was not done. Re-surveyed with GTMP.
	Fentale	2010	10	1.7	
	Bosset	2007	19	1.7	MDA stopped in 2011. An impact survey was not done. Re-surveyed with GTMP.
East Wollega	Sibu Sire	2007	24.5	3.5	No woreda-level baseline data; antibiotic distribution commenced using region-level prevalence data (shown).
	Sasiga	2010	9.6	0.7	
	Diga	2010	14	2.5	
Ilu Aba Bora	Gechi	2011	23.2	1.6	
Jimma	Sokoru	2007	24.5	3.5	No woreda-level baseline data; antibiotic distribution commenced using region-level prevalence data (shown).
	Omonada	2011	12.8	2.8	No baseline data. Data shown are from an impact survey conducted after 3 years of antibiotic distribution.
North Shewa	Dera	2010	34.1	8.7	
	Hidhebu Abote	2008	42.9	4.8	
	Wore Jarso	2010	16	9.5	
West Arsi	Arsi Negele	2009	39.6	6.9	
West Shewa	Dendi	2010	27.4	0	
	Gindeberet	2011	55.3	1.7	
	Abune Gindeberet	2011	55.3	1.7	
	Bako Tibe	2010	37	0.5	

[a]Population-based prevalence survey.
[b]Population-level prevalence in those aged 1–9 years.
[c]Population-level prevalence in those aged ≥15 years.
MDA, mass drug administration; TF, trachomatous inflammation – follicular.

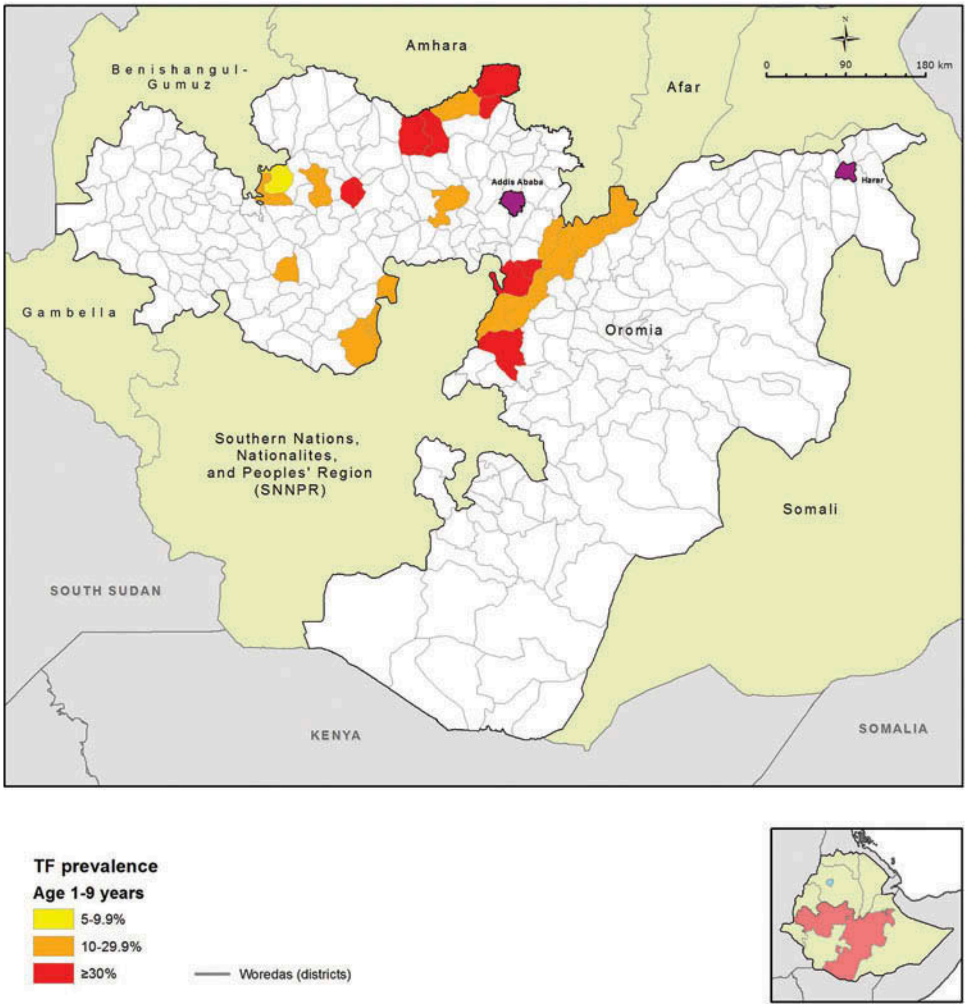

Figure 1. Map of woredas with previous trachoma mapping, or in which interventions against trachoma had commenced prior to the Global Trachoma Mapping Project, Oromia, Ethiopia, 2012.

Because trachoma was expected to be highly and widely endemic in the region, surveys were initially conducted at sub-zone level, i.e. generally involving the combination of several contiguous woredas into a single evaluation unit (EU). The objectives of each survey were to determine the prevalence of TF in children aged 1–9 years, and to estimate the prevalence of trichiasis among people aged 15 years and older, each at sub-zonal level; and to identify risk factors associated with TF and trichiasis in these age groups.

Materials and methods

In general, the methodology used for this work followed that published previously for the Global Trachoma Mapping Project (GTMP),[9] with context-specific details added. Surveys were initially undertaken at sub-zonal level, with woredas grouped following sociodemographic divisions and existing administrative boundaries, in order to form contiguous EUs of approximately 500,000 inhabitants.

Prior to the start of field work, fieldworkers were deployed to obtain a list of all kebeles (the smallest administrative units with population estimates) and geres (kebele divisions consisting of about 30 households each) in all woredas included in each survey, from the respective woreda health offices. Where an EU comprised more than one woreda, the number of kebeles selected from each woreda was proportional to that woreda's population. Kebeles were then selected with a probability proportional to size technique. This provided all individuals in the survey populations an equal probability of selection. At the second stage, one gere was randomly selected (by drawing lots) from the list of all geres in each selected kebele. An additional gere was sampled within the kebele if teams were unable to sample 30 households in the first selected gere.

Based on the most recent census data, it was estimated that 48 children aged 1–9 years would be found in each gere.[6] Therefore, to achieve the target framework of 1222 children in sampled households in each EU, 1222/48 = 25.5 clusters were needed, so 26 clusters were planned to be visited per EU. All individuals at least 1 year old in selected geres were invited to be included, and the gere was considered to be the cluster unit for the purposes of analysis.

