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The Burden of and Risk Factors for Trachoma in Selected Districts of Zimbabwe: Results of 16 Population-Based Prevalence Surveys

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ABSTRACT

Background: Trachoma, a leading cause of blindness, is targeted for global elimination as a public health problem by 2020. In order to contribute to this goal, countries should demonstrate reduction of disease prevalence below specified thresholds, after implementation of the SAFE strategy in areas with defined endemicity. Zimbabwe had not yet generated data on trachoma endemicity and no specific interventions against trachoma have yet been implemented.

Methods: Two trachoma mapping phases were successively implemented in Zimbabwe, with eight districts included in each phase, in September 2014 and October 2015. The methodology of the Global Trachoma Mapping Project was used.

Results: Our teams examined 53,211 people for trachoma in 385 sampled clusters. Of 18,196 children aged 1–9 years examined, 1526 (8.4%) had trachomatous inflammation–follicular (TF). Trichiasis was observed in 299 (1.0%) of 29,519 people aged ≥15 years. Of the 16 districts surveyed, 11 (69%) had TF prevalences ≥10% in 1–9-year-olds, indicative of active trachoma being a significant public health problem, requiring implementation of the A, F and E components of the SAFE strategy for at least 3 years. The total estimated trichiasis backlog across the 16 districts was 5506 people. The highest estimated trichiasis burdens were in Binga district (1211 people) and Gokwe North (854 people).

Conclusion: Implementation of the SAFE strategy is needed in parts of Zimbabwe. In addition, Zimbabwe needs to conduct more baseline trachoma mapping in districts adjacent to those identified here as having a public health problem from the disease.

Introduction

Trachoma is an infectious eye disease caused by the bacterium *Chlamydia trachomatis*. Classed by the World Health Organization (WHO) as a neglected tropical disease, trachoma is the world's leading infectious cause of blindness. It is thought to be a public health problem in 42 countries, mostly in Africa and the Middle East.[1] Early signs are most commonly found in young children, with female adults (who generally spend more time with children) having the highest burden of advanced, blinding disease.[2] Globally, 200 million are thought to be at risk.[1]

Infection is thought to be transmitted from eye to eye by flies, fingers and fomites bearing ocular or nasal secretions of infected individuals.[3–6] Repeated conjunctival infection causes chronic inflammation, eventually causing scarring and (in some people) in-turning of the eyelids so that the eyelashes touch the eye, a condition called trichiasis.[7,8] Trachomatous conjunctival scarring also reduces tear secretion, predisposing the cornea to ulceration, which may lead to its opacification: the ultimate mechanism through which trachoma produces blindness.[8]

Trachoma is normally found in isolated, resource-limited settings where water scarcity and low levels of sanitation and healthcare access are commonplace—conditions thought to facilitate *C. trachomatis* transmission.[3,5,9] In addition to direct blinding effects on individuals, trachoma profoundly affects the economies of endemic communities, where it is estimated that $2.9 to $8 billion in productivity is lost every year from the disease.[10,11] It is against this background that trachoma has been targeted by WHO for elimination as a public health problem by the year 2020,[12] defined as an estimated prevalence of the clinical sign trachomatous inflammation–follicular (TF) of <5% in children aged 1–9 years, and an estimated prevalence of the clinical sign trachomatous trichiasis in those aged 15 years and greater of <0.2%.

Zimbabwe is a landlocked country in Southern Africa bordering Zambia, Mozambique, Botswana and South Africa. The estimated total population is 13,061,239, with 8,771,520 people (67.2%) living in rural areas. The country's major ethnic groups are the Shona, Ndebele, Karanga, Ndau, Zezuru, and Manyika. Trachoma is known in Zimbabwe's rural health clinics, but reporting on it has hitherto only been included under "general eye conditions" in national health information systems, with no formal estimates of prevalence or incidence of clinical presentation.[13] To date, therefore, few data exist to guide stakeholders to understand the burden of trachoma in the country, or to plan interventions where required.

There are a few specific reports on trachoma in Zimbabwe. Published in 1970, a survey in the area North-East of Harare found that 30% of the 0–5 years age group, and 23% of the 6–15 years age group, had a follicular conjunctivitis consistent with active trachoma.[14] A cataract surgery outreach to Gokwe South district in 2015 found so many cases of trichiasis that more surgeries were carried out for trichiasis than for cataract (unpublished data, Dr B. Macheka). It is also notable that Zimbabwe borders trachoma-endemic districts in Zambia to the North,[15] and Mozambique to the North-East.[16]

As is common in many developing countries, in Zimbabwe's rural districts, factors normally associated with trachoma are present—extreme poverty is commonplace, water access is limited, and sanitation provisions are minimal. However, the status of trachoma endemicity in large areas of the country is unclear. Definitive district-level prevalence data are needed in order to guide the Ministry of Health and their partners to plan for national trachoma elimination as a public health problem.

