Epidemiological and Interventional Study of Camel Trypanosomosis in Selected Districts of Somali and Oromia Regional States, Ethiopia

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Abstract: Camel trypanosomosis (surra) is one of the most important diseases which affects the health and production potential of camels in eastern Ethiopia. A longitudinal study was conducted to investigate the prevalence, associated risk factors and vectors in Babile, Shinile and Fafan districts. In addition, parasite (chemotherapy and chemoprophylaxis) and vector control (pour-on, insecticide-impregnated targets and traps) methods were implemented. Both serum and entomological samples were collected 4 times a year to estimate the seasonal prevalence of *T. evansi,* and assess the abundance and diversity of vectors, respectively. A total of 1790 blood samples were collected before intervention (358 per season). *T. evansi* was detected in 5.1% and 8.73% of camels by using the buffy coat method (BCM) and Card Agglutination Trypanosomiasis Test (CATT)/*T. evansi*), respectively. In this study, the prevalence of camel trypanosomosis was significantly higher in Babile (12.6%) than Shinile (5%) district ($P<0.05$), in adults (10.4%) than in young (7.7%) camels ($P<0.05$), in poor (20.8%) than good (3.4%) body condition camels $P<0.05$, and in wet (14.3%) than early wet (2.2%) season, ($P<0.05$). The biting fly with the highest apparent density was *Stomoxys* followed by *Tabanus*, *Chrysops*, and *Haematopota* species. Strong association was observed between the apparent density of biting flies caught and the incidence of *T. evansi* infection. Moreover, *T. evansi* infection was higher in anemic than non-anemic animals ($P<0.05$). The serological prevalence of camel trypanosomosis was significantly lower ($P<0.05$) after intervention than the pre-intervention periods (95% CI= 6.8-59.3%). During the post-intervention period, the prevalence of camel trypanosome infection was significantly ($P<0.05$) reduced (95% CI=3.0-7.8%) in comparison to the control Fafan districts (95% CI=10.3-17.7%). The implementation of diverse intervention methods on the parasite and its vectors resulted in a decreased incidence of *T. evansi* infection. This interventional study might serve as a model for the control of surra in low-income settings with community participatory approach.

Keywords: *Agglutination test*, *Buffy coat, Camel, Chemoprophylaxis, Chemotherapy, T. evansi, Vector control*

Introduction

Camels are most numerous in the arid areas of Africa. The East Africa Region consists of over 80% of the African and two-thirds of the world's camel population (Schwartz and Dioli, 1992). However, camel production in this region became challenging because of prevalent diseases like trypanosomosis (surra) and other related factors. Trypanosomosis is the most important cause of camel morbidity and mortality and affects the economy in camel-rearing areas with morbidity of up to 30% and mortality of around 3% (Njiru *et al*., 2002). It is caused by *Trypanosoma evansi*, which is widespread, and transmitted mechanically by haematophagus biting flies. *T. evansi* infected animals exhibit highly variable clinical signs, which depend on the nature of hosts and geographic areas. These characteristics make surra not only a multispecies but also a polymorphic disease (Desquesnes *et al*., 2013). Clinically it is manifested by weakness; lethargy; tachycardia; fever; pale mucosa; subcutaneous edema particularly in brisket and eyelids; nasal and ocular discharges; abortion in pregnant camel; and weight loss (Derakhshanfar *et al*., 2010).

Among all the pathogenic trypanosomes, *T. evansi* has the widest host range and geographical distribution. Surra affects mainly camels but other species of animals can also be affected. In some countries, the incidence of surra increases significantly following a rainy season when biting fly populations have greatly increased (OIE, 2013). Recently, an outbreak of camel trypanosomosis, with extensive mortality and abortion was reported in Iran (Derakhshanfar *et al*., 2010). A prevalence of 4.7% and 20.6% were reported in Eygpt (Amer *et al*., 2011) and eastern Ethiopia (Zeleke and Bekele, 2001), respectively.

Numerous approaches may be used to decrease the occurrence of trypanosomosis and its effects. A combination of several approaches has been applied in different parts of the globe (Pacholek *et al*., 2000). In Ethiopia, some efforts have been made to control the disease with chemotherapy, which is the most commonly practiced method. Vector control had also been applied in the country (Hailemariam *et al*., 2008).

In Ethiopia, camels are kept in arid and semi-arid lowlands of Borana, Somali and Afar region (Teshome

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et al., 2003). Most previous studies conducted on camel trypanosomosis were based on a cross-sectional study design, which fails to show the seasonal dynamics of the disease and vectors, and its diversity. Therefore, the current study was conducted to investigate the epidemiology of the disease and impact of interventional strategies implemented in the study areas.

Materials and Methods

Study Areas

The study was conducted from September 2018 to November 2022 in three areas (Shinile, Babile, Fafan) in Somali and Oromiya Regional States of Ethiopia. There are four seasons in all districts such as early wet season (Spring) (March, April and May); wet season (Summer) (June, July and August); early dry season (Autumn) (September, October and November) and dry season (Winter) (December, January and February).

Shinile district is located in the Somali Regional State of Ethiopia. The district has a total population of 103,052 camels. The altitude of the study area ranges from 500 to 1,100 meter above sea level (m.a.s.l.), with average maximum and minimum temperature of 31.8°C and 18°C, respectively. The rainfall ranges from 50-600 mm per year. The area experiences a bimodal rainfall occurring from late March to late May and also between late July and September (CSA, 2007).

Fafan district is located in the Somali Regional State of Ethiopia, 620 kilometers southeast of Addis Abeba, the nation's capital. Jigjiga, Kebribeyah, Harshin, Babile, Awbare, Gursum, Tullu Guled, and Gololchen are its eight districts. The average minimum and maximum temperatures in the region are around 20 and 35 °C, respectively, and are high throughout the year. Rainfall is bimodal and averages 660 mm annually. There are 81,221 camels in the region. Pastoralism (34.1%), agro-pastoralism (56.8%), and sedentary production systems (9.1%) account for the majority of the community's livelihood (CSA, 2007).