Survey teams

Survey teams comprised a trachoma grader, a data recorder, and a driver. Graders and recorders attended the standardized 5-day training using GTMP training manual version 1, held in Bishoftu, Oromia, with both graders and recorders trained in the survey rationale and methodology, and each having to pass an examination before being considered for the survey team. Full details are provided elsewhere.[9]

Ethical review

Ethical approval was obtained from Oromia Regional Health Bureau Ethics Review Committee (BEFO/HBTFH/1-8/2110) and the Ethics Committee of the London School of Hygiene & Tropical Medicine (6319). Official letters of permission were obtained from each zonal and woreda health office.

Informed verbal consent was obtained from all study participants. For children aged <15 years, consent was obtained from the head of household. Verbal consent was considered most appropriate because of low literacy rates among the survey population. People with active trachoma (TF and/or trachomatous inflammation – intense) were provided with a course of tetracycline hydrochloride 1% eye ointment and given instruction for its use. Participants found to have trichiasis were referred to the nearest eye health facility for further assessment. The cost of lid surgery for those with trichiasis was borne by the project.

Risk factors

Water, sanitation and hygiene variables were collected by data recorders by direct observation and via standardized interview questions with the household head. Variables related to water access and source type for both drinking and washing, and sanitation types, used WHO/UNICEF Joint Monitoring Program definitions.[9,10]

Data on climatic variables possibly related to trachoma risk were obtained during fieldwork and from existing data sources, using knowledge of the epidemiology of trachoma in other environments. Altitude was collected directly at the time of the surveys by recording global positioning system (GPS) coordinates at each household. Climate variables derived from local meteorological stations were obtained from WorldClim variables (worldclim.org), at a resolution of 2.5 arc-minutes (~5 km).[11] Variables chosen were those considered to be potentially relevant to *C. trachomatis* infection transmission, including mean annual temperature, mean annual precipitation, precipitation in the driest month, maximum temperature in the hottest month, and minimum temperature in the coldest month. Climatic variables were assigned to households at cluster level, with the cluster GPS coordinates derived from the means of household GPS coordinates.

Data analysis

Descriptive data and prevalence results were produced using R 3.0.2 (2013, R Foundation for Statistical Computing, Vienna, Austria). TF prevalence in children aged 1–9 years was adjusted for age in 1-year age-bands using the latest available census data.[12] Trichiasis prevalence in those aged ≥15 years was adjusted for age and sex in 5-year age-bands. Trichiasis prevalence for the whole population was estimated by halving the ≥15 years' trichiasis prevalence.[13] Confidence intervals (CIs) were generated by bootstrapping adjusted mean cluster-level outcome proportions. Raster point values for climatic variables were extracted using ArcGIS 10.3 (Spatial Analyst; Esri, Redlands, CA, USA). Data clustering was analyzed using Anselin Local Morans I statistic at polygon level, with contiguity of edges and corners between polygons used to define spatial relationships, and outcomes standardized for the number of associated polygons, in ArcGIS 10.3 (Spatial Statistics).

Risk factor analysis was performed using Stata 10.2 (Stata Corp, College Station, TX, USA). A multi-level hierarchical model was used to account for clustering at gere and household level. Co-linearity of variables was examined using Mantel-Haenszel tests of association, but was not an absolute exclusion criterion. A stepwise inclusion approach was used for the multivariable model, with variables considered for inclusion if the univariable association was significant at the $p < 0.10$ level (Wald's test). Variables were retained in the model if statistical significance was found at the $p < 0.05$ level (Likelihood ratio test).

Results

All 18 rural zones of Oromia region were included in the surveys. A total of 59 sub-zone level EUs, covering 252 woredas, were surveyed from December 2012 to

July 2013. Remapping (by adding additional clusters) occurred in sub-zones found to have TF prevalences in 1–9-year-olds <10%, following the WHO recommendation[8] that district-level data be obtained in this circumstance. This affected seven sub-zones covering 38 woredas, resulting in their division into woreda-sized EUs for district-level mapping. For reasons of practicality, remapping was truncated after 20 of these woredas had been remapped (from May to July 2014), with the provisional decision not to remap the remaining 18 low prevalence woredas based on results from the first 20, and challengeable should further research suggest that it be reviewed.

A total of 79 EUs were surveyed, with 46,244 households in 2037 clusters visited, and 139,105 people sampled for inclusion. A total of 127,357 participants (91.6%) consented and were examined, with a mean of 2.75 people examined in each household. A total of 41,642 children aged 1–9 years, and a total of 69,481 individuals aged 15 years or older were examined. In total, 9008 cases of TF and 865 cases of trichiasis were identified.

The age-adjusted TF prevalence among children aged 1–9 years ranged from a low of 1.1% (95% CI 0.3–2.2%) in Gaji woreda of West Wellega, to a high of 48.7% (95% CI 41.6–57.1%) in the Horo Guduru zone woredas (Figure 2). The mean age-adjusted TF prevalence over all EUs was 23.4% (95% CI 22.8–24.2%) in the same age group. Of 79 EUs surveyed, 56 (71%) showed a TF prevalence ≥10% among children aged 1–9 years. In other words, 218 (87%) of 252 woredas included in the surveys were part of EUs that had TF prevalence ≥10%. Each of these woredas require mass distribution of azithromycin, together with implementation of the F and E components of the SAFE strategy, for at least 3 years before impact survey.

A relatively low prevalence of TF was observed in the western part of Oromia, including EUs in Ilu Ababora, Kelem Wellega, and part of West Wellega