We conducted 16 district-level population-based trachoma prevalence surveys in two phases, in 2014 and 2015, with the aims of estimating the prevalence of TF in children aged 1–9 years, and the prevalence of trichiasis in those aged 15 years and greater, as well as obtaining data on the water, sanitation, and hygiene (WASH) variables most commonly associated with trachoma. We report the results of those surveys in this paper.

Methods

Study design and study sites

With few existing data, we were not confident of where formal surveys were justified, so a phased approach was used. In the first phase, in September 2014, eight population-based cross sectional prevalence surveys were carried out, with one district selected from each of the eight provinces of Zimbabwe (Manicaland, Mashonaland East, Mashonaland Central, Mashonaland West, Midlands, Masvingo, Matabeleland South, Matabeleland North). Districts were selected based on suspected trachoma endemicity from existing government reports. In the second phase, districts adjacent to phase 1 districts in which the TF prevalence in children aged 1–9 years was ≥5% were considered for further surveys; these were undertaken in October 2015.

The overall survey protocol was implemented according to the published methodology for the Global Trachoma Mapping Project (GTMP),[17] with Zimbabwe-specific adaptations related to selection of populations to survey, as outlined in the previous paragraph, and procedures for obtaining consent and assent (see below). Surveys were carried out with existing administrative districts used as evaluation units. Table 1 identifies the districts selected for phases 1 and 2.

Sample size estimation and sampling procedures

The sample size calculation used the single population proportion for precision formula. To have 95% confidence (α = 5%) of estimating a true TF prevalence in 1–9-year-olds of 10% with an absolute precision of 3%, assuming a cluster survey design effect of 2.65 and inflation by a factor of 1.2 to account for non-response, each survey needed to include sufficient households to expect 1222 children to be resident.[17] This sample size was also more than adequate to estimate a true TF prevalence in 1–9-year-olds of 4% with an absolute precision of 2%.[18] In rural Zimbabwe, the mean household size is 4.4 people and approximately 26% of the population is aged 1–9 years,[19] providing an average of 1.14

Table 1. Districts selected for the first two phases of trachoma mapping in Zimbabwe, 2014–2015.

| | Districts | |
Province	Phase 1	Phase 2
Manicaland	Chipinge	
Mashonaland East	Mudzi	Mutoko, Uzumba Maramba Pfungwe
Mashonaland Central	Mbire	Rushinga, Centinary
Mashonaland West	Kariba	Hurungwe,
Midlands	Gokwe North	Gokwe South
Masvingo	Chivi	
Matabeleland South	Magwe	
Matabeleland North	Binga	Lupane, Hwange

1–9 year-olds per household. Therefore, 1222/1.14 = 1073 households were required per district.

Two-stage cluster sampling was used for each survey, with enumeration areas, (the lowest administrative units used for generating census data in Zimbabwe) sampled in the first stage; a sample of 45 households from each enumeration area was selected in the second stage. Selection of 24 enumeration areas per district was performed using a probability proportional to size, systematic sampling methodology, using enumeration area population sizes obtained from the Zimbabwe National Statistics Agency.[19] Substitution of selected enumeration areas was only permitted with approval of the study coordinator, and only when field teams found that the village no longer existed, or was unreachable by vehicle, motorcycle, boat or foot. In those cases, teams visited the geographically next-nearest enumeration area. An additional cluster was selected in Mutoko district to ensure an adequate sample size was obtained.

Household selection was performed on the day of the survey, at village level. As household listings were not available, compact segment sampling was used. The survey team liaised with the village chief who provided a map in which segments, each comprising approximately 45 households, were demarcated. Teams then randomly selected one segment by drawing straws, and included all households in the selected segment.

At sampled households, graders examined consenting individuals for signs of trachoma using the WHO simplified grading system,[7] 2.5× magnifying loupes, and sunlight illumination. All data were recorded electronically in a custom-made smartphone application (LINKS, Task Force for Global Health, US), as previously described.[17]

Survey teams

Teams were composed of one grader, one recorder, one village chief/guide and a driver. Graders were Ophthalmic Nurses who had been trained and certified by the GTMP. Recorders were GTMP-certified Provincial Health Information Officers. Eight survey teams were trained, using version 3 of the standardized GTMP training system,[20] in Kwekwe, Zimbabwe.

At the central level, coordination and supervision were organized by the National NTD Task Force Committee through the Epidemiology and Disease Control Department, Ministry of Health and Child Care. Four field supervisors (members of the Zimbabwe Neglected Tropical Diseases steering committee) ensured quality data collection.

