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# Sero-prevalence of *Taenia solium* Cysticercosis and *Taenia solium* Taeniasis in California, USA

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*Objectives* – *Taenia solium* Cysticercosis is a leading cause of epilepsy and neurological disability in the developing world. It is caused by ingestion of the eggs of the tapeworm, *T. solium* Taeniasis. The prevalence of either *T. solium* Cysticercosis or *T. solium* Taeniasis in the United States in populations at risk is poorly understood. The primary objectives of this study are to perform the first study of the sero-prevalence of *T. solium* Cysticercosis and *T. solium* Taeniasis in an at-risk community in the USA, specifically rural Southern California; identify *T. solium* Taeniasis positive individuals, and treat positive individuals for the tapeworm *T. solium* Taeniasis. *Methods* – Community based sero-prevalence study of antibodies to *T. solium* Cysticercosis and *T. solium* Taeniasis in 449 subjects living in a federally funded, predominantly Hispanic residential community; and in two migrant farm worker camps in rural Ventura County, California, USA. For this study, fingerstick blood samples were obtained. Serum immunoblots for both *T. solium* Cysticercosis and *T. solium* Taeniasis were performed. *Results* – The sero-prevalence of *T. solium* Cysticercosis was 1.8% and the sero-prevalence of *T. solium* Taeniasis by serum immunoblot was 1.1%. *Taenia solium* Cysticercosis and *T. solium* Taeniasis antibodies were not detected in children. The sero-prevalence of *T. solium* Taeniasis was highest in the migrant farm worker community. Handwashing frequency was correlated with *T. solium* Taeniasis sero-positivity. *Conclusion* – The sero-prevalence of *T. solium* Cysticercosis and *T. solium* Taeniasis in this population, as detected by serum immunoblot, approximates the prevalence in some endemic areas of Latin America. Importantly, most patients likely had prior exposure, not active infection. This study establishes for the first time, the relative sero-prevalence of *T. solium* Cysticercosis and *T. solium* Taeniasis in at-risk populations in the United States.

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Neurocysticercosis results from ingestion of eggs and proglottids from the adult tapeworm, *Taenia solium* (*T. solium* Taeniasis). The tapeworm, *T. solium* Taeniasis lives in the human intestine and is acquired by eating poorly cooked pork infected with the larval form of cysticercosis. Neurocysticercosis is a growing public health problem in the United States (1, 2). In Hispanics and Latinos, neurocysticercosis accounts for 13.5% of emergency room visits for seizures (1). Recent data indicates that Cysticercosis is an important cause of death among Hispanics in California (2). This growth is mainly due to immigration from endemic developing countries (3). It is estimated that *T. solium* Cysticercosis affects 50 million people worldwide; however, despite hospital-based data, and data from an orthodox Jewish community in New York, the prevalence of *T. solium* Cysticercosis and *T. solium* Taeniasis in the United States is poorly understood (1, 4, 5).

It is likely that migrant farm workers and their families are at particular risk for *T. solium* Cysticercosis and *T. solium* Taeniasis. Farm workers in California and the United States emigrate primarily from Mexico and Central America, where the prevalence of *T. solium* Cysticercosis and *T. solium* Taeniasis is high. Until recently, the principal methods for detecting tapeworm infections have been stool microscopy, or the detection of *T. solium* Taeniasis antigens in stool (6). The sensitivity of both of these techniques is low and obtaining stool specimens is awkward, and exposes family members and field workers to infection (6, 7). Recently, Wilkins et al. developed a fingerstick *T. solium* Taeniasis immunoblot to complement the widely available cysticercosis immunoblot (7). The new serum *T. solium* Taeniasis immunoblot is highly sensitive (95%) and specific (100%) (6, 7). The use of a fingerstick immunoblot represents a significant advance. In this study, we utilize both the highly sensitive *T. solium* Cysticercosis and *T. solium* Taeniasis immunoblot obtained by fingerstick. We report the sero-prevalence of antibodies to *T. solium* cysticercosis and *T. solium* Cysticercosis in a federally funded predominantly Hispanic residential community for farm workers and their families, and nearby migrant farm worker camps.

## Materials and methods

We conducted a population-based study in the agricultural region of eastern Ventura County, near the town of Fillmore, California. Fillmore has a population of 13,643 (2000 US Census), of which 66.6 percent are Hispanic (8). This community was selected because it is the closest farming community to Olive View/UCLA Medical Center, the study's originating medical center. In this region there are two migrant farm worker camps and one federally funded residential community for farm workers and their families. At the time of the survey (September through December 2001), the total population of the residential community was 501 and the population of the farm worker camps was approximately 200.