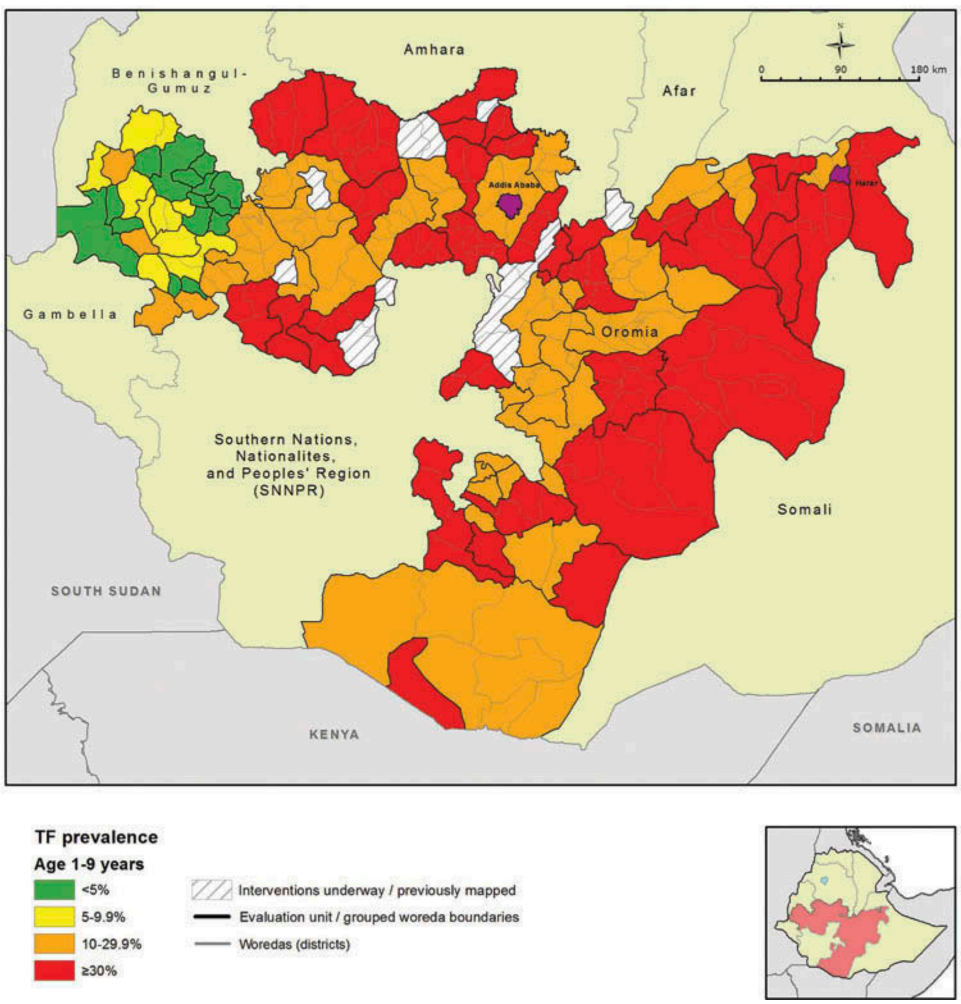

Figure 2. Prevalence of trachomatous inflammation – follicular (TF) in children aged 1–9 years by evaluation unit, Global Trachoma Mapping Project, Oromia, Ethiopia, 2012–2014.

(Figure 2). This area formed a group of 22 contiguous low prevalence EUs; an overall low prevalence EU grouping statistically significant at the $p < 0.05$ level (Anselin Local Moran's I).

The age- and sex-adjusted trichiasis prevalence in those aged 15 years and older ranged from 0.0% (95% CI 0.0–0.1%) in Nole Kaba to 2.5% (95% CI 1.6–3.6%) in the EU covering Kersa, Mean, Tiro, and Afeta woredas of Jimma Zone (Figure 3). The mean age- and sex-adjusted trichiasis prevalence over all EUs was 0.82% (95% CI 0.70–0.94%) in those aged 15 years or older. Overall, 72 EUs had a trichiasis prevalence in those aged 15 years or older that was higher than the elimination threshold of 0.2%. In other words, 240 woredas (95.2% of all woredas included in the surveys) were part of EUs that had a prevalence of trichiasis suggestive of a significant public health problem.

TF and trichiasis prevalences by EU are listed in Tables 2 and 3, respectively.

Clustering of TF and trichiasis

Null models for both TF and trichiasis considering age and sex showed statistically significant clustering at EU, kebele (cluster) and household levels. For TF, the estimate for the standard deviation of the random effects intercept on the odds scale for between-EU clustering was 5.8 (standard error, SE, 1.16, $p < 0.0001$); for between-kebele clustering was 4.3 (SE 1.04, $p < 0.0001$); and for between-household clustering was 3.5 (SE 1.05, $p < 0.0001$). For trichiasis, the estimate for the standard deviation of the random effects intercept on the odds scale for between-EU clustering was 2.10 (SE 1.08, $p < 0.0001$); for between-kebele clustering was 2.05 (SE 1.07, $p < 0.0001$); and for between-household clustering was 1.94 (SE 1.19, $p < 0.0001$). For both TF and trichiasis, clustering was strongest at the EU level, but the model adjusting for clustering at both EU and kebele level was a better fit to the data (likelihood ratio test, $p < 0.0001$). All subsequent analyses using

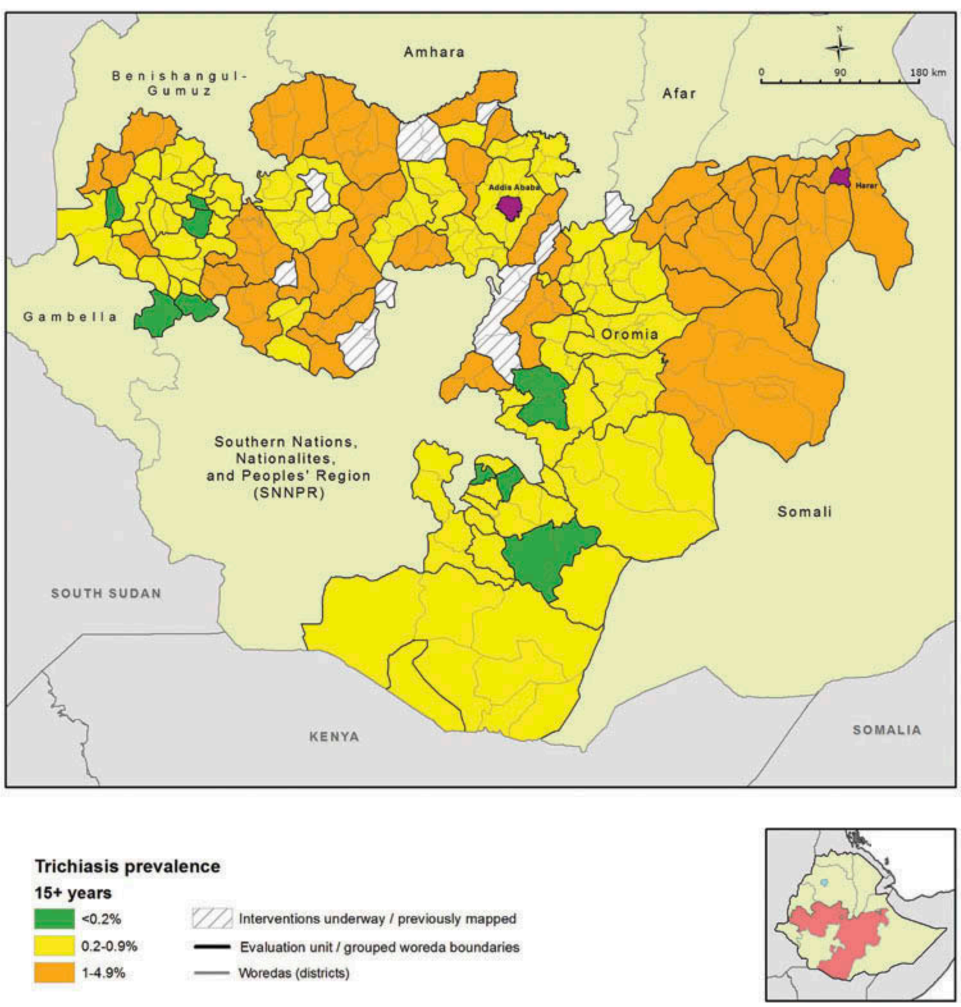

Figure 3. Prevalence of trichiasis in adults aged ≥15 years, Global Trachoma Mapping Project, Oromia, Ethiopia, 2012–2014.