Ethics statement

The survey protocol was approved by the National Ethical Regulatory Board (Medical Research Council of Zimbabwe; reference MRCZ/A/1893) and the Ethics Committee of the London School of Hygiene & Tropical Medicine (reference numbers 6319 and 8355). Participation in the survey was voluntary. Survey team members explained to village chiefs and members of the selected households the purpose of the survey and what their participation involved. Participants were assured of confidentiality and were made aware that decisions on whether or not to take part would in no way affect future service provision. No adverse effects were anticipated from participating. For all individuals with trichiasis or active trachoma, referral or antibiotic treatment, respectively, was provided. Written, informed consent was obtained from all adults aged ≥18 years, and from parents, caregivers, or heads of households for those under 18 years of age. Assent was obtained from individuals aged 15–17 years after parental informed consent had been granted.

WASH and climate data

WASH variable data were collected by data recorders using direct observation and 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 Programme definitions for improved

and unimproved water and sanitation sources.[21,22] We sought climatic data possibly related to *C. trachomatis* infection transmission,[23] based on knowledge of the epidemiology of trachoma in comparable environments. Data derived from local meteorological stations were obtained from WorldClim/BioClim (worldclim.org),[24] at a resolution of 2.5 arc-minutes (~5km): mean annual temperature, mean annual precipitation, and maximum temperature in the hottest month. Altitude was recorded by collecting Global Positioning System coordinates at each household at the time of survey.

Data management

Descriptive data were produced using Excel 2010. Adjusted prevalence and confidence intervals were calculated using R 3.0.2 (The R Foundation for Statistical Computing, 2013). In order to estimate the population-level outcomes required for existing WHO guidelines, both TF and TT proportions were adjusted at cluster-level. This was done to partially account for the fact that conducting surveys during daylight hours results in a proportion of school-attending children and working adults (often males) remaining unexamined. The TF prevalence in children aged 1–9 years was adjusted for age in 1-year age-bands using the latest available census data.[19] Trichiasis prevalence estimates in those aged 15 or more years were adjusted for age and sex in 5-year age-bands. For each district, the overall outcome prevalence was estimated by taking the arithmetic mean of adjusted cluster-level proportion estimates from that district. Trichiasis prevalence for the whole population was estimated by halving the 15+ years trichiasis prevalence.[25] Confidence intervals were generated using a bootstrapping approach, randomly resampling with replacement from the set of all adjusted cluster-level outcome proportions for each district, and calculating the arithmetic mean of these proportions from the set of resampled clusters. A 95% confidence interval was estimated by taking the 2.5th and 97.5th centiles of these results, obtained over 10,000 replicates. Bootstrap estimates assumed normally distributed proportions, which held in all but the very lowest trichiasis prevalence estimates. The confidence intervals for zero counts were estimated by an exact binomial confidence interval.

Raster point values for climatic variables were extracted using ArcGIS 10.3 (Spatial Analyst). Risk factor analysis was performed using Stata 10.2 (Stata Corp, TX, USA). A multi-level hierarchical model was used to account for clustering at enumeration area and household level. Co-linearity of variables was not an absolute exclusion criterion, but was assessed using Mantel-Haenszel tests of association. A stepwise inclusion approach was used for the multivariable model, with variables considered for inclusion if the univariable association was significant at the $p < 0.05$ level (Wald's test). Variables were retained in the model if statistical significance was found at the $p < 0.05$ level (Likelihood ratio test).

Estimation of design effect

The increase in variance of the estimated proportion of children with TF in each district, due to the clustered design of the survey, is given by the design effect (DE). The DE for each district was estimated by dividing the bootstrapped variance estimate of the cluster-level TF proportions by the equivalent simple random sampling (SRS) variance estimate for the same sample size.

Assuming SRS, if p is the proportion of children examined with TF in a given district, and n is the total number of children examined in the same district, then the SRS variance in this proportion is given by $p(1-p)/n$, the formula for the variance of a Normally distributed sample proportion.

Results

Trachoma survey phases 1 and 2 were conducted in September 2014 and October 2015 respectively. The districts targeted in phase 2 were based on their proximity to those phase 1 districts in which a TF prevalence of greater than 5% in children had been observed. Table 2 shows data on numbers of people registered and examined for each district. A total of 17,299 households were visited, from which 55,992 people were registered. Of these, 53,211 (95%) were examined. Of those examined, 23,360 (43.9%) were males.

Results of examination by district are shown in Table 3. Of 18,196 children aged 1–9 years examined, 1526 (8.4%) had TF, whereas TF was observed in only 225 (4.1%) of 5496 children aged 10–14 years. No children aged 1–9 years, and only three children aged 10–14 years, had trichiasis. Of the 29,519 individuals aged 15 years and greater who were examined, 299 cases of trichiasis were identified (1.0%). Overall, 36 cases of trichiasis were in those aged 15–39 years, and 263 cases were in those aged 40 years or greater.

