

Cystic Echinococcosis in Turkana, Kenya: The Role of Cross-Sectional Screening Surveys in Assessing the Prevalence of Human Infection

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Abstract. Cystic echinococcosis (CE) is a neglected zoonotic disease caused by *Echinococcus granulosus*. Infection leads to formation of cysts within the viscera of the human host. In the 1980s, the transhumant population of northwest Turkana, Kenya, was found to have the highest prevalence of CE in the world. In 1983, AMREF Health Africa and the Kenya Medical and Research Institute launched a CE Control Program in northwest Turkana, screening and treating the local people. This epidemiological study of CE in Turkana analyses approximately 30 years of surveillance and surgical data. Cyst data were categorized using the World Health Organization CE ultrasound classification system before being analyzed for cyst, patient, and population characteristics, and surveillance data from 1985 are compared with more recent surveillance data to assess changes in prevalence in the control region since the commencement of control activities. In 1985, the prevalence of CE among the Turkana was 5.6%. In 2010–2011 and 2011–2012, calculated CE prevalence rates were 1.9% and 3.8%, respectively. Since the 1980s, the age distribution of people with CE in Turkana has shifted: initially, cases of CE appeared predominantly within younger age groups, but recent data reveal a higher prevalence within older age groups. The frequency of infection in females also significantly decreased. The reduction in CE prevalence from 5.6% in the 1980s to 1.9–3.8% in 2010–2012 and the shift in age distribution of CE-infected individuals over time indicate that the prevalence of CE in Turkana has decreased since the control program began.

BACKGROUND

***Echinococcus granulosus* and cystic echinococcosis.**

Echinococcus granulosus sensu lato is a cestode of the family Taeniidae which, in humans, causes cystic echinococcosis (CE).¹ Typically considered accidental or aberrant hosts of *E. granulosus*, humans become infected with this zoonotic parasitic disease by unintentionally ingesting *E. granulosus* eggs produced by adult worms residing within the intestines of definitive animal hosts (fecal–oral route).^{1,2} When humans become infected, cysts form in the viscera, most commonly in the liver and secondarily in the lungs, but can occur in any organ or tissue in the body.^{1–3} While 60–75% of patients in most endemic countries of the world are asymptomatic,⁴ complications of CE can arise due to cyst rupture and spread of parasitic material or growth of the space-occupying lesions which interfere with organ function.⁵

Control and prevention of CE. Control and prevention of *E. granulosus* is achieved through animal control and treatment, education, food safety precautions, proper hygiene, use of abattoirs, legislation, and surveillance.⁶ A vaccine for the G1 strain in sheep has also been developed but has yet to be used in the control program.⁷ Many of the CE control programs have been “island based.”⁸ These control programs in Iceland, Tasmania, New Zealand, Cyprus, and the Falkland Islands have successfully reduced and even eliminated CE in humans, and effected significant declines in the rates of *E. granulosus* infection in dogs and sheep.⁸ These programs focused on education, destroying infected offal through the use of abattoirs, regularly deworming dogs with arecoline and since 1982 with praziquantel, reducing local dog populations, and avoiding close contact with dogs.⁸

A number of mainland control programs have also been successful in reducing the public health importance of CE. These include programs in Chile and Argentina. In Chile, the program focused on the 6-weekly praziquantel dosing of dogs in two regions and drastically reduced the prevalence of *E. granulosus* in dogs and sheep in both areas.⁹ In the Province of Rio Negro, Argentina, the program used ultrasound (US) surveys between 1997 and 2002.¹⁰ All human US-detected cases were classified based on World Health Organization (WHO) guidelines, and patients were either observed or treated with albendazole, puncture-aspiration-injection-reaspiration (PAIR), or surgery, depending on cyst size and stage.¹⁰ By 2008, the total number of cases for all age groups was 33, and represented a significant reduction from the 146 cases notified when the program commenced.¹¹

Highlighting the importance of incorporating an educational component in the control program, a 1989 study screened 12 groups of pastoralists living in semidesert regions of Kenya, Sudan, Ethiopia, and Tanzania and found that, although most people recognized CE, they did not relate the parasite to the large abdominal swellings common in infected individuals.⁶ US surveys are particularly useful, as they have a significant educational component—they can be used in remote, rural communities to communicate information to a large number of people, households, communities, and even nations, and can influence national policies.¹²

The CE Control Program in Turkana, Kenya. The Turkana people of northwest Kenya are transhumant pastoralists.¹³ “Transhumance” refers to the seasonal migration of people and livestock to different regions.¹⁴ In the early 1980s, the Turkana of northwest Kenya were recorded as having the highest prevalence of CE in the world.¹³ Risk factors included a large, young immunologically naïve dog population, human behavioral factors facilitating transmission particularly to women and children, a complete lack of abattoirs, and devastating droughts occurring approximately every 10 years

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which killed up to 70% of the livestock population.^{15–19} With limited access to medical and veterinary care, people went undiagnosed and untreated.^{15–18}

The dog played a significant cultural role in Turkana society, kept as protection against wild animals and cattle rustlers and as pets in the home.^{16,18} Because of this close relationship with dogs, women in Turkana who spent the most time in the home and around dogs (thereby increasing their frequency of exposure to the parasite), were found to have higher rates of CE than men.¹⁷ Small children also remained home and in close contact with dogs until old enough to adopt gender roles.^{16–18} Improper disposal of infected offal contributed to high rates of *E. granulosus* infection in dogs. At the time the control program was being developed, there were no abattoirs for proper inspection and disposal of infected livestock offal: viscera of slaughtered animals containing viable cysts were fed to dogs, enabling and perpetuating the *E. granulosus* life cycle.^{18,20}

