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Short Communication

Epidemiology of *Taenia solium* in Nepal: is it influenced by the social characteristics of the population and the presence of *Taenia asiatica*?

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Abstract The transmission of the zoonotic pork tapeworms *Taenia solium* and *T. asiatica* depends on a combination of specific risk factors, such as open defecation, backyard pig raising and the consumption of raw or undercooked pork and viscera. A community-based survey was conducted among 289 households in south–eastern Nepal to study the heterogeneity of these risk factor frequencies as a function of the social composition of the population. The frequency of open defecation, backyard pig raising and pork consumption differed significantly ($P < 0.005$) among the different coexisting caste and ethnic groups. In the same survey, the taeniosis prevalence was examined among the different groups. Tapeworm carriers were identified at a high prevalence among the Dum, one of the most disadvantaged communities of Nepal. A PCR-RFLP assay revealed that all collected tapeworm specimens were *T. asiatica*, a species thus far not known to occur in South Asia. These results can help to understand the epidemiology of *T. solium* in Nepal, which appears to be more complex than thought so far.

keywords epidemiology, Nepal, social composition, *Taenia asiatica*, *Taenia solium*

Introduction

Taenia solium is a neglected zoonotic parasite endemic to most underdeveloped countries and regions where pig raising and pork consumption are not restricted (Dorny *et al.* 2009). Its life cycle involves humans as definitive and pigs as intermediate hosts, but its clinical importance is mainly related to the accidental intake of tapeworm eggs by humans and their development into cysticerci in the host's central nervous system – a condition called neurocysticercosis. The presence of this parasite in Nepal was first reported more than 30 years ago (cited by Joshi *et al.* 2004); yet further research has remained limited. As a result, very little is known about the local risk factors and the public health importance of this zoonosis.

The epidemiology of the *T. solium* is characterised by a focal distribution of human tapeworm carriers and porcine cysticercosis cases. Socio-economic, cultural and religious differences between communities have been claimed responsible for this phenomenon (Morales *et al.* 2006; Somers *et al.* 2006; Carabin *et al.* 2009). Indeed, the transmission of this pork tapeworm strongly depends on the presence of a combination of specific risk factors. Open defecation, pigs having free access to human faeces and uncontrolled slaughtering of infected pigs are major factors and are strongly linked to poverty and underdevelopment. To complete the parasite's life cycle, humans must eat infected pork raw or undercooked, which is mainly influenced by cultural preferences.

Recent literature suggests that the transmission dynamics of *T. solium* can be affected by co-occurring *Taenia* species, most notably *T. hydatigena*, *T. saginata* and *T. asiatica* (Conlan *et al.* 2009). The latter is a parasite with an analogous life cycle to that of *T. solium*, but with different behaviour in its intermediate hosts. In pigs, *T. asiatica* cysticerci are most commonly found in the liver, whereas *T. solium* cysticerci mostly occur in the muscles. *T. asiatica* is not known to cause cysticercosis in humans and thus has much less clinical importance. This parasite's geographical distribution is presumed to be restricted to South-East Asia, not affecting South Asian countries such as Nepal (Eom *et al.* 2009).

The majority of the Nepalese population belongs to two distinct groups the caste-origin Hindu and the *Janjati* or indigenous nationalities. The complex migratory history of these groups has given rise to a coexisting mix of ethnic and caste groups, each with their own socio-economic status and cultural and religious practices (Pandey 2005). The caste or ethnic group to which a person belongs also influences his attitude towards pigs and pork. In the Hindu caste system, pigs are considered untouchable and can only be touched, raised and eaten by the lowest Hindu castes, the *Dalit*. In this respect, *the Dum*, one of the most disadvantaged *Dalit* communities usually living in urban slums, are known as traditional herdsmen of the Hurra pig, a primitive breed indigenous to the southern Terai plains of Nepal. In contrast, most *Janjati* consider pigs as valuable and use them in certain religious ceremonies.

So far the possible impact of this heterogeneity in cultural practices on the transmission of pork tapeworms has not received due attention. Therefore, this study aimed to determine the intraregional differences in transmission risk factors and taeniosis prevalences.

Materials and methods

Between 2009 and 2011, we conducted a community-based survey in the eastern Terai of Nepal, a region with a high density of pigs and pork consumers. The study was set in Mrigauliya (Morang district), a rural village inhabited by a heterogeneous population: upper and lower Hindu castes and hill- and Terai-originating Janjati. Four *Dum* communities in nearby cities were also included.

A one-stage cluster sampling design was used to select the study area. One ward was randomly selected in Mrigauliya, and all households in this ward were included in the survey. The four *Dum* communities were selected based on their proximity to this study area. In total, 289 households were included in the study, comprising hill *Janjati* (n = 24), Terai *Janjati* (n = 110), high-caste Hindus (n = 51), *Dum* (n = 78) and other *Dalit* groups (n = 26). The education level and average life span, taken as proxy for the socio-economic status, were highest among the high-caste Hindus, followed by the hill *Janjati* and the Terai *Janjati* (results not shown). Both parameters were lowest among *Dalit*, and among the *Dum* in particular.

