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Distance to water source and altitude in relation to active trachoma in Rombo district, Tanzania

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Summary

Objectives—To investigate the relationship between distance to water source, altitude and active trachoma in children in Rombo district, Tanzania.

Methods—In each of Rombo's 64 villages, 10 *balozis* (groups of 8–40 households) were selected at random and all resident children aged 1–9 years were examined for clinical signs of active trachoma. The households of these children and village water sources were mapped using differentially corrected global positioning system data to determine each household's altitude and distance to the nearest water supply.

Results—We examined 12 415 children and diagnosed 1171 cases of active trachoma (weighted prevalence = 9.1%, 95% CI: 8.0, 10.2%). Active trachoma prevalence ranged from 0% to 33.7% across villages. Increasing distance to the nearest water source was significantly associated with rising trachoma prevalence (age-adjusted odds ratio for infection (OR) for highest quartile compared to lowest = 3.56, 95% CI 2.47, 5.14, *P* for trend <0.0001). Altitude was significantly inversely associated with trachoma prevalence (age-adjusted OR for highest quartile compared to lowest = 0.55, 95% CI 0.41, 0.75, *P* for trend <0.0001). These associations remained significant after adjustment in multivariate analysis.

Conclusions—Trachoma is endemic in Rombo district, although the prevalence varies considerably between villages. Spatial mapping is a useful method for analysing risk factors for active trachoma.

Keywords

trachoma; water; altitude; Tanzania; survey

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Introduction

Trachoma is the most common infectious cause of blindness (Resnikoff *et al*. 2004) and results from conjunctival infection with *Chlamydia trachomatis*. The infection is transmitted from person to person in infected secretions by direct contact, fomites (such as shared cloths and towels), eye-seeking flies and possibly through droplet spread. It is a disease of poor and marginalised people living in hot and dry regions.

Active trachoma is most commonly seen in young children. Its severity and frequency are thought to determine the risk of developing blinding complications later in life (Grayston *et al*. 1985; Beatty *et al*. 1994), although host factors are also likely to play a role (Mabey *et al*. 2003). The development of scarring, thickening of the conjunctiva and distortion of the eyelid may lead to inversion of the eyelashes so that they abrade the eye, leading to corneal opacity and eventual visual impairment or blindness (Grayston *et al*. 1985).

Lack of water is thought to be a risk factor for trachoma (West *et al*. 1989; Katz *et al*. 1996; Schemann *et al*. 2002) because hygiene practices such as face washing protect against disease (West *et al*. 1995; Ejere *et al*. 2004). In Southern Malawi (Tielsch *et al*. 1988), Nepal (West *et al*. 1989; Katz *et al*. 1996) and Tanzania (West *et al*. 1989), prevalence of trachoma was strongly associated with distance, or time taken to walk, to the nearest water supply. This is assumed to be related to the amount of water that individuals can carry home per trip. Cairncross (1999) has suggested that up to a particular threshold the distance or time to water source does not affect the amount of water brought into the household or its subsequent use, while above this level, distance to water source corresponds with a drop in the amount of water carried.

However, the precise role that water plays in transmission remains to be defined (Emerson *et al*. 2000). McCauley et al found that perceptions regarding the amount of water available and household priorities for water use, rather than the actual amount of water brought into the home, were the primary determinants of the cleanliness of children's faces (McCauley *et al*. 1990,1992).

It therefore appears that it is mainly water *use* which affects trachoma transmission (West *et al*. 1989; Bailey *et al*. 1991), and this is related to water *supply*. To protect against trachoma, water must be used to improve hygiene, by washing faces and potential fomites. When water access is poor, face- and hand-washing decline (Gilman *et al*. 1993).

The relationship between trachoma and altitude has not previously been investigated. The prevalence of other infectious diseases, such as malaria, is related to altitude (Ellman *et al*. 1998), probably due to the decline in insect density at higher altitudes (Siziya *et al*. 1997; Bodker *et al*. 2003) and the temperature dependence of the parasite's developmental cycle in the mosquito (Macdonald 1957; Attenborough *et al*. 1997). Since flies are mechanical vectors of ocular *C. trachomatis* (Emerson *et al*. 2004; Miller *et al*. 2004), a similar relationship between altitude and prevalence may exist for trachoma. Population density may also fall at higher altitude, and this is related to trachoma transmission (Mabey & Fraser-Hurt 2002).