The Babile district is found in the eastern Hararghe Zone Oromia Regional State, Ethiopia, at approximately 557 km east of Addis Ababa (i.e. Ethiopia's capital city) and and 31 km from the town of Harar. The area is located between 9°, 23' N latitude and 42°, 53' E longitude. It has an average annual rainfall of 410–800 mm and an annual temperature range of 24-28 °C and the district is characterized by a semi-arid and arid climate. From the north, it is bordered by Gursum; to the west, by Fedis; to the northwest, by Harari National Regional State; and to the east, south, and southwest, by Somalia National Regional State. The district has 300 residents in 21 rural *kebeles* (the smallest administrative unit) and owns 12,000 camels (BDDLRF, 2018).

Study Population

The study population comprises dromedary camels of all sexes, different age groups, and body conditions in Babile, Shinile districts and the negative control Fafan district. The age of camels was categorized as young (less than 4 years) and adult (4 and above years). The body condition score of the camels was categorized as poor and good.

Study Design

A longitudinal study was conducted in all the study areas. Blood samples were collected 4 times a year (at 3-month intervals) to estimate the seasonal prevalence of *T. evansi*. Besides, entomological samples were collected to assess the abundance and diversity of vectors.

Site Selection and Sample Size Determination

The administrative districts were selected based on their accessibility, camel population, and previous disease reports. The same principles were applied for the selection of districts from each administrative zone. Sampling units were selected based on multistage sampling method. There were 25 *kebeles* (peasant association) in Babile, 35 *kebeles* in Shinile district, and 27 *kebeles* in the Fafan district. From each district, three *kebeles* were randomly selected. Within the *kebele's* simple random sampling method was used for the selection of villages. To assess the effectiveness of the intervention, Fafan district was selected as a negative control, because the area has similar agroecological conditions, management systems, and borders for both study sites (Shinile and Babile).

The sample sizes were calculated based on the formula given by Thrusfield (Thrusfield, 2007) and by considering the previous report of 11.7% in Shinile (Tadesse *et al.*, 2012) and 8.1% in Babile (Mohammed *et al.*, 2015). Thus, using the expected prevalence reports, the sample size estimated for the actual prevalence study was 358 animals in each single visit of four classified seasons, with 174 animals from Babile and 184 from Shinile. Therefore, a total of 1790 animals (736 from Shinile, 696 from Babile, and 358 from the negative control Fafan district) were selected.

The effectiveness of intervention methods applied in this study was assessed by comparing the post-intervention prevalence of camel trypanosomosis on 358 animals during the wet season with the pre-intervention prevalence of camel trypanosomosis on 358 animals during the wet season. Similarly, the same seasons and sample size were used to analyze the changes in the control area.

Laboratory Methods

Blood sample collection, PCV determination and parasite detection: From each selected animal, 10ml of jugular blood was collected using heparinized and plain vacutainer tubes. Then, the tubes were placed in a box containing ice packs and transported to Haramaya University, Parasitology Laboratory. Samples were kept in a slant position at room temperature until serum started to separate and then centrifuged at 2700 rpm for 10-15 minutes. Finally, the serum was decanted into a sterile cryovial tube and was stored at -20°C until tested by CATT/*T. evansi* test kits. For the PCV determination, phase contrast buffy coat examination was used. Blood samples were drawn into heparinized microhaematocrit

capillary tubes up to 3/4 of the height and sealed with Cristaseal and centrifuged at 12,000 rpm for five minutes to separate the blood cells and to concentrate trypanosomes using centrifugal forces. Meanwhile, capillaries were also used to measure the PCV values for the determination of anemia. Thus, it was considered as anemic if the PCV is less than 27% (OIE, 2017). The capillary tube was cut 1mm below the buffy coat to include the top layer of red cells. The content of the capillary tube was expressed on the slide, homogenized on a clean glass slide and covered with a coverslip. Then the slide was examined under 40x objective for the presence of parasites. To further characterize the species of the parasite, thin blood films were made for positive samples and examined using Giemsa stain (Basaznew *et al*., 2012). Morphological examination of the parasites was used to identify *T. evansi* according to the procedure of Desquesnes *et al.* (2013).

Serological examination: The seroprevalence of camel trypanosomosis was conducted by using the card agglutination trypanosomiasis test (CATT)/*T. evansi*. The CATT/*T. evansi* is a direct rapid card agglutination test, which uses formaldehyde-fixed, freeze-dried trypanosomes expressing a predominant variable antigen type of *T. evansi* (RoTat 1.2) stained with Coomassie blue. The positive samples were determined at cut-off point dilutions 1:4 and above. Accordingly, 25µl of camel serum, diluted 1:4 in CATT-buffer, was pipetted onto a reaction zone of a plastic-coated test card. After adding one drop (about 45µl) of CATT reagent, the reaction mixture was spread out using a stirring rod and allowed to react on a Card Test Rotator for 5 minutes at 70rpm (Songa *et al*., 1990). Samples that show agglutination were considered positive for *T. evansi* antibody.

Collection of entomological samples: An entomological survey was conducted at each study site. To do this, 96 traps were deployed for a total of 20 days each season, and captured flies were collected every 3 days. Biting flies were captured using different traps (Nzi and Vavoua) baited with acetone and cattle urine (Dia *et al*., 2004). Before collecting flies in a screw-capped bottle, the fly count was done within 24-hour intervals to determine the seasonal abundance and the flies were preserved in 70% ethanol. The type of vectors, site of collection, ecology or type of vegetation was recorded. After collection, the samples were taken to Haramaya University, College of Veterinary Medicine, Parasitology Laboratory, for identification were based on (Acapovi *et al*., 2001). The density of fly population was calculated by dividing the number of flies caught by the number of traps deployed and the number of days of deployment and expressed as fly/trap/day (FTD). (Leak *et al.,* 1988).

Intervention

Chemotherapeutic and prophylactic drugs: Curative diminazene aceturate, suramin sodium and melarsamine hydrochloride (cymelarsan) and prophylactic (isometamidium chloride and quinapyramine chloride) were used. Curative drugs were given for both BCM and/or seropositive camels, while chemoprophylaxis was given to test negative camels. The chemoprophylaxis was given every 3 months at the beginning of each season for one year. The efficiency of intervention measures was evaluated after one year by estimating the prevalence of trypanosomosis in the study population (Bourdichon, 1998).

