

## Prevalence of Risk Factors and Severity of Active Trachoma in Southern Sudan: An Ordinal Analysis

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**Abstract.** We aimed to investigate prevalence of potential risk factors, and associations between risk factors and active trachoma in southern Sudan. Surveys were undertaken in ten sites and children aged 1–9 years examined for trachoma. Risk factors were assessed through interviews and observations. Using ordinal logistic regression, associations between severity of active trachoma and risk factors were explored. Trachomatous inflammation-intense (TI) was considered more severe than trachomatous inflammation-follicular (TF). A total of 7,418 children were included in the analysis. Risk factors and prevalences were unclean face, 52.3%; face washed less than twice daily, 50.8%; water collection > 30 minutes, 38.1%; absence of latrines, 95.4%; garbage disposal within 20 m, 74.4%; cattle ownership, 69.2%; and flies, 83.3%. After adjusting for age and sex, unclean face, less frequent face washing, cattle ownership, and increasing fly density were found to be independently associated with severity of active trachoma. Our study suggests that facial hygiene and environmental sanitation are priority trachoma-control interventions in southern Sudan.

### INTRODUCTION

Trachoma is an eye disease caused by ocular infection with *Chlamydia trachomatis*, which can result in blindness after cycles of repeated infections. The evidence is substantial that trachoma transmission is associated with poor personal hygiene and environmental sanitation risk factors.<sup>1–3</sup> In southern Sudan, the nomadic nature of most communities has been suggested to be associated with flies, poor hygiene, and poor sanitation.<sup>4</sup> It is estimated that only 27% and 16% of the population in southern Sudan has access to improved water sources and sanitation facilities, respectively.<sup>5</sup> Trachoma risk-factor studies are needed to investigate the relative importance of transmission mechanisms in different communities because these may vary, reflecting differences in environment and cultures. Thus, to tailor delivery of appropriate interventions to address the facial hygiene and environmental sanitation (the “F” and “E” components of the SAFE strategy) for particular populations, risk factors for trachoma must be understood.

Trachoma occurs in stages with each grade corresponding to increasing disease severity.<sup>6</sup> The WHO simplified grading scheme is used extensively for clinical diagnosis of trachoma.<sup>7</sup> In the simplified grading scheme, trachomatous inflammation-follicular (TF) is defined as five or more follicles of 0.5 mm or greater on the tarsal conjunctiva, and trachomatous inflammation-intense (TI) is defined as pronounced thickening of the tarsal conjunctiva and inflammation that obscures > 50% of the underlying blood vessels. Both presenting signs, TF and TI, are considered “active trachoma,” although TI is more severe. Progression of active trachoma to trachomatous scarring (TS) has been found to be higher in children with persistent TI compared with TF.<sup>8</sup> Laboratory tests for *C. trachomatis* have demonstrated higher infection rates in persons with TI compared with TF.<sup>9</sup> Severity of TI compared with TF has further been underscored by quantitative polymerase

chain reaction (PCR) studies, which confirmed higher infection loads in persons with TI compared with TF.<sup>10,11</sup> The grades of active trachoma described in the simplified grading system are not exclusive and are frequently observed together as TF and TI. Published trachoma risk-factor studies have explored association of risk factors and dichotomous outcomes of one grade or a combination of both grades categorized together as “active trachoma.” The relationship between severity of active trachoma signs and risk factors has not yet been studied. The objectives of this study were to assess the prevalence of risk factors and to investigate the relationship between risk factors and severity of active trachoma signs based on an ordinal scale of disease progression where TI was considered more severe than TF.

### PARTICIPANTS AND METHODS

**Study population.** The sampling plan and trachoma grading have been described elsewhere.<sup>12,13</sup> In brief, population based cross-sectional surveys were conducted in ten sites in southern Sudan between 2001 and 2005. The study sites were selected on the basis of pragmatic program implementation criteria of (a) anecdotal reports of blinding trachoma; (b) security and accessibility; and (c) feasibility of initiating trachoma-control interventions after the survey. The targeted sample size was to allow for estimation of 50% prevalence of active trachoma in children of age 1–9 years; within a precision of 10% at 95% confidence limit and a design effect of 5 in each site. Using a two-stage cluster random sampling design, villages (clusters) were randomly selected in each site; and in each selected village, households (defined as persons eating daily from the same cooking pot) were selected by the random-walk method.<sup>14</sup> Only children of age 1–9 years were included in the sample.