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The aim of this study was to investigate the relationship between distance to water source and altitude and active trachoma in children in Rombo district, Tanzania.

Methods

Rombo district contains 64 villages, each with 1500–9500 residents. We undertook a survey of all 64 villages between June and October 2002. For each village 10 *balozis* (groups of 8–40 households) were selected at random. All children aged 1–9 years resident in selected balozis were eligible for participation.

After collecting information on age, gender, educational attainment and ethnicity, each child was examined for clinical signs of trachoma by a trained trachoma grader, using binocular loupes (× 2.5) and the 'WHO simplified system' (Thylefors *et al*. 1987). With this system, 'active trachoma' is defined as the presence of TF (trachomatous inflammation – follicular) and/or TI (trachomatous inflammation – intense) in either eye. The occurrence of one or more flies making contact with the eyelid margin or tissue internal to the lid margin during the time taken to prepare for examination and examine the child ('fly-eye') was also recorded.

Good inter-observer agreement between examiners for clinical signs of trachoma was confirmed by comparing independent diagnoses on the same sets of children (k statistics for TF and TI each >0.80).

The geographical position of each household was recorded using a Trimble roving receiver device (Trimble Navigation Ltd, CA, USA). Water sources were located by questioning residents and their geographical positions recorded. Global Positioning System (GPS) data were differentially corrected using GPS Pathfinder Office (version 2.80, Trimble Navigation Ltd), at the Trimble reference station of the Joint Malaria Project, Kilimanjaro Christian Medical Centre, Moshi, Tanzania. For Kwalakamu village, more detailed information on households, such as housing type and roof type and on 'crowding' (mean number of individuals of all ages per bedroom for each household), was also collected.

Ethical approval for the project was granted by the ethics committees of the Kilimanjaro Christian Medical Centre and the London School of Hygiene & Tropical Medicine. Written informed consent was obtained from the parent or guardian of each enrolled child. Verbal consent to take GPS readings and gather attribute information on physical structures was obtained from each household head.

Children with active trachoma were supplied with a 6 weeks course of twice-daily 1% tetracycline eye ointment. Each community was provided with information regarding prevention of trachoma.

Statistical analysis

Maps were produced using ArcMap (version 3.1, Environmental Systems Research Institute), which also calculated straight-line distances from households to nearest water source. We assumed that villagers travelled to the nearest (by straight-line distance) water source.

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Data were analysed using STATA version 8.0. Logistic regression was performed using the svy estimation commands for sample-survey data, to adjust for our sampling scheme and clustering of cases within households. Strata were villages, primary sampling units were balozis and sampling weights were ratios of village size to number of children sampled for each village.

For the subanalysis of Kwalakamu village the svy commands were again used, but only primary sampling units (balozis) were specified.

Results

About 5599 households contained eligible children. We interviewed respondents from 5587 (99.8%); for the remainder no responsible adult could be found, or the householder declined to participate. Of 12 545 children aged 1–9 years resident in these households, 12 415 (99.0%) were examined. The remaining 130 eligible children were either not traced at school or at home, or parental consent for ocular examination was refused. Of the 5587 households participating, 4901 were successfully mapped (87.7%). The primary reasons for households not being mapped were limitations of GPS equipment (location or weather preventing reading of satellite signals), and incorrect recording of household numbers. No household refused consent for mapping.

Among 12 415 children examined there were 1171 cases of active trachoma (unweighted district-level prevalence = 9.4%, 95% CI 8.9%, 9.9%, weighted prevalence = 9.1%, 95% CI 8.0%, 10.2%). Prevalence in individual villages varied substantially, ranging from 0.0% to 33.7% (Figure 1).

Prevalence of active trachoma decreased strongly with increasing age, but there was no relationship with gender (Table 1). Prevalence was substantially higher in Masai than in other ethnic groups. Children with a fly on their eye ('fly-eye'-positive) were significantly more likely to have active trachoma (age-adjusted OR 3.98, 95% CI 2.98, 5.31). Prevalence of 'fly-eye' positivity was inversely correlated with altitude (Figure 2).