### Survey method

Bilingual survey team members underwent training by a Public Health specialist (FS) so that the questionnaire and samples would be obtained in a standardized fashion. The team conducted a house-to-house study in the federally funded residential community. In the migrant farm worker camps, due to the barracks style of housing, a house-to-house survey was not possible. The team conducted the study in a centralized, common area of the camp.

Prior to the survey, the leaders of each community were contacted and informed about the study. Notices approved by the research committee were posted in public areas. The team members introduced themselves and communicated the nature of the study. Informed consent was first obtained from adults and, in the case of children; a child assent form was obtained in addition to obtaining parental consent. The study and all survey instruments were reviewed and approved by the Human Subjects Protection Committee at Olive View/UCLA Medical Center and the Centers for Disease Control and Prevention.

A questionnaire was developed to obtain information on age, gender, race/ethnicity, educational level, country of origin, years of residence in the United States, occupation, travel history, household income, number of household residents, history of seizures, epilepsy and other neurological and medical information. Based on surveys conducted in central and south America, specific questions about risk factors unique to *T. solium* cysticercosis and *T. solium* Taeniasis were included: exposure to pigs, pork consumption, and sanitation conditions. The survey was developed in consultation with experts in the epidemiology of cysticercosis (FS and MM). The survey was then piloted with Spanish speaking subjects, revised, piloted again, and ultimately translated into identical Spanish and English versions.

Study participants were assigned a numeric code: no personal identifiers were included in blood samples sent to the Centers for Disease Control in order to ensure confidentiality. At no times were participants asked their immigration status. Participants were assured that no identifying information would be used or communicated for any purpose other than the study, and assured that no governmental agency would have access to identifying data. Each survey member was assigned a teammate to verify all entries and to ensure that the study numbers matched the surveys and the blood samples.

Blood samples were obtained using a 'soft touch II' spring-loaded finger stick device and lancet. Drops of blood were obtained and placed directly onto standardized PKU filter paper using the technique of Jafri et al. (9). The blotted papers were labeled with numbers only, dried on racks, and placed in sealed zip lock bags containing a silicone desiccant. After collection, filter paper containing blood samples were stored in a −10°C refrigerator and then express-mailed to the

Immuno-Parasitology Laboratory at the Centers for Disease Control in Atlanta, Georgia, where immunoblots were performed (7, 9).

Antibodies from the blood spots were extracted by ultrasonication with PBS/Tween 20 buffer as previously described (7). *Taenia solium* Cysticercosis antibodies were determined by enzyme-linked immuno-electrotransfer blot using the technique reported by Jafri et al. (9). For detecting adult tapeworm infections we used a screening test, the EITB-T for *T. solium* Taeniasis, which detects antibodies specific for either one of a pair of glycoproteins purified from adult tapeworm culture supernatant (7). Sero-positive individuals for adult tapeworm-specific antibodies (EITB-T+) were also tested with a coproantigen test for the presence of tapeworm antigens in their stool. Subjects testing positive for *T. solium* Cysticercosis or *T. solium* Taneiasis were contacted and offered computerized axial tomography (CT scan) of the brain, stool examination and treatment with niclosamide.

### Data entry and analysis

Data was entered using Epic-Info version 6.0. Cross-field edit checks and double data entry were employed to ensure optimal data quality. All data management and data analysis were conducted using SAS. The Mantel–Haenszel $\chi^2$, Kruskal–Wallis, Fisher exact (for dichotomous data), and *t*-tests (for continuous data) were used to evaluate apparent differences for significance. The association between *T. solium* sero-positivity and each of the potential risk factors was expressed as an odds ratio (OR) with a 95% exact confidence interval (CI).

## Results

### Population characteristics

A total of 449 subjects aged 4 months to 64 years old were enrolled in the study. A total of 349 subjects lived in the 100-unit residential community (population 501). One hundred subjects lived in the two farm worker camps in the region (estimated combined population of the two camps = 200). Overall, 447 subjects (99.6%) were of Hispanic or Latino ethnicity. Key social and demographical data are shown in Table 1. Of the 449 subjects enrolled, 167 were children (aged 0–17) and 282 were adults (aged 18 and older). In adults, the ages ranged from 18 to 68 years (mean: 34.28; SD: 11.59). Children's ages ranged from <12 months to 17 years (mean: 9.83; SD: 4.42).

