Transactions of the Royal Society of Tropical Medicine and Hygiene (2008) **102**, 432—438

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Risk factors for active trachoma in children and trichiasis in adults: a household survey in Amhara Regional State, Ethiopia

Jeremiah Ngondi [a,b,*], Teshome Gebre [c], Estifanos B. Shargie [c], Patricia M. Graves [a], Yeshewamebrat Ejigsemahu [c], Tesfaye Teferi [c], Asrat Genet [d], Aryc W. Mosher [a], Tekola Endeshaw [c], Mulat Zerihun [c], Ayenew Messele [c], Frank O. Richards Jr [a], Paul M. Emerson [a]

[a] *The Carter Center, 1 Copenhill Avenue, Atlanta, GA 30307, USA*
[b] *Department of Public Health and Primary Care, Institute of Public Health, University of Cambridge, Robinson Way, Cambridge CB2 0SR, UK*
[c] *The Carter Center, P.O. Box 13373, Woreda 17, Kebele 19, Addis Ababa, Ethiopia*
[d] *Amhara Regional Health Bureau, P.O. Box 495, Bahir Dar, Ethiopia*

Received 21 October 2007; received in revised form 19 February 2008; accepted 19 February 2008

KEYWORDS
Trachoma;
Trichiasis;
Active trachoma;
Risk factors;
Prevention and control;
Ethiopia

Summary Identification of risk factors is essential for planning and implementing effective trachoma control programmes. We aimed to investigate risk factors for active trachoma and trichiasis in Amhara Regional State, Ethiopia. A survey was undertaken and eligible participants (children aged 1—9 years and adults aged 15 years and above) examined for trachoma. Risk factors were assessed through interviews and observations. Using ordinal logistic regression, associations between signs of active trachoma in children and potential risk factors were explored. Associations between trichiasis in adults and potential risk factors were investigated using conventional logistic regression. A total of 5427 children from 2845 households and 9098 adults from 4039 households were included in the analysis. Ocular discharge [odds ratio (OR) = 5.9; 95% CI 4.8—7.2], nasal discharge (OR = 1.6; 95% CI 1.3—1.9), thatch roof in household (OR = 1.3; 95% CI 1.0—1.5), no electricity in household (OR = 2.4; 95% CI 1.3—4.3) and increasing altitude ($P_{trend} < 0.001$) were independently associated with severity of active trachoma. Trichiasis was associated with increasing age ($OR_{per\ 5\ year\ increase} = 1.5$; 95% CI 1.4—1.7), female gender (OR = 4.5; 95% CI 3.5—5.8), increasing prevalence of active trachoma in children ($P_{trend} = 0.003$) and increasing altitude ($P_{trend} = 0.015$).

* Corresponding author. Tel.: +44 0 122 376 3929; fax: +44 0 122 333 0330.
E-mail address: jn250@cam.ac.uk (J. Ngondi)

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doi:10.1016/j.trstmh.2008.02.014

1. Introduction

Trachoma is associated with individual and environmental risk factors: facial cleanliness; eye-seeking flies; crowding; water access and water use; face washing; pit latrines; cattle ownership/cohabitation; garbage disposal and socio-economic status (Emerson et al., 2000a; Pruss and Mariotti, 2000). The environmental risk factors may vary between settings, hence the need for risk factor studies to identify factors relevant to specific environments. Understanding risk factors is essential in designing appropriate interventions for the 'F' and 'E' components of the SAFE strategy (Surgery, Antibiotics, Facial cleanliness and Environmental improvements). Numerous trachoma risk factor studies have been conducted in Ethiopia: Gurage zone (Alemayehu et al., 2005; Melese et al., 2004; Taye et al., 2007); Jimma zone (Zerihun, 1997); Wolayita Sodo (Regassa and Teshome, 2004); North Gondar zone (Alene and Abebe, 2000); Gurage, Oromia and South Welo zones (Cumberland et al., 2005); Hiran, Shewa and Sidamo regions (De Sole, 1987); Sidamo region (Sahlu and Larson, 1992); Kambata Tembaro zone (Haileselassie and Bayu, 2007); and Dalocha district (Bejiga and Alemayehu, 2001). However, these previous risk factor studies were limited to small geographic areas and therefore it is difficult to generalise their findings.