**Severity of active trachoma signs.** Eligible children were examined for trachoma signs by integrated eye-care workers (IECW) using the WHO simplified grading scheme.<sup>7</sup> Trainee examiners had to achieve at least 80% interobserver agreement in identifying trachoma signs compared with the senior examiner to participate in the survey. Clinical signs of inflam-

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matory trachoma (TF and TI) were graded for each eye separately. An ordinal severity score of active trachoma comprising three categories was then assigned to all eligible subjects on the bases of the worst-affected eye: 1 = no TF, no TI; 2 = TF only; and 3 = TI with or without TF.

**Risk-factor measurement.** Structured interviews with mothers of children as principal household respondents and direct observations were used to measure personal and environmental (household) risk factors. Interviews were conducted by community health workers experienced in conducting household health interviews. Standard questionnaires were printed and precoded in English, and interviews were conducted in a variety of local languages. Prior to the survey, the questionnaire was translated and then back-translated in the field by two interviewers who were familiar with both English and the local languages to ensure its accuracy.<sup>15</sup> Interviewers were trained to standardize translation and completing of the questionnaire. The survey tool was then piloted in each study site in two villages that had not been sampled, to validate questions and observations.

**Personal factors.** *Age and sex.* The age and sex of each eligible child were recorded. Reported age was verified by health record cards when available, historical events calendar, or the mother's birth history.

*Unclean face.* Prior to screening for signs of trachoma, faces of children were briefly inspected for cleanliness and defined as "not clean" if nasal and/or ocular discharge were present. All other possible criteria were ignored.

**Household factors.** *Household crowding.* An index was derived on basis of the total number of individuals residing in the household: 1–5 members; 6–10 members; and > 10 members.

*Face washing frequency.* Frequency of washing children's faces was determined by asking the mother or caregivers the number of times children's faces were washed in a day and categorized as not washed, washed once, and washed two or more times daily.

*Access to water.* The person responsible for water collection reported on how long it took for a return journey to collect water from the main water source, including time spent in the queue. Water accessibility was analyzed in two categories:  $\leq 30$  minutes, and  $> 30$  minutes.

*Pit latrine.* Each household head was asked if there was a latrine in the household. The presence and usage of a latrine were confirmed by visual inspection.

*Garbage disposal.* The distance from the house to where the solid waste was disposed of was estimated and classified as  $\leq 20$  m or  $> 20$  m.

*Cattle ownership.* The household head was asked if the family owned cattle.

*Fly density.* In four study sites (Kongor, Mankien, Narus, and Kimotong), household-fly density was determined by examining the presence of flies on children's faces and around the doorways for about half a minute. Fly density was graded as none (0 flies), few (1–4 flies), or many ( $\geq 5$  flies).

**Statistical methods.** Descriptive statistics were used to examine the characteristics of the sample and prevalence of outcomes and risk factors. Differences in proportions were compared using chi-square test. To investigate the association between severity of active trachoma and risk factors, hierarchical regression models were developed using generalized linear models (GLMs).<sup>16</sup> The multilevel structure of

GLMs allowed for non-independence of the household variables, enabled clustering of individual observations within households, and allowed for variability at individual and household levels. We fitted an ordinal logistic regression model to study associations between risk factors and severity of active trachoma signs.<sup>17</sup> This model allowed for analysis of a polytomous ordinal response on a set of predictors and computed odds ratios (OR) of having a more severe active trachoma sign compared with a less severe sign. Univariate analysis was conducted for each potentially explanatory risk factor. Multivariable models were then developed by stepwise regression analysis for model selection. This involved starting with a null model then proceeding in a sequential fashion of adding/deleting explanatory variables if they satisfied the entry/removal criterion, which was set at 5% significance level using a log-likelihood ratio test. Age and sex were retained in all multivariable models to control for any potential confounding effects. Sensitivity analyses were conducted using conventional logistic regression, and multinomial logistic regression analysis that does not make the ordinal assumption. Statistical analysis was conducted using Stata 8.2 (Stata Corporation, College Station, TX).