**Table 1** Characteristics of the 449 subjects surveyed

| | Number (%) of subjects | | |
|---|---|---|---|
| | Residential site ($n = 349$) | Migrant camps ($n = 100$) | Significance (chi-square), *P* |
| Sex | | | |
| Male | 175 (50.1) | 95 (95.0) | <0.0001 |
| Female | 174 (49.9) | 5 (5.0) | |
| Age (years) | | | |
| 0–17 | 164 (47.0) | 3 (3.0) | <0.0001 |
| ≥18 | 185 (53.0) | 97 (97.0) | |
| Primary occupation | | | |
| Farm worker | 59 (16.9) | 77 (77.0) | <0.0001 |
| Factory | 44 (12.6) | 2 (2.0) | |
| Housewife | 24 (6.9) | 0 (0.0) | |
| Construction | 3 (0.9) | 9 (9.0) | |
| Student | 163 (46.7) | 1 (1.0) | |
| Other | 56 (16.0) | 11 (11.0) | |
| Raised or lived with pigs for ≥1 month | | | |
| Yes | 115 (33.0) | 43 (43.0) | 0.057 |
| No | 233 (66.8) | 56 (56.0) | |
| Not sure | 1 (0.3) | 1 (1.0) | |
| City of origin (type) | | | |
| Urban | 217 (62.2) | 37 (37.0) | <0.0001 |
| Rural | 126 (36.1) | 63 (63.0) | |
| Country of origin | | | |
| Mexico | 206 (59.0) | 94 (94.0) | <0.0001 |
| United States | 138 (39.5) | 6 (6.0) | |
| El Salvador | 4 (1.1) | 0 (0.0) | |
| Guatemala | 1 (0.3) | 0 (0.0) | |

The demographics of the residential facility and the migrant farm worker camps were significantly different. Ninety-five percent of subjects from the migrant farm worker camps were adult males, vs 50.1% of subjects in the residential community ($P < 0.0001$). Subjects from the migrant farm worker camps were more likely born in rural areas (63% vs 36%, $P < 0.0001$). Ninety-four percent of the subjects from the migrant farm worker camp were born in Mexico, compared with 59% of subjects from the residential community ($P < 0.0001$). The frequency of travel for the migrant farm workers to Latin America was significantly higher than the residential community ($P < 0.05$, Kruskal–Wallis).

### Sero-prevalence of *T. solium* Cysticercosis

Of 449 subjects, eight individuals had antibodies to *T. solium* Cysticercosis, for a total sero-prevalence of 1.8%. The sero-prevalence among the 282 adults was 2.8%, vs 0.0% for children ($P < 0.05$, Fisher exact test). All eight subjects were from different families; six resided in the residential community and two lived within the migrant farm worker camps. There was no difference between the sero-prevalence of Cysticercosis among the Hispanic residential population or the migrant farm worker

camps (1.7% vs 2.0%). All subjects positive for *T. solium* Cysticercosis were born in Latin America: seven were from Mexico, and one was from El Salvador. All subjects spoke Spanish as their primary language. All eight had made multiple visits back to their home country and/or other endemic areas as moving to the US Handwashing frequency, consumption of raw pork, travel frequency, and rural origin were not significantly associated with sero-positivity for cysticercosis. Five subjects returned for follow-up examination and brain CT scanning: one subject had a calcification consistent with neurocysticercosis, but no active cysts were identified.

### Sero-prevalence of *T. solium* Taeniasis

Of 449 subjects, five individuals had antibodies to *T. solium* Taeniasis, for a total sero-prevalence of 1.1%. The sero-prevalence among the 282 adults was 1.7%. Antibodies to *T. solium* Taeniasis were not detected in children. Four of the five positive subjects were male; one was female. All five subjects were born in Mexico, were from different families; two resided in the residential community and three lived within the migrant farm worker camps. The sero-prevalence of *T. solium* Taeniasis among the Hispanic residential population was 0.57%, vs 3.0% among migrant farm workers [$P = 0.08$, Fisher exact test, prevalence ratio = 5.2 (95% CI: 0.9–30.9)]. None reported a history of worms in the stool, epilepsy, seizures, headache or losses of consciousness. Three of the five subjects (60%) reported living in a household with a pig. Two subjects tested positive for both *T. solium* Taeniasis and *T. solium* cysticercosis, indicating possible autoinfection.

All five subjects were contacted regarding their results, and four (80%) returned for CT scans of the brain, stool samples and treatment with niclosamide. Microscopy and stool coproantigens were negative in all four subjects. One subject (25%) reported worm fragments after treatment. CT scan in one subject (25%) exhibited a calcification consistent with neurocysticercosis.