A recent national survey of blindness in Ethiopia revealed that Amhara region had the highest prevalence of both active trachoma in children aged 1–9 years (62.6%) and trichiasis in adults aged 15 years and above (5.2%) (Berhane et al., 2006). Despite trachoma being such a serious public health problem in Amhara, only limited risk factor studies have been conducted previously (Alene and Abebe, 2000). In December 2006 and January 2007 we conducted a state-wide trachoma prevalence survey to facilitate planning of trachoma control interventions in the entire Amhara Regional State (Emerson et al., 2008). We also aimed to investigate potential risk factors associated with trachoma in order to tailor delivery of the SAFE strategy in Amhara. The specific objectives for this risk factor study were to explore the associations between potential risk factors and active trachoma in children aged 1–9 years and associations between potential risk factors and trichiasis in adults.

2. Methods

2.1. The study population

The sampling plan and trachoma grading have been described elsewhere (Emerson et al., 2008). A population-based cross-sectional survey was conducted between December 2006 and January 2007 in each of the ten zones that comprise Amhara region, located in north-western Ethiopia. A multistage cluster random sampling design was used to select 160 clusters, each of 25 households, to give a sample of 4000 households. Clusters were defined as kebeles. All eligible participants in the selected households were examined for trachoma. In accordance with the WHO trachoma prevalence indicators (Solomon et al., 2006), only children aged 1–9 years were included in the analysis of risk factors for active trachoma while adults aged 15 years and above were included in analysis of risk factors for trichiasis (Figure 1). In total, there were 5427 eligible children aged 1–9 years from 2845 households and 9098 adults aged 15 years and above from 4039 households included in the analysis. There were no children aged 1–9 years living in 1194 of the surveyed households.

2.2. Trachoma examination

Eligible participants were examined for trachoma signs by integrated eye care workers (IECW) using the WHO simplified

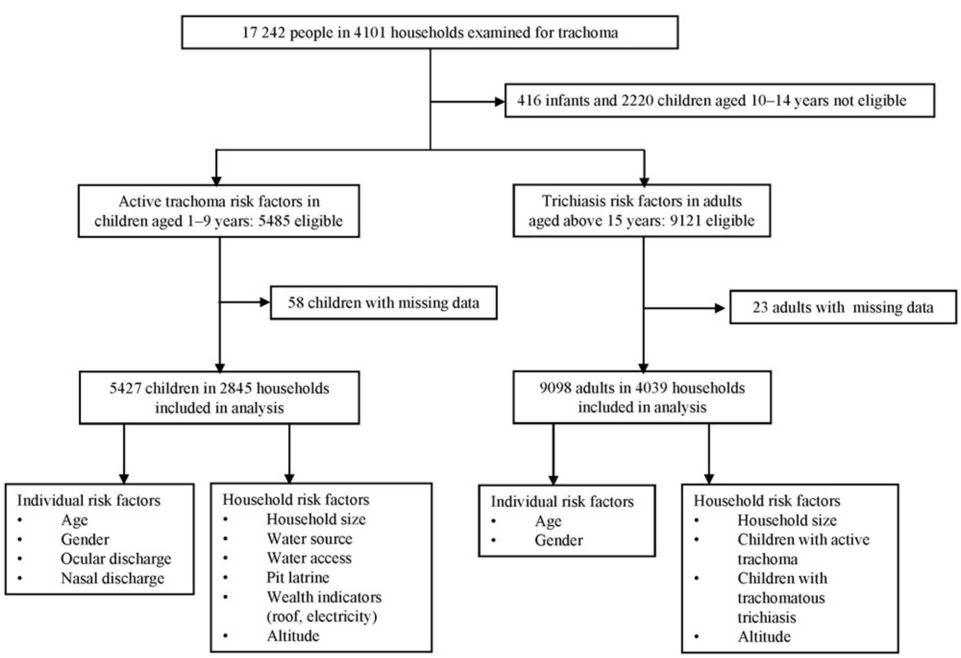

Figure 1 Profile of the sample population.

grading scheme (Thylefors et al., 1987). Trainee examiners had to achieve at least 80% inter-observer agreement in identifying trachoma signs compared to the senior examiner to participate in the survey. Clinical signs of active trachoma, trachomatous inflammation-follicular (TF) and trachomatous inflammation-intense (TI), were graded for each eye separately. An ordinal severity score of active trachoma comprising three categories was then assigned to all eligible children based on the worst affected eye: where '1' was no TF, no TI; '2' TF only; and '3' TI with or without TF (Ngondi et al., 2007). Eligible adults aged 15 years and above were assigned a dichotomous outcome for trachomatous trichiasis (TT) based on the worst affected eye. TT was defined as the presence of at least one eyelash touching the eyeball or evidence of epilation of eyelashes.

