Universidade Nova de Lisboa

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Knowledge is not enough: the role of health education in reducing soil-transmitted helminths and *Schistosoma mansoni* infections in schoolchildren in rural Côte d'Ivoire

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DISSERTAÇÃO PARA A OBTENÇÃO DO GRAU DE MESTRE EM CIÊNCIAS BIOMÉDICAS COM ESPECIALIDADE EM PARASITOLOGIA MÉDICA

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To mummy, daddy and Tomasi

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RESUMO

As doenças infeciosas continuam a ser a principal causa de mortalidade infantil em países em desenvolvimento e um quarto destas doenças são causadas por helmintas e protozoários. Globalmente, os helmintas parasitam mais de mil milhões de pessoas e as suas infeções podem causar danos irreversíveis como um atraso no desenvolvimento físico e cognitivo. As infeções mais comuns são feitas por geohelmintas e *Schistosoma mansoni* e a sua principal estratégia de controlo é a quimioterapia preventiva. No entanto, como esta abordagem não previne a reinfeção, é essencial explorar estratégias complementares como a melhoria do saneamento e a educação para a saúde.

Neste estudo, investigamos duas questões que relacionam o conhecimento das crianças com as suas taxas de infeção: (1) se o nível de conhecimento no início do estudo influencia a infeção e (2) se um pacote de educação para a saúde (visualização de um desenho animado seguido de uma sessão de desenhos) aumenta o conhecimento e diminui a taxa de infeção. No início do estudo, crianças (N=2500) pertencentes a 25 escolas na Costa do Marfim foram submetidas a um rastreio de geohelmintas (*Ascaris lumbricoides*, *Trichuris trichiura* e ancilostomídeos) e *S. mansoni* e o seu conhecimento foi averiguado através de um questionário. De seguida, todos os participantes foram tratados com albendazol e praziquantel. Treze escolas foram selecionadas para serem submetidas duas vezes ao pacote de educação para a saúde e as restantes doze serviram de controlo. Onze meses após o tratamento, repetiram-se o mesmo rastreio e questionário.

As prevalências encontradas são semelhantes às reportadas por outros estudos na mesma região. Em todas as escolas, onze meses após o tratamento, as prevalências de todos os parasitas (exceto *Trichuris trichiura*) diminuíram significativamente. Embora os questionários tenham revelado que as crianças já possuíam um conhecimento razoável proveniente das aulas, crianças em escolas expostas ao pacote tiveram resultados 10% superiores aos daquelas em escolas não expostas. No entanto, este ganho de conhecimento não reduziu as taxas de infeção. Da mesma forma, no início do estudo, crianças com mais conhecimento não estavam menos infetadas. Finalmente, crianças em escolas com acesso a água potável e latrinas também não estavam menos infetadas do que crianças em escolas sem saneamento básico.

Concluímos que na escola já é fornecida alguma informação útil e que isto, juntamente com o efeito do tratamento, pode explicar as prevalências relativamente baixas encontradas. Ainda assim, mostrámos que o pacote de educação para a saúde pode acrescentar conhecimento. A nossa conclusão de que mais conhecimento não se traduz necessariamente em taxas de infeção menores, pode dever-se ao facto das crianças subestimarem o risco destas infeções assim como as escolas possuírem saneamento inadequado e sujo. Estes fatores podem impedir que as crianças usem todo o conhecimento que têm para melhorar os hábitos de higiene. O pacote realça os riscos das infeções mas os resultados sugerem que este assunto poderia ser reforçado. As medidas preventivas recomendadas devem ser, tanto quanto possível, ajustadas ao saneamento existente, mas não se podem esperar os melhores resultados sem uma melhoria simultânea do saneamento.

Palavras-chave: Geohelmintas, *Schistosoma mansoni*, pacote de educação para a saúde, conhecimento, crianças, África Ocidental

ABSTRACT

Infectious diseases remain the leading cause of death in children in developing countries and a quarter of these diseases are caused by helminthic or protozoan parasites. Helminths parasitize over one thousand million people worldwide and their infections can cause irreversible damage to the host, such as physical and intellectual growth retardation. The most common infections are caused by soil-transmitted helminths (STH) and *Schistosoma mansoni*. Currently, their main control strategy is preventive chemotherapy. However, because this approach does not prevent reinfection, it is crucial to explore complementary strategies such as sanitation improvement and health education.