Using a questionnaire, information was gathered regarding the main risk factors for *T. solium* and *T. asiatica* transmission, that is, open defecation, backyard pig raising and frequent (i.e. weekly) pork consumption. In addition, suspected tapeworm carriers were identified by self-detection – the declaration of passing tapeworm segments in the stool. These cases were subsequently asked to identify a tapeworm segment out of a series of photos of common human helminths to eliminate false-positive statements. Thus identified tapeworm carriers were given niclosamide (2 g) and a purgative (bisacodyl, 10 mg) to kill and expel the tapeworm. Finally, collected tapeworm specimens were analysed by a PCR-RFLP assay of the mitochondrial 12S rDNA gene (Somers *et al.* 2007). Based on two specific restriction enzymes, *Dde*I and *Hinf*I, this molecular tool is able to differentiate the three human *Taenia* species: *T. solium*, *T. asiatica* and *T. saginata*.

Fisher's exact test was used to test whether differences in risk factor frequencies existed between the different caste and ethnic groups, using a significance level of 5%. Next, all ten pairwise comparisons between the five included caste and ethnic groups were performed using Fisher's exact test at the Bonferroni corrected significance level of 0.5% (0.05/10).

Ethical aspects

All participants were asked for their informed consent prior to being enrolled in the study. At the end of the study period, the inhabitants of the selected areas were invited to undergo a free medical check-up during a locally organised public health camp. This study was approved by the Nepal Health Research Council and by the Ethical Review Board of Ghent University Hospital.

Results

Results of open defecation was significantly more common ($P < 0.005$) among *Dalits* and Terai *Janjati* than among hill *Janjati* and high-caste Hindus, whereas the *Dum* took an intermediate position (Figure 1a).

The hill *Janjati* raised pigs significantly more frequently ($P < 0.005$) than the other *Dalit*, whereas the Terai *Janjati* and the *Dum* took a middle position. High-caste Hindus did not raise pigs (Figure 1b).

Weekly pork consumption was significantly more frequent ($P < 0.005$) among the *Dum* than among any other

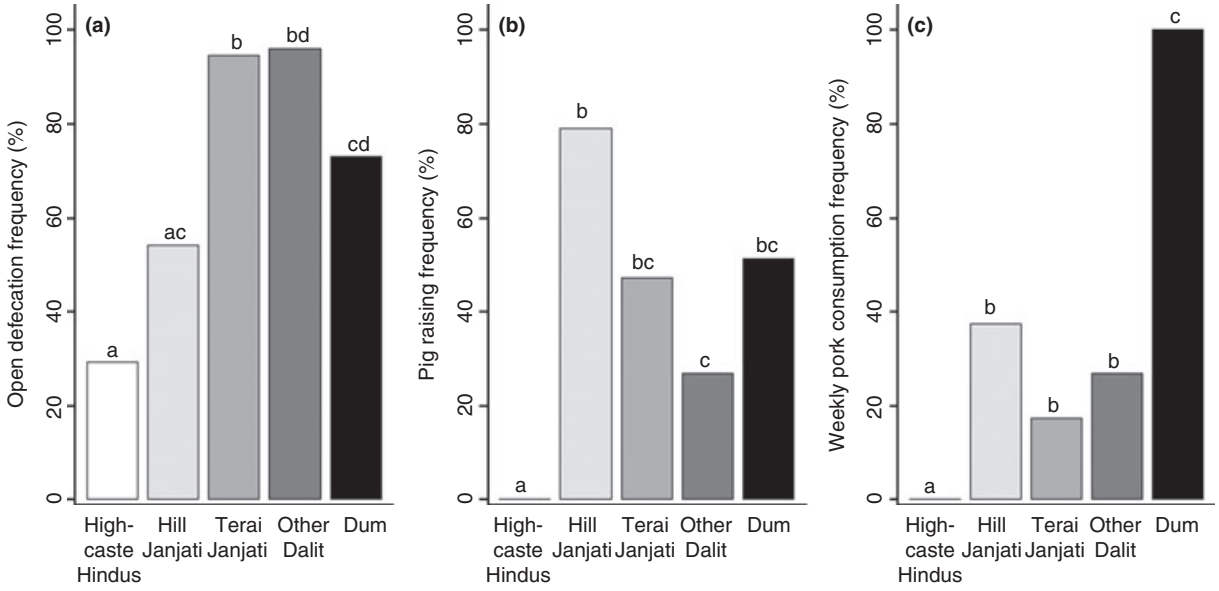

Figure 1 Frequency of *Taenia solium* and *T. asiatica* transmission risk factors (a–c) in south–eastern Nepal, among five caste and ethnic groups, ordered by decreasing socio-economic status. Groups denoted by a different letter differ significantly from each other ($P < 0.005$).

caste or ethnic group. High-caste Hindus consumed no pork at all (Figure 1c).

Tapeworm carriers were only identified in the *Dum* community, at a remarkably high prevalence of 13.5% (71/524). All of these carriers were provided with niclosamide and bisacodyl. After three rounds of community visits, tapeworms could be collected from 16 (22.5%) suspected carriers. Unexpectedly, molecular diagnosis revealed that all collected specimens were *T. asiatica*, and not *T. solium*.