In 1982, the Kenyan Ministry of Health requested AMREF Health Africa (formerly the African Medical and Research Foundation) to initiate a CE pilot control program in Turkana. This program was launched in October 1983 and was a close partnership between the Ministry of Health, AMREF Health Africa, Ministry of Agriculture, and other local nongovernmental organizations.²⁰ The pilot control area comprised a 9,000 km² region in northwestern Turkana, which had been previously identified as having the highest surgical incidence of CE in the district (40 per 100,000 per year in the entire district when there were no hospitals; and 96 per 100,000 per year in the entire district with 220 per 100,000 per year in northwest Turkana alone after medical facilities were improved⁶); high prevalence of *E. granulosus* in dogs (63.5%) compared with the rest of the district (23%); high dog-to-human ratio; and presence of wild animals (golden and silver-backed jackals) which served as reservoir definitive hosts.^{16,18,20}

Control efforts were numerous and varied, focusing on methods previously proven to be successful in other regions. The program started with an educational component, which focused on reducing contact with dogs, preventing cysts being fed to dogs during slaughter of livestock, and raising awareness of the need to reduce the huge stray dog population and the usefulness of owning healthy dogs.^{13,20} Visual and aural education methods were used, including videos of each group with the CE problem, images of operations, and demonstration of the parasites in dogs.^{13,20} Women were primarily targeted for education, as they had the highest frequency of exposure to the parasite and highest rates of disease. Initially, education was provided vertically by the educational officers of the control team. Community members were then trained to provide continuous education, thus disseminating the information throughout the community in a continuous and repetitive manner, extending years into the program and overlapping with US screenings.

Echinococcus granulosus prevalence in the dog population was monitored by dosing dogs with arecoline.¹³ The dog population was reduced, and the remaining dogs were registered and treatment was attempted every 6 weeks with praziquantel.^{13,20} In addition, female dogs were spayed.^{13,20} The program used cross-sectional community-based US prevalence studies as a means of surveillance.¹³ The initial mass community-based US and serological study,

enrolling approximately a third of the population living in the endemic area, was conducted following the education program to assess the initial CE prevalence in the pilot control area.²¹ To monitor the impact of the program, regular cross-sectional US surveys, initially accompanied by serological studies, were planned.²¹ Subsequently, patients who self-reported at the hospitals and clinics in the region were followed up and treated as necessary, and an assessment of the changing demographic composition of the patient population and US status of cysts in patients in the control area were evaluated.²¹ In pastoral populations where livestock are kept for the purposes of cementing friendships, marriage, etc., and rarely slaughtered for food, surveillance is virtually impossible where there are no slaughter facilities. Surveillance of the control outcomes, therefore, had to be conducted in the human population. This approach has also been implemented in Argentina in the Rio Negro region.^{8,10,11,22,23}

Initial US and serological surveys were conducted in northwest Turkana from July to September 1985. These surveys revealed an estimated CE prevalence of 6.6% (extrapolated 6.5–9.4%) detected by US, with an average cyst size 8.0 cm.²¹ US was far superior to serology by enzyme-linked immunosorbent assay (ELISA) in the detection of CE: while a cystic mass was detected in 198 patients (47 males, 151 females) using US, ELISA was positive in only 76 patients (19 males, 57 females).²¹ In a later publication, the data collected during those months in northwest Turkana were analyzed for cases of CE detected by US only, giving a prevalence of 5.6%.⁶ Prevalence was approximately twice as high in women (6.9%) as men (3.5%).⁶ This represented the highest known prevalence of CE found in the world at that time. All patients in the district discovered during the surveys were offered treatment and followed up.

With some variations, the CE control program in Turkana continued for approximately 30 years. Patients were screened intermittently, but usually at the same time of year and in roughly the same locations, using US, and control activities continued as funding permitted. With the development of US and albendazole came the acceptance of PAIR that provided a less invasive yet effective mode of treatment to radical surgery, when previously had been the only treatment option.^{24,25} All three methods were used to treat people in Turkana.^{24,25} The WHO standardized US classification of CE was published in 2003 and led to changes in treatment methodologies based on cyst stage²⁶: while drug therapy and PAIR is recommended for simple cysts lacking septa and daughter cysts, surgery is recommended for more complex cyst stages containing those features.²⁷ Although many screening and control activities ceased as of 2012, members of AMREF Health Africa continue to offer surgical intervention to CE patients to this day.

The WHO standardized US classification of CE. For all data collected from patients in Turkana, cysts were classified using the WHO standardized US classification of CE, which divides cysts into six different stages (with some sub-categorization) depending on their morphology. US was used because it can be applied in field settings, many people can be screened during a short period of time at low cost and without side effects or patient preparation, and because the diagnostic features are as clear for US as with other imaging techniques, such as hospital-based technologies, including magnetic resonance imaging or computed tomography, and much better than X-rays.^{21,26}