Insecticide-impregnated traps and targets: Both insecticide (deltamethrin) impregnated traps and target screens were deployed in selected sites where the amounts of vectors were high. The local communities were responsible for keeping and maintaining the targets and traps from theft and damage. After one year, the prevalence of the disease and the abundance of the vectors were assessed (Raymond & Favre, 1991).

Community based interventions: Herd owners were invited and trained to have a good understanding of the health care of their animals, nutrition, timed treatment, and prophylaxis against the diseases (Seigel *et al*., 1988). The community in the selected areas as well as other stakeholders was invited to discuss the importance of fly and trypanosomosis control. In addition, community, animal health workers were selected from farmers of a given community who were trained on trap making, trypanocidal drug management, utilization and treatment of individual cases.

Statistical Analysis

Initial validation of the data, simple descriptive analyses, and summarizing of the results in tables and charts were done. The status of the disease was computed and compared before and after intervention methods. Then the data was transferred to statistical packages SPSS version 11.0 and statistical analysis was performed to estimate the prevalence (percentage) and the level of agreement between diagnostic tests (Kappa statistics, K). Two sample students t-test was used to assess the difference in mean PCV between *T. evansi* positive and negative animals. Chi-square and logistic regression tests were used to see the presence of associations between *T. evansi* infection and potential risk factors such as age, sex, body condition of camel, season of the year, and intervention. A *P-value* less than 0.05 was considered as having a significant association at 95% confidence level.

Results

Pre-Intervention Parasitological and Serological Prevalence

During the pre-intervention study, among 1432 samples, *T. evansi* was detected in 73 (5.1%; 95% CI: 4.02%-6.37%) and 125 (8.73%; 95% CI: 7.32%-10.31%) camels by using BCM and CATT/*T. evansi* test, respectively (Table 1). The prevalence of *T. evansi* was higher in Babile (12.6%) than Shinile (5%) district (Table 1).

Table 1. Pre-intervention parasitological and serological profile of *T. evansi*.

District	*Kebele*	No. of examined camels	**Result based on buffy coat method**			**Result based on CATT/*T. evansi* test**		
			No. positive (%; 95%CI)	OR	p-value	No. positive (%; 95%CI)	OR	p-value
Babile	Daketa	222	28 (12.6; 8.5-17.7)	3.0	0.0017	47 (21.2; 16.0-27.1)	3.4	0.000
	Anod	231	15 (6.5; 3.7-10.5)	1.5	0.3472	23 (9.9; 6.4-14.6)	1.4	0.3237
	Mullu	243	11 (4.5; 2.3-8.0)	1.0		18 (7.4; 4.4-11.4)	1.0	
	Total	**696**	**54 (7.8; 5.9-10.0)**			**88 (12.6; 10.3-15.3)**		
Shinile	Harewa	301	9 (3; 1.4-5.6)	1.8	0.3325	19 (6.3; 3.8-9.7)	3.1	0.0196
	Gebi	199	6 (3.1; 1.1-6.4)	1.8	0.3600	13 (6.5; 3.5-10.9)	3.2	0.0213
	Millo	236	4 (1.7; 0.4-4.3)	1		5 (2.1; 0.7-4.9)	1.0	
	Total	**736**	**19 (2.6; 1.6-4.0)**			**37 (5; 3.6-6.9)**		

The different risk factors considered including age, body condition score and seasonal difference were significantly associated with *T. evansi* infection (*P<0.05)* (Table 2). The PCV of *T. evansi* infected camels was significantly lower than non-infected ($P < 0.05$) camels (Table 3).

Out of 73 camels with positive results in the parasitological test (BCM), 72 were also positive by CATT/*T. evansi* test. Thus, the comparative sensitivity of CATT/*T. evansi* test was found to be 71% (Table 4).

Table 2. Pre-intervention serological profile of camel trypanosomosis with potential risk factors using univariable logistic regression.

Risk factors	Categories	No. of examined camels	No. positive (%; 95% CI)	Odds ratio	P-value
Sex	Female	981	91 (9.3; 7.5-11.3)	1.00	
	Male	451	34 (7.5; 5.3-10.4)	0.66	0.056
	Total	**1432**	**125 (8.7; 7.3-10.3)**		
Age	Adult	547	57 (10.4; 8.0-13.3)	1.00	
	Young	885	68 (7.7; 6.0-9.6)	0.032	0.04
	Total	**1432**	**125 (8.7; 7.3-10.3)**		
Body condition	Poor	437	91 (20.8; 17.1-24.9)	36.06	0.003
	Good	995	34 (3.4; 2.4-4.7)	1.00	
	Total	**1432**	**125 (8.7; 7.3-10.3)**		
Season	Early wet	358	8 (2.2; 1.0-4.3)	1.00	
	Dry	358	26 (7.3; 4.8-10.5)	1.40	0.014
	Early dry	358	39 (10.6; 7.9-14.6)	2.09	0.006
	Wet	358	52 (14.3; 11.0-18.6)	7.463	0.000
	Total	**1432**	**125 (8.7; 7.3-10.3)**		

Table 3. Mean PCV value of parasitemic and aparasitemic animals.

Status	**No. Examined**	**No. of animals with:**		**Mean PCV (%) ± SD**	**t-test**	**P-value**
		PCV <27%	PCV > 27%			
Parasitemic	125	88 (70.4 %)	37 (29.6%)	23.08±2.56	8.869	0.001
Aparasitemic	1307	226 (17.3%)	1081 (82.7%)	26.84±3.65		
Total	**1432**	**314(21.92%)**	**1118(78.1%)**	**26.60±3.65**		

Table 4. Cross-tabulation of parasitological and serological tests.