Lower handwashing frequencies were associated with *T. solium* Taeniasis sero-positivity. *Taenia solium* Taeniasis sero-positive subjects reported an average handwashing frequency of 3.2 times/day, vs 6.4 for those sero-negative ($P = 0.001$, Student's *t*-test). Other risk factors, including consumption of raw pork, frequency of travel to home country, and rural origin were not significantly associated with sero-positivity for *T. solium* Taeniasis.

## Discussion

In this study, we detected antibodies to *T. solium* Cysticercosis and the adult tapeworm, *T. solium* Taeniasis in a residential community and migrant farm worker camps in rural Southern California. The sero-prevalence of *T. solium* Cysticercosis was 1.8% overall, and 2.8% in adults. The *T. solium* Cysticercosis sero-prevalence rate was significantly higher in adults than children, in whom *T. solium* Cysticercosis antibodies could not be detected. The sero-prevalence of *T. solium* Taeniasis was 1.1% in the population overall, and 1.7% in adults. The sero-prevalence of *T. solium* Taeniasis tended to be higher in the migrant farm worker community than the Hispanic residential community. The relatively high prevalence in this US population likely reflects the endemic nature of *T. solium* in the subjects' place of origin, specifically Mexico and Latin America (10–12).

The absence of *T. solium* Taeniasis among children was surprising, but 71% of the children were born in the United States, and 83% had no history of exposure to pigs. In addition, children born in the United States are less likely to have exposure to porcine cysticercosis, and may have better toilet facilities, than their counterparts in Latin America. Porcine cysticercosis is essential for the life cycle of *T. solium* Taeniasis (13). Pigs raised in endemic countries have greater access to human feces due to poorer sanitation, undergo incomplete or inadequate meat inspection, and are frequently consumed incompletely cooked (14). As a result, pork in endemic regions in Latin America have a higher risk of cysticercosis than that pork from the United States. For example, Garcia et al. found that the sero-prevalence of cysticercosis in pigs in the Peruvian highlands ranges between 42 and 75% (15). In Mexico, the origin of most adult subjects in this study, porcine cysticercosis rates are 14% (16).

Contributing to the high sero-prevalence of *T. solium* Taeniasis in our study is the higher sensitivity of the new *T. solium* Taeniasis immunoblot compared with techniques used in prior field studies, specifically microscopy and coproantigen detection. The yield of microscopy in confirmed *T. solium* Taeniasis infections ranges from 36 to 56% (17, 18). Detection of *T. solium* Taeniasis coproantigen is more sensitive than microscopy (76% sensitivity), but less sensitive than the immunoblot used in the present study (17, 18). In this study, microscopic stool examination and coproantigen were negative in those sero-positive for *T. solium* Taeniasis, although one reported worm fragments in stool after treatment. This may

have been due to not using a purgative agent (19). Traditional treatment with niclosamide alone frequently does not yield a scolex, but greater clearance of the worm and scolex can be achieved from a combination of electrolyte-polyethylene glycol solution given orally 2 h before and after niclosamide 2000 mg (19).

The prevalence rates for *T. solium* Cysticercosis likely reflect prior exposure to *T. solium* Cysticercosis rather than active infection, as CT scans did not show active cysts, just granulomas that had calcified. Likewise, only one subject positive for *T. solium* Taeniasis reported worm fragments after treatment, which also suggests the possibility that the others positive for *T. solium* Taeniasis did not have active infection, but rather prior exposure. Therefore, a limitation of sero-prevalence studies in cysticercosis, such as this one, is that an immunoblot may be positive in those without active disease. The immunoblot may be positive in individuals who do not have active cysts, as well as in those with prior exposure with or without calcified granulomas. Therefore, sero-prevalence studies may overestimate active disease. Nevertheless, sero-prevalence studies do provide a measure of overall exposure, and an estimate of the overall risk of the population studied.

This study provides important, previously unknown data on the sero-prevalence of *T. solium* Cysticercosis and *T. solium* Taeniasis in rural California and the United States. Populations at risk for *T. solium* Cysticercosis and *T. solium* Taeniasis in the United States have been identified: migrant farm workers, and Hispanic adults. The frequency of handwashing was correlated with *T. solium* Taeniasis sero-positivity. Sero-prevalence rates of *T. solium* Cysticercosis and *T. solium* Taeniasis in this US population are similar to the reported prevalence in some endemic (but not hyper-endemic) regions of Mexico and Latin America. We hope this study will increase awareness among physicians and public health agencies about *T. solium* Cysticercosis and *T. solium* Taeniasis, and lead to greater efforts to identify and treat tapeworm carriers who transmit cysticercosis to others.

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