Cystic lesions (CL), often small, are considered early cysts, if they are CE at all—they have no pathognomonic signs, and as such their etiology is uncertain.²⁶ Active cyst stages displaying morphological characteristics that are pathognomonic for CE are the CE1 and CE2 stages. Surrounded by a laminated membrane, CE1 cysts are round- or oval-shaped, unilocular, and anechoic (echo-free); whereas CE2 cysts, while also anechoic, contain daughter cysts.²⁶ For the purpose of this study, CE2 cysts are subcategorized as either CE2A (septated or partially filled with daughter cysts) or CE2B (completely filled with daughter cysts).²⁶ CE3A and CE3B are transitional stages following the active stages and leading to inactive stages.²⁶ These stages also display pathognomonic signs for CE: CE3A cysts can be distinguished by the detachment of the laminated membrane from the cyst wall, creating a wavy appearance within the cyst, called the “water lily” sign; and CE3B cysts are identified by their contents of daughter cysts within an echogenic, solid matrix of degenerated material.²⁶ Inactive CE4 and CE5 stages, though they have no pathognomonic signs, are suggestive of CE and can be distinguished from other stages by their lack of daughter cysts and their hyperechoic appearance, indicating semisolid degenerated contents, without (CE4) or with calcification (CE5).²⁶ CE5 cysts are characterized by a hyperechoic calcified semicircular appearance which casts an anechoic shadow.²⁶ Though typically viewed as inactive and therefore infertile, studies have shown that CE4 cysts can in some cases still contain viable parasitic material (Figure 1).^{26,28}

The current study. The aim of this study was to explore the outcome of the CE control program in Turkana, Kenya, by assessing the changes in overall cyst composition and patient populations. The patient populations under observation are the population within the control region between 2010 and 2012, and the population of the entire Turkana District between 1983 and 2012. Data from the 2010–2012 population in the control region provide an estimate of prevalence within the control region, which, when compared with earlier data, allows for an evaluation of the outcome of the control program. By comparing prior and current rates of disease and evaluating demographics of the population of infected individuals as it has changed over time, this study intended to provide an assessment of the control program’s success. Data from the patient population of Turkana District from 1983 to 2012 provided an insight into the overall changes in this greater patient population.

MATERIALS AND METHODS

This data set included surveillance data from 1983 to 2012 on patients with CE, and surveillance data from 2010 to 2012 on all screened patients (with and without CE) collected via AMREF Health Africa Control Program in northwest Turkana, Kenya, in conjunction with the Kenya Medical and Research Institute (KEMRI) and the Cystic Echinococcosis in sub-Saharan Africa Research initiative. Data were received as written patient notes and US images. All cysts were classified using the WHO standardized US classification of CE on each patient examination, facilitating evaluation of changes, if any, over time. Data were then broken down based on cyst, patient, and population characteristics, and graphed for the purpose of descriptive analysis.

The US prevalence data come from three surveys (1985, 2010–2011, and 2011–2012). These surveys were conducted at the same time of year in the same geographical location. The transhumant nature of the population suggests that this survey technique would facilitate maximizing the potential of screening the same or similar groups of people who inhabit that particular location at that time of year. After consenting to be screened, patients’ age and gender were recorded and they were examined standing, using: a portable Siemens 3.0 MHz real-time linear transducer (Sonoline 1300) powered by a small 1 kW electric generator (Bosch)²¹; a Dynamic Imaging concept/G 3.5 MHz convex transducer; or a SonoSite Titan US system C60/5-2 MHz convex transducer. Liquid paraffin or aqueous gel was used as the transducing medium, and all segments of the liver, the spleen and kidneys were routinely examined. If the patients indicated there was an issue in other locations, then these locations were also investigated. Video display unit images of suspected CE lesions were recorded digitally or on thermal paper and appended to a standardized form recording the patients’ details. Copies were provided to the infected individuals, who were counseled as to their status and were recommended to visit the closest health facility for further follow up. Uninfected individuals were notified that they did not have CE.

When the control programs began, the patients were screened using US and serology; but due to the low sensitivity and specificity of serological tests for CE and the lack of clinical information provided by these tests regarding the size, location, and stage of the cysts, serology was phased out and only US use was continued.^{13,20,21,30} As a painless, non-invasive technique which provides immediate visual results,

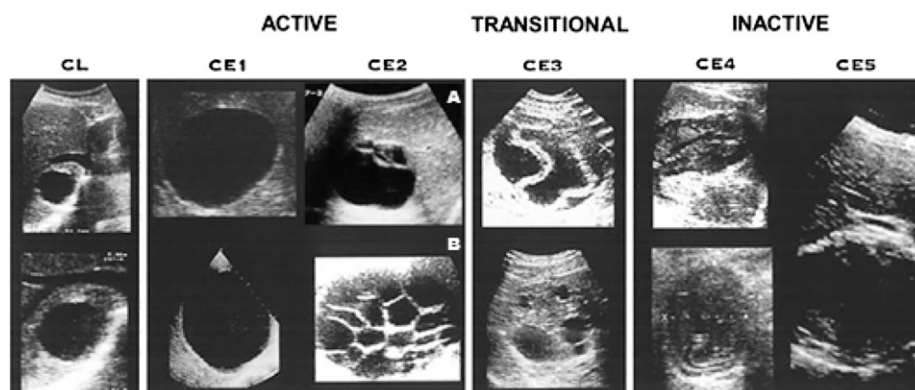


FIGURE 1. World Health Organization standardized ultrasound classification of cystic echinococcosis (CE)^{26,27} (adapted)²⁹.

US screening was readily accepted by the inhabitants of Turkana and attracted almost all the residents to participate.²¹ This facilitated the rapid screening of all individuals present in the vicinity, providing representative age and gender prevalence data of US-accessible cases of CE (US does not go through air or bone, so does not readily detect cysts in the lungs or in osseous locations).

Ethical considerations. At the onset of the program in 1983 there were no institutional review boards (IRBs) in Kenya and informed consent was sought individually or from the chief of the village. With the development of IRBs the mass screening program was put through the KEMRI IRB and patients' informed consent was obtained. A proposal for the analysis of the data provided for this study was submitted to the AMREF Health Africa Ethics and Scientific Review Committee and the St. George's University IRB.