**Ethical clearance.** The Institutional Review Board of Emory University approved the survey protocol, and clearance to conduct the surveys was obtained from the Sudan Peoples Liberation Movement Secretariat of Health (SPLM/Health). Verbal consent to participate was sought from the parents of children in accordance with the Declaration of Helsinki. Personal identifiers were removed from the data set before analyses were undertaken.

## RESULTS

### Demographic characteristics of the sample population.

Data on demographic characteristics, trachoma prevalence, and risk factors are shown in Table 1. A total of 7,418 children of age 1–9 years in 3,213 households were included in the analysis. In four sites where household fly density was assessed, 1,444 households were included in the analysis. Overall, the mean age was 4.7 years (SD, 2.8) years. The proportion of children of aged 1–4 years was higher than the mean proportion of the other locations in Mankien (58.2% versus 46.9%,  $P < 0.001$ ) and Narus (54.1% versus 48.2%,  $P = 0.002$ ) but lower in Boma (44.9% versus 49.3%,  $P = 0.015$ ) and Katigiri (41.2% versus 49.4%,  $P < 0.001$ ). The sex distribution of the sample was similar in all study sites except in Narus, where the proportion of girls was higher than the mean proportion of the other locations (57.9% versus 49.6%,  $P < 0.001$ ).

**Prevalence of active trachoma signs.** Overall, prevalence of active trachoma signs (TF and/or TI) was 64.5% (range, 41.7–87.8%). Prevalence of active trachoma severity scores was: no TF, no TI = 35.5% (range, 12.2–58.3%); TF only = 21.9% (range, 13.8–38.1%); and any TI = 42.6% (range, 23.8–64.2%).

**Prevalence of potential risk factors.** Unclean faces were observed in 52.3% (range, 18.1–81.1%) of children (Table 1). Boys had a higher prevalence of unclean faces compared with girls (54.9% versus 49.7%,  $P < 0.001$ ). Overall 46.6% (range, 16.4–77.3%) and 47.2% (range, 22.2–70.4%) of households had < 5 members and 6–10 members, respectively. Caregivers

TABLE 1  
 Characteristics of sample population, prevalence of active trachoma signs, and prevalence of potential risk factors by study site