There was a strong and highly significant association between active trachoma and distance to nearest water source (Table 2), which remained after adjustment for confounders (Table 3 – adjusted OR for last quartile compared to first = 2.99, 95% CI 2.09, 4.28). There was a statistically significant inverse association between active trachoma and altitude (Table 2), which remained after adjustment for confounders (Table 3 – adjusted OR for last quartile compared to first = 0.56, 95% CI 0.41, 0.76).

Subanalysis – Kwalakamu village

Fifty-five cases of active trachoma were identified in children aged 1–9 years from a total of 246 children examined (prevalence = 22.4%, 95% CI 17.2%, 27.6%), which was higher than the weighted whole-district prevalence (9.1%, 95% CI 8.0%, 10.2%). Only age was significantly related to trachoma, although a weak association was evident between crowding and 'fly-eye' and active trachoma (Table 4). Prevalence increased with increasing

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distance to nearest water source and decreased with increasing altitude, although these associations did not reach statistical significance.

Discussion

In this cross-sectional survey of children in Rombo we found that the overall prevalence of active trachoma was 9.1% (95% CI 8.0, 10.2%). Prevalence had a strong dose-response relationship with distance to water source, and this association persisted after control for confounders. Prevalence fell with increasing altitude.

The association between active trachoma and distance to water found in this study is consistent with other studies (Marshall 1968; Assaad *et al.* 1969; West *et al.* 1989,1996; Cairncross & Cliff 1987; Tielsch *et al.* 1988; Katz *et al.* 1996; Hoechsmann *et al.* 2001). Although the exact reasons for this are debatable, it is widely accepted that the more difficult it is to access water, the higher the trachoma prevalence.

The relationship between altitude and trachoma prevalence has not previously been investigated, but an association is feasible. The prevalence of trachoma may fall with increasing altitude because population density [which is directly associated with trachoma transmission (Mabey & Fraser-Hurt 2002)] decreases, because rainfall increases and water supplies are more reliable at higher altitudes in Rombo (Majule 2003), or because fly densities decrease (Figure 2). Decreasing prevalence with altitude may also occur because (according to local anecdote) households of higher socio-economic status tend to reside higher up the slopes of Mt. Kilimanjaro. Many ‘down-slope’ communities are relatively new, comprising people who have moved from up-mountain because of lack of land, and therefore do not have the cohesiveness of more established villages. An investigation of the relationship between fly density, markers of socio-economic status and altitude in this district would be informative.

The use of spatial analysis has not yet been fully exploited within public health as a whole (Graham *et al.* 2004), but its application in research of trachoma (Polack *et al.* 2005) and other infectious diseases (Hay *et al.* 2001; Brooker 2002; Tatem & Hay 2004) is increasing. While many studies have examined the relationship between distance to water supply and trachoma prevalence, they have had to rely on reports of time to water source, which may be unreliable; GIS provides an alternative approach. This study was large, including more than 12 000 children, and benefited from a very high participation rate in the trachoma survey, minimising selection bias. The simplified WHO grading system is well established and examinations were conducted by experienced graders.

There were several limitations to this study. The trachoma prevalence survey was undertaken approximately 2 months before exposure data were collected. However, the exposures of altitude and distance to water were likely to have been stable over this time period and both exposure and outcome data were collected during the dry season. Only 87% of households had GPS data available. However, since data were absent due to equipment limitations or incorrect recording of household identification numbers, we expect that this was essentially random.

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A number of different water sources may have been used by many households. Distance to water source may not directly translate into *time* to water source, or *effort required* to obtain water. Distance to nearest water source may therefore be an incomplete measure of the distance travelled to the water source, and this may have resulted in non-differential misclassification of distance to nearest water source, with consequent underestimation of the association with trachoma prevalence.

This study has provided the first evidence for an association between altitude and trachoma prevalence. There are a number of plausible explanations for this, including differences in socio-economic status, water availability and fly density with altitude. This study has also added support to the importance of distance to nearest water source for trachoma transmission.