The time interval between discovery of CE in a patient and subsequent treatment varied widely and depended on availability of treatment and the willingness of the patients to be treated. CE was asymptomatic in most cases, so the perceived need for treatment was absent and most patients with CE refused treatment and went about their daily lives. Patients often did not present at health centers until the condition became apparent. Treatment could not be administered without patient consent. As surgery was invasive, patients were often hesitant or unwilling to be treated. The members of the control program informed all patients found with CE of their condition and, as appropriate, endeavored to advocate for treatment, but treatment cannot be forced on an individual regardless of clinicians' opinion or judgment. Patients also were not mandated to remain within the control area, be monitored between screenings, or forced to engage in the screening process, so screenings for some of these patients were years apart. The Lopiding, Kakuma, and Lodwar Hospitals, which were served by AMREF Health Africa's surgical services, were the major treatment sites for patients with CE. This data set included Turkana patients, treated and untreated, over the 1983–2012 period. Each patient was identified and every effort was made to follow them up.

RESULTS

2010–2012 US surveillance data and outcome of the screening program. Surveillance data for screened individuals with (CE+) and without CE (CE-) for the years 2010–2012 were analyzed. The demographic composition (gender and age) of the populations screened in each recent survey (2010–2011, 2011–2012) were determined and compared with the demographic composition of the population screened in 1985, based on data published in Macpherson and others.²¹ A total of 3,553, 3,179, and 4,188 people were scanned with US in the 1985, 2010–2011, and 2011–2012 screenings, with males representing 38.2%, 39.5%, and 39.9% of those screened, and females representing 61.8%, 60.5%, and 60.1% of those screened, respectively. Tests of proportions for gender, comparing the proportions of males and females screened in 1985 to 2010–2011, 1985 to 2011–2012, and 2010–2011 to 2011–2012 failed to achieve significance for all comparisons (adjusted alpha, $P = 0.05 / 3 = 0.17$).

In addition to gender distributions, age distributions were also investigated. Patients were categorized into 5 age groups: 0–5 years, 6–15 years, 16–25 years, 26–50 years, and > 50 years. The 0–5 age group constituted 15.4% of the

screened population in 1985, 22.9% in 2010–2011, and 25.7% in 2011–2012; the 6–11 age group constituted 26.6% of the screened population in 1985, 24.6% in 2010–2011, and 23.9% in 2011–2012; the 16–25 age group constituted 23.2% of the screened population in 1985, 10.8% in 2010–2011, and 11.9% in 2011–2012; the 26–50 age group constituted 32.0% of the screened population in 1985, 29.0% in 2010–2011, and 29.0% in 2011–2012; and the > 50 age group constituted 2.8% of the screened population in 1985, 11.8% in 2010–2011, and 9.4% in 2011–2012. Tests of proportions of age groups using an adjusted alpha ($\alpha = 0.05 / 10$ comparisons = 0.005) revealed significant differences in the proportion of patients in the 0–5, 16–25, and < 50 age groups between 1985 and 2010–2011, and between 1985 and 2011–2012.

Standardized prevalence values for CE patients per 1,000 people, male CE patients per 1,000 males, and female CE patients per 1,000 females were calculated from patient data collected in 1985²¹ (adapted from Macpherson and others), 2010–2011, and 2011–2012. The overall percent prevalence of CE was revealed to be 5.6% in 1985 (3.5% in males, 6.9% in females), 1.9% in 2010–2011 (1.9% in males, 1.9% in females), and 3.8% in 2011–2012 (3.1% in males, 4.2% in females). Test of proportions comparing overall CE prevalence per 1,000 people, CE prevalence in males per 1,000 males, and CE prevalence in females per 1,000 females using an adjusted alpha ($\alpha = 0.05 / 6$ comparisons = 0.0083) achieved significance in the assessment of overall prevalence between 1985 and 2010–2011 ($P < 0.001$), and between 1985 and 2011–2012 ($P < 0.001$); as well as in the assessment of prevalence in females between 1985 and 2010–2011 ($P < 0.001$), and between 1985 and 2011–2012 ($P < 0.001$). Test of proportions comparing CE prevalence in males failed to achieve significance for either the 1985-to-2010–2011 or 1985-to-2011–2012 comparison.

Standardized prevalence values (per 1,000) in males and females by age group for the year 1985 were then calculated using data published by Macpherson and others.²¹ These values were compared with standardized prevalence values in males and females by age groups for the 2010–2011 and 2011–2012 screenings (Figure 2).

Tests of proportions of CE prevalence by age groups using an adjusted alpha ($\alpha = 0.05 / 10 = 0.005$) revealed significant differences in the overall CE prevalence in the 6–15, 16–25, and 26–50 age groups ($P < 0.001$) between 1985 and 2010–2011, and in the 16–25 age group ($P < 0.001$) between 1985 and 2011–2012. Tests of proportions of CE prevalence by age groups in males using an adjusted alpha ($\alpha = 0.05 / 10 = 0.005$) revealed a significant difference in CE prevalence in males in the 16–25 age group ($P < 0.001$) between 1985 and 2010–2011. Tests of proportions of CE prevalence by age groups in females using an adjusted alpha ($\alpha = 0.05 / 10 = 0.005$) revealed a significant difference in CE prevalence in females in the 6–15, 16–25, and 26–50 age groups ($P < 0.001$) between 1985 and 2010–2011, and in the 16–25 age group ($P < 0.001$) between 1985 and 2011–2012.