2.3. Risk factor measurement

Structured interviews with heads of household and observations were used to measure individual and household risk factors. Interviewers were health workers experienced in conducting household health interviews. Prior to the survey, the questionnaire was translated and printed in the Amharic language and field tested in a non-survey cluster to determine the validity of the pre-coded answers. During household interviews, respondents were asked about: their source of drinking water; time to collect water; toilet facilities and proxy indicators of wealth. We defined the source of drinking water as being 'safe' if it was a capped spring, protected hand-dug well, tube well, borehole, cart with small tank or piped water. Other water sources were described as 'unsafe' and were unprotected springs; unprotected hand-dug wells and surface water. Latrine presence, if reported, was verified by observation. Our proxy indicators of wealth were electrification of the household and roof construction material for the main dwelling. Altitude was measured for each household using a Global Positioning System device (eTrex GPS Personal Navigator, Garmin International, Olathe, KS, USA). Prior to screening for signs of trachoma, faces of children were briefly inspected for ocular discharge and nasal discharge. Ocular discharge was defined as any material of any colour or consistency in the corner of the eyes or matting of the eyelashes caused by such a discharge (tears, medication and make-up were excluded). Nasal discharge was defined as the presence of dry exudates of any colour below one or both nostrils.

2.4. Statistical analysis

Statistical analysis was conducted using Stata 8.2 (Stata Corp., College Station, TX, USA). Distribution of trachoma prevalence and risk factors were assessed using contingency tables and χ^2 tests, while differences in means were compared using *t* tests. To investigate the association between trachoma (active trachoma and trichiasis) and risk factors, hierarchical regression models were developed using generalized linear models (GLM) (McCullagh and Nelder, 1989). The multilevel structure of GLM allowed for non-independence of the household variables, enabled clustering of individual observations within households and allowed for variability at individual, household and kebele levels. We fitted an ordinal logistic regression model to study associations between risk factors and severity of active trachoma signs (Hosmer and Lemeshow, 2000). 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 to a less severe sign. Risk factors for trichiasis were explored using conventional logistic regression for dichotomous outcomes. 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. Potential confounding effects were minimized by retaining age and gender in all multivariable models.

2.5. Ethical considerations

Verbal informed consent to participate in interviews and trachoma screening was sought from the heads of the household, each individual and the parents of children aged 10 years and younger in accordance with the tenets of the declaration of Helsinki. Personal identifiers were removed from the data set before analyses were undertaken.

3. Results

3.1. Characteristics of study participants and prevalence of trachoma

Figure 1 summarises the sample population. A total of 5427 children aged 1—9 years were included in the risk factor analysis for active trachoma. The mean age of children was 4.9 years (SD 2.4); however, mean age was slightly lower amongst boys compared to girls (4.8 vs. 5.0 years; *t* test, $P = 0.003$). There was no difference in the proportion of boys compared to girls. Prevalence of active trachoma severity scores was: no TF, no TI = 53.2%; TF only = 24.9%; and any TI = 21.9%. Trichiasis risk factors were assessed in 9098 people aged 15 years and above with a mean age of 34.9 years (SD 15.7). There were differences in the mean age between males (36.6 years) and females (33.5 years) aged 15 years and above (*t* test, $P < 0.001$); and the proportion of females (57.0%) was higher than males. Prevalence of TT in persons aged 15 years and above was 6.0%.

3.2. Association between severity of active trachoma signs and risk factors

Results from univariable and multivariable ordinal logistic regression models are shown in Tables 1 and 2, respectively. Univariable analysis showed that ocular discharge (OR = 7.3; 95% CI 6.1—8.6), nasal discharge (OR = 4.0; 95% CI 3.3—4.9), increasing household size ($P_{trend} = 0.022$), unsafe water source (OR = 1.4; 95% CI 1.1—1.8), thatch roof (OR = 1.3; 95% CI 1.1—1.6), no electricity in household (OR = 4.1; 95% CI 2.3—7.5) and increasing altitude

Table 1 Univariable ordinal logistic regression analysis of association between severity of active trachoma (no TF, no TI; TF only; any TI) and potential risk factors for trachoma