Figure 1 and Table 4 show the adjusted prevalence of TF among 1–9-year-olds, by district. Table 5 presents recommendations for implementation of SAFE, based on adjusted prevalence of TF and trichiasis in each surveyed district. Five districts had TF prevalence

Table 2. Sampling by district, Global Trachoma Mapping Project, Zimbabwe, 2014–2015.

			Individuals				
Province	District	Households (n)	Registered (n)	Examined (n, %)	Absent (n, %)	Refused (n, %)	Other (n, %)
Manicaland	Chipinge	1073	3827	3735 (97.6)	53 (1.4)	39 (1)	
Mashonaland Central	Mbire	1079	2800	2749 (98.2)	33 (1.2)	18 (0.6)	
	Rushinga	1078	2817	2803 (99.5)	11 (0.4)	3 (0.1)	
	Centenary	1076	2708	2706 (99.9)	0 (0)	2 (0.1)	
Mashonaland East	Mudzi	1086	3590	3326 (92.6)	253 (7)	11 (0.3)	
	Mutoko	1126	3416	3377 (98.9)	37 (1.1)	2 (0.1)	
	Uzumba Maramba Pfungwe	1074	3351	3255 (97.1)	29 (0.9)	67 (2)	
Mashonaland West	Kariba	1063	3630	3285 (90.5)	338 (9.3)	7 (0.2)	
	Hurungwe	1079	3504	3307 (94.4)	193 (5.5)	4 (0.1)	
Masvingo	Chivi	1063	3074	2592 (84.3)	473 (15.4)	3 (0.1)	6[a](0.2)
Matabeleland North	Binga	1072	3376	2928 (86.7)	383 (11.3)	65 (1.9)	
	Lupane	1096	3882	3826 (98.6)	37 (1)	15 (0.4)	4[b](0.1)
Matabeleland South	Mangwe	1097	3664	3602 (98.3)	58 (1.6)	4 (0.1)	
	Hwange	1079	4215	4155 (98.6)	41 (1)	18 (0.4)	1[c](0)
Midlands	Gokwe north	1082	4583	4069 (88.8)	504 (11)	9 (0.2)	1[d](0)
	Gokwe South	1076	3555	3496 (98.3)	57 (1.6)	1 (0)	1[e](0)
Totals		17,299	55,992	53,211 (95)	2500 (4.5)	268 (0.5)	13(0)

[a]Disabled.
[b]Three recently deceased, three blind.
[c]Unable to follow instructions.
[d]Two blind, one unable to examine due to facial burns, one reason not given.
[e]Recent reaction to eye medication prevented examination.

<5%, the elimination threshold for TF. In these districts, according to WHO guidelines, the A, F and E components of SAFE are not necessary for the purposes of trachoma's elimination as a public health problem. A total of eight districts had a TF prevalence between 5 and 9.9%, and a further three (Centenary, Gokwe South and Lupane) had a TF prevalence of 10–29.9%; according to WHO guidelines, these 11 districts require implementation of the A, F and E components of SAFE before resurvey.

Figure 2 and Table 6 show the adjusted district-level prevalence of trichiasis in the population aged ≥15 years, and estimated surgery backlogs. Of 16 districts, 10 (62.5%) had adjusted trichiasis prevalence ≥0.2%. Overall the estimated trichiasis backlog was 5506 individuals. This figure was highest in Binga district, where an estimated 1297 people will need to be counselled for possible surgery.

Estimation of design effect

The median number of children examined per cluster was 45 (Interquartile range [IQR]: 37–56); TF cases per cluster was three (IQR: 1–5); proportion of children with TF per cluster was 0.058 (IQR: 0.025–0.120), and the median number of children examined per district was 1142 (IQR: 1011–1267.25). The median bootstrap variance of the primary sampling unit (cluster-level) TF proportions was 11.0×10^{-5} (IQR: 4.1–34.5), and the median DE over all 16 districts with a median of 45 children examined per cluster was 2.20 (IQR: 1.27–3.47).

Table 3. Examination results, Global Trachoma Mapping Project, Zimbabwe, 2014–2015.