We conducted a cluster-randomized trial to investigate two issues that relate schoolchildren's knowledge with infection rates. The first is whether the level of knowledge in a baseline population of schoolchildren influences infection rates. The second is whether a health education package (cartoon-video followed by a drawing session) can increase knowledge and decrease infection. At baseline, children from 25 schools in Western Côte d'Ivoire (N=2500) were screened for STH (hookworm, *A. lumbricoides*, *T. trichiura*) and *S. mansoni* using the Kato-Katz technique and their knowledge regarding these infections was assessed using a questionnaire. All participants were then treated with albendazole and praziquantel. Thirteen schools were selected to undergo the intervention with the health education package and the remaining twelve served as control (only preventive chemotherapy). The health education package was repeated six months later. Finally, eleven months after drug administration, children were re-screened for the same parasites and their knowledge was re-assessed using the same questionnaire.

Prevalence levels for all parasites were in line with those reported by previous studies in this region. In all schools, eleven months after treatment, prevalence rates of all parasites, except for *Trichuris trichiura*, were significantly lower than at baseline. Although the questionnaires revealed that children already had a fair amount of knowledge received in class, children from schools which underwent the health education package scored 10% higher in the questionnaire than those in control schools. However, this gain in knowledge did not result in lower infection rates. Likewise, at baseline children with higher questionnaire scores were not less infected. Finally, children in schools with basic sanitation (access to safe water and latrines) were not less likely to be infected.

We conclude that children already receive some useful health-related knowledge in school and this, together with the effect of chemotherapy, may explain why the prevalences are relatively low. Still, we found that health education packages can further increase schoolchildren's knowledge. Our conclusion that higher knowledge levels do not necessarily result in lower infection rates may be a consequence of children underestimating the risks of these infections and of schools having inadequate or dirty sanitation facilities. These factors may prevent children from taking full advantage of their knowledge to improve hygiene behaviours. Although the package highlighted the risks, our results suggest that this topic could be further reinforced. The recommendations of preventive measures should be as much as possible adjusted to the existing sanitation, but optimal results cannot be expected without concurrent sanitation improvement.

Keywords: Soil-transmitted helminths, *Schistosoma mansoni*, health education package, knowledge, schoolchildren, West Africa

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LIST OF ACRONYMS

AIDS – Acquired Immune Deficiency Syndrome

CDC – Centers for Disease Control and Prevention

CLTS – Community Led Total Sanitation

DALYs – Disability-Adjusted Life Years

EPG – Eggs per Gram

ERR – Egg Reduction Rate

GEE – Generalized Estimating Equations

HIV – Human Immunodeficiency Virus

HPV – Human Papillomavirus

KAPB – Knowledge, Attitudes, Practices and Beliefs

MDA – Mass Drug Administration

NTD – Neglected Tropical Disease

OR – Odds Ratio

RR – Risk Ratio

SES – Socioeconomic Status

STH – Soil-Transmitted Helminths

WHO – World Health Association

YLDs – Years Lived with Disability

1. INTRODUCTION

Infectious diseases remain the leading cause of death in children in developing countries (WHO, 2003). The overall aim of this study is to contribute to the development of educational methods that can minimize this problem by improving health-related hygiene knowledge and behaviour. Infectious diseases are caused by pathogenic agents (such as bacteria, viruses, fungi or parasites) which, by invading the host, harm the host's tissue and can be transmitted to other individuals (Janeway *et al*., 1999). Besides affecting the health and development of infected individuals, infectious diseases have an important impact on whole societies, their economies and political systems (Fonkwo, 2008).

Currently, a quarter of infectious diseases are caused by helminthic and protozoan parasites (Alum *et al.*, 2009). Helminths infect over one fourth of the world's population and they are the most common infectious agents of humans in developing countries (WHO, 1998; de Silva *et al.*, 2003; Hotez *et al.*, 2008). Some of these helminthic infections have been considered to be the greatest cause of physical and intellectual growth retardation (Bethony *et al.*, 2006). Despite their negative impact of the educational, economic and public-health sectors they continue to be highly neglected. Human helminthiasis account for the largest burden of Neglected Tropical Diseases (NTD) (Murray *et al*., 2013; Utzinger *et al.,* 2012; Hotez *et al*., 2014). These infections are associated with underdeveloped countries, particularly in Sub-Saharan Africa, East Asia, China, India and South America, where inadequate water supply and sanitation, crowded living conditions, difficult access to health care and low levels of education are all aggravating factors (Alum *et al*., 2009; Mascarini-Serra, 2011).

Progress to reduce helminthic infections' impact has been slower in Sub-Saharan Africa when compared to that of other regions of the world (de Silva et al., 2003; Bethony et al., 2006). In fact, NTDs are still the most common health problem affecting the poorest people living in Sub-Saharan Africa (Hotez and Kamath, 2009).