Table 2. Prevalence of trachomatous inflammation – follicular (TF) in children aged 1–9 years by evaluation unit, Global Trachoma Mapping Project, Oromia, Ethiopia, 2012–2014.

Zone	Evaluation unit	Children aged 1–9 years examined, *n*	TF cases, *n*	Unadjusted TF, %	Adjusted TF, % (95% CI)
Arsi	Amigna, Bele Gasgar, Robe, Seru, Shirka	1091	307	28.1	29.6 (23.4–36.4)
	Aseko, Chole, Gololcha (Arsi), Guna, Merti	878	221	25.2	24.3 (17.1–31.8)
	Degeluna Tijo, Enkelo Wabe, Limuna Bilbilo, Lude Hitosa, Tena	1022	243	23.8	20.9 (14.2–27.4)
	Deksis, Dodota, Jeju, Sire, Sude	1036	315	30.4	30.1 (24.1–38.1)
	Hitosa, Munessa, Tiyo, Ziway Dugda	1017	274	26.9	23.6 (15.7–31.5)
Bale	Agarfa, Dinsho, Gasera, Goba, Sinana	1023	480	46.9	42.3 (35.7–51.0)
	Berbere, Dolo Mena, Gura Damole, Harena Buluk, Meda Welabu	1041	441	42.4	38.8 (32.5–45.5)
	Dawe Kachen, Dawe Serer, Ginir, Gololcha (Bale), Goro (Bale), Lege Hida, Rayitu, Seweyna	1008	432	42.9	40.4 (33.2–49.3)
Borena	Abaya, Bule Hora, Dugda Dawa, Gelana	1292	502	38.9	37.1 (30.2–43.7)
	Arero, Dehas, Dire, Miyo, Moyale, Teltele, Yabelo	882	272	30.8	29.2 (20.9–38.6)
	Dillo, Melka Soda	1073	485	45.2	43.5 (35.4–53.1)
East Harerge	Babile, Chinaksen, Gursum, Jarso	1076	487	45.3	42.3 (34.2–48.3)
	Bedeno, Deder, Malka Balo	993	354	35.6	30.9 (23.2–39.6)
	Fedis, Girawa, Golo Oda, Meyu, Midega Tola	1187	575	48.4	46.6 (37.9–54.1)
	Goro Gutu, Kersa, Meta	1120	394	35.2	34.6 (29.2–40.3)
	Haro Maya, Kombolcha, Kurfa Chele	1061	267	25.2	25.0 (18.8–30.5)
	Kumbi	1046	426	40.7	38.0 (32.2–43.2)
East Shewa	Ada'a, Gimbichu, Liben	758	297	39.2	37.8 (31.4–46.0)
	Adama	711	262	36.8	34.7 (24.1–37.8)
	Boset	891	303	34.0	31.2 (27.1–43.8)
East Wollega	Boneya Boshe, Jimma Arjo, Leka Dulecha, Nunu Kumba, Wama Hagalo, Wayu Tuka	840	177	21.1	19.8 (13.0–27.9)
	Diga, Gobu Seyo, Gudeya Bila, Guto Gida, Sasiga	845	184	21.8	18.4 (11.0–27.6)
	Gida Kiremu, Haro Limu, Ibantu, Kiramu, Limu	994	441	44.4	43.2 (34.3–51.3)
Guji	Adola, Hambela Wamena, Liben (Guji), Odo Shakiso, Wadera	1265	469	37.1	35.5 (29.2–42.7)
	Afele Kola (Dima), Ana Sora, Gora Dola, Saba Boru	1071	264	24.6	24.8 (18.1–33.0)
	Bore, Girja (Harenfema), Kercha, Uraga	1253	434	34.6	29.7 (21.3–37.4)
Horo Guduru	Ababo, Abay Chomen, Abe Dongoro, Amuru, Guduru, Horo (Horo Guduru), Jarte Jardega, Jimma Genete, Jimma Rare	967	488	50.5	48.7 (41.6–57.1)
Illu Aba bora	Ale	631	42	6.7	4.9 (1.5–8.7)
	Alge Sachi, Bilo Nopha, Metu Zuria	843	71	8.4	5.5 (2.1–10.2)
	Badele Zuria, Chora, Chwaka, Dabo Hana, Dega, Dorani, Meko	943	157	16.6	16.0 (10.0–23.4)
	Bicho, Borecha, Dedesa, Hurumu, Yayu	803	212	26.4	21.0 (14.1–28.3)
	Bure	694	73	10.5	8.8 (4.4–13.8)
	Darimu	954	95	10.0	7.3 (3.5–12.2)
	Didu	762	82	10.8	10.2 (6.6–14.6)
	Halu (Huka)	549	10	1.8	1.2 (0.4–1.9)
	Nono Sale	332	74	22.3	22.4 (15.0–30.1)
Jimma	Chora Botor, Limu Kosa, Limu Seka	933	215	23.0	20.5 (13.4–28.2)
	Dedo, Seka Chekorsa	1012	488	48.2	45.9 (38.8–52.2)
	Gera, Nono Benja, Setema, Sigmo	972	479	49.3	46.3 (37.7–53.5)
	Goma, Guma, Shebe Sambo	991	431	43.5	41.5 (32.9–50.2)
	Kersa (Jimma), Mena (Jimma), Tiro Afeta	1103	400	36.3	35.5 (27.3–44.4)
Kelem Wollega	Anfilo, Gidami, Sayo	879	29	3.3	3.2 (1.0–4.9)
	Dale Sadi, Gawo Kebe, Lalo Kile	937	89	9.5	8.6 (4.1–13.0)
	Dale Wabera	886	42	4.7	6.3 (2.7–10.9)
	Hawa Galan	1331	154	11.6	10.0 (4.6–16.0)
	Jimma Horo	1027	22	2.1	2.9 (1.0–5.6)
	Yama Logi Welel	931	41	4.4	4.2 (1.7–6.2)
North Shoa	Abichuna Gne'a, Aleltu, Jida, Kembibit	861	223	25.9	25.5 (18.2–33.6)
	Debre Libanos, Kuyu, Wuchale, Yaya Gulele	968	466	48.1	47.1 (40.0–55.9)
	Degem, Dera, Gerar Jarso, Wara Jarso	824	411	49.9	48.4 (40.3–58.0)
South West Shewa	Akaki, Bereh, Mulo, Sebeta Hewas, Sululta, Walmara	881	290	32.9	29.8 (21.2–38.5)
	Ameya, Goro, Waliso, Wenchi	1159	391	33.7	32.1 (22.6–41.8)
	Becho, Dawo, Ilu, Kersana Malima, Seden Sodo, Sodo Daci, Tole	1006	316	31.4	30.3 (23.2–37.6)
West Harerge	Anchar, Goba Koricha, Habro	1040	391	37.6	36.3 (28.7–45.8)
	Boke, Daro Lebu, Gemechis, Oda Bultum	1231	416	33.8	33.4 (27.3–41.2)
	Chiro Zuria, Hawi Gudina, Mieso	1047	304	29.0	28.3 (22.4–35.3)
	Doba, Burka Demtu, Mesela, Tulo	978	207	21.2	21.8 (14.4–30.4)

(*Continued*)

Table 2. (Continued).