Factor	Paluer	Padak	Kongor	Boma	Kiech Kuon	Mankien	Katigiri	Tali	Narus	Kimotong	Overall
Number of children of age 1-9 years	995	639	789	860	553	1,271	505	454	772	580	7,418
Prevalence of active trachoma signs (%)											
Active trachoma*	87.8	77.9	43.3	60.8	81.6	65.6	50.3	74.0	41.7	60.7	64.5
Trachoma severity score											
No TF, no TI	12.2	22.1	56.7	39.2	18.4	34.5	49.7	26.0	58.3	39.3	35.5
TF only	24.0	13.8	14.2	20.6	29.1	23.7	25.3	38.1	17.9	18.6	21.9
Any TI	63.8	64.2	29.2	40.2	52.4	41.9	25.0	35.9	23.8	42.1	42.6
Personal characteristics (%)											
Age group											
1-4 years	47.8	50.2	48.9	44.9	51.4	58.1	41.2	47.4	54.1	32.2	48.8
5-9 years	52.2	49.8	51.1	55.1	48.6	41.9	58.8	52.6	45.9	67.8	51.2
Sex											
Male	51.3	48.4	52.5	52.4	48.8	50.2	48.7	50.7	42.1	48.8	49.5
Female	48.7	51.6	47.5	47.6	51.2	49.8	51.3	49.3	57.9	51.2	50.5
Children with unclean faces (%)	79.6	81.1	18.1	68.8	60.8	67.2	30.0	51.5	18.9	19.5	52.3
Number of households	416	262	343	341	260	409	242	248	405	287	3,213
Household characteristics (%)											
Household crowding											
< 5 members	23.8	32.8	44.6	39.3	50.8	16.4	59.1	71.4	77.3	67.2	46.6
6-10 members	64.2	59.2	51.0	50.7	45.4	70.4	37.2	27.4	22.2	32.1	47.2
> 10 members	12.0	8.0	4.4	10.0	3.8	13.2	3.7	1.2	0.5	0.7	6.2
Daily face washing frequency											
≥ 2 times	57.0	76.0	80.8	11.7	44.2	39.1	45.0	36.3	46.9	57.5	49.2
1 time	40.6	21.8	17.8	55.1	50.4	52.3	53.7	59.7	52.1	34.5	41.3
None	2.4	2.3	1.5	33.1	5.4	28.6	1.2	4.0	1.0	8.0	9.5
Water access											
≤ 30 minutes	55.3	48.9	52.5	78.3	77.3	66.7	89.3	78.6	54.6	26.8	61.9
> 30 minutes	44.7	51.1	47.5	21.7	22.7	33.3	10.7	21.4	45.4	73.2	38.1
Pit latrine											
Yes	0.2	2.7	12.2	4.1	0	1.5	26.0	0	3.5	0.7	4.6
No	99.8	97.3	87.8	95.9	100	98.5	74.0	100	96.5	99.3	95.4
Garbage disposal from house											
> 20 m	17.5	53.1	43.4	26.7	21.2	25.2	17.8	5.6	9.1	41.5	25.6
≤ 20 m	82.5	46.9	56.6	73.3	78.8	74.8	82.2	94.4	90.9	58.5	74.4
Cattle ownership											
No	4.3	22.5	42.3	55.7	0.8	9.5	95.5	30.6	52.3	6.3	30.8
Yes	95.7	77.5	57.7	44.3	99.2	90.5	4.5	69.4	47.7	93.7	69.2
Household fly density†											
None (0)			23.6			0.5			26.4		17.7
Few flies (1-4)			51.0			31.5			61.0		48.7
Many flies (≥ 5)			25.4			68.0			12.6		33.6

\* TF, trachomatous inflammation-follicular; TI, trachomatous inflammation-intense.

† Household fly density assessed in 4 study sites only: 1,444 households with 3,412 children aged 1-9 years included in analysis.

of children in 90.5% of households reported washing children's faces one or more times per day. Reports of washing children's faces less than once per day were more common in Boma and Mankien (33.1% and 28.6%, respectively). Overall, unclean face was associated with reported lower frequency of face washing (OR = 2.1; 95% confidence interval [CI] 1.7–2.6;  $P_{\text{trend}} < 0.001$ ). The overall proportion of households reporting water access within 30 minutes was 61.9% (range, 26.8–89.3%). Pit latrines were observed in only 4.6% of households, with no latrines at all observed in Kiech Kuon or Tali. Overall, 25.6% (range, 5.6–53.1%) of households disposed of garbage > 20 m away from the house. The proportion of households reporting owning cattle was 69.2% (range, 4.5–99.2%). In four sites where fly density was recorded, 17.9% of 1,444 households had no flies while few (1–4) flies and many ( $\geq 5$ ) flies were observed in 48.7% and 33.6% of households, respectively.

**Association between severity of active trachoma signs and risk factors.** Results from univariate and multivariable ordinal regression models are shown in Tables 2 and 3, respectively. Univariate analysis showed that unclean face (OR = 5.2; 95% CI 4.5–5.9), household crowding ( $P_{\text{trend}} < 0.001$ ), less frequent face washing ( $P_{\text{trend}} < 0.001$ ), absence of pit latrine (OR = 2.3; 95% CI 1.6–3.3), cattle ownership (OR = 2.3; 95% CI 1.9–2.7), and increasing household fly density ( $P_{\text{trend}}$

< 0.001) were associated with increased relative odds of having a more severe active trachoma sign (no TF, no TI; TF only; and any TI); however, older age was associated with decreased odds (OR = 0.7; 95% CI 0.6–0.8).