Discussion

In this study, we investigated the occurrence of risk factors for the transmission of the zoonotic pork tapeworms *T. solium* and *T. asiatica* in five caste and ethnic groups in south–eastern Nepal. Significant differences were found in the frequencies of open defecation, backyard pig raising and frequent pork consumption. Open defecation tended to be more common as the socio-economic status decreased. However, the *Dum*, assumed to be the poorest group in our study, did not have the highest open defecation frequency, perhaps because two of the four *Dum* communities had been the subject of toilet construction programmes. The hill *Janjati* more commonly raised pigs, but tended to keep their pigs in sheds, whereas the Terai *Janjati* and *Dalit* preferred tethering and free ranging systems. All *Dum* households reported to consume pork at least once a week, which was significantly more often than the other *Dalit* and the *Janjati*. Frying and boiling were the most common ways of preparing pork among all pork-consuming respondents, but some *Dum* claimed to eat undercooked meat and viscera of home-raised Hurra piglets during certain religious and social festivities. High-caste Hindus neither raised nor ate pigs.

Identification of tapeworm carriers and subsequent tapeworm isolation and species determination revealed that *T. asiatica* is endemic to the south–east of Nepal. This raises questions about the true geographical spread of this parasite, because it does not appear to be restricted to South–East Asia, as thought so far (Eom *et al.* 2009). On the other hand, no *T. solium* tapeworm carriers could be identified in our study, although this parasite is known to be endemic to Nepal, and the transmission risk factors were present in the studied populations. This might be due to the low tapeworm recovery rate in our study or to the low sensitivity of self-detection for *T. solium* proglottids, which are immobile and, consequently, less visible, unlike *T. asiatica* and *T. saginata* tapeworms (Somers *et al.* 2007). However, predominance of one tapeworm species in a certain area may also be caused by interspecific competition, as suggested by Conlan *et al.* (2009), and therefore does not necessarily exclude a high prevalence of other species in other areas.

Strong intraregional differences in transmission risk exist between caste and ethnic groups in Nepal, complicating the epidemiology of the pork tapeworms. In our study, we could not identify a clear link between the socio-economic

status of a group and its overall frequency of transmission risk factors, reflecting the importance of cultural and social risk factors. The high taeniosis prevalence among the *Dum* suggests, however, that certain groups might be of particular importance for maintaining the life cycles of the zoonotic pork tapeworms. In our study, we could only identify *T. asiatica*, and not *T. solium*, which is the only pork tapeworm of clinical importance. However, given the fact that both tapeworms share the same risk factors, we hypothesise that such groups might also be at higher risk for *T. solium* transmission. Moreover, in other areas, *T. solium* might have a competitive advantage over *T. asiatica*, in line with the hypothesis of interspecific competition (Conlan *et al.* 2009). More research is therefore warranted to identify other such high-risk groups in Nepal, and to confirm our findings for *T. solium*. Such information could eventually lead to targeted control programmes, which would not only have an impact on the targeted groups, but also on the population as a whole.

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References

Carabin H, Millogo A, Praet N *et al.* (2009) Seroprevalence to the antigens of *Taenia solium* cysticercosis among residents of three villages in Burkina Faso: a cross-sectional study. *PLoS Neglected Tropical Diseases* **3**, e555.

Conlan JV, Vongxay K, Fenwick S, Blacksell SD & Thompson RC (2009) Does interspecific competition have a moderating effect on *Taenia solium* transmission dynamics in Southeast Asia? *Trends in Parasitology* **25**, 398–403.

Dorny P, Praet N, Deckers N & Gabriel S (2009) Emerging food-borne parasites. *Veterinary Parasitology* **163**, 196–206.

Eom KS, Jeon HK & Rim HJ (2009) Geographical distribution of *Taenia asiatica* and related species. *The Korean Journal of Parasitology* **47**(Suppl.), S115–S124.

Joshi DD, Maharjan M, Johnsen MV, Willingham AL, Gaihr Y & Sharma M (2004) Taeniasis/cysticercosis situation in Nepal. *The Southeast Asian Journal of Tropical Medicine and Public Health* **34**(Suppl. 1), S252–S258.

Morales J, Martinez JJ, Garcia-Castella J *et al.* (2006) *Taenia solium*: the complex interactions, of biological, social, geographical and commercial factors, involved in the transmission dynamics of pig cysticercosis in highly endemic areas. *Annals of Tropical Medicine and Parasitology* **100**, 123–135.

Pandey TR (2005) Culture and politics of caste in the Himalayan kingdom. *Occasional Papers in Sociology and Anthropology* **9**, 63–90.

Somers R, Dorny P, Nguyen VK *et al.* (2006) *Taenia solium* taeniasis and cysticercosis in three communities in north Vietnam. *Tropical Medicine & International Health* **11**, 65–72.

Somers R, Dorny P, Geysen D *et al.* (2007) Human tapeworms in north Vietnam. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **101**, 275–277.

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