		Age (years)											
		1–9				10–14				15 years or greater				
Province	District	n	TF[a]	TI[b]	Trichiasis	n	TF	TI	Trichiasis	n	TF	TI	Trichiasis	Total
Manicaland	Chipinge	1330	64	3	0	553	33	1	0	1852	53	5	6	3735
Mashonaland Central	Centenary	799	229	22	0	263	17	9	1	1644	6	11	16	2706
	Mbire	710	65	57	0	210	2	5	0	1829	5	12	41	2749
	Rushinga	889	99	13	0	328	16	0	0	1586	13	0	10	2803
Mashonaland East	Mudzi	1144	92	0	0	505	17	1	0	1677	57	7	10	3326
	Mutoko	1068	83	9	0	471	32	3	0	1838	32	20	3	3377
	Uzumba Maramba Pfungwe	1007	73	0	0	455	27	1	0	1793	49	7	14	3255
Mashonaland West	Hurungwe	1023	27	2	0	411	6	0	0	1873	10	0	3	3307
	Kariba	1096	68	2	0	403	7	0	0	1786	3	0	7	3285
Masvingo	Chivi	1169	15	13	0	167	1	1	0	1256	1	0	3	2592
Midlands	Gokwe north	1292	101	0	0	598	20	0	1	2179	23	5	22	4069
	Gokwe South	1193	206	15	0	455	12	3	0	1848	11	2	21	3496
Matabeleland North	Binga	1156	130	14	0	7	2	0	1	1765	6	2	58	2928
	Hwange	1634	45	4	0	194	3	0	0	2327	1	0	7	4155
	Lupane	1546	186	13	0	134	8	1	0	2146	71	36	15	3826
Matabeleland South	Mangwe	1140	43	10	0	342	22	5	0	2120	14	5	63	3602
	Totals	18,196	1526	177	0	5496	225	30	3	29,519	355	112	299	53,211

[a]TF, Trachomatous inflammation–follicular.
[b]TI, Trachomatous inflammation–intense.
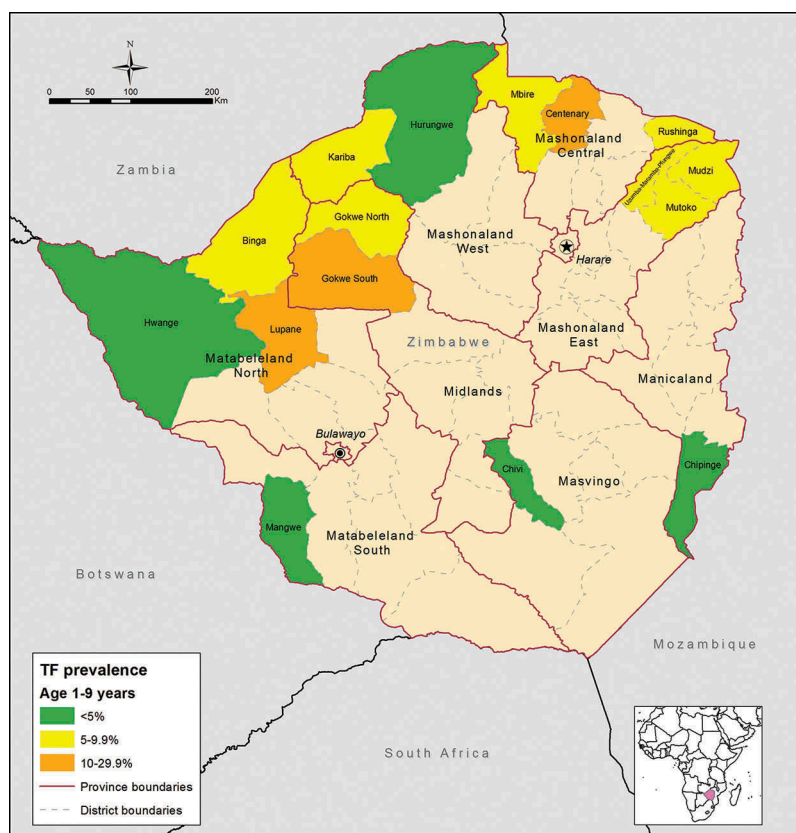
Figure 1. Estimated prevalence of trachomatous inflammation–follicular (TF) among children aged 1–9 years, by district, Global Trachoma Mapping Project, Zimbabwe, 2014–2015.

Table 4. Estimated population-level prevalence of trachomatous inflammation–follicular (TF) in children aged 1–9 years by district, Global Trachoma Mapping Project, Zimbabwe, 2014–2015.

Province	District	TF Unadj[a]	TF Adj[b]	95% CI[c]
Manicaland	Chipinge	4.8	4.3	[3.1–5.5]
Mashonaland Central	Centenary	28.7	**27.8**	[21.6–35.5]
	Mbire	9.2	7.8	[5.3–11]
	Rushinga	11.1	9.4	[7.1–11.4]
Mashonaland East	Mudzi	8.0	8.2	[6.5–10]
	Mutoko	7.8	6.7	[4.4–9.7]
	Uzumba Maramba Pfungwe	7.2	6.9	[5.0–8.8]
Mashonaland West	Hurungwe	2.6	2.4	[1.2–4.1]
	Kariba	6.2	5.5	[3.9–7.5]
Masvingo	Chivi	1.3	1.5	[0.7–2.3]
Midlands	Gokwe north	7.8	7.5	[5.1–10.1]
	Gokwe South	17.3	**16.5**	[13.0–20.1]
Matabeleland North	Binga	11.2	9.6	[6.3–13.8]
	Hwange	2.8	2.2	[1.3–3.1]
	Lupane	12.0	**11.9**	[8.0–15.2]
Matabeleland South	Mangwe	3.8	3.2	[2.0–4.3]

[a]Unadjusted (crude) prevalence estimate.
[b]Adjusted for age in 1-year age groups using the latest available census data; Districts with a TF prevalence where mass distribution of azithromycin is recommended are highlighted in bold.
[c]95% confidence interval estimated by bootstrapping the adjusted cluster-level estimates to account for the clustered design of the sampling.