Two multivariable models were fitted: the first assessed independent risk factors in all eligible children, and the second assessed effects of household fly density adjusting for variables found to be independent risk factors in the first model (Table 3). Multivariable analysis showed that age (OR = 0.8; 95% CI 0.7–0.9), unclean face (OR = 4.7; 95% CI 4.1–5.4), less frequent face washing ( $P_{\text{trend}} = 0.002$ ), cattle ownership (OR = 1.8; 95% CI 1.6–2.2), and increasing household fly density ( $P_{\text{trend}} = 0.002$ ) were independent predictors of increased odds of having a more severe active trachoma sign after adjusting for the effects of the other covariates. Sensitivity analysis by conventional logistic regression and multinomial logistic regression revealed odds ratios consistent with those presented in the ordinal analysis, and no new risk factors became apparent (data not shown).

## DISCUSSION

In this study, associations between risk factors and severity of active trachoma signs were modeled using ordinal logistic regression.<sup>17</sup> In the WHO simplified scheme, active trachoma is

TABLE 2

Univariate ordinal logistic regression analysis of association between severity of active trachoma (no TF, no TI; TF only; any TI) and potential risk factors\*

Factor	No. of children ( <i>n</i> = 7,418)	Prevalence (%)			Odds ratio	95% CI	<i>P</i> value
		No TF, no TI	TF only	Any TI			
Age group (years)							
1–4	3,620	32	23	45	1.0		
5–9	3,798	39	21	40	0.7	0.6–0.8	< 0.001
Sex							
Male	3,676	35	22	43	1.0		
Female	3,742	36	22	42	0.9	0.8–1.1	0.283
Unclean face							
No	3,541	52	20	28	1.0		
Yes	3,877	21	24	56	5.2	4.5–5.9	< 0.001
Household crowding							
1–5	2,570	40	21	39	1.0		
6–10	3,982	33	23	44	1.5	1.3–1.8	< 0.001
> 10	866	31	21	48	1.7	1.3–2.3	< 0.001
Face washing frequency							
$\geq 2$ times	3,697	38	22	39	1.0		
1 time	2,922	33	22	45	1.4	1.2–1.6	< 0.001
None	799	32	18	51	1.9	1.5–2.5	< 0.001
Water access							
$\leq 30$ minutes	4,631	36	23	42	1.0		
> 30 minutes	2,787	35	20	44	1.1	0.9–1.3	0.296
Pit latrine							
Yes	332	48	23	29	1.0		
No	7,086	35	22	43	2.3	1.6–3.3	< 0.001
Garbage disposal							
> 20 m	1,954	40	15	45	1.0		
$\leq 20$ m	5,464	34	25	42	1.2	1.0–1.4	0.102
Cattle ownership							
No	2,148	45	22	33	1.0		
Yes	5,270	32	22	46	2.3	1.9–2.7	< 0.001
Household fly density†							
None	524	59	14	27	1.0		
Few (1–4)	1,573	49	19	32	1.6	1.1–2.1	0.005
Many ( $\geq 5$ )	1,315	37	22	41	3.1	2.2–4.3	< 0.001

\* TF, trachomatous inflammation-follicular; TI, trachomatous inflammation-intense.

† Fly density: 1,444 households with 3,412 children aged 1–9 years included in analysis.

TABLE 3

Multivariable ordinal logistic regression analysis of risk factors for severity of active trachoma (no TF, no TI; TF only; any TI) adjusted for sex\*

Model†	Factor	Odds ratio	95% CI	P value
I. All eligible children	Age group (5–9 years)	0.8	0.7–0.9	< 0.001
	Unclean face	4.7	4.1–5.4	< 0.001
	Face washing (1 time)	1.3	1.1–1.5	$P_{\text{trend}} = 0.002$
	Face washing (none)	1.3	1.0–1.6	
	Cattle ownership	1.8	1.6–2.2	< 0.001
II. Household fly density	Few flies	1.3	1.0–1.8	$P_{\text{trend}} = 0.002$
	Many flies	1.7	1.2–2.4	

\* TF, trachomatous inflammation-follicular; TI, trachomatous inflammation-intense.