1.1. Soil-transmitted helminths and *S. mansoni*

1.1.1. Transmission dynamics and the environment

Helminths are worms, some of which are parasites that can infect humans (Hotez *et al*. 2008). There are two major phyla of helminths: Nematoda and Platyhelminthes. The phylum Nematoda includes *Ascaris lumbricoides* (also known as giant roundworm) (Figure 1), *Trichuris trichiura* (also known as human whipworm) (Figure 3) and hookworms (*Ancylostoma duodenale* and *Necator americanus*) (Figure 5). The phylum Platyhelminthes (flatworms) includes the trematodes (also known as flukes), such as *Schistosoma mansoni* (Figure 7), and the cestodes (also known as tapeworms), such as *Taenia solium* (pork tapeworm). These parasites cause diseases known as helminthiasis of which the most common are those caused by intestinal helminths (*A. lumbricoides*, *T. trichiura* and hookworms) followed by schistosomiasis (infections caused by *Schistosoma* spp.) and lymphatic filariasis (Hotez *et al*. 2008). The present study will focus on the three major soil-transmitted helminths (*A. lumbricoides*, *T. trichiura* and hookworms) and *S. mansoni*.

Soil-transmitted helminths infect humans through contact with soil contaminated with parasite eggs or larvae that thrive in warm and moist soils, which explains why they are most common in tropical and sub-tropical regions. The soil becomes contaminated when an infected individual defecates the helminths' eggs. These eggs are extremely resistant and may persist in the soil for several years waiting to infect a host (Addiss, 2013).

A. lumbricoides and *T. trichiura* have very similar life cycles. Both species infect the host through oral ingestion of mature worm eggs. Eggs can be found on fruit or vegetables which were not properly washed, untreated drinking water or dirty hands, for example.

Figure 1. *A. lumbricoides* egg and adult worm. Image adapted from https://twitter.com/ascarislombriga.

In the case of *A. lumbricoides* (Figure 2), once swallowed, eggs hatch in the intestine and the larvae migrate through the blood stream to the lungs. After maturing between 10 and 14 days in the lungs, they penetrate the alveolar walls, ascend the bronchial tree to the throat, and are then swallowed reaching the lumen of the small intestine, where they develop into adult worms. Two to three months after the ingestion of the infective eggs, the adult female will begin oviposition producing approximately 200,000 eggs per day. Eggs can be fertilized or not depending on the presence or absence of a male adult worm. Eggs are released into the environment with the hosts' faeces. Unfertilized eggs can be ingested but are not infective. In contrast, fertile eggs embryonate and become infective sometime between 18 days and several weeks after their release. The length of this period depends on environmental conditions; ideal conditions are when the soil is moist, warm and shady. Eggs are very resistant and, therefore, can remain viable for several months or even years. Adults live between one and two years (Cross, 1996).