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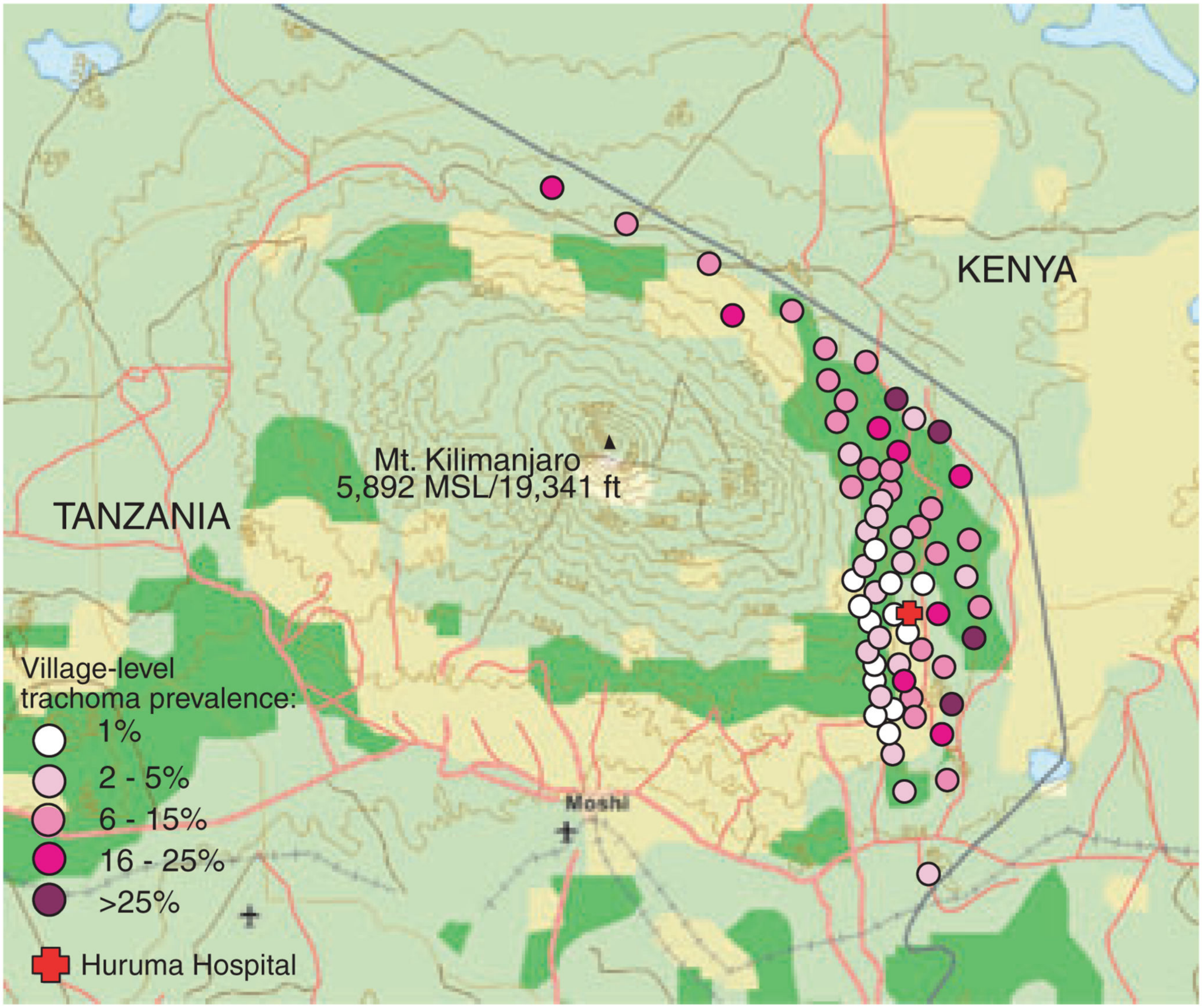

Figure 1.

Rombo district, Tanzania, showing the prevalence of active trachoma in children aged 1–9 years, by village. Background World Basemap from http://www.geographynetwork.com courtesy of ESRI. Copyright© ESRI. All rights reserved.