Risk factor	Total children ($n=5427$)	Prevalence (%)			Odds ratio	95% CI	*P*-value
		No TF, no TI	TF only	Any TI			
Age (per additional year)					1.0	0.9—1.0	<0.001
Gender							
Male	2733	54	25	21	1.0		
Female	2694	52	25	23	1.1	1.0—1.3	0.073
Ocular discharge							
No	4052	65	19	17	1.0		
Yes	1375	19	43	38	7.3	6.1—8.6	<0.001
Nasal discharge							
No	4262	59	23	18	1.0		
Yes	1165	33	32	35	4.0	3.3—4.9	<0.001
Household size (per additional person)					1.1	1.0—1.2	0.022
Type of water source							
Safe	3632	51	26	24	1.0		
Unsafe	1795	58	23	18	1.4	1.1—1.8	0.003
Time to water source (min)							
≤30	3823	54	23	23	1.0		
>30	1604	50	30	20	1.2	0.9—1.5	0.164
Pit latrine							
Yes	1424	52	24	24	1.0		
No	4003	54	25	21	0.9	0.8—1.2	0.619
Type of roof							
Tin	2147	56	25	19	1.0		
Thatch	3280	51	25	24	1.3	1.1—1.6	0.007
Electrification of household							
Yes	185	79	14	7	1.0		
No	5242	52	25	22	4.1	2.3—7.5	<0.001
Altitude (m)							
<1000—1500	646	68	21	11	1.0		$P_{trend} < 0.001$
1501—2000	2086	58	23	19	1.8	1.2—2.8	
2001—2500	2267	47	27	26	3.2	2.1—4.8	
>2500	428	38	29	32	5.4	3.1—9.5	

TF: trachomatous inflammation-follicular; TI: trachomatous inflammation-intense.

Table 2 Multivariable ordinal logistic regression analysis, adjusted for age and gender, of risk factors for severity of active trachoma (no TF, no TI; TF only; any TI)

Risk factor	Odds ratio	95% CI	*P*-value
Ocular discharge	5.9	4.8—7.2	<0.001
Nasal discharge	1.6	1.3—1.9	<0.001
Thatch roof	1.3	1.0—1.5	0.022
No electrification of household	2.4	1.3—4.3	0.004
Altitude (m)			
<1500—2000	1.8	1.2—2.6	$P_{trend} < 0.001$
2001—2500	2.7	1.8—4.1	
>2500	3.8	2.3—6.4	

TF: trachomatous inflammation-follicular; TI: trachomatous inflammation-intense.

Table 3 Univariable logistic regression analysis of the association between trichiasis and potential risk factors

Risk factor	Total adults ($n = 9098$)	Adults with TT ($n = 542$)	Prevalence of TT (%)	Odds ratio	95% CI	P-value
Age (per 5-year increase in age)				1.4	1.4—1.5	<0.001
Gender						
Male	3910	136	3	1.0		
Female	5188	406	8	2.5	2.0—3.1	<0.001
Household size (per additional person)				0.8	0.7—0.9	<0.001
Children <15 years with TT in household						
No	9043	534	6	1.0		
Yes	55	8	15	2.8	1.1—7.4	0.036
Proportion of children aged 1—9 years with active trachoma in household (%)						
0 to ≤25	3022	129	4	1.0		
>25 to ≤75	1577	73	5	1.1	0.8—1.5	$P_{trend} < 0.001$
>75	4499	340	8	1.9	1.5—2.4	
Altitude (m)						
<1000—1500	1111	37	3	1.0		$P_{trend} = 0.002$
1501—2000	3450	190	6	1.8	1.2—2.8	
2001—2500	3750	275	7	2.5	1.6—3.9	
>2500	787	40	5	1.6	0.9—2.8	

TT: trachomatous trichiasis.

($P_{trend} < 0.001$) were associated with increased relative odds of having a more severe active trachoma sign (no TF, no TI; TF only; and any TI). Increasing age (per additional year) was associated with reduced odds of active trachoma ($P_{trend} < 0.001$).

Multivariable analysis showed that ocular discharge (OR = 5.9; 95% CI 4.8—7.2), nasal discharge (OR = 1.6; 95% CI 1.3—1.9), thatch roof (OR = 1.3; 95% 1.0—1.5), no electricity in household (OR = 2.4; 95% 1.3—4.3) and increasing altitude ($P_{trend} < 0.001$) were independent predictors of increased odds of having a more severe active trachoma sign after adjusting for the effects of age and gender.

