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Epidemiology of polyparasitism with *Taenia solium*, schistosomes and soil-transmitted helminths in the co-endemic village of Malanga, Democratic Republic of Congo

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A B S T R A C T

Helminth co-infections are common in sub-Saharan Africa. However, little is known about the distribution and determinants of co-infections with *Taenia solium* taeniasis/cysticercosis. Building on a previous community-based study on human cysticercosis in Malanga village, we investigated co-infections with *Taenia solium*, soil-transmitted helminths (STHs) and *Schistosoma* spp and associated risk factors in a random subsample of 330 participants. Real time PCR assays were used to detect DNA of soil-transmitted helminths (STHs), *T. solium* and *Schistosoma* in stool samples and *Schistosoma* DNA in urine samples. Serum samples were tested for *T. solium* cysticercosis using the B158/B60 monoclonal antibody-based antigen ELISA. Bivariate analysis and logistic regression were applied to assess associations of single and co-infections with common risk factors (age, sex, area, hygiene) as well as pair wise associations between helminth species.

Overall, 240 (72.7%) participants were infected with at least one helminth species; 128 (38.8%) harbored at least two helminth species (16.1% with STHs-*Schistosoma*, 14.5% with STHs-*T. solium* taeniasis/cysticercosis and 8.2% with *Schistosoma-T. solium* taeniasis/cysticercosis co-infections). No significant associations were found between *Schistosoma-T. solium* taeniasis/cysticercosis co-infection and any of the risk factors studied. Males (OR = 2 (95%CI = 1.1–5), p = 0.03) and open defecation behavior (OR = 3.8 (95%CI = 1.1–6.5), p = 0.04) were associated with higher odds of STHs-*T. solium* taeniasis/cysticercosis co-infection. Village districts that were found at high risk of *T. solium* taeniasis/cysticercosis were also at high risk of co-infection with STHs and *T. solium* taeniasis/cysticercosis (OR = 3.2 (95%CI = 1.1–7.8), p = 0.03). Significant pair-wise associations were found between *T. solium* cysticerci and *Necator americanus* (OR = 2.2 (95%CI = 1.2–3.8), $p < 0.01$) as well as *Strongyloides stercoralis* (OR = 2.7 (95%CI = 1.1–6.5), p = 0.02).

These findings show that co-infections with *T. solium* are common in this polyparasitic community in DRC. Our results on risk factors of helminth co-infections and specific associations between helminths may contribute to a better integration of control within programmes that target more than one NTD.

1. Introduction

Schistosomiasis, soil-transmitted helminths (STHs) and *Taenia solium* infections are part of the common neglected tropical diseases (NTDs) in rural and poor urban settings of sub-Saharan Africa (Hotez and Kamath, 2009). STHs and *Schistosoma* spp can cause long-term chronic morbidity including anemia and iron-deficiency (Friedman et al., 2005; Hall et al., 2008; Jonker et al., 2012), malnutrition and impaired child growth and cognition (Jukes et al., 2002; Stephenson and Latham, 2000). In addition, *Schistosoma* infections may cause liver

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and urogenital tissue damage (Gryseels et al., 2006). *T. solium* infections include taeniasis (infection with theadult tapeworm following consumption of under-cooked or raw pig meat) and cysticercosis (infection with the larval stage of the parasite after ingestion of eggs with fecally-contaminated water or food). *T. solium*-related morbidity is strongly associated with neurocysticercosis, a major cause of epilepsy and various neurological disorders within endemic regions (Garcia et al., 2003; Ndimubanzi et al., 2010). Geographic distributions of these parasitic worms overlap in many endemic territories. Moreover, some species share transmission routes, risk factors, risk groups and/or within-host habitats. Consequently, concomitant infections with multiple parasite species can occur in the human host, with potential interactions. Knowledge about the distribution and determinants of helminth co-infections are useful for designing integrated control programs that target multiple infections at once (Brooker et al., 2009).

Over the two past decades, increased attention has been given to polyparasitism with helminths (schistosomes and STHs) as well as to helminth-plasmodium co-infections. These studies have shown that school-age children are at the highest risk of co-infections and that polyparasitism is associated with higher odds of morbidity than single infections (for a review see (Brooker et al., 2007; Naing et al., 2013; Supali et al., 2010; Vaumourin et al., 2015; Viney and Graham, 2013)). Moreover, co-infections seem to be more common in children (mainly boys) from households with poor socioeconomic status (Bisanzio et al., 2014; Raso et al., 2006) and low access to sanitation and clean water (Bisanzio et al., 2014; Righetti et al., 2012). The geo-spatial distribution of helminth co-infections is markedly heterogeneous at both local and regional scales, depending on individual (genetic, sex, age), household (socioeconomic status, crowding), geographical (elevation, distance to water bodies) and climatic (temperature) factors (Raso et al., 2006; Brooker and Clements, 2009; Ellis et al., 2007; Pullan et al., 2008; Soares Magalhaes et al., 2011). The distribution of co-infections with STHs and *Schistosoma* as well as helminths-*Plasmodium* co-infection has been found to be determined by the distribution of the least common species and its environmental risk factors (Brooker and Clements, 2009; Soares Magalhaes et al., 2011; Brooker et al., 2006; Brooker et al., 2012; Yajima et al., 2011).