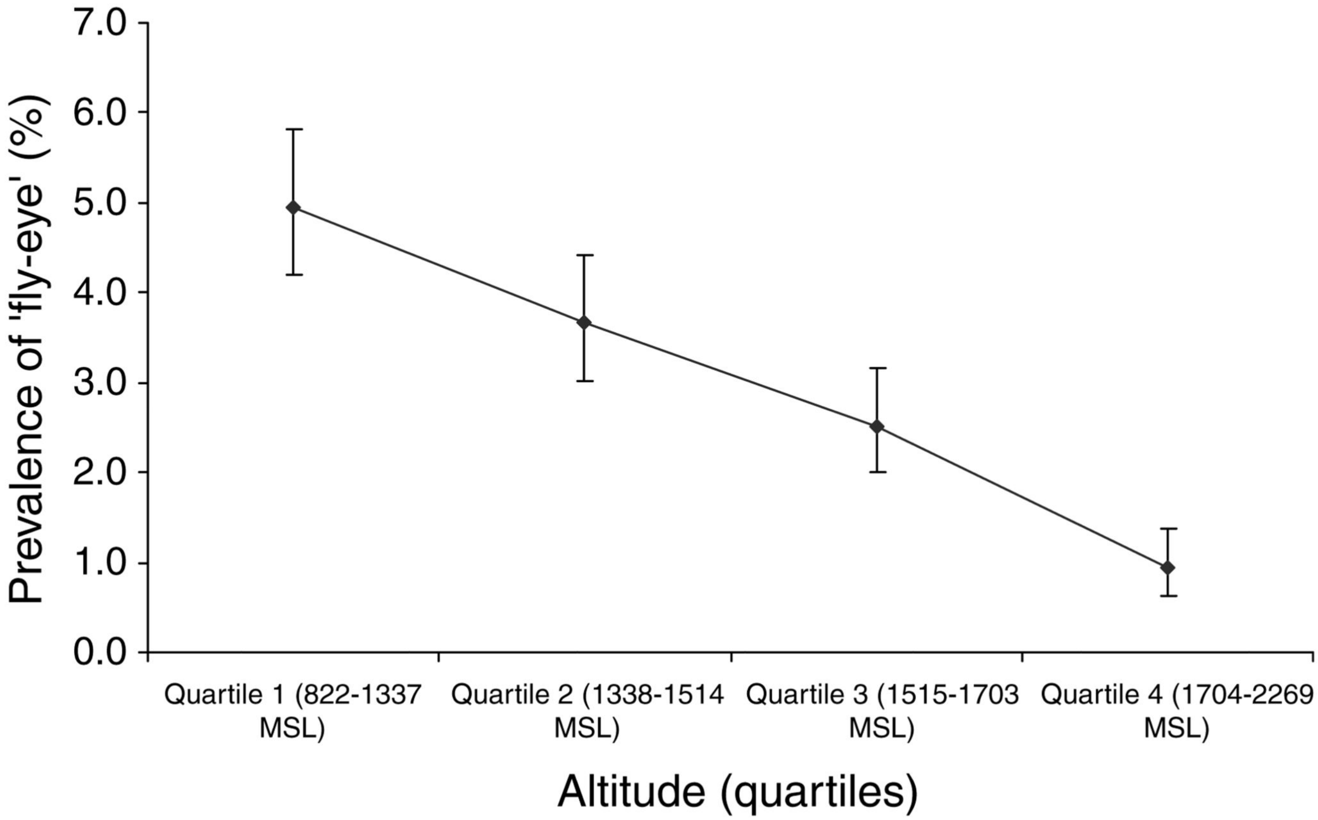

Figure 2.
Relationship between altitude and the prevalence of ‘fly-eye’ in Rombo district, Tanzania. MSL, metres above sea level. Error bars are 95% confidence intervals.