† Model I assessed independent risk factors in 7,418 children of age 1–9 years. Model II assessed effect of household fly density in 3,412 children adjusting for the effects of age, sex, unclean face, face washing and cattle ownership.

graded as trachomatous inflammation-follicular (TF) or as trachomatous inflammation-intense (TI). We used four arguments from the existing literature to justify classifying TI as being a more severe form of active trachoma than TF. Firstly, pathogenesis of trachoma is initially characterized by lymphoid follicles (stage TF), whereas papillary hypertrophy (stage TI) is seen with advancing severity.<sup>6</sup> Secondly, participants seen in longitudinal studies with persistent TI are more likely to progress to scarring (stage TS) than those with only TF.<sup>8</sup> Thirdly, patients with TI are more likely to provide ocular swabs positive for *C. trachomatis* than those with TF.<sup>9</sup> And fourthly, patients with TI provide ocular swabs that have a greater quantifiable load of *C. trachomatis* than those with TF.<sup>10,11</sup> Therefore, we used ordinal logistic regression, where TI was considered more severe than TF, which in turn is a more severe sign of trachoma than a normal conjunctiva. The method does not assume that TF causes TI or that the relationship between the three orders (normal, TF only, and any TI) is linear.

Ordinal logistic regression has advantages over the conventional logistic regression models that have been used previously. Earlier studies evaluating risk factors for active trachoma signs have either conducted subgroup analysis of dichotomous outcomes “TF or not” and “TI or not,” or have grouped TF and TI together as a single outcome “active trachoma or not.” These approaches have been accepted but have limitations that do not allow full exploitation of the information in the available data. Individuals may have both TF and TI at the same time, such that using dichotomous outcomes introduces multiple hypotheses testing in overlapping subgroups of the sample. Dichotomization of the outcomes is a data reduction technique and yields an odds ratio that may not represent the true relationship between the two active trachoma grades and the risk factors. Use of ordinal logistic regression produces a single summary of effect estimate over both levels of active trachoma signs, which is more precise.

Although more precise than previous risk-factor analyses for active trachoma, the results of our study are consistent with the existing literature.<sup>1–3</sup> Factors independently associated with severity of active trachoma signs were young age, unclean face, face washing less than twice daily, household cattle ownership, and a high household fly density. These findings provide essential baseline data that can be used in the design of interventions and specific activities relevant to southern Sudan. Unclean face and young age were the most important risk factors in our study. Interventions designed to

improve facial cleanliness in children under 5 years of age should be implemented. These should probably focus on behavior change promoting face washing among mothers and the older children (who are also caregivers) and on changing attitudes to facial cleanliness among men and the decision makers. Village-based health education can be effective in increasing the prevalence of clean faces in children but is likely to be undermined if water is scarce.<sup>18</sup> Water was generally accessible within a 30-minute round-trip in five of the ten locations surveyed and for 60% of the households overall, indicating that the ways in which water is used may be more important than its availability. This has also been observed in The Gambia<sup>19</sup> and Tanzania<sup>20,21</sup> and should be amenable to change with health education. In locations where water is scarce, the program will need to promote face washing with small quantities of water<sup>22</sup> and to advocate for provision of water.

Our study also found independent associations between severity of active trachoma signs with cattle ownership and household fly density. The high prevalence of flies documented in this study is likely to be a result of people living in close proximity with cattle and the very low access to latrines (less than one in 20 households overall). In the absence of latrines, the usual method of human feces disposal is open defecation in the bush between households and surrounding the villages. Human feces and, to a lesser extent, cattle dung are known to be the preferred breeding media for the fly vector of trachoma, *Musca sorbens*.<sup>23,24</sup> In addition, anecdotal evidence suggests that people who keep cattle close to the house dispose of human feces in the cattle pens, thus providing a favorable breeding environment for of *M. sorbens*. Use of pit latrines and improving sanitary conditions in areas shared by cattle and humans are likely to have a great impact in reducing fly-mediated transmission of trachoma.<sup>2</sup> Low socioeconomic status has been associated with active trachoma in risk-factor analyses conducted in many trachoma-endemic countries, including Malawi,<sup>25</sup> Ethiopia,<sup>26,27</sup> Brazil,<sup>28</sup> and Nepal.<sup>29</sup> The communities surveyed in this study from southern Sudan were characterized by extreme poverty, with > 90% of the population living on < 1 USD per day.<sup>5</sup>