Zone	Evaluation unit	Children aged 1–9 years examined, *n*	TF cases, *n*	Unadjusted TF, %	Adjusted TF, % (95% CI)
West Shewa	Adda Berga, Ejere (Addis Alem), Meta Robi	950	348	36.6	35.4 (27.3–43.4)
	Ambo Zuria, Jibat, Nono, Tikur Enchini, Toke Kutaye	1058	330	31.2	29.1 (22.9–37.2)
	Bako Tibe, Cheliya, Ilu Gelan, Dano, Mida Kegn	1100	438	39.8	39.8 (31.0–47.3)
	Dendi, Ifata, Jeldu	1084	190	17.5	17.0 (12.4–22.1)
West Arsi	Adaba, Kokosa, Nenesebo	1159	143	12.3	13.2 (7.5–18.6)
	Dodola, Gedeb Asasa, Kore	1381	317	23.0	21.9 (15.6–29.7)
	Shalla, Shashemene, Siraro	1327	620	46.7	45.8 (37.8–55.1)
	Wondo, Kofele	1497	383	25.6	27.3 (20.0–35.5)
West Wollega	Ayra, Guliso, Jarso, Nejo	714	28	3.9	3.9 (1.2–7.7)
	Babo	997	25	2.5	2.5 (1.0–4.8)
	Begi	1079	109	10.1	9.3 (6.5–12.8)
	Boji Chekorsa	778	20	2.6	2.8 (0.7–5.9)
	Boji Dirmeji	640	8	1.3	1.2 (0.3–2.1)
	Gaji	780	10	1.3	1.1 (0.3–2.2)
	Gimbi	713	20	2.8	1.8 (0.8–3.3)
	Gudetu Kondole	1197	174	14.5	14.3 (8.5–19.9)
	Haru	708	20	2.8	2.9 (1.2–4.6)
	Homa, Yubdo	742	53	7.1	5.7 (2.1–8.5)
	Kiltu Kara, Mana Sibu	949	82	8.6	8.0 (3.7–13.8)
	Lalo Asabi	705	18	2.6	2.9 (0.4–6.6)
	Nole Kaba	741	33	4.5	4.3 (1.2–7.2)
	Sayo Nole	789	25	3.2	2.1 (0.4–4.5)

CI, confidence interval.

hierarchical regression models accounted for both the EU and kebele in which examined individuals resided.

TF risk factors

Full univariable results for the outcome TF in children aged 1–9 years are shown in Table 4. A multivariable analysis was performed to identify independent predictors for TF in this age group. Younger age, female sex, greater time to main source of washing water, household adults' use of open defecation, and lower annual precipitation, were all independent predictors of TF. Living at higher altitudes was associated with decreased odds of TF in children. Full multivariable results are shown in Table 5.

Risk factors for trichiasis

Full univariable results for the outcome of trichiasis in those aged 15 years and older are shown in Table 6. A multivariable analysis was performed to identify independent predictors of trichiasis in this age group. Increasing age, female sex, living alone, living in a household in which adults practiced open defecation, lower altitudes, hottest maximum annual temperatures, and lower mean annual precipitation were associated with the presence of trichiasis. The full multivariable results are shown in Table 7.

Discussion

Determining the prevalences of TF and trichiasis is crucial before developing and implementing interventions for the elimination of trachoma. This survey compiled these essential baseline prevalence data for the whole of Oromia Region. EUs covering 218 out of 252 districts surveyed (87%) had TF prevalences in 1–9-year-old children ≥10%, warranting immediate implementation of the A, F and E components of SAFE, in accordance with WHO recommendations.[4] EUs covering a further 14 woredas had a TF prevalence between 5.0 and 9.9%, and need a single round of antibiotic treatment, plus implementation of the F and E components of SAFE, before impact survey. Collectively, this is a huge undertaking and will require intricate coordination as well as significant funding if the blinding effects of trachoma are not to continue into the next generation in Oromia.

Younger children were at the highest risk of TF in this study. Most studies report a higher odds of TF in younger children.[14–17] This may be because of improved hygiene practices with age, or partial immunity conferring a decreased risk or duration of infection or inflammatory response.[18] It is possible that the pre-school age group may provide a more focused and efficient target for impact surveys in providing evidence of a diminished prevalence of trachoma for elimination programs.

In adults, the odds of trichiasis was 3.96 times higher in women than in men. This finding is in agreement

Table 3. Prevalence of trichiasis in adults aged ≥15 years by evaluation unit, Global Trachoma Mapping Project, Oromia, Ethiopia, 2012–2014.