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Table 1

Table showing the relationship between demographic characteristics and active trachoma

	No. active trachoma cases	Number	Weighted[†] prevalence of active trachoma (95% CI)	Age-adjusted OR (95% CI)
Overall	1171	12 415	9.1% (8.0–10.2)	–
Age				
1 year	192	1338	13.8% (11.4–16.1)	1.00
2 and 3 years	433	2968	14.6% (12.5–16.6)	1.07 (0.86–1.33)
4 and 5 years	269	2727	9.2% (7.7–10.7)	0.63 (0.51–0.79)
6 and 7 years	174	2984	5.5% (4.3–6.7)	0.37 (0.28–0.47)
8 and 9 years	100	2369	4.1% (3.1–5.1)	0.27 (0.20–0.35) *P* for trend <0.0001
Gender				
Male	596	5739	9.3% (7.9–10.6)	1.00
Female	575	5504	9.0% (7.8–10.1)	1.07 (0.86-1.33)
Ethnicity				
Chagga	1015	11 296	8.9% (7.8–10.1)	1.00
Kamba	7	54	14.7% (3.9–25.5)	1.79 (0.75-4.24)
Masai	13	32	42.9% (30.9–54.9)	6.99 (3.58–13.67)
Mpare	76	497	14.1% (10.0–18.2)	1.62 (1.12–2.35)
Msambaa	33	294	9.1% (5.3–12.9)	0.97 (0.59–1.57)
Other	27	241	9.8% (3.8–15.9)	1.05 (0.51–2.14)
Presence of 'fly-eye'[‡]				
No	1062	12 072	8.4% (7.4–9.5)	1.00
Yes	109	342	31.9% (25.9–37.9)	3.98 (2.98–5.31)

[†]Refers to sampling weights, relating to number of children sampled per village and village size.

[‡]'Fly-eye' is defined as contact with the eyelid margin or tissue internal to the lid margin during the time taken to prepare for examination and examine the child. OR, Odds ratio.

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Table 2

The relationship between household altitude and distance to water and prevalence of active trachoma in 1–9-year-old children in Rombo district, Tanzania

	No. trachoma cases	*n*	Weighted[†] prevalence (95% CI)	Age-adjusted OR (95% CI)
Distance to water quartiles (metres)[‡]				
1 (0.0–79.0)	130	2761	4.1% (2.9–5.3)	1.00
2 (79.1–190.5)	208	2760	7.0% (5.4–8.6)	1.79 (1.29–2.47)
3 (190.6–496.1)	312	2756	10.9% (9.0–12.9)	2.83 (2.00–4.01)
4 (496.2–4855.7)	358	2745	13.4% (11.1–15.7)	3.56 (2.47–5.14)
				Age-adjusted *P* for trend <0.0001
Altitude quartiles (MSL)[‡]				
1 (822.2–1337.3)	371	2744	14.6% (11.9–17.3)	1.00
2 (1337.4–1514.8)	192	2758	6.0% (4.4–7.6)	0.37 (0.26–0.53)
3 (1514.9–1703.8)	167	2755	6.0% (4.5–7.4)	0.36 (0.26–0.50)
4 (1703.9–2268.5)	278	2765	9.0% (7.3–10.7)	0.55 (0.41–0.75)
				Age-adjusted *P* for trend <0.0001

[†]Refers to sampling weights, relating to number of children sampled per village and village size.

[‡]Altitude and distance refer to GPS measurements taken from each child's household.

OR, odds ratio.

MSL, metres above sea level.

Table 3

Multivariate adjusted association between household distance to water source, household altitude, age and presence of 'fly-eye' and prevalence of active trachoma in 1–9-year-old children in Rombo district, Tanzania

	Multivariate adjusted OR
Distance to water quartiles (metres)‡	
1 (0.0–79.0)	1.00
2 (79.1–190.5)	1.67 (1.21–2.31)
3 (190.6–496.1)	2.52 (1.78–3.56)
4 (496.2–4855.7)	2.99 (2.09–4.28)
P for trend	<0.001
Altitude quartiles (MSL)‡	
1 (822.2–1337.3)	1.00
2 (1337.4–1514.8)	0.40 (0.28–0.56)
3 (1514.9–1703.8)	0.42 (0.30–0.60)
4 (1703.9–2268.5)	0.56 (0.41–0.76)
P for trend	<0.001
Age	
1 year	1.00
2 and 3 years	1.05 (0.84–1.31)
4 and 5 years	0.66 (0.52–0.83)
6 and 7 years	0.36 (0.28–0.47)
8 and 9 years	0.29 (0.22–0.38)
P for trend	<0.001
Presence of 'fly-eye'	
No	1.00
Yes	3.21 (2.35–4.38)

‡Altitude and distance refer to GPS measurements taken from the child's household.