Tests		**Parasitological (BCM)**			**Kappa value**	***P. value***
		Positive	**Negative**	**Total**		
Serological CATT/*T. evansi*	**Positive**	72	53	125	0.709	0.001
	Negative	1	1306	1307		
	Total	73	1359	1432		

Entomological Survey Result

A total of 6,843 biting flies were caught during this study period. From these, 1547, 816, 541, and 3831 biting flies were collected in the early dry, mid dry, early wet, and mid wet season, respectively (Table 5). The apparent fly density was found to be 0.12fly/trap/day, 0.04 fly/trap/day,0.02fly/trap/day, and 3.4fly/trap/day for *Tabanus*, *Cheropsis*, *Hematopota,* and *Stomoxys,* respectively. The proportions of biting flies caught during the study period were *Tabanus* (4%) *Cheropsis* (0.5%), *Hematopota* (0.5%) and *Stomoxies* (95.0%). Sex identification was performed on 6,843 biting flies caught; accordingly, 57.9% were found to be females (Table 5).

The proportion of total fly catches were: for *Tabanus* 1%, 0.12%, 0.02%, and 8%; for *Haematopota* 0.12%, 0.02%, 0.03%, and 3%; for *Cheropsis* 0.22 %, 0.16%, 0.01%, and 0.4%; for *Stomoxys* 22.62%, 11.92%, 7.9%, and 53% during early dry, mid dry, early wet, and mid wet season, respectively (Figure 1).

Table 5. Summarized entomological result.

Kebele	**No. of traps**	**Dry seasons**								**Wet seasons**								**Total**	**FTD**
		Early				**Mid**				**Early**				**Mid**					
		T	H	C	S	T	H	C	S	T	H	C	S	T	H	C	S		
Daketa	16	22	6	8	701	0	0	7	212	0	0	0	167	59	5	3	1014	2204	4.6
Anod	16	11	0	3	183	3	1	0	116	1	0	0	99	37	6	2	875	1337	2.9
Mullu	16	9	0	4	296	2	0	2	158	0	1	0	151	45	9	1	593	1271	2.7
Harewa	16	9	1	0	145	1	0	1	109	0	0	0	80	22	4	0	382	754	1.6
Gebi	16	10	0	0	121	2	0	0	123	0	0	0	30	26	3	2	484	801	1.7
Millo	16	4	1	0	101	0	0	1	98	0	0	0	12	11	0	0	248	476	0.9
Total	96	65	8	15	1547	8	1	11	816	1	1	0	539	200	27	8	3596	6843	2.38

T= Tabanus; H= Haematopota; C= Chrysops; S= Stomoxys.

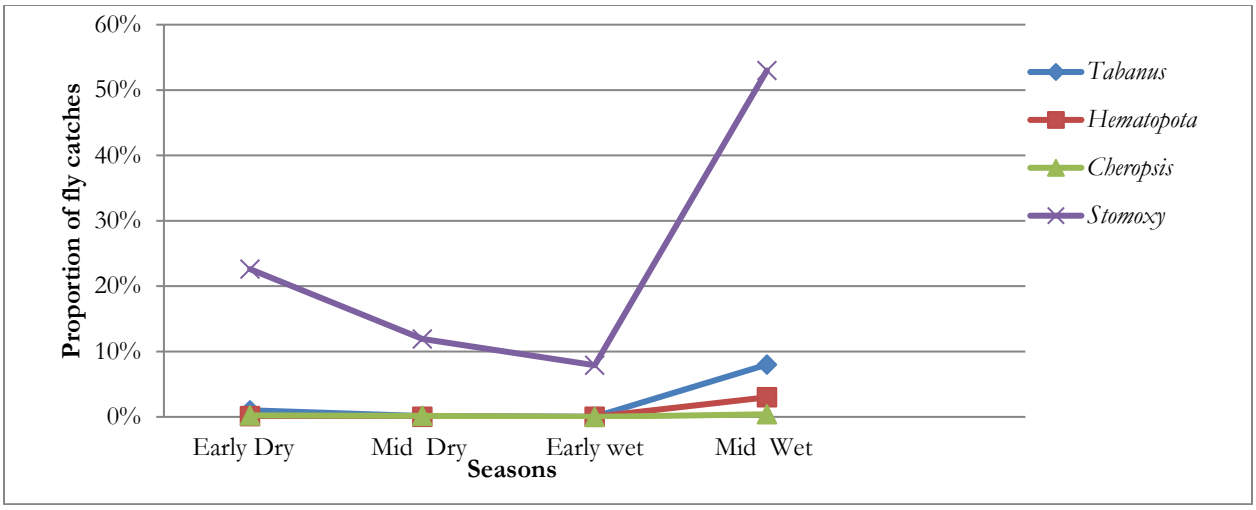

Figure 1. Biting flies apparent density in different seasons.

Post-intervention Serological Prevalence

The post-intervention seroprevalence of *T. evansi* was 13 (7.3%) and 5 (2.73%) in Babile and Shinile districts, respectively (Table 6). In the post-intervention study, age and body condition scoring were significantly associated with seropositivity (Table 7).

The risk of contracting trypanosome infection was reduced by 20.1(95% CI=6.8-59.3) times at the post-intervention period (Table 8).

At post-intervention period, total prevalence reduced from 18% to 7.5% and 11% to 2.7% in Babile and Shinile districts, respectively (Figure 2).

Table 6. Post-intervention serological profile of camel trypanosomosis using CATT/*T. evansi* test.

Region	District	No. examined	No. positive (%, 95%CI)	Odds ratio	p-value
Oromia	Daketa	72	8 (11.1; 4.9-20.7)	3.1	0.1426
	Anod	52	3 (5.8; 1.2-15.4)	1.5	0.6781
	Mullu	50	2 (4.0; 0.5-13.2)	1.0	
	Total	**174**	**13 (7.47; 4.0-12.4)**		
Somali	Harewa	73	2 (2.7; 0.4-9.7)	1.4	0.7723
	Gebii	60	2 (3.3; 0.4-11.5)	1.7	0.6568
	Millo	51	1 (1.9; 0.05-10.4)	1.0	
	Total	**184**	**5 (2.7; 0.9-6.2)**		

Table 7. Post-intervention serological profile of camel trypanosomosis with various risk factors using univariable logistic regression.