CE prevalence was calculated for the combined age groups 0–25, representing patients born after the commencement of the pilot control program. CE prevalence in the 0–25 age group was found to be 44.43 per 1,000 (29.53 males with CE per 1,000 males, 55.39 females with CE per 1,000 females) in 1985,²¹ 5.94 per 1,000 (5.99 males with CE per 1,000 males, 5.89 females with CE per 1,000 females) in 2010–2011, and

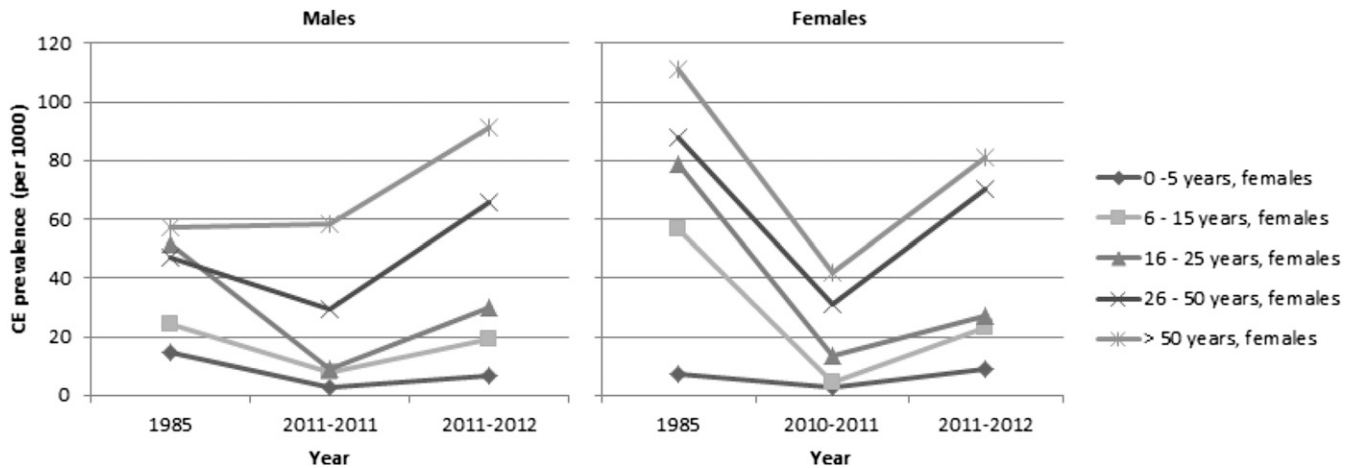


FIGURE 2. Standardized prevalence values for male cystic echinococcosis (CE) patients per 1,000 males, and female CE patients per 1,000 females, calculated from patient data collected in 1985²¹ (adapted from Macpherson and others), 2010–2011, and 2011–2012.

15.93 per 1,000 (12.84 males with CE per 1,000 males, 18.49 females with CE per 1,000 females) in 2011–2012 (Figure 3).

Tests of proportions comparing CE prevalence in the 0–25 and > 25 age groups using an adjusted alpha ($\alpha = 0.05 / 4 = 0.0125$) were significant for the 0–25 and > 25 age groups ($P < 0.001$) between 1985 and 2010–2011, and for the 0–25 age group ($P < 0.001$) between 1985 and 2011–2012.

1983–2012 surveillance data for patients with CE. Between 1983 and 2012, data were archived for 2,182 cysts in 961 patients. Patient ages were grouped into 5-year intervals (0–5, 6–15, 16–25, 26–50, > 50) to observe changes in age distributions of patients over the course of the control program.

A Somers' d ordinal test for patient age over time was significant for age ($\Delta = 0.169, P < 0.001$) as well as overall ($\Delta = 0.175, P < 0.001$). Data on gender were then factored in to assess whether there were any observable changes in this distribution among patients in Turkana with CE (Figure 4).

A Pearson χ^2 was significant ($P < 0.001$), and an ordinal Somers' d test was also significant for gender as a dependent variable $d = -0.042 (P < 0.01)$, and overall ($P < 0.01$).

Cysts were grouped based on the WHO classification. Each group was analyzed by age of patients in whom cysts were discovered by the year in which they were discovered (Figure 5).

Somer's d ordinal tests on population age distribution over time achieved significance for CLs ($\Delta = 0.340, P < 0.001$), CE1 cysts ($\Delta = 0.184, P < 0.000$), CE2B cysts ($\Delta = 0.347, P < 0.001$), CE3A cysts ($\Delta = 0.424, P < 0.001$), CE3B cysts ($\Delta = 0.323, P < 0.001$), CE4 cysts ($\Delta = 0.398, P < 0.001$), and CE5 cysts ($\Delta = 0.409, P < 0.01$). A Somers' d ordinal test on population age distribution over time for CE2A cysts ($\Delta = 0.154, P = 0.202$) failed to achieve significance.