TF risk factors

Independent predictors of TF were identified on multivariable analysis. The full univariable results are shown in Table 7. In the multivariable model (Table 8), children aged 1–5 years had odds of having TF 1.7 times those of children aged 6–9 years (95%CI 1.49–1.99). In addition, children who lived in households with a total of four or more children had odds of TF 1.7 times those of children living in a household with fewer children (95%CI 1.27–2.15). Children living in households in which adults practised

Table 5. Recommendations for implementation of components of the SAFE strategy based on prevalence of trachomatous–inflammation follicular (TF) and trichiasis, Zimbabwe, 2014–2015.

Prevalence	Names of districts (n)	Recommendation[a]
TF prevalence in 1–9 years (%)		
< 5%	Chipinge, Chivi, Mangwe, Hurungwe, Hwange (n = 5)	No A, F, E needed for elimination of trachoma as a public health problem
≥ 5% and < 10%	Mudzi, Mbire, Kariba, Gokwe North, Mutoko, UMP, Rushinga, Binga (n = 8)	Targeted A as appropriate to program needs (e.g., 1 round of MDA); Conduct F,E
≥ 10% and < 30%	Centenary, Lupane, Gokwe South (n = 3)	Implementation at district; 3 rounds of A (MDA) plus implementation of F and E, then re-survey
Trichiasis prevalence in those aged 15 years or greater (%)		
< 0.2	Chivi, Kariba, Hwange, Mutoko, Rushinga, Hurungwe (n = 6)	A public health approach to delivery of trichiasis surgery not necessary for elimination of trachoma as a public health problem
≥ 0.2	Mudzi, Chipinge, UMP, Lupane, Gokwe South, Centenary, Gokwe North, Mangwe, Mbire and Binga (n = 10)	Scaling up of efforts to train trichiasis surgeons and implementation of community-based case detection and management

[a]S, Trichiasis **S**urgery; A, **A**ntibiotics; F, **F**acial cleanliness; E, **E**nvironmental improvement.
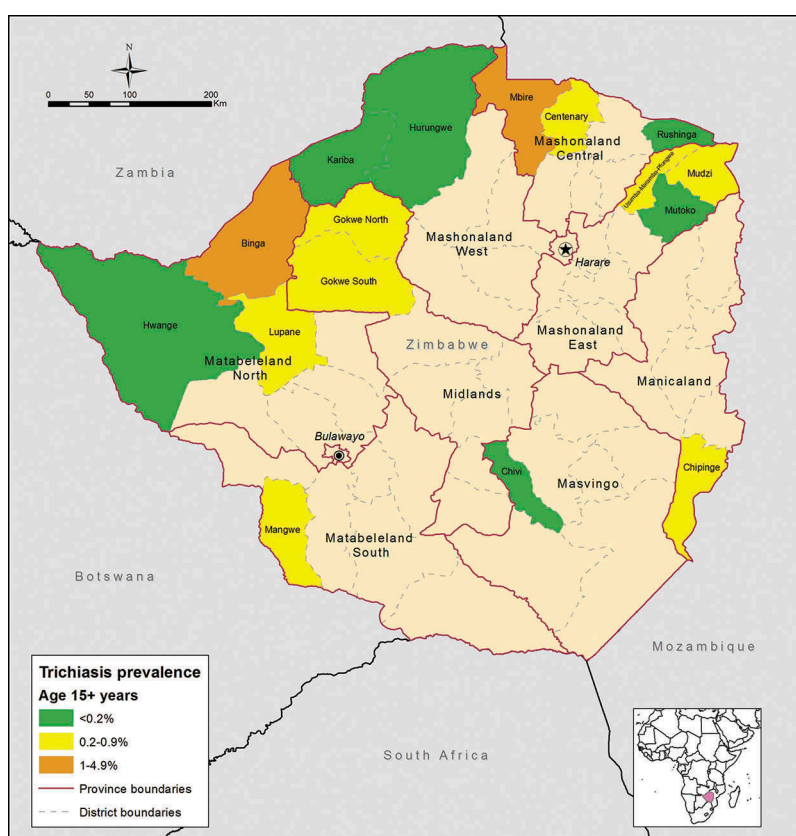
Figure 2. Adjusted prevalence of trichiasis in adults aged 15 years or greater, by district, Global Trachoma Mapping Project, Zimbabwe, 2014–2015.

open defecation were more likely to have TF than those who did not (OR = 1.9, 95%CI 1.65–2.28).