Risk factors	Categories	No. examined	No. positive (%; 95%CI)	Odds ratio	P- value
Sex	Female	239	12 (5.0; 2.6-8.5)		
	Male	119	6 (5.0; 1.9-10.6)	1.680	0.288
	Total	**358**	**18 (5; 3.0-7.8)**		
Age	Adult	149	11 (7.4; 3.7-12.8)		
	Young	209	7 (3.3; 1.3-6.7)	0.697	0.045
	Total	**358**	**18 (5; 3.0-7.8)**		
Body condition	Poor	42	3 (7.1; 1.5-19.5)		
	Good	316	15 (4.7; 2.7-7.7)	0.83	0.000
	Total	**358**	**18 (5; 3.0-7.8)**		

Table 8. Comparison of prevalence of camel trypanosomosis before and after intervention using univariable logistic regression analysis.

Data collection	No. examined (No. positive; %) in:			Odds ratio (95% CI)	p-value
	Babile	Shinile	Both		
Pre-intervention	174 (32; 18.4)	184 (20; 11.0)	358 (52; 14.5)	20.1 (6.8-59.3)	<0.001
Post-intervention	174 (13; 7.5)	184 (5; 2.7)	358 (18; 5.0)		

Serological Prevalence of Camel Trypanosomosis in the Control Fafan Districts

A total of 358 camels were sampled, including 124, 124, and 110 from the *kebeles* Dhkehayo, Kudametana, and Kubijara, respectively. Of these, 49 (13.7%) of them had camel trypanosomosis (Table 9). Age and body condition score were among the risk factors taken into account that were substantially associated with *T. evansi* infection (*P<0.05*) (Table 10).

The chance of developing trypanosome infection was decreased by odds ratio 3 (95% CI=3.0-7.8%) times during the post-intervention period, compared to the prevalence of camel trypanosomosis in the control districts (Table 11).

Table 9. Serological prevalence of *T. evansi* in control Fafan districts using CATT/ *T. evansi* test.

District	*Kebeles*	No. examined	No. positive (%, 95%CI)	OR	p-value
Fafan	Dhkehayo	124	28 (22.6; 15.6-30.9)	5.1	0.0002
	Kudametana	124	15 (12.1; 6.9-19.2)	2.4	0.0760
	Kubijara	110	6 (5.5; 2.0-11.5)	1.0	
	Total	**358**	**49 (13.7; 10.3-17.7)**		

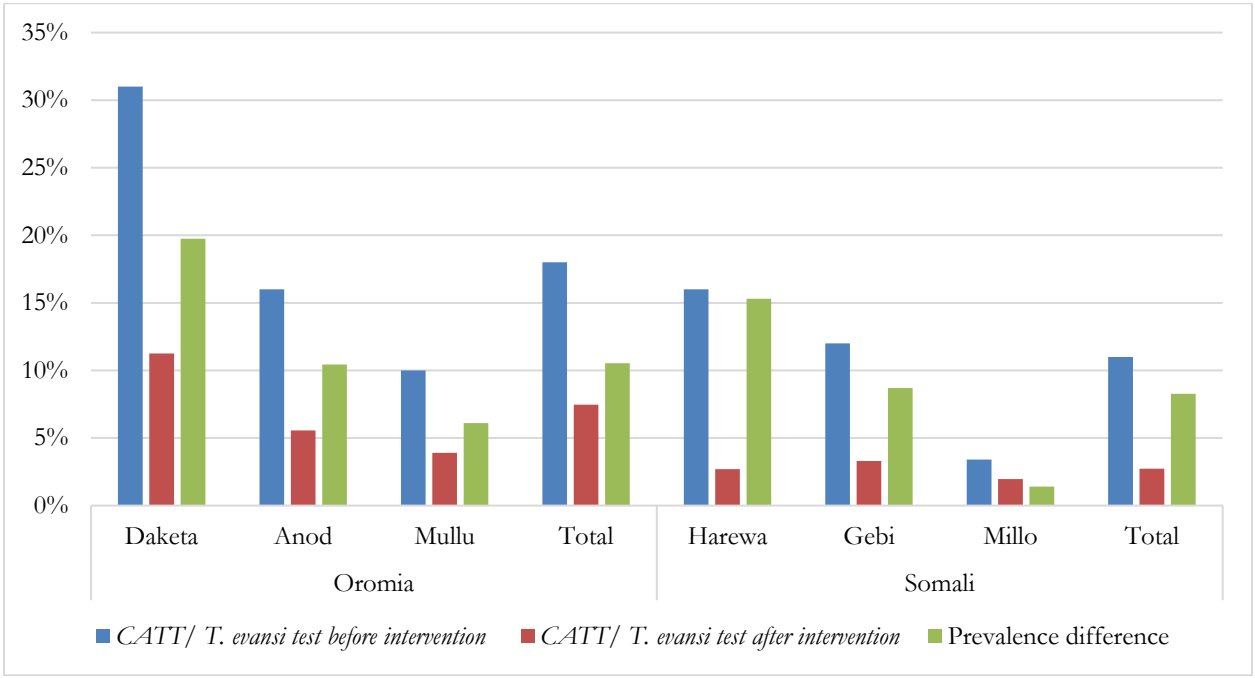

Figure 2. Comparison of prevalence of camel trypanosomosis before and after intervention.

Table 10. Univariable logistic regression analysis of seroprevalence with respect to different risk factors in control Fafan district.

Risk factors	Categories	No. examined	No. positive (%, 95%CI)	Odds ratio	P- value
Sex	Female	117	24 (20.5; 13.6-29.0)	1.0	
	Male	241	25 (10.4; 6.8-14.9)	2.431	0.003
	Total	**358**	**49 (13.7; 10.3-17.7)**		
Age	Adult	141	14 (9.92; 5.5-16.1)	1.0	
	Young	217	35 (16.1; 11.5-21.7)	1.929	0.04
	Total	**358**	**49 (13.7; 10.3-17.7)**		
Body condition	Poor	46	11 (23.9; 12.6-38.8)	1.0	
	Good	312	38 (12.2; 8.8-16.3)	0.384	0.016
	Total	**358**	**49 (13.7; 10.3-17.7)**		

Table 11. Comparison of prevalence of camel trypanosomosis after intervention and control using univariable logistic regression analysis.