DISCUSSION

2010–2012 surveillance data. Surveillance data received for all screened individuals for the years 2010–2012 were analyzed to observe changes in prevalence, thus indirectly assessing the pilot control program which began in 1983. During each of the three screenings (1985, 2010–2011, 2011–2012), a remarkably similar number of people were seen, suggesting that these samples may represent the

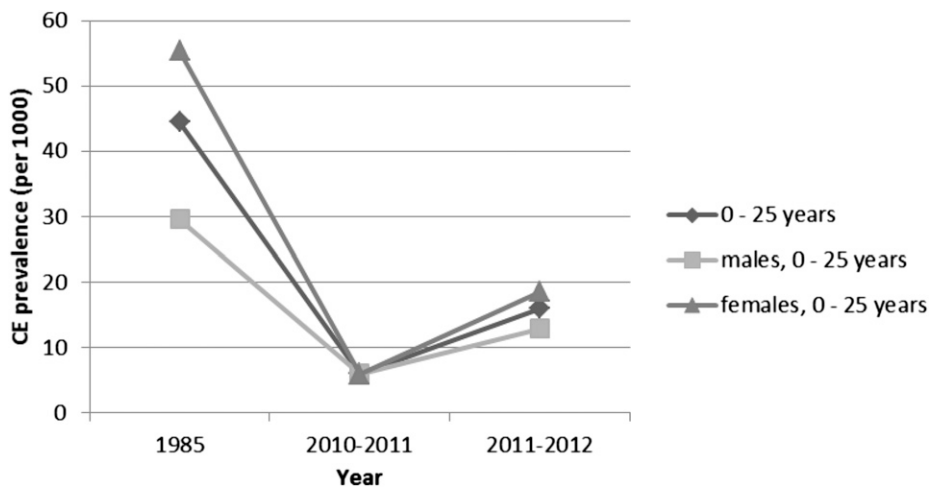


FIGURE 3. Comparison of the 0–25 age group prevalence values for 1985²¹ (adapted from Macpherson and others), 2010–2011, and 2011–2012.

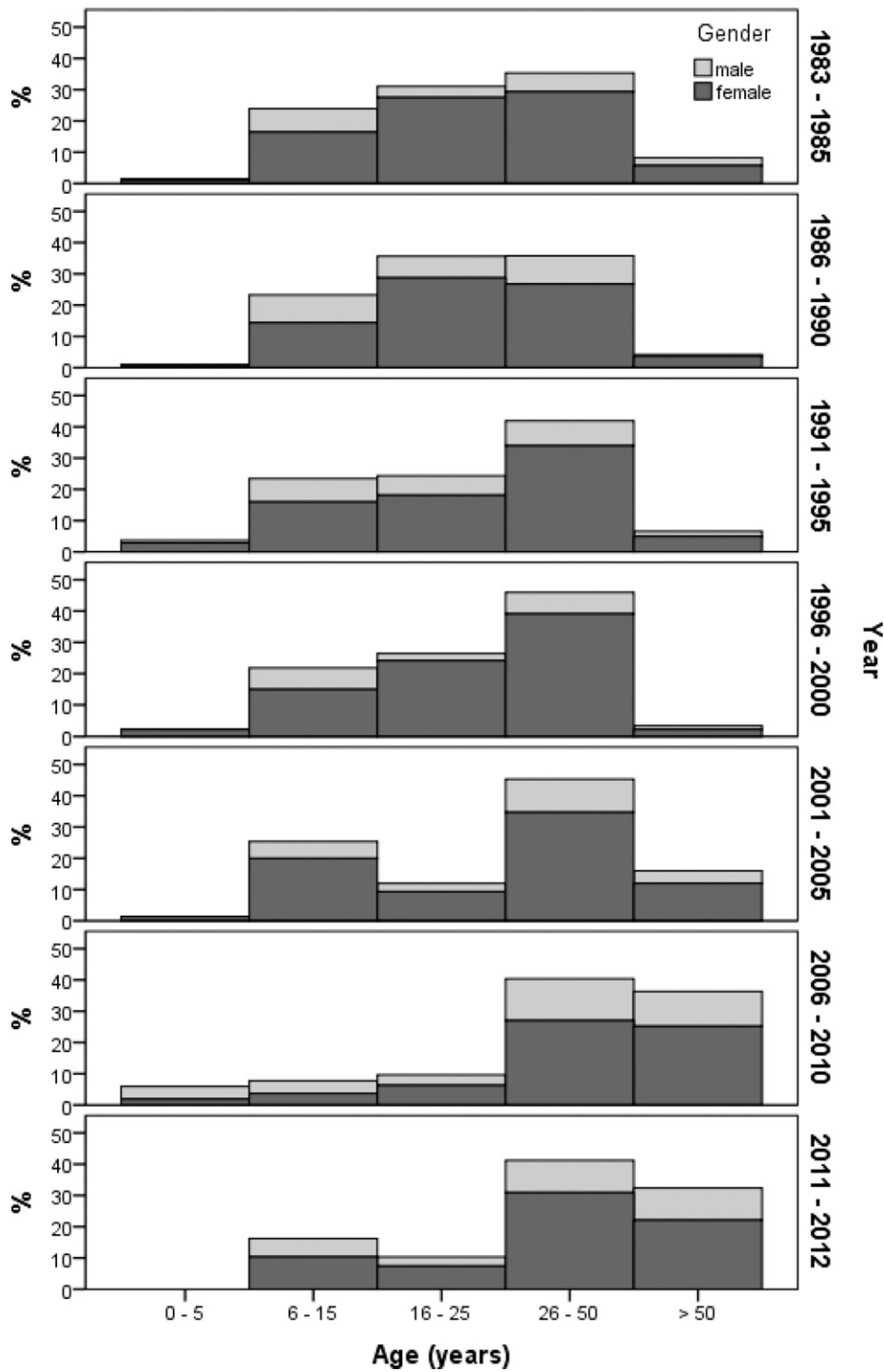


FIGURE 4. Combined age and gender data showing changes in the characteristics of the cystic echinococcosis (CE)+ patient population in the Turkana control area from 1983–2012.

carrying capacity of the area in which people were sampled in the pilot control region. The US surveys tended to screen everyone who was present in the vicinity at that time, making this as representative a sample of the population as possible given the Turkana’s transhumant lifestyle. The male-female distribution has also remained constant over time, although the age distribution of the 1985 screened sample is significantly different from that of more recent 2010–2011 and

2011–2012 surveys. Stability of the gender distribution, however, facilitates comparison between the surveys.