Although the risk factors for trachoma are considered individually in this study, in practice, the complex interplay of these determinants is responsible for creating the overall epidemiologic environment conducive for hyperendemic blinding trachoma. Our results suggest that in southern Sudan, trachoma transmission is a function of poor facial hygiene, poor environmental sanitation, eye-seeking flies, and the high

number of children with TI who form a formidable reservoir of infection. However, the relative attributable risks of transmission for each factor cannot be estimated. Further sociological studies would allow enhanced understanding of local customs, beliefs, practices, and circumstances as well as identification of possible barriers and solutions to poor facial hygiene and environmental sanitation in this population. However, delivery of the full SAFE strategy for trachoma control, which uses surgery to prevent vision loss due to trichiasis, antibiotics to reduce the community chlamydial load, hygiene promotion and health education to increase facial cleanliness and participation in antibiotic distribution, and provision of water and sanitation as the hardware to enhance hygiene and reduce eye-seeking flies, could be expected to be effective without further research.

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## REFERENCES

1. Prüss A, Mariotti SP, 2000. Preventing trachoma through environmental sanitation: a review of the evidence base. *Bull World Health Organ* 78: 258–266.
2. Emerson PM, Cairncross S, Bailey RL, Mabey DC, 2000. Review of the evidence base for the “F” and “E” components of the SAFE strategy for trachoma control. *Trop Med Int Health* 5: 515–527.
3. Frick KD, Mecaskey JW, 2002. Resource allocation to prevent trachomatous low vision among older individuals in rural areas of less developed countries. *Doc Ophthalmol* 105: 1–21.
4. Tizazu T, Mburu FM, 1983. Prevalence and causes of vision loss in southern Sudan. *Soc Sci Med* 17: 1785–1788.
5. New Sudan Center for Statistics and Evaluation/UNICEF, 2004. *Towards a Baseline: Best Estimates of Social Indicators for Southern Sudan*. Available at: <http://www.unsudanig.org/docs/Towards%20A%20Baseline%20Best%20Estimates%20of%20Social%20Indicators%20for%20Southern%20Sudan,%202004,%20NSCSE,%20UNICEF.pdf>. Accessed October 20, 2005.
6. MacCallan A, 1931. The epidemiology of trachoma. *Br J Ophthalmol* 15: 369–411.
7. Thylefors B, Dawson C, Jones B, West S, Taylor H, 1987. A simple system for the assessment of trachoma and its complications. *Bull World Health Organ* 65: 477–483.
8. West SK, Muñoz B, Mkocho H, Hsieh YH, Lynch MC, 2001. Progression of active trachoma to scarring in a cohort of Tanzanian children. *Ophthalmic Epidemiol* 8: 137–144.
9. Solomon AW, Peeling RW, Foster A, Mabey DC, 2004. Diagnosis and assessment of trachoma. *Clin Microbiol Rev* 17: 982–1011.
10. Solomon AW, Holland MJ, Burton MJ, West SK, Alexander ND, Aguirre A, Massae PA, Mkocho H, Muñoz B, Johnson GJ, Peeling RW, Bailey RL, Foster A, Mabey DC, 2003. Strategies for control of trachoma: observational study with quantitative PCR. *Lancet* 362: 198–204.