Data collection	**Areas**	**No. of examined animal**	**No. positive (%, 95%CI)**	**Odds ratio**	**P- value**
Post-intervention	Babile and Shinile	358	18 (5.0; 3.0-7.8)	1.00	
Control	Fafan	358	49 (13.7; 10.3-17.7)	3.0	<0.001

Discussion

The overall prevalence of *T. evansi* in camel was 5.1% and 8.73% based on parasitological and serological examinations, respectively. Previous reports from Ethiopia supported the present finding; for example, a parasitological prevalence of 5% in Ogaden (Abebe, 1991), 6.25% in Jigjiga Zone (Eshetu *et al.*, 2013), and 4.7% in Fentale district East Shoa Zone of the Oromia Region (Tadewos *et al.*, 2011). However, the present result was not in agreement with the findings from eastern Ethiopia (18.18%) (Zeleke and Bekele, 2001), Bale (2.1%) (Hagos *et al.*, 2009), Afar (6.54%) (Demeke, 2000), and Jigjiga Zone (3.9%) (Tadesse *et al.*, 2012). The current serological prevalence was relatively similar to the reports of Zarif-Fard and Hashemi-Fesharki (2000) in Iran (10%), but lower than the report of Birhanu *et al.* (2015) (13.7%) and Mohammed *et al.* (2015) (23.77 %). These disagreements might arise due to differences in agroecology and the seasonal variations that might have affected the abundance and diversity of vectors responsible for the transmission of *T. evansi* (Barghash *et al.*, 2014).

The prevalence of *T. evansi* was significantly ($P<0.05$) varied among *kebeles* of each district. The maximum parasitological and serological prevalence of the disease was observed in Daketa *kebele* of Babile district (21.2 %), whereas the lowest was recorded in Millo *kebele* of Shinile district (2.1%). These differences may arise from variations in vector density, management systems, ecological differences, and lack of veterinary services. For instance, the higher prevalence in Daketa *kebele* of Babile district might be associated with the favorable agroecology characterized by having several animal watering points as well as the presence of better vegetation cover along with the availability of year-round natural or artificial ponds.

In our finding, camel trypanosomosis was numerically higher in female (9.35%) than male (7.5%) camels, which is in line with the report of Bhutto *et al.* (2010). Meanwhile, the high infection rate in adults than young is supported by the findings of Delafasse and Doutoum (2004) and Atarhouch *et al.* (2003) who stated that young calves below one year of age were free of *T. evansi* infection. This could be due to the fact that pastoralists keep young camels in the abode and they do not go to areas where the fly diversity is high (Gutierrez *et al.*, 2000). Our study also showed that there was a strong association between the body condition of camel and *T. evansi* infection. *T. evansi* infection was significantly higher in poor body condition than good body condition camels. However, poor body condition could be a consequence of *T. evansi* infection characterized by progressive loss of body condition (Salim *et al.*, 2011).

Pre-intervention prevalence of camel trypanosomosis was found to be significantly higher in wet season (14.3%) followed by early dry (10.6%), dry (7.4%), and early wet (2.2%) seasons. The Odds ratio indicated, the risk of trypanosomosis in the early wet season was 7.5 times lower than wet season. Other findings also showed, the prevalence of *T. evansi* was higher in wet season (13.6 %) than dry season (8.4%) (Bekele, 2010). The prevalence of surra is affected by climatic and ecological conditions, and the distribution and abundance of the insect vectors. Usually, local epidemics of surra arises following favorable conditions including stabling of many animals together, presence of adequate rainfall favors conducive breeding ground for biting flies (Barghash *et al.*, 2014).

Biting flies are crucial for the transmission of *T. evansi* (Enwezor and Sackey, 2005). Studies in different tropical areas have shown a positive correlation between seasonal outbreaks of camel trypanosome and the increase in the abundance and diversity of vectors throughout the wet season (Njiru *et al.*, 2002). The highest apparent density of biting flies was recorded for *Stomoxys* (3.4 fly/trap/day) followed by *Tabanus* (0.12fly/trap/day), *Chrysops* (0.04 fly/trap/day) and *Haematopota* (0.02fly/trap/day). Similar findings were

reported by Endalu *et al.* (2016) 3.38 *Stomoxys* /trap/day in Dangur District, and 0.49 *Chrysops* /trap/day and 0.77 *Haematopota*/trap/days. However, the current finding revealed the lower number of flies caught compared with what has been documented previously by Denu *et al.* (2012) who reported apparent density of *Stomoxys* 15.04 fly/trap/day. In the present study, very few biting flies were caught in the early wet and dry season which correlated with the prevalence of *T. evansi* infection in the study area. Previous study conducted in a tropical area showed that there is an association between the occurrence of *T. evansi* infection and the density of biting flies (Tadewos *et al.*, 2011).

The highest proportion of *T. evansi* infection was detected in anemic camels (70.4 %). Anemia appears to be a major component of the pathology of surra (Desquesnes, 2004). A lower mean PCV value was reported by Desquesnes *et al.* (1999) in parasitaemic animals than the aparasitaemic animals. This could be caused by the trypanosomes' production of hemolysin, which causes hemolysis of red blood cells, extravascular RBC destruction, erythrophagocytosis, immune-mediated erythropoiesis depression, and non-specific factors that make red blood cells more fragile (Abdel-Rady, 2008). Therefore, if an animal's PCV value is low and there are no other medical conditions causing anemia, it may be a good indication of trypanosome infection (Enwezor and Sackey, 2005).

Camel trypanosome prevalence was significantly reduced by 65% as compared to the post-intervention period beside when compared to control areas prevalence reduced by 63.5%. The control of trypanosome infection in camel can be effectively implemented by integrating trypanocidal drugs (chemotherapeutic and prophylactic drugs), insecticide-impregnated or non-impregnated traps and targets, pour on techniques and with community-based interventions (OIE, 2013).