3.3. Association between trichiasis and risk factors

Tables 3 and 4 summarise the univariable and multivariable logistic regression of associations between trichiasis and potential risk factors, respectively. Univariable analysis showed that increasing age ($OR_{per\ 5\ year\ increase} = 1.4$; 95% CI 1.4—1.5), female gender (OR = 2.5; 95% CI 2.0—3.1), children with trichiasis in the household (OR = 2.8; 95% CI 1.1—7.4), increasing proportion of children with active trachoma ($P_{trend} < 0.001$) and increasing altitude ($P_{trend} = 0.002$) were associated with increased odds of trichiasis. Multivariable analysis showed that increasing age ($OR_{per\ 5\ year\ increase} = 1.5$; 95% CI 1.4—1.7), female gender (OR = 4.5; 95% 3.5—5.8), increasing proportion of children with active trachoma ($P_{trend} = 0.003$) and increasing altitude ($P_{trend} = 0.015$) were independent predictors of increased odds of trichiasis.

4. Discussion

In this large trachoma risk factor study in Amhara Regional State of Ethiopia we found active trachoma in children to be independently associated with ocular discharge, nasal discharge, proxy indicators of low socio-economic status in households (thatch roof and no electrification) and increasing altitude. Trachomatous trichiasis in adults was

Table 4 Multivariable logistic regression analysis of risk factors for trichiasis

Risk factor	Odds ratio	95% CI	P-value
Age (per 5-year increase)	1.5	1.4—1.7	<0.001
Female gender	4.5	3.5—5.8	<0.001
Proportion of children aged 1—9 years with active trachoma in household (%)			
>25 to ≤75	1.4	1.0—2.1	$P_{trend} = 0.003$
>75	1.5	1.2—2.0	
Altitude (m)			
<1500—2000	1.7	1.1—2.9	$P_{trend} = 0.015$
2001—2500	2.5	1.5—4.1	
>2500	1.4	0.7—2.6	

independently associated with increasing age, female gender, increasing prevalence of active trachoma in children in the household and increasing altitude. We did not find any associations between active trachoma and time to collect water or between household ownership and use of pit latrines, probably due to the homogeneous prevalence of hyperendemic trachoma in Amhara region.

We found higher odds of active trachoma in households using unsafe water sources; however, active trachoma was not associated with time taken to collect water. The quantity of water allocated for hygiene purposes has been suggested to be a more important predictor of active trachoma compared to household access to water and the absolute amount of water used in the household (Bailey et al., 1991; Polack et al., 2006; West et al., 1989). Therefore, the association between unsafe water sources and increased risk of active trachoma seen in our study suggests that households using these unsafe water sources may be collecting less water overall and probably have a reduced opportunity to allocate it for hygiene purposes.

Our survey revealed that pit latrines were present in 24.3% of households in Amhara (Emerson et al., 2008). By contrast, Alene and Abebe (2000) documented no household latrines in 414 households sampled in 1998 in Jangua Mariam locality of North Gondar zone. Less than 4% of households had access to any form of sanitation in Amhara by 2004 and the striking increase in household latrine coverage is probably due to recent pit latrine construction following intensive community mobilization advocated as part of the SAFE strategy in Amhara region since 2004 (O'Loughlin et al., 2006). Two previous trachoma risk factor studies from Ethiopia have documented lower odds of active trachoma in children living in households with pit latrines compared to households without pit latrines (Cumberland et al., 2005; Zerihun, 1997). In addition, reviews of the literature suggest that latrines are associated with reduced risk of active trachoma (Emerson et al., 2000a; Pruss and Mariotti, 2000). However, we did not find any evidence of a protective effect of pit latrines against active trachoma in our study. This lack of 'latrine effect' observed in our study could be the result of the homogenous high prevalence of active trachoma in Amhara or the relatively recent increase in pit latrine access. Nonetheless, pit latrines remain important in reducing open human faeces, the main breeding medium for trachoma fly vector *Musca sorbens* (Emerson et al., 2000b, 2001) and this is likely to be associated with reduced transmission of trachoma among these trachoma hyperendemic communities in the future.

The presence of clearly defined ocular and nasal discharge were both associated with increasing severity of active trachoma in this study. It can be argued that such discharges are risk factors for both the acquisition and transmission of trachoma since they are associated with increased frequency of fly-eye contacts by the trachoma vector *M. sorbens* (Emerson et al., 2000b). Yet clinical activity may also contribute to production of the discharge. The balance between cause and effect is not clear and of lesser programmatic relevance than the absence of ocular and nasal discharge.