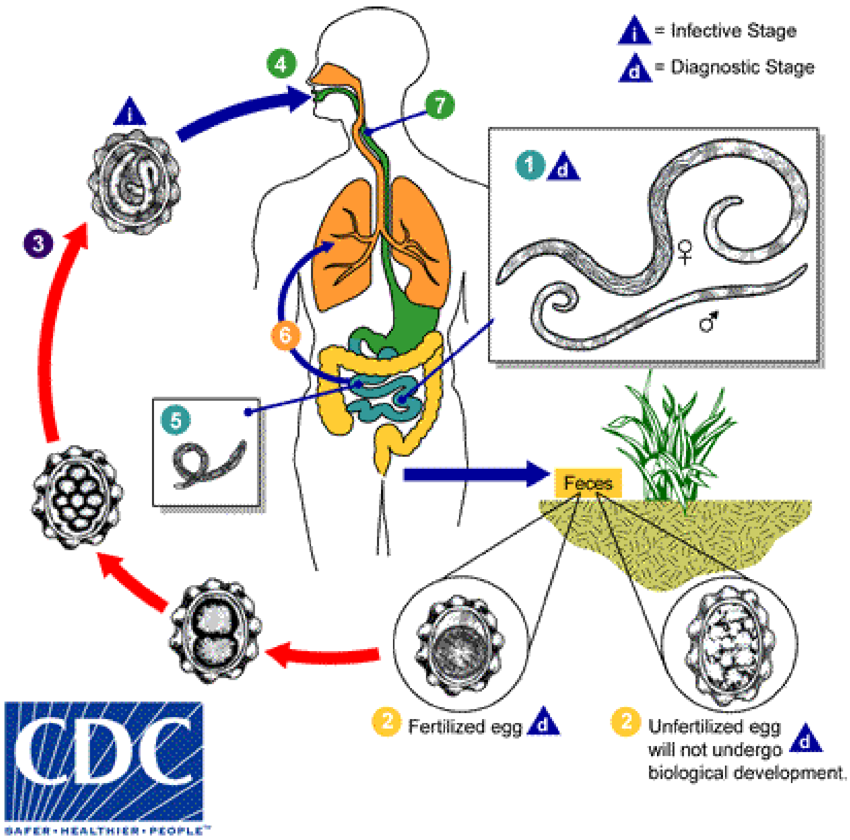

Figure 2. *A. lumbricoides* life cycle. Figure from Centers for Disease Control and Prevention (CDC) (www.cdc.gov).

Figure 3. *T. trichiura* egg and adult worm. Image adapted from http://razasporcinas.com/parasitos-trichuris-trichiura-de-cerdos-pueden-ser-cura-a-enfermedades-humanas-autoinmunes-razas-porcinas/ and http://www.cdc.gov/dpdx/trichuriasis/.

In the case of *T. trichiura* (Figure 4), after being swallowed, eggs hatch in the small intestine. The larvae will then mature and establish themselves as adults in the cecum and ascending colon. Female adult worms begin oviposition 60 to 70 days after the ingestion of the infective eggs and live up to one year during which they shed between 3,000 and 20,000 eggs per day. The unembryonated (fertilized, but not yet developing) eggs are released with the hosts' stool and develop in the soil until they embryonate, and become infective 15 to 30 days later (Cross, 1996).

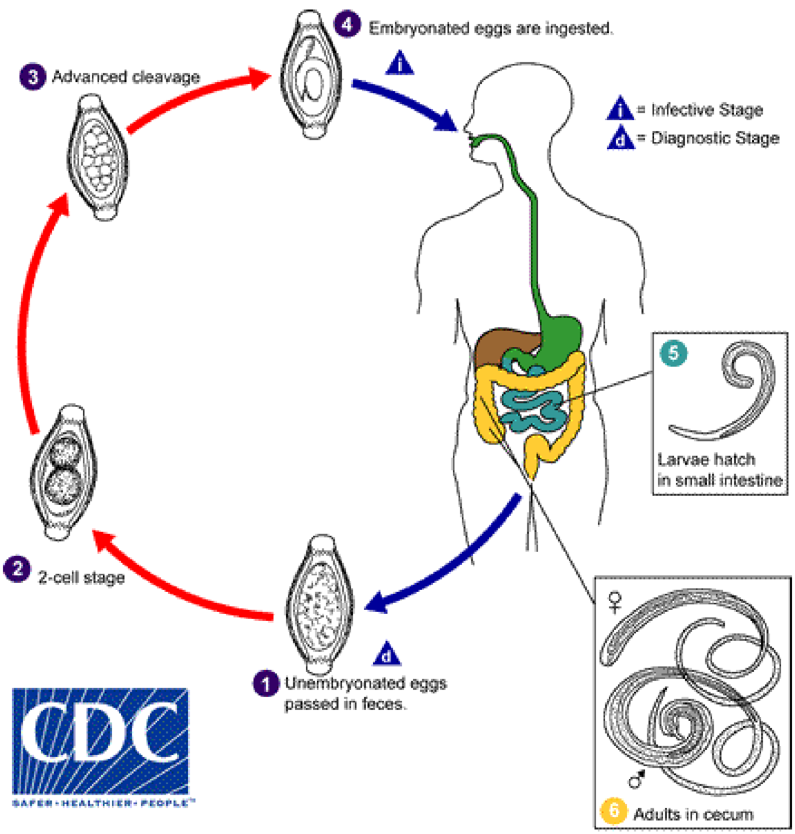

Figure 4. *T. trichiura* life cycle. Figure from CDC (www.cdc.gov).

Figure 5. Hookworm egg, rhabditiform larvae (small) and adult worm (big). Image adapted from http://www.nhs.uk/news/2009/01January/Pages/WormsImmuneSystem.aspx and http://www.healthline.com/health/hookworm.

A. duodenale and *N. americanus* are the two species of helminths that are most commonly referred to as hookworms. They are also soil-transmitted helminths but their life cycle (Figure 6) differs considerably from those of *A. lumbricoides* and *T. trichiura*. Hookworm eggs are also passed to the environment through an infected host's stool.