Conclusion

The study area had a high prevalence of camel trypanosomosis, with a higher rate in Babile than in Shinile district. The prevalence of camel trypanosomosis was affected by different risk factors such as age, body condition score and season. The abundance and diversity of biting flies and the incidence of the disease coincides with the wet season of the year. The use of trypanocidal drugs (chemotherapeutic and prophylactic drugs), insecticide-impregnated or non-impregnated traps and targets, pour on techniques and with the integration of community-based intervention approaches resulted in a decrease of *T. evansi* seroprevalence in the study areas. Hence, the application of the cohesive eradication program should be strengthened in the study area to minimize camel production and productivity losses due to trypanosomosis.

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Conflict of Interests

The authors declare that they have no competing interests.

References

Abdel-Rady, A. (2008). Epidemiological studies (parasitological, serological and molecular techniques) of *Trypanosoma evansi* infection in camels (*Camelus dromedarius*) in Egypt. *Veterinary World*, 1 (11): 325-328.

Abebe Wosene (1991). Traditional husbandry practices and major health problems of camels in the Ogaden, Ethiopia. *Nomadic Peoples*, 29: 21-30.

Acapovi, G. L., Yao, Y, Goran, E. N., Dia, M. L. & Desquesnes, M. (2001). Relative abundance of tabanids in the savannah regions of Cote d' Ivôire. *Revue d' Eleavge et de Médéecine Veterinaire des pays Tropicaux*, 54 (2): 109-114.

Amer, A., Ryu, O., Tada, C., Fukuda, Y., Inoue, N. & Nakai, Y. (2011). Molecular identification and phylogenetic analysis of *Trypanosoma evansi* from dromedary camels (*Camelus dromedarius*) in Egypt: aApilot study. *Acta Tropica,* 117 (1): 39-46.

Atarhouch, T., Rami, M., Bendahman, M.N. & Dakkak, A. (2003). Camel trypanosomosis in Morocco 1: Result of a first epidemiological survey. *Veterinary Parasitology*, 111:277-286. https://doi.org/10.1016/s0304-4017(02)00382-5.

Barghash, S.M., El-Naga, T.R., El-Sherbeny, E.A. & Darwish, A.M. (2014). Prevalence of *Trypanosoma evansi* in Maghrabi camels (*Camelus dromedarius*) in Northern-West Coast, Egypt using molecular and parasitological methods. *Acta Parasitologica Globalis*, 5:125–132.

Basaznew Bogale, Ferew Kelemework & Mersha Chanie (2012). Trypanomosis in camel (*Camelus dromedarius*) in Delo-Mena district, Bale Zone, Oromia Region, southwest Ethiopia. *Acta Parasitologica Globalis*, 3 (1): 12–15.

BDDLRF (2018). Babile District Development of Livestock Resources and Fishery (BDDLRF). A technical report.

Bekele, M. (2010). An epidemiological study of major camel diseases in the Borana lowland, southern Ethiopia, DCG (Drylands Coordination Group) Report No. No. 58, 09, 2010, Oslo, Norway.

Bhutto, B., Gadahi, J., Shah, G. Dewani, P. & Arijo, A.G. (2010). Field investigation on the prevalence of trypanosomiasis in camels in relation to sex, age,

breeds and herd size. *Pakistan Veterinary Journal,* 30 (3): 175-177.

Birhanu, H., Fikru, R., Said, M., Kidane, W., Gebrehiwot, T., Hagos, A., Alemu, T., Dawit, T., Berkvens, D., Goddeeris, B.M. & Büscher, P. (2015). Epidemiology of *Trypanosoma evansi* and *Trypanosoma vivax* in domestic animals from selected districts of Tigray and Afar Regions, northern Ethiopia. *Parasites and Vectors*, 8: 212. https://doi.org/10.1186/s13071-015-0818-1.

Bourdichon, A. J. (1998). Report on the use of the trypanocidal drug 'trypan'. *The Journal of Protozoology Research*, 8: 258-262.

CSA (2007). Population and Housing Census Report, Central Statistical Agency (CSA), Ethiopia.

Delafasse, A. & Doutoum, A.A. (2004). Prevalence of *Trypanosoma evansi* infection and associated risk factors in camels in eastern Chad. *Veterinary Parasitology*, 119:155-164.

Demeke, H. (2000). The prevalence of camel trypanosomosis in the saltconvey routes of Afar-Tigray, DVM Thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit.

Denu, T.A., Asfaw, Y. & Tolossa, Y.H. (2012). Bovine trypanosomosis in three districts of south west Oromia Ethiopia. *Ethiopian Veterinary Journal,* 16:29-39.

Derakhshanfar, A., Mozaffari, A.A. & Zadeh, A.M. (2010). An outbreak of trypanosomiasis (surra) in camels in the southern Fars province of Iran: Clinical, hemathological and pathological findings. *Research Journal of Parasitology*, 5 (1): 23-26.

Desquesnes, M. (2004). *Livestock Trypanosomoses and Their Vectors in Latin America*, CIRAD-EMVT OIE publication, OIE, Paris, France.

Desquesnes, M., Dargantes, A., Lai, D.H., Lun, Z.R., Holzmuller, P. & Jittapalapong, S. (2013). *Trypanosoma evansi* and surra: A review and perspectives on transmission, epidemiology, and control, impact, and zoonotic aspects. *Bio-Med Research International*, 2013: 321237. https://doi.org/10.1155/2013/321237.

Desquesnes, M., Michel, J.F., deLa Rocque, S., Solano, P., Millogo, L., Bengaly, Z. & Sidibe, I. (1999). Enquête parasitologique et sérologique (ELISA-indirect) sur les trypanosomoses des bovins dans lazone de Sidéradougou, Burkina Faso. *Revue d'Elevage et de Medecine Veterinaire des Pays Tropicaux*, 52: 223-232.

Dia, M.L., Desquesnes, M., Elsen, P., Lancelot, R. & Acapovi, G. (2004). Evaluation of new trap for tabanids and stomoxines. *Bulletin de la Societe Royale Belge d'Entomologie*, 140: 72-81.

Endalu Mulatu, Kumela Lelisa & Delesa Damena (2016). Prevalence of bovine trypanosomiasis and apparent density of tsetse fly in eastern part of Dangur district, north western Ethiopia. *Journal of Veterinary Science and Technology*, 7:4.