Zone	Evaluation Unit	Adults ≥15 years examined, *n*	Trichiasis cases, *n*	Unadjusted trichiasis, %	Adjusted trichiasis, % 95% CI
Arsi	Amigna, Bele Gasgar, Robe, Seru, Shirka	1371	10	0.7	0.3 (0.1–0.7)
	Aseko, Chole, Gololcha (Arsi), Guna, Merti	1280	21	1.6	0.9 (0.5–1.4)
	Degeluna Tijo, Enkelo Wabe, Limuna Bilbilo, Lude Hitosa, Tena	1332	15	1.1	0.8 (0.2–1.5)
	Deksis, Dodota, Jeju, Sire, Sude	1282	18	1.4	0.7 (0.4–1.2)
	Hitosa, Munessa, Tiyo, Ziway Dugda	1394	31	2.2	1.3 (0.7–2.0)
Bale	Agarfa, Dinsho, Gasera, Goba, Sinana	1514	7	0.5	0.3 (0.1–0.7)
	Berbere, Dolo Mena, Gura Damole, Harena Buluk, Meda Welabu	1137	12	1.1	0.7 (0.3–1.0)
	Dawe Kachen, Dawe Serer, Ginir, Gololcha (Bale), Goro (Bale), Lege Hida, Rayitu, Seweyna	1303	33	2.5	1.5 (0.9–2.1)
Borena	Abaya, Bule Hora, Dugda Dawa, Gelana	1283	14	1.1	0.7 (0.2–1.1)
	Arero, Dehas, Dire, Miyo, Moyale, Teltele, Yabelo	1275	29	2.3	0.9 (0.5–1.6)
	Dillo, Melka Soda	1170	12	1.0	0.6 (0.3–1.0)
East Harerge	Babile, Chinaksen, Gursum, Jarso	1364	30	2.2	1.1 (0.6–1.6)
	Bedeno, Deder, Malka Balo	1321	30	2.3	1.1 (0.6–1.6)
	Boke, Daro Lebu, Gemechis, Oda Bultum	1403	37	2.6	1.2 (0.7–1.7)
	Fedis, Girawa, Golo Oda, Meyu, Midega Tola	1586	49	3.1	1.7 (1.2–2.4)
	Goro Gutu, Kersa, Meta	1537	47	3.1	1.4 (0.8–2.2)
	Haro Maya, Kombolcha, Kurfa Chele	1478	42	2.8	1.4 (0.6–2.0)
	Kumbi	1096	30	2.7	1.0 (0.5–1.6)
East Shewa	Ada'a, Gimbichu, Liben	1235	42	3.4	1.5 (0.8–2.5)
	Adama	1318	31	2.4	1.2 (0.4–1.3)
	Boset	1580	32	2.0	0.9 (0.7–1.8)
East Wollega	Boneya Boshe, Jimma Arjo, Leka Dulecha, Nunu Kumba, Wama Hagalo, Wayu Tuka	1477	18	1.2	0.7 (0.3–1.1)
	Diga, Gobu Seyo, Gudeya Bila, Guto Gida, Sasiga	1470	14	1.0	0.5 (0.2–1.0)
	Gida Kiremu, Haro Limu, Ibantu, Kiramu, Limu	1453	29	2.0	1.1 (0.5–1.9)
Guji	Adola, Hambela Wamena, Liben (Guji), Odo Shakiso, Wadera	1354	19	1.4	0.9 (0.3–1.9)
	Afele Kola (Dima), Ana Sora, Gora Dola, Saba Boru	1163	1	0.1	0.0 (0.0–0.1)
	Bore, Girja (Harenfema), Kercha, Uraga	1314	9	0.7	0.3 (0.1–0.6)
Horo Guduru	Ababo, Abay Chomen, Abe Dongoro, Amuru, Guduru, Horo (Horo Guduru), Jarte Jardega, Jimma Genete, Jimma Rare	1458	32	2.2	1.5 (0.7–2.3)
Illu Aba bora	Ale	1612	7	0.4	0.3 (0.0–0.7)
	Alge Sachi, Bilo Nopha, Metu Zuria	1720	11	0.6	0.5 (0.1–1.1)
	Badele Zuria, Chora, Chwaka, Dabo Hana, Dega, Dorani, Meko	1593	25	1.6	1.1 (0.5–2.0)
	Bicho, Borecha, Dedesa, Hurumu, Yayu	1644	24	1.5	1.1 (0.6–1.8)
	Bure	1617	6	0.4	0.3 (0.0–0.7)
	Darimu	1695	10	0.6	0.3 (0.1–0.7)
	Didu	1582	3	0.2	0.1 (0.0–0.1)
	Halu (Huka)	1600	9	0.6	0.3 (0.1–0.6)
	Nono Sale	780	1	0.1	0.1 (0.0–0.3)
Jimma	Chora Botor, Limu Kosa, Limu Seka	1614	26	1.6	1.0 (0.4–1.6)
	Dedo, Seka Chekorsa	1511	49	3.2	2.3 (1.4–3.3)
	Gera, Nono Benja, Setema, Sigmo	1349	28	2.1	1.6 (0.7–2.8)
	Goma, Guma, Shebe Sambo	1634	35	2.1	0.9 (0.5–1.4)
	Kersa, Mena, Tiro Afeta	1523	63	4.1	2.5 (1.6–3.6)
Kelem Wollega	Anfilo, Gidami, Sayo	1630	8	0.5	0.4 (0.1–0.7)
	Dale Sadi, Gawo Kebe, Lalo Kile	1617	14	0.9	0.6 (0.2–0.9)
	Dale Wabera	1817	19	1.0	0.7 (0.3–1.1)
	Hawa Galan	1846	30	1.6	1.0 (0.5–1.3)
	Jimma Horo	1765	4	0.2	0.1 (0.0–0.2)
	Yama Logi Welel	1766	5	0.3	0.2 (0.0–0.5)
North Shoa	Abichuna Gne'a, Aleltu, Jida, Kembibit	1728	10	0.6	0.5 (0.1–1.0)
	Debre Libanos, Kuyu, Wuchale, Yaya Gulele	1682	23	1.4	0.6 (0.3–1.0)
	Degem, Dera, Gerar Jarso, Wara Jarso	1582	52	3.3	2.0 (1.3–2.9)
South West Shewa	Akaki, Bereh, Mulo, Sebeta Hewas, Sululta, Walmara	1553	19	1.2	0.7 (0.3–1.3)
	Ameya, Goro, Waliso, Wonchi	1716	55	3.2	1.7 (0.9–2.4)
	Becho, Dawo, Ilu, Kersana Malima, Seden Sodo, Sodo Daci, Tole	1508	25	1.7	0.8 (0.4–1.2)
West Arsi	Adaba, Kokosa, Nenesebo	1289	5	0.4	0.3 (0.1–0.6)
	Dodola, Gedeb Asasa, Kore	1368	4	0.3	0.1 (0.0–0.3)
	Shalla, Shashemene, Siraro	1416	35	2.5	1.7 (1.0–2.5)
	Wondo, Kofele	1659	16	1.0	0.7 (0.2–1.2)
West Harerge	Anchar, Goba Koricha, Habro	1527	49	3.2	1.6 (1.0–2.5)
	Chiro Zuria, Hawi Gudina, Mieso	1461	46	3.1	1.8 (1.1–2.3)
	Doba, Burka Demtu, Mesela, Tulo	1455	29	2.0	1.0 (0.5–1.3)

(*Continued*)

Table 3. (Continued).