11. Burton MJ, Holland MJ, Faal N, Aryee EA, Alexander ND, Bah M, Faal H, West SK, Foster A, Johnson GJ, Mabey DC, Bailey RL, 2003. Which members of a community need antibiotics to control trachoma? Conjunctival *Chlamydia trachomatis* infection load in Gambian villages. *Invest Ophthalmol Vis Sci* 44: 4215–4222.
12. Ngondi J, Onsarigo A, Adamu L, Matende I, Baba S, Reacher M, Emerson P, Zingesser J, 2005. The epidemiology of trachoma in Eastern Equatoria and Upper Nile States, southern Sudan. *Bull World Health Organ* 83: 904–912.
13. Ngondi J, Ole-Sempele F, Onsarigo A, Matende I, Baba S, Reacher M, Matthews F, Brayne EP, 2006. Blinding trachoma in post-conflict southern Sudan. *PLoS Med* 3: e478.
14. World Health Organization, 1991. *Training for Mid-level Managers: The EPI Coverage Survey*. Geneva: WHO. WHO document WHO/EPI/MLM/91.10.
15. Armstrong BK, White E, Saracci R, 1992. The design of questionnaires. *Principles of Exposure Measurement in Epidemiology*. New York: Oxford University Press, 137–168.
16. McCullagh P, Nelder J, 1989. *Generalized Linear Models*. New York: Chapman and Hall.
17. Hosmer D, Lemeshow S, 2000. *Applied Logistic Regression*. New York: John Wiley & Sons, Inc.
18. Ngondi J, Onsarigo A, Matthews F, Reacher M, Brayne C, Baba S, Solomon AW, Zingesser J, Emerson PM, 2006. Effect of 3 years of SAFE (surgery, antibiotics, facial cleanliness, and environmental change) strategy for trachoma control in southern Sudan: a cross-sectional study. *Lancet* 368: 589–595.
19. Bailey R, Downes B, Downes R, Mabey D, 1991. Trachoma and water use; a case control study in a Gambian village. *Trans R Soc Trop Med Hyg* 85: 824–828.
20. Polack S, Kuper H, Solomon AW, Massae PA, Abuelo C, Cameron E, Valdmanis V, Mahande M, Foster A, Mabey D, 2006. The relationship between prevalence of active trachoma, water availability and its use in a Tanzanian village. *Trans R Soc Trop Med Hyg* 100: 1075–1083.
21. West S, Lynch M, Turner V, Muñoz B, Rapoza P, Mmbaga BB, Taylor HR, 1989. Water availability and trachoma. *Bull World Health Organ* 67: 71–75.
22. McCauley AP, Lynch M, Pounds MB, West S, 1990. Changing water-use patterns in a water-poor area: lessons for a trachoma intervention project. *Soc Sci Med* 31: 1233–1238.
23. Hafez M, Attia M, 1958. Studies on the ecology of *Musca sorbens* Wied. in Egypt. *Bull Soc Entomol Egypte* 42: 83–121.
24. Emerson PM, Bailey RL, Walraven GE, Lindsay SW, 2001. Human and other faeces as breeding media of the trachoma vector *Musca sorbens*. *Med Vet Entomol* 15: 314–320.
25. Tielsch JM, West KP Jr, Katz J, Keyvan-Larijani E, Tizazu T,

- Schwab L, Johnson GJ, Chirambo MC, Taylor HR, 1988. The epidemiology of trachoma in southern Malawi. *Am J Trop Med Hyg* 38: 393-399.
26. Zerihun N, 1997. Trachoma in Jimma zone, south western Ethiopia. *Trop Med Int Health* 2: 1115-1121.
  27. Sahlu T, Larson C, 1992. The prevalence and environmental risk factors for moderate and severe trachoma in southern Ethiopia. *J Trop Med Hyg* 95: 36-41.
  28. Luna EJ, Medina NH, Oliveira MB, de Barros OM, Vranjac A, Melles HH, West S, Taylor HR, 1992. Epidemiology of trachoma in Bebedouro State of Sao Paulo, Brazil: prevalence and risk factors. *Int J Epidemiol* 21: 169-177.
  29. Katz J, West KP Jr, Khatry SK, LeClerq SC, Pradhan EK, Thapa MD, Ram SS, Taylor HR, 1996. Prevalence and risk factors for trachoma in Sarlahi district, Nepal. *Br J Ophthalmol* 80: 1037-1041.