MSL, metres above sea level.

OR, odds ratio

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Table 4

Examination of potential confounders in Kwalakamu village, Rombo

Risk factor	No. trachoma cases	$n^{†}$	Weighted[§] prevalence (%) (95% CI)	Age-adjusted OR (95% CI)
Gender				
Male	22	118	18.6 (10.2–27.1)	1.00
Female	33	128	25.8 (12.3–39.3)	1.79 (0.63–5.05)
Age group				
<2 years	8	29	27.6 (7.6–47.6)	1.00
2 and 3 years	23	57	40.4 (25.9–54.8)	1.78 (0.62–5.08)
4 and 5 years	16	60	26.7 (11.8–41.5)	0.95 (0.32–2.83)
6–9 years	8	100	8.0 (2.5–13.5)	0.23 (0.07–0.70)
				P for trend = 0.003
Crowding[§§]				
0.00–1.99	6	42	14.3 (0.0–29.6)	1.00
2.00–3.99	28	115	24.3 (12.6–36.1)	1.93 (0.57–6.53)
≥4.00	21	88	23.9 (17.1–30.6)	1.79 (0.51–6.32)
				Age-adjusted *P* for trend = 0.54
Number of children under 5 years per household				
0–1	16	75	21.3 (9.4–33.3)	1.00
2	31	110	28.2 (20.8–35.6)	1.20 (0.57–2.54)
≥3	8	60	13.3 (2.5–24.2)	0.38 (0.15–0.94)
				Age-adjusted *P* for trend = 0.06
Presence of 'fly-eye'				
No	43	212	20.3 (11.0–29.6)	1.00
Yes	12	34	35.3 (20.5–50.1)	1.44 (0.50–4.13)
House type				
Brick and/or wood	27	125	21.6 (14.0–29.2)	1.00
Mud only	28	120	23.3 (9.9–36.8)	1.03 (0.43–2.45)
Presence of animals				
Outside house	11	53	20.8 (9.4–32.1)	1.00
Inside house	41	185	22.2 (14.4–29.9)	1.21 (0.67–2.20)
No animals owned	3	7	42.9 (29.1–56.6)	3.32 (0.89–12.37)
Distance to nearest water source[‡], quartiles (metres)				
1 (151.9–502.0)	11	54	20.4 (1.5–39.2)	1.00
2 (502.1–661.8)	6	55	10.9 (5.7–16.1)	0.47 (0.12–1.75)
3 (661.9–842.0)	15	56	26.8 (17.8–35.8)	1.77 (0.48–6.54)
4 (842.1–1235.8)	17	52	32.7 (21.8–43.6)	1.92 (0.54–6.82)
				Age-adjusted *P* for trend = 0.03
Altitudet[‡], quartiles (MSL)				
1 (1393.0–1458.8)	14	56	25.0 (21.3–28.7)	1.00

Risk factor	No. trachoma cases	*n*†	Weighted[§] prevalence (%) (95% CI)	Age-adjusted OR (95% CI)
2 (1458.9–1480.7)	18	54	33.3 (25.8–40.8)	1.76 (1.11–2.80)
3 (1480.8–1591.3)	7	54	13.0 (0.0–26.3)	0.49 (0.13–1.78)
4 (1591.4–1599.3)	10	53	18.9 (0.0–42.5)	0.72 (0.13–3.98)
				Age-adjusted *P* for trend = 0.12

Each risk factor is adjusted for the effect of each other risk factor in the table, plus adjustment for ethnicity and clustering of cases at the household level. Model adjusts for age group (divided as shown), distance to nearest water source and altitude.

[§]Refers to sampling weights, relating to number of children sampled per village and village size.

[§§]Measured as number of individuals/number of bedrooms per household.

[†]Total number of individuals does not always equal total number of individuals surveyed due to incomplete information on some variables for some surveyed children.

[‡]Altitude and distance refer to GPS measurements taken from the child's household.
OR, odds ratio.

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