Zone	Evaluation Unit	Adults ≥15 years examined, *n*	Trichiasis cases, *n*	Unadjusted trichiasis, %	Adjusted trichiasis, % 95% CI
West Shewa	Adda Berga, Ejere (Addis Alem), Meta Robi	1555	28	1.8	1.0 (0.5–1.5)
	Ambo Zuria, Jibat, Nono, Tikur Enchini, Toke Kutaye	1457	15	1.0	0.4 (0.2–0.7)
	Bako Tibe, Cheliya, Ilu Gelan, Dano, Mida Kegn	1632	33	2.0	1.2 (0.7–1.8)
	Dendi, Ifata, Jeldu	1653	10	0.6	0.4 (0.1–0.9)
West Wollega	Ayra, Guliso, Jarso (West Wollega), Nejo	1689	12	0.7	0.4 (0.1–0.7)
	Babo	1782	14	0.8	0.4 (0.1–0.7)
	Begi	1795	21	1.2	1.0 (0.5–1.7)
	Boji Chekorsa	1783	13	0.7	0.4 (0.2–0.8)
	Boji Dirmeji	1801	15	0.8	0.6 (0.3–1.0)
	Gaji	1642	4	0.2	0.1 (0.0–0.2)
	Gimbi	1581	18	1.1	0.5 (0.3–0.9)
	Gudetu Kondole	1750	27	1.5	1.3 (0.7–2.0)
	Haru	1638	10	0.6	0.4 (0.1–0.8)
	Homa, Yubdo	1554	9	0.6	0.2 (0–0.4)
	Kiltu Kara, Mana Sibu	1582	18	1.1	1.1 (0.4–1.9)
	Lalo Asabi	1677	9	0.5	0.2 (0.1–0.4)
	Nole Kaba	1586	2	0.1	0.0 (0.0–0.1)
	Sayo Nole	1510	4	0.3	0.2 (0–0.5)

CI, confidence interval.

Table 4. Multilevel univariable analysis of factors related to trachomatous inflammation – follicular (TF) in children aged 1–9 years, Global Trachoma Mapping Project, Oromia, Ethiopia, 2012–2014.

Variable		*n*	TF, %	Univariable odds ratio (95% CI)[a]	*P*-value[b]
Individual					
Age, years	1–4	17,092	28.6	2.36 (2.22–2.50)	<0.0001
	5–9	24,550	16.8	1	
Sex	Male	20,679	21.4		
	Female	20,963	21.8	1.05 (0.99–1.11)	<0.0001
Household					
Children aged 1–9 years in household, *n*	1–3	36,822	22.6	1	
	≥4	4820	14.6	1.12 (0.99–1.25)	0.1473
Inhabitants in household, *n*	1–5	30,507	25.4	1	
	≥6	11,135	11.3	1.00 (0.91–1.11)	0.2879
Open defecation (no facilities, bush, or field)	Yes	15,576	30.7	1.18 (1.09–1.27)	
	No	26,066	16.2	1	
Drinking source surface water[c]	Yes	7733	24.0	1.00 (0.87–1.15)	0.7583
	No	33,909	21.1	1	
Time to main source of drinking water, minutes[d]	<30	19,657	17.3	1	
	≥30	21,985	25.6	1.11 (1.01–1.22)	0.0391
Washing source surface water[c]	Yes	9081	22.7	0.99 (0.87–1.13)	0.1213
	No	33,949	20.5	1	
Time to main source of water used for face-washing, minutes[d]	<30	20,176	17.3	1	0.014
	≥30	21,436	25.7	1.14 (1.04–1.25)	
	All washing at source	30	6.7	2.30 (0.34–15.55)	
Cluster-level geoclimatic					
Altitude[e], m above sea level	<2500	37,034	21.5	1	
	≥2500	4,595	22.4	0.41 (0.33–0.50)	<0.0001
Maximum temperature of warmest month[f], °C	<25	5,606	25.8	1	
	≥25	36,036	21.0	2.05 (1.64–2.59)	
Mean annual precipitation[f], mm	<1000	9,319	37.7	8.53 (6.89–10.57)	<0.0001
	1000–1499	16,308	22.0	3.18 (2.61–3.87)	
	≥1500	16,015	11.9	1	

[a]Multilevel univariable random effects regression accounting for clustering at evaluation unit and kebele (cluster) level.
[b]Wald's test.
[c]River, dam, lake, canal.
[d]Time for round-trip estimated by household head.
[e]From GPS coordinates of household collected at time of survey.
[f]From estimates of mean kebele (cluster) coordinates extracted from Bioclim rasters (Worldclim.org).
CI, confidence interval.

with the last Ethiopian National Survey on blindness, low vision and trachoma, and other studies in Ethiopia and elsewhere; females are disproportionately affected by trichiasis.[19–21] The reason for this is unclear, but may be related to increased contact with children in societies where women are the primary caregivers, or to a genetically determined propensity to a more intense immuno-inflammatory reaction to *C. trachomatis* infection. The strength of this association in Oromia is among the highest reported.[20]

Table 5. Multilevel multivariable analysis of factors related to trachomatous inflammation – follicular (TF) in children aged 1–9 years, Global Trachoma Mapping Project, Oromia, Ethiopia, 2012–2014.

Variable		Multivariable odds ratio[a]	*p*-value[b]
Individual			
Age 1–4 years (reference 5–9 years)		2.36	<0.00001
Female sex		1.08	0.011
Household			
Open defecation (no facilities, bush, or field)		1.16	<0.0001
Time to main source of water used for face-washing, minutes	<30	1.00	0.0391
	≥30	1.12	
	All washing at source	2.43	
Cluster-level geoclimatic			
Altitude[c], m above sea level	≥2500	0.44	<0.0001
Mean annual precipitation[d], mm	<1000	2.03	0.0022
	1000–1499	1.59	
	≥1500	1.00	

[a]Multilevel multivariable random effects logistic regression accounting for clustering at evaluation unit and kebele (cluster) level.
[b]Likelihood ratio test of inclusion/exclusion of variable in final model.
[c]From GPS coordinates of households.
[d]Mean kebele (cluster) coordinates extracted from Bioclim rasters (Worldclim.org).

In our study 37.4% of children lived in households that used open defecation, and these children were more likely to have TF than children living in a household with any form of latrine. Trachoma is commonly linked with low levels of sanitation.[22–24] The link between trachoma and sanitation may be direct through enhanced density of the *Musca sorbens* flies thought to mechanically transmit *C. trachomatis* from eye to eye, or may just be an indirect metric for social deprivation, with its associated lower economic and educational opportunities overall.

We found an association between TF and increased reported time to the household's source of water used for face washing. Trachoma has been associated with poor access to water,[25,26] but is also found in areas where water is not necessarily in short supply.[27–29] The volume of water used by a household has been shown to decrease markedly when the round-trip to source and back takes more than 30 minutes,[30] but

Table 6. Multilevel univariable analysis of factors related to the presence of trichiasis in adults aged ≥15 years, Global Trachoma Mapping Project, Oromia, Ethiopia, 2012–2014.