Living in areas where annual rainfall was at least 600 mm was associated with an increased odds of TF (OR = 2.8, 95%CI 2.15–3.7). This effect was not altered by the inclusion of altitude in the model. Children living in households in which the maximum annual outside temperature exceeded 35° C had lower odds of trachoma than children who lived in cooler areas. (OR = 0.3, 95%CI 0.21–0.39). Annual mean temperature was not included in the final model due to co-linearity with the maximum annual temperature. Living in a household at an altitude of more than 750 m above sea level was

Table 6. Estimated population-level prevalence of trichiasis and estimated trichiasis surgery backlogs by district, Global Trachoma Mapping Project, Zimbabwe, 2014–2015.

Province	District	Estimated population ≥15 years[a]	Trichiasis unadj[b] (%)	Trichiasis adj[c] (%)	95% CI[d]	Estimated trichiasis cases[e]
Manicaland	Chipinge	153,948	0.32	0.32	[0–0.6]	493
Mashonaland Central	Centenary	63,256	0.97	0.53	[0.3–0.8]	335
	Mbire	42,438	2.24	1.36	[0.8–1.9]	577
	Rushinga	38,142	0.63	0.12	[0–0.2]	46
Mashonaland East	Mudzi	68,645	0.6	0.23	[0–0.4]	158
	Mutoko	75,278	0.16	0.12	[0–0.3]	90
	Uzumba Maramba Pfungwe	58,012	0.78	0.34	[0.1–0.6]	197
Mashonaland West	Hurungwe	169,586	0.16	0.05	[0–0.1]	85
	Kariba	21,312	0.39	0.13	[0–0.3]	28
Masvingo	Chivi	85,540	0.24	0.16	[0–0.4]	137
Midlands	Gokwe north	123,818	1.01	0.69	[0.4–1]	854
	Gokwe South	157,627	1.14	0.42	[0.2–0.6]	662
Matabeleland North	Binga	71,654	3.29	1.81	[1.2–2.6]	1297
	Hwange	32,285	0.3	0.12	[0–0.2]	39
	Lupane	51,598	0.7	0.35	[0.1–0.6]	181
Matabeleland South	Mangwe	34,112	2.97	0.96	[0.6–1.3]	327
	Total	1,247,251	-	-	-	5506

[a]Population Census 2012, Zimbabwe National Statistics Agency.
[b]Unadjusted (crude) prevalence estimate.
[c]Adjusted for sex and age in 5-year age groups using the latest available census data.
[d]95% confidence interval estimated by bootstrapping the adjusted cluster-level estimates to account for the clustered design of the sampling.
[e]Estimated by applying the adjusted trichiasis prevalence to the estimated rural population aged 15 years or greater in each district.

Table 7. Multilevel univariable associations with trachomatous inflammation–follicular (TF) in children aged 1–9 years, Global Trachoma Mapping Project, Zimbabwe, 2014–2015.

Variable		n	TF%	Odds Ratio	95% CI	p-value[a]
Individual						
Sex	Male	9231	8.6	1	–	
	Female	8965	8.2	0.97	0.87–1.08	0.5936
Age	1–5	11,302	9.6	1.54	1.36–1.73	<0.0001
	6–9	6894	6.5	1	–	
Household						
Number of household inhabitants	1–5	13,412	8.4	1		
	≥6	4784	8.4	1.0	0.82–1.22	0.938
Number of children in household	1–3	16,002	8.1	1		
	≥4	2194	10.5	1.42	1.14–1.77	0.0016
Surface water drinking source	Yes	2095	8.1	0.97	0.79–1.20	0.8193
	No	16,101	8.4	1		
Time to drinking water source	<30 minutes	9229	7.6	1		
	≥30 minutes	8967	9.2	1.30	1.12–1.53	0.0008
Surface water washing source	Yes	2444	7.6	0.88	0.70–1.12	0.3134
	No	15,752	8.5	1		
Time to washing water source	All washing done at source	194	2.1	0.19	0.06–0.62	0.0405
	<30 minutes	9126	7.8	1	–	
	≥30 minutes	8876	9.2	1.27	1.09–1.49	
Household open defecation	Yes	9413	10.3	1.94	1.66–2.28	<0.0001
	No	8783	6.4	1		
Household unimproved latrine	Yes	10,999	10.1	2.19	1.85–2.59	<0.0001
	No	7197	5.8	1		
Household unimproved washing source	Yes	7387	9.9	1.51	1.29–1.77	<0.0001
	No	10,809	7.4	1		
Cluster-level geoclimate[b]						
Altitude	<750 m	6258	9.9	1		
	≥750 m	11,925	7.6	0.70	0.59–0.82	<0.0001
Annual rainfall	<600 mm	2797	4	1		
	≥600 mm	15,399	9.2	3.11	2.37–4.08	<0.0001
Annual mean temperature	<23°C	15,033	7.8	1		
	≥23°C	3163	11.3	1.67	1.38–2.02	<0.0001
Annual maximum temperature	<35°C	16,353	8.8	1		
	≥35°C	1843	4.8	0.45	0.33–0.61	<0.0001

[a]Wald's test.
[b]Estimated from the mean of household GPS coordinates at cluster-level, with climate variables extracted from Bioclim rasters (worldclim.org) at 2.5 arc-minutes (~5km) resolution.