Consistent with the findings of Melese et al. (2004), our study found evidence suggestive of household clustering of trichiasis. Adults residing in households where there were children aged less than 15 years with trichiasis had a three-fold increase in the odds of having trichiasis, although this association had a wide confidence interval. True clustering of trichiasis by household could be due to environmental or genetic factors and merits further study. Our study also suggests increased risk of trichiasis in adults with close contact with children with active trachoma, especially among women. Therefore, reduction in active trachoma among children through implementation of the full SAFE strategy should be anticipated not only to lower the risk of scarring complications in the children later in life but will probably decrease the infection pool and the risk of progression from trachomatous scarring to trichiasis in adults.

Unlike previous studies reporting decreasing prevalence of trachoma in children in altitudes increasing from 1800 m to over 3000 m in Gurage zone, Oromya Regional State (Alemayehu et al., 2005; Haileselassie and Bayu, 2007; Sahlu and Larson, 1992; Taye et al., 2007), we found increasing prevalence of active trachoma and trichiasis with increasing altitude. We measured altitude for each household while the other studies measured altitude at the village level. Our study differs over previous studies since we had a larger sample (160 clusters of 25 households) thus providing a fairly large sample for each altitude stratum. The range of altitudes in Amhara was from 509 m to over 3040 m, compared to 1800 m to over 3000 m in Gurage. Alemayehu et al. (2005) suggested that the decline in trachoma prevalence seen at altitudes of over 2500 m was associated with a decline in the frequency of fly-eye contacts made by the trachoma vector *M. sorbens*. This was investigated further by Taye et al. (2007) who found that the intensity of fly-eye contacts by *M. sorbens* decreased by altitude strata: median 9.5 (interquartile range 0—32) contacts per ten minutes at 1800—2000 m; 6 (0—64) at 2200—2500 m; and 0 (0—0) at >3000 m. The suggestion that altitude can be used as a marker for mapping trachoma in Ethiopia is probably not valid since the effect appears to be limited to the very highest areas where altitude exceeds 3000 m (Alemayehu et al., 2005). In Amhara, we found high prevalence of trachoma at all altitudes, while households living at relatively higher altitudes were found to be at a particularly high risk for both active trachoma and trichiasis. It is possible that altitude in Amhara is associated with other environmental or socio-economic factors not captured by our survey; nonetheless, the relationship between increasing prevalence of trachoma and increasing altitude requires further investigation.

In conclusion, this study found active trachoma in children to be independently associated with ocular discharge, nasal discharge, proxy indicators of low socio-economic status and increasing altitude, while trichiasis was independently associated with increasing age, female gender, increasing prevalence of active trachoma in children and increasing altitude.

Authors' contributions: PME, EBS, PMG, YE, TG, AWM and FOR designed the survey; EBS, YE, TG, TT, AG, TE, MZ, AM and AWM supervised and conducted field work; JN, PMG and YE supervised data management, cleaning, and production of the analysis data set; JN, PME and PMG conducted the analysis; JN, PME and PMG drafted the manuscript, which all authors edited and approved. JN is guarantor of the paper.

Acknowledgements: We thank the MALTRA project coordinators Mr Alemneh Jalew, Mr Adugna Berhanu, Mr Kassa Birhan, Mr Ababu Yassin, Mr Temesgen Assefa, Mr Muluken Asrese, Mr Tadegegn Worku and Mr Melisachew Adane, as well as Carter Center staff Mr Gedeon Yohannes, Mr Abate Tilahun and Mr Berhan Ayele for their hard work. We are grateful to Dr Fiona Matthews from the Medical Research Council Biostatistics Unit at the Institute of Public Health, Cambridge who provided statistical advice during the data analysis; Mr Frew Demeke, Mrs Sirgut Mulat and Ms Kelly Callahan from The Carter Center who provided considerable logistical support; Dr Eshetu Gurmu from Addis Ababa University Population Studies and Research Center who coordinated data entry and cleaning. We are indebted to all the survey participants who gave freely of their time in the survey.

Funding: Funding for this work was provided by The Carter Center Malaria Control Program, and staff were allocated to the survey by the Amhara Regional Health Bureau.

Conflicts of interest: None declared.

Ethical approval: Amhara Regional Health Bureau, Bahir Dar, Ethiopia and Emory University Institutional Review Board, Atlanta, GA, USA (IRB 1816).

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