Variable		*n*	Trichiasis, %	Univariable odds ratio (95% CI)[a]	*p*-value[b]
Individual					
Age, years	15–24	19,622	0.1	1	<0.0001
	25–34	18,468	0.5	3.46 (2.20–5.30)	
	35–44	13,122	1.0	6.73 (4.40–10.20)	
	45–54	8204	2.1	14.34 (9.50–21.50)	
	55–64	4913	3.3	24.32 (16.10–36.00)	
	≥65	5152	4.8	37.90 (25.40–56.70)	
Sex	M	30,706	0.5	1	<0.0001
	F	38,775	1.7	3.36 (2.82–4.00)	
Household					
Children aged 1–9 years in household, *n*	0	32,110	1.5	1.89 (1.15–3.08)	<0.0001
	1–3	34,809	0.9	1.15 (0.70–1.87)	
	≥4	2562	0.7	1	
Inhabitants in household[c], *n*	1	6643	2.6	2.59 (1.95–3.42)	<0.0001
	2–5	47,183	1.2	1.34 (1.06–1.68)	
	≥6	15,655	0.7	1	
Open defecation (no facilities, bush, or field)	Yes	22,722	1.7	1.45 (1.23–1.70)	<0.0001
	No	46,759	0.9	1	
Drinking source surface water[d]	Yes	11,786	1.4	1.21 (0.97–1.49)	0.08
	No	57,695	1.2	1	
Time to main source of drinking water, minutes[e]	≥30	35,285	1.3	1.00 (0.84–1.16)	0.931
	<30	34,196	1.1	1	
Washing source surface water[d]	Yes	13,892	1.3	1.14 (0.94–1.40)	0.1857
	No	55,589	1.2	1	
Time to main source of washing water[e], minutes	≥30	34,367	1.3	2.14 (0.25–18.22)	0.7839
	<30	35,054	1.1	1	
	All washing at source	60	1.7	1.00 (0.85–1.17)	
Cluster-level geoclimatic					
Altitude[f], m above sea level	<1500	8973	1.7	1	<0.0001
	1500–2499	54073	1.2	0.86 (0.65–1.12)	
	≥2500	6419	0.7	0.34 (0.22–0.54)	
Maximum temperature of warmest month[g], °C	<25	7714	0.7	1	<0.0001
	≥25	61767	1.3	2.35 (1.67–3.29)	
Mean annual precipitation[g], mm	<1000	12409	2.2	2.92 (2.06–4.13)	<0.0001
	1000–1499	24357	1.3	1.83 (1.35–2.46)	
	≥1500	32715	0.7	1	

[a]Multilevel univariable random effects regression accounting for clustering at evaluation unit and kebele (cluster) level.
[b]Wald's test.
[c]Presented as binary living alone/not living alone in the final model, but displayed in further categories here for illustrative purposes.
[d]River, dam, lake, canal.
[e]Time for round-trip estimated by household head.
[f]From GPS coordinates of households collected at time of survey.
[g]Mean kebele (cluster) coordinates extracted from Bioclim rasters (Worldclim.org).
CI, confidence interval.

Table 7. Multilevel multivariable analysis of factors related to the presence of trichiasis in adults aged ≥15 years, Global Trachoma Mapping Project, Oromia, Ethiopia, 2012–2014.

Variable		Multivariable odds ratio[a]	*p*-value[b]
Individual			
Age, years	15–24	1.00	<0.0001
	25–34	3.25	
	35–44	7.20	
	45–54	15.62	
	55–64	24.98	
	≥65	41.81	
Female sex		3.96	<0.0001
Household			
Living alone		1.30	<0.0001
Open defecation (no facilities, bush, or field)		1.26	0.006
Cluster-level geoclimatic			
Altitude[c], m above sea level	<1500	1.00	<0.0001
	1500–2499	0.93	
	≥2500	0.50	
Maximum temperature of warmest month[d], °C	≥25	1.89	0.0017
Mean annual precipitation[d], mm	<1000	2.55	<0.0001
	1000–1499	2.06	
	≥1500	1.00	

[a]Multilevel multivariable random effects logistic regression accounting for clustering at evaluation unit and kebele (cluster) level.
[b]*p*-value from Likelihood ratio test of inclusion/exclusion of variable in final model.
[c]Estimate from GPS coordinates of household.

more distant access to water does not necessarily mean that less is used for any particular water-requiring activity. The interaction between trachoma and water access is likely to be complex, given this difference between water availability and water use, and any proposed water access interventions should clearly be paired with general health and facial hygiene education. We acknowledge that effective ways to encourage sustained behavior change, in both developing and developing countries, have so far been elusive.

We found that TF was associated with living in lower altitudes, and in drier areas. The distribution of trachoma has previously been associated with climatic and geographical factors, such as lower altitude,[31,32] lower precipitation,[33] and higher mean annual temperature.[17,33] The cause of the relationship of these factors with trachoma is unclear, but it is likely that locations subjected to extremes of any environmental variable will be relatively sparsely populated, limiting transmission potential, and that the people who have the option to migrate from these areas would be relatively economically advantaged anyway. It is likely that these climatic associations will not be universal and will be limited to specific geographical areas. It has been suggested that these associations could be used in politically or geographically difficult environments for stratifying risk and targeting interventions,[34] although more work is needed to determine when and how this type of focused approach could be used for elimination programs in stable environments.

The highly focal distribution of trachoma has been described previously.[26,35–37] In keeping with this, we found that both TF and TT were highly clustered at EU, kebele and household level. Of note, despite the overall prevalence of trachoma being exceedingly high throughout most of Oromia, a group of EUs in Kelem Wellega and West Wellega Zones in the western part of the region had relatively uniformly low prevalences, while closely neighboring EUs (in areas such as Horo Guduru and East Wellega Zones) had TF prevalences amongst the highest in Oromia. Further study is warranted to identify the underlying factors associated with such steep prevalence gradients.

Both active and potentially blinding trachoma are highly prevalent in Oromia, indicating that trachoma is a significant public health problem in at least 218 woredas of the region. The high prevalence of trichiasis among women deserves urgent and special attention and suggests that programs need to ensure that the major part of their trichiasis management approach is tailored to the needs of women. Programs need to also focus on creating open-defecation-free environments and on increasing access to water as part of trachoma elimination efforts. Further study is warranted to determine why the western part of Oromia has a relatively low prevalence of TF compared to the other parts of the region.

Declaration of interest

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

Funding

This study was principally funded by the Global Trachoma Mapping Project (GTMP) grant from the United Kingdom's Department for International Development (ARIES: 203145) to Sightsavers, which led a consortium of non-governmental organizations and academic institutions to support ministries of health to complete baseline trachoma mapping worldwide. The GTMP was also funded by the United States Agency for International Development (USAID), through the ENVISION project implemented by RTI International under cooperative agreement number AID-OAA-A-11-00048, and the END in Asia project implemented by FHI360 under cooperative agreement number OAA-A-10-00051. A committee established in March 2012 to examine issues surrounding completion of global trachoma mapping was initially funded by a grant from Pfizer to the International Trachoma Initiative. AWS was a Wellcome Trust Intermediate Clinical Fellow (098521) at the London School of Hygiene & Tropical Medicine. None of the funders had any role in project design, in project implementation or analysis or interpretation of data, in the decisions on where, how or when to publish in the peer-reviewed press, or in preparation of the manuscript.

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Appendix

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