The first evaluation of the pilot control program in Turkana in 1985 found that 5.6% of the patients in the control region were infected with CE.⁶ According to analysis of epidemiological data, as of 2010–2012 prevalence significantly decreased from 5.6% to 1.9–3.8%. This is a reduction by a third to a half. As control activities were taking place in the interim, reduction

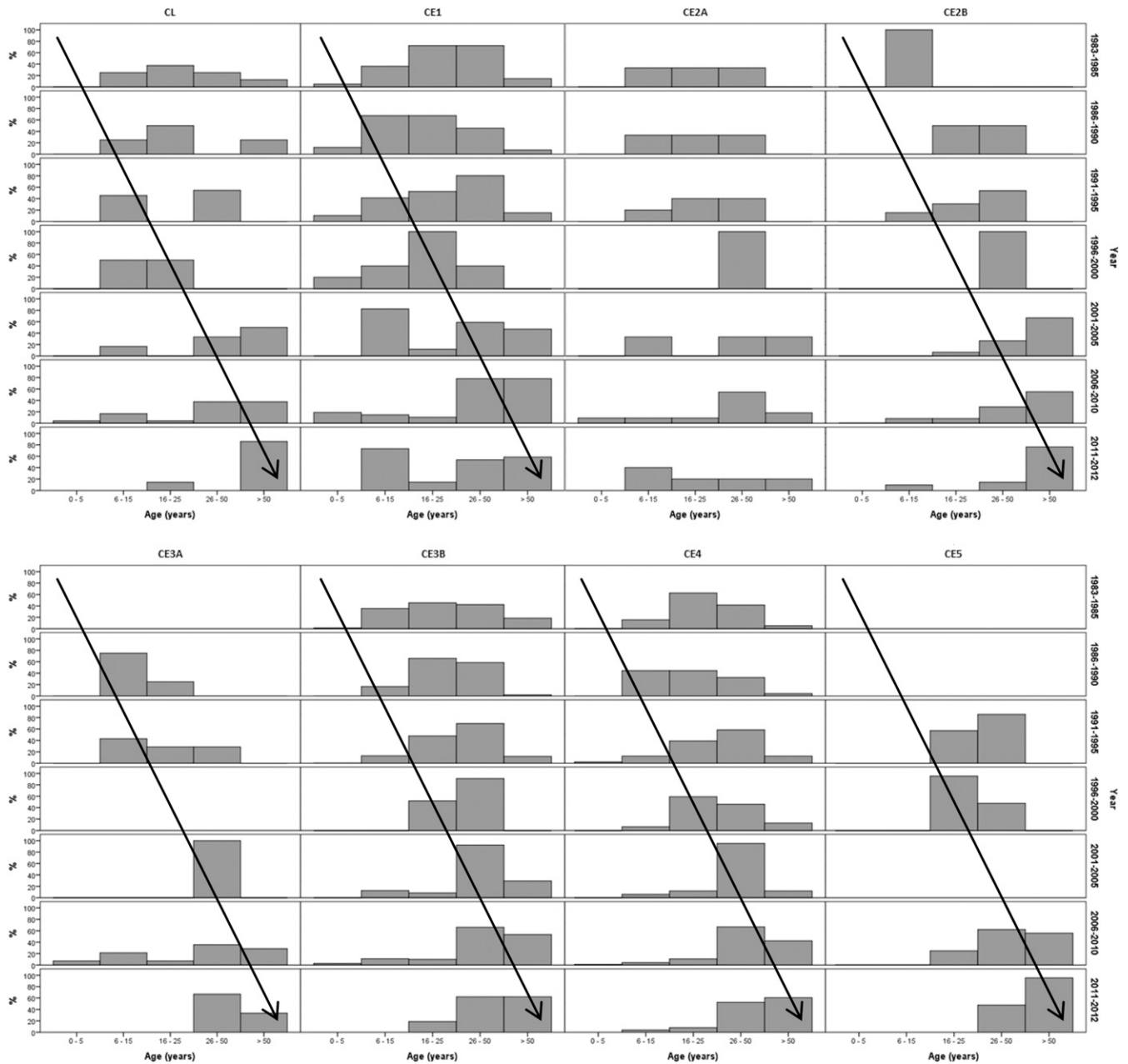


FIGURE 5. Distribution by year of cysts in each stage by age of patients in which they were detected.

in prevalence between 1985 and 2012 is an outcome to which the control program may have contributed.