Despite this growing interest in helminth co-infections, little is known about the epidemiology of co-infections with *T. solium* taeniasis/cysticercosis. A recent review on *T. solium* taeniosis/cysticercosis and the co-distribution with schistosomiasis in Africa mentioned the scarcity of such data, due to under-reporting of *T. solium* infections in many African countries (Braae et al., 2015). One of the reasons is the lack of a good field-applicable diagnostic tool enabling simultaneous detection of STHs, *Schistosoma* spp and *Taenia* spp. Indeed, schistosomiasis and STHs infections are commonly diagnosed using coprology, which is neither sensitive enough for detecting *Taenia* spp nor specific for distinguishing *T. solium* and *T. saginata* eggs (Praet et al., 2013). Recent development of DNA-based methods has enabled discrimination of morphologically identical species, and combination of PCR assays has allowed the simultaneous detection of different intestinal parasite species (Gordon et al., 2011). This provides an interesting opportunity to study the epidemiology of polyparasitism for a broader number of parasite species.

The Democratic Republic of Congo (DRC) is estimated to have the second or third highest number of cases of schistosomiasis and STHs infections in sub-Saharan Africa (Hotez and Kamath, 2009) but there is an overall paucity of data supporting this statement (Rimoin and Hotez, 2013). The country is also reported to be endemic for *T. solium*, though data are scarce (Zoli et al., 2003). Recent surveys conducted in some villages of Kimpese health district (in Bas-Congo province) point to co-endemicity of *Schistosoma*, STHs and *T. solium* infections in that area. In a study among schoolchildren in Bas-Congo, 32.1% were positive for schistosome infection (both *S. mansoni* and *S. haematobium*), and 56.4% for STHs infections (i.e: *Ascaris lumbricoides*, hookworm and *Trichiuris trichiura*), respectively [Linsuke et al: Schistosomiasis in schoolchildren of Kinshasa and Bas-Congo provinces, Democratic Republic of Congo, unpublished]. In 24 villages of the same area, 23.4% of the inhabitants above five years of age were positive for *T. solium* taeniasis (Madinga et al., 2017). Finally, in the village community of Malanga, a *T. solium* cysticercosis prevalence of 21% was reported (Kanobana et al., 2011). The current study is embedded in the latter study (Kanobana et al., 2011) and aims to investigate the epidemiology of co-infections with *T. solium*, *Schistosoma* spp and STHs at local level, herewith generating evidence to inform an integrated approach towards NTD control. We focus on prevalence and risk factors of helminth co-infections with *T. solium* taeniasis/cysticercosis as well as associations between different helminth species.

2. Methods

2.1. Ethical statements

This study was approved by the Ethical Committee of the University of Kinshasa, DRC, by the Institutional Review board of the Institute of Tropical Medicine in Antwerp, Belgium and by the Ethical Committee of the University of Antwerp, Belgium. Voluntary written informed consent was obtained from each participant before taking part in the study. For individuals below the consenting age (18 years), parents or legal guardians were asked to consent on their behalf on a separate consent form. Also literate children above 14 were requested to provide their own assent.

2.2. Study area and population

The field study was conducted in Malanga (5°33′S and 4°21′E), a village situated in the rural health district of Kimpese, Bas-Congo province in western DRC (Fig. 1). The village is divided in six administrative districts: Malanga gare (MG), Malanga Quartier 1 (MQ1), Malanga Quartier 2 (MQ2), Malanga Quartier 3 (MQ3), Camp Militaire (CM) and ICB (old wood factory settlement). Geographically, MG and ICB are separated from the rest of the village by a distance of approximately five kilometers. The village lies along two small rivers and water supply depends on the proximity to one of the following three water points: i) Water point A: situated along the first river, between MG and ICB; ii) Water point B: situated along the first river downstream of the water point A and close to MQ2 and MQ3 and iii) Water point C, situated along the second river and close to MQ1 and CM. Drinking water comes either from the river or from two artisanal water wells built in the vicinity of water points A and C. Subsistence farming and free-roaming pig husbandry are the main economic activities of the village inhabitants. Of 1250 individuals census population in 2009, a total of 943 (75.4%) inhabitants were willing to participate in the initial study (Kanobana et al., 2011). Up to the time period covered by the current study, no control activity was implemented in the study area. Currently, school-based mass treatment campaigns against schistosomiasis and STH infections are gradually being implemented throughout the country, following a national plan against NTDs adopted in 2012 (République Démocratique du Congo MdSP, 2012). These campaigns target school aged children (5–15 years) using praziquantel and albendazole while preschool children (under five) and pregnant women are systematically treated for STH infections only, using mebendazole, by child and mother health programs. So far, there is no national control strategy for *T. solium* taeniasis/cysticercosis.

2.3. Study design and data collection

The current study is based on a posteriori objectives and methods from an initial study which assessed prevalence and risk factors of *T. solium* cysticercosis in a village-community (Kanobana et al., 2011). The original study was a population-wide cross sectional survey, conducted in August 2009 and including all consenting villagers above