Enwezor, F.N.C. & Sackey, A.K.B (2005). Camel trypanosomosis: A review. *Veterinarski Arhiv*, 75: 439-452.

Eshetu, Z., Desta, B. & Amare, L.B. (2013). Prevalence of *Trypanosoma evansi* infection in the one-humped camel (*Camelus dromedarius*) in Jijiga Administrative Zone of the Ethiopian Somali Region. *Global Veterinaria,* 10 (2): 233-238.

Gutierrez, C., Juste, M.C., Corbera, J.A., Magnus, E., Verloo, D. & Montoya, J.A. (2000). Camel trypanosomosis in the Canary Islands: Assessment of seroprevalence and infection rates using the card agglutination test (CATT/*T. evansi*) and parasite detection tests. *Veterinary Parasitology*, 90:155-159.

Hagos, A., Yilkal, A., Esayass, Alemu, T., Fikru, R, Feseha, G. Ab, Goddeeris, B.M. & Claes, F. (2009). Parasitological and serological survey on trypanosomis (surra) in camels in dry and wet areas of Bale Zone, Oromyia Region, Ethiopia. *Revue de Médecine Vétérinaire,* 160 (12): 569-573.

Hailemariam Lemecha, Desalegn Lidetu & Ibrahim Hussein (2008). Prevalence and distribution of camel trypanosomosis in the semi-arid and arid Awash Valley of Ethiopia. *Ethiopian Journal of Animal Production*, 8: 1–9.

Leak, S., Awuome K., Duffera, W., Dumont, P., Feron, A., Jeannin, P., Mahamat, B., Mawuena K., Minengu M., *et al.* (1988). Determination of tsetse challenge and its relationship with trypanosome prevalence in African livestock within the African Trypanotolerant Livestock Network. Proceedings of a meeting held 23-27 November 1987, Nairobi, Kenya, pp: 43-54.

Mohammed, T., Woyessa, M., Brihanu, T. & Hiko, A. (2015). Camel trypanosomosis in Babile district, Eastern Hararghe Zone, Oromia Regional State, eastern Ethiopia. *Academic Journal of Animal Diseases*, 4 (3): 141-145.

Njiru, Z. K., Bett, O., Ole-Mapeny, I. M., Githiori, J. & Ndung'u, J. M. (2002). Trypanosomosis and helminthosis in camels: comparison of ranch and traditional camel management systems in Kenya. *Journal of Camel Research and Practice*, 55: 67-71.

OIE (Office International des Epizooties) (2013). *Trypanosoma evansi* infections (including surra): Aetiology, epidemiology diagnosis prevention and control references. OIE (World Organisation for Animal Health), technical disease card. *Retrieved from*: https://www.woah.org/fileadmin/Home/eng/Animal_Health_in_the_World/docs/pdf/Disease_cards/TRYPANO_EVANSI.pdf.

OIE (Office International des Epizooties) (2017). OIE reference laboratory for animal trypanosomoses of African origin, compendium of standard diagnostic protocols for animal trypanosomoses of African origin, Office International des Epizooties (OIE), Montpellier, France. *Retrieved from*: https://www.woah.org/nttat/Attached%20files/A16-REC-COMPENDIUM_PROTOCOLES_TRYPANO-En.pdf.

Pacholek, X., Gamatic, D., Vias Franek, S. G. & Tibayrenc, R. (2000). Prevalence of *Trypanosoma evansi* trypanosomosis in young camels in west Niger. *Revue. Elev Med. Vet. Pays. Trop.*, 53 (2): 177-182.

Raymond, H.L. & Favre, J. (1991). Essai de lute contre les taons de Guyane Francaise; comparaison du RUV

165, du BUTOX 50 et du BUTOX 7,5 pour la protection des bovins et des chevaux. *Rapport INRA*. Roussel-UCLAF, Mars 1991, 17pp.

Salim, B., M. Bakeit, A., Kamau J., Nakamura, I. & Sugimoto, C. (2011). Molecular epidemiology of camel trypanosomiasis based on ITS1 rDNA and RoTat 1.2 VSG gene in the Sudan. *Parasites and Vectors*, 4: 31.

Schwartz, H. & Dioli, M. (1992). The one-humped camel in Eastern Africa: A pictorial guide to diseases, health care and management, Verlag Josef-Margraf, Weikersheim, Germany.

Seigel, S. & Castellan, N. J. (1988). Non-parametric statistics for behavioural sciences, 2nd ed., McGraw-Hill, New York, USA. pp: 399.

Songa, E.B., Paindavoine, P., Wittouck, E., Viseshakul, N., Muldermans, S., Steinert, M. & Hamers, R. (1990). Evidence for kinetoplast and nuclear DNA homogeneity in *Trypanosoma evansi* isolates. *Molecular and Biochemical Parasitology*, 43:167-179.

Tadesse, A., Omar, A., Aragaw, K. Mekbib, B. & Sheferaw, D. (2012). A study on camel trypanosomosis in Jijiga Zone, eastern Ethiopia, *Journal of Veterinary Advances*, 2 (5): 216-219.

Tadewos Kassa, Tadesse Euguale & Hassen Chaka (2011). Prevalence of camel trypanosomosis and its vectors in Fentale district, South East Shoa Zone, Ethiopia. *Veterinarski Arhiv,* 81 (5): 611-621.

Teshome, H., Molla, B. & Tibbo, M. (2003). A serosurveillance study of camel brucellosis in three camel-rearing regions of Ethiopia. *Tropical Animal Health and Production*, 35:381-389.

Thrusfield, M. (2007). Veterinary epidemiology, 3rd ed. Blackwell Science Ltd, U.K.

Zarif-Fard, M.R. & Hashemi-Fesharki, R. (2000). Study on tissue and blood protozoa of camels in southern Iran. *Journal of Camel Practice and Research*, 7 (2): 193-194.

Zeleke, M. & Bekele, T. (2001). Effect of season on the productivity of camels (*Camelus dromedarius*) and the prevalence of their major parasites in eastern Ethiopia. *Tropical Animal Health and Production*, 33: 321-329.