Probability of infection with CE increases with frequency of exposure to the parasite. When the program commenced, as exposure occurred primarily in the home, women and children were more susceptible and thus it was not surprising that women exhibited higher rates of disease and rates were comparable between male and female children. By educating the community, reducing the dog population, etc., frequency of exposure and therefore infection were likely to be reduced, particularly in these susceptible groups. This is consistent with the finding that reduction in prevalence is due almost entirely to reduction in the prevalence of CE among women. When standardized epidemiological values are considered, attention is drawn to the youngest and oldest age groupings, the

only overall groupings whose differences between the years fail to achieve significance. The sample size of the youngest age group (0–5) was very small and prevalence in this group was low to begin with, so any conclusions regarding this group are limited; however, the observation that the prevalence of CE in the oldest age group has remained the same since the commencement of the pilot control program while the prevalence in the majority of younger age groups has decreased is particularly noteworthy, given that these older patients were already alive and potentially infected prior to the beginning of the control program. Drawing conclusions regarding the features of this age group—as with the youngest age group—also presents with significant limitations due to the low frequency of patients in this age group and low life expectancy among the Turkana in general, given the harsh conditions in which

they live. Despite these limitations, prevalence reduction in the overarching < 25 age group has potentially positive implications: subjects under the age of 25 were born during or after the control program was initiated, and lower prevalence of disease in these patients may reflect changes facilitated by the control program's various activities. Although it cannot be concluded with certainty that the control program led to these results, these observed outcomes mirror those of other successful control programs.^{8,31}

1983–2012. The demographic data of patients with CE collected as a part of the CE control program in northwest Turkana were then explored to identify whether there had been any changes in the demographic composition of the CE+ group in Turkana, what those might be, and what they reflect regarding the outcomes of the control program. Data for each time interval were based on a convenience sample of patients screened during that time period. A patient therefore may appear either in multiple time intervals, or only once depending on their presence in the control area for screening during each time interval. Although a patient may have been seen multiple times within one time interval, data for that patient are included only once per time interval.

From 1983 to 1985, the majority of Turkana with CE were within the younger age groups, primarily between 6 and 35 years of age. This distribution remained relatively consistent over the next 5 years, but changes in the age distribution began to appear in 1991, with a slow shift toward most Turkana people with CE being over the age of 26 by around 2008. This reduction in patient numbers in the younger age groups and increase in patients in the older age groups is consistent with the fact that the under 25 age group would contain individuals born during or after the start of control activities, and the 26 to 35 age group would contain the last individuals who were alive prior to the commencement of control activities. As such, those who were born during control activities or after they ceased stood to gain the most from these activities: risk of exposure would have been reduced with reduction of the dog population, behavioral changes, etc., resulting in a lower likelihood of infection among these individuals.

Overall, more Turkana women are infected with CE than men, but as the 1983–2012 data cannot be standardized it is important to take into account the demographic composition of the population and the standardized epidemiological values calculated using the 2010–2012 surveillance data: when these were considered along with the descriptive analysis of 1983–2012 data on CE patients only, the finding of decreasing disparity between infection rates of men and women is supported. Since women were more susceptible to CE and targeted for education, increasingly similar rates of CE between men and women over time suggests a reduction in parasite transmission which may be due to control activities and behavioral change in the population which was most heavily infected and therefore had vested interest in behavioral change.

CONCLUSIONS

Conclusions that may be drawn from this study have to take into account the challenging conditions encountered, which included the transhumant lifestyle of the population, low education and literacy rates, transmission-supportive customs and behaviors, and environmental factors.^{15,18,20,32} With the exception of surveillance data from 2010–2011 and

2011–2012, the data collected only represent CE-infected subjects, and do not include uninfected subjects. This limits the ability to assess prevalence from this data set, leaving only the 2010–2012 surveillance data to assess and compare prevalence rates. As a convenience (albeit large) sample, the prevalence calculated from the 2010–2012 data must still be treated as an estimate since it remains unclear what percentage of the population in the region the data set from 2010–2012 represents. Because of the transhumant nature of the Turkana people and the anonymized storage of data, it was possible that some people may have been screened more than once. Additionally, as cooperation in US screening for CE was not mandated or forced, these data and the associated analyses do not account for those people who chose not to engage in the screening process. The number of people who chose not to partake in US surveillance, however, is likely insignificant, as US is widely accepted by and attractive to the Turkana.

Taken altogether, descriptive analysis of the data collected by the CE control program in northwest Turkana, Kenya, showed changes in prevalence and infected population demographics potentially reflecting the positive impact of the program. An additional comprehensive survey would allow for a more complete analysis and comparison of the population at present to the population in the early 1980s. This would allow for more precise determinations of the nature and causes of the observed changes. The outcomes discussed in this paper could have been due to any number of changes within the community or country, including behavioral changes reducing parasite transmission; education of the community regarding the nature of the disease and proper disposal of offal (not feeding offal to dogs); reduction of the young susceptible dog population; construction and maintenance of abattoirs; or even climate change. Impact on disease transmission through education is a slow process and change is rarely effected through educational programs alone.³³ In control programs such as this one, education facilitates the implementation of biological control efforts (dog reduction and treatment, treatment of infected individuals, provisional slaughter facilities and changing feeding practices to dogs). Efforts to educate the community over time may have resulted in behavioral change and reduced parasite transmission; but substantial changes in prevalence were most likely brought about early on through reduction of dog population and regular treatment of dogs with praziquantel. This is consistent with findings of successful control programs elsewhere in the world.

As many of the control activities—excepting surgical safaris—have ceased, the authors advise that this comparative survey be commenced as soon as possible while the control program's efforts are still recent, and prior to the potential commencement of new activities which may confound additional data collection and analysis.

Received August 5, 2016. Accepted for publication April 6, 2017.

Published online May 30, 2017.

Acknowledgments: The authors would like to acknowledge Amref Health Africa (formerly the African Medical and Research Foundation), the Kenya Medical Research Institute (KEMRI), the Deutsche Forschungsgemeinschaft (DFG), and the Cystic Echinococcosis in Sub-Saharan Africa Research initiative for commencing, funding, and carrying out the CE control program in Turkana, Kenya, from which the data set analyzed in this study was derived. The authors would also

like to acknowledge St. George's University for providing the means to complete this study.

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