Table 8. Independent predictors of trachomatous inflammation–follicular (TF) in children aged 1–9 years, Global Trachoma Mapping Project, Zimbabwe, 2014–2015.

Variable	Odds Ratio	p-value[a]
Age 1–5 years	1.7	<0.0001
≥4 children aged 1–9 years living in the household	1.7	0.014
Household use of open defecation	1.9	0.0002
Altitude ≥750 metres	0.6	<0.0001
Annual rainfall ≥600 mm	2.8	<0.0001
Annual maximum temperature ≥35°C	0.3	<00001

[a]Likelihood ratio test of inclusion/exclusion of variable in final model.

associated with a decreased odds of TF (OR = 0.6, 95%CI 0.52–0.73) (Table 8).

Discussion

We have estimated the prevalence of TF and trichiasis in selected areas of Zimbabwe. Making data available on the epidemiology of trachoma at district level is the first critical step towards planning for the implementation of the SAFE strategy. Based on our results, 11 districts (69% of those districts surveyed) were confirmed to have active trachoma as a public health problem according to WHO guidelines, with prevalence of TF >5% in children aged 1–9 years (Table 3). Of 16 districts mapped, 3 (19%) had TF prevalence >10% and, according to WHO recommendations require implementation of the A, F and E components of SAFE for at least 3 years before re-survey. This is to say that these districts need to start MDA with azithromycin as soon as possible.

We found that TF was less likely to be found at higher altitudes, consistent with a recent systematic review of trachoma risk factors.[26] In addition, the decreasing risk of TF with increasing maximum annual temperatures has been reported before,[27] thought to be associated with decreased eye-seeking fly activity at higher temperatures.[28] However, decreasing fly activity at lower temperatures has also been used to explain the converse relationship.[26] The associations with TF found in this analysis may aid program managers to target perceived higher risk areas in Zimbabwe, although caution may be needed in that climate-related risk factors may associate with trachoma only in specific geographic locales.

These data show that there is a significant trichiasis surgery backlog that needs to be addressed, with the highest numbers of surgeries needed in Binga (1297), Gokwe North (854) and Gokwe South (662) districts (Table 6). These results confirm previous observations by ophthalmologists regarding the burden of trichiasis in Gokwe, in which a visiting cataract surgery outreach team was overwhelmed in 2015 by the number of individuals found to have trichiasis, and ended up performing more trichiasis than cataract surgeries. In districts with adjusted trichiasis prevalence ≥0.2% in adults, significant expansion of existing trichiasis surgical services is needed. In keeping with the known limitations of carrying out household surveys during the day, of those aged 15 years and greater, 62.0% of those examined were female. It has yet to be established whether those males who are missing from the surveys are representative of those who were included. This is a potential limitation, particularly when extrapolating survey results to population-level trichiasis estimates, and the significance of this may need to be established with further research. Further limitations of our work include the risk of multiple comparisons inflating the alpha error in the multivariable analysis, and the difficulty in ensuring consistent clinical grading over time, even with rigorous initial training. Although some believe that photography might have allowed more consistent grading across graders and time, as well as facilitating a process of auditing, there are inherent practical difficulties in reliably capturing large numbers of images from children who may not be enthusiastic about being examined,[29] in transmitting those images elsewhere using low bandwidth internet connections, and in having the pictures reviewed by suitably qualified graders.

Table 5 shows recommended intervention strategies in districts surveyed according to the population-level prevalence estimates of TF and trichiasis. Based on this analysis, significant efforts will be needed in Zimbabwe to implement the SAFE strategy in order to achieve elimination of trachoma as a public health problem by the year 2020.

Zimbabwe, by mapping trachoma in 16 districts to date, has made a much needed start towards generating the evidence base for planning a national trachoma program. We readily acknowledge, however, that our findings are only applicable to the districts studied here, and should not be interpreted as being representative of the country as a whole. An important corollary of this is that areas adjacent to the high-prevalence districts found in these surveys (Figure 1) should now be considered suspected endemic. Further efforts to more completely delineate the

endemic foci, and to put in place interventions where they are required, should now follow.

Declaration of interest

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

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Appendix

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