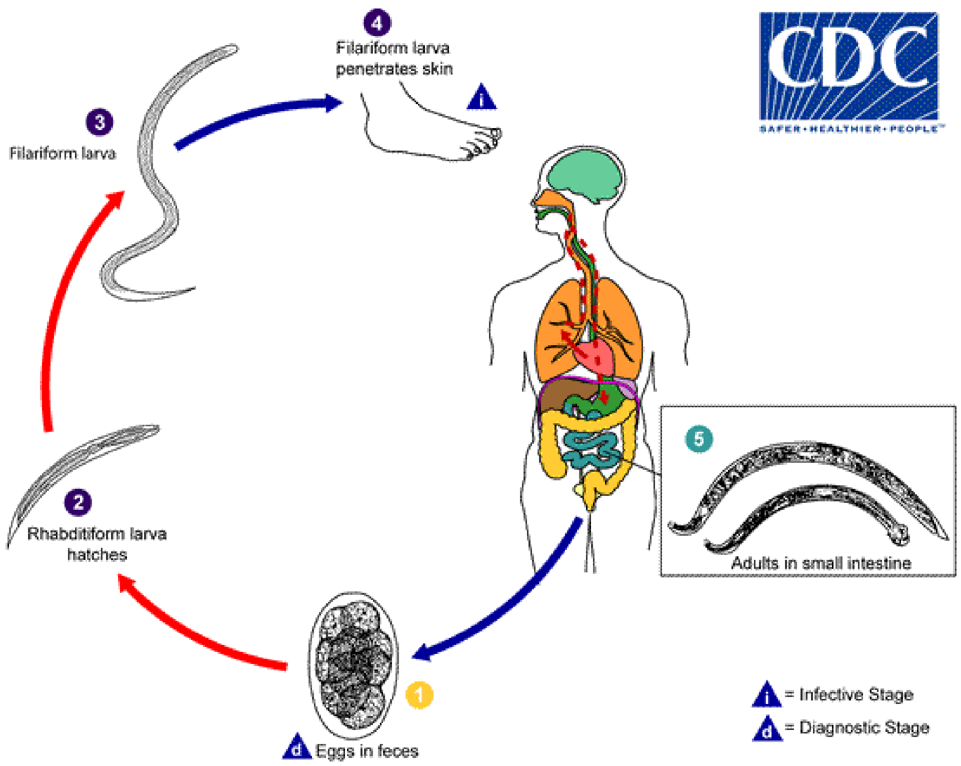

Figure 6. Hookworm life cycle. Figure from CDC (www.cdc.gov).

Under favourable conditions, between one and two days later eggs hatch and release rhabditiform larvae. Five to ten days later, these larvae have developed into filariform larvae, which are infective and can survive up to four weeks in appropriate environmental conditions. Upon direct contact with the human host, they penetrate the skin and migrate through the blood stream to the heart and then lungs. The larvae then penetrate the pulmonary alveoli, ascend the bronchial tree up to the pharynx where they are swallowed. Once they reach the small intestine, they mature into adults that attach to the intestinal wall. Adults can live for several years in their host releasing up to 30,000 eggs per day (Cross, 1996).

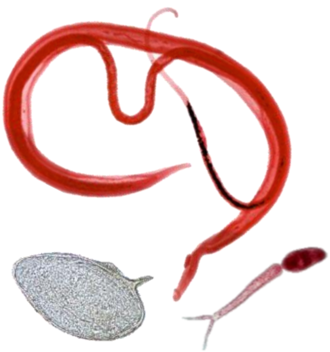

Figure 7. *S. mansoni* egg, cercariae (small) and adult worms (female and male copulating). Adapted from https://yooniqimages.com/images/detail/105229644/Creative/male-and-female-human-blood-flukes-in-copulation-schistosoma-mansoni-the-trematode-flatworm-parasites-that-cause-schistosomiasis-lm, http://2010.igem.org/Team:Imperial_College_London/Schistosoma and http://www.pathologyoutlines.com/topic/parasitologyschisto.html.

S. mansoni is not a soil-transmitted helminth. It has a more complex life cycle (Figure 8) which requires the presence of a specific intermediate host (freshwater snail of the *Biomphalaria* genus) (Morgan *et al*., 2001). Eggs are also passed into the environment through the definitive (human) hosts' faeces. They then hatch releasing larvae (miracidia) which swim until they find a *Biomphalaria* snail to penetrate and serve as intermediate host. After two generations of sporocysts in the snail, infective larvae (cercariae) are released back into the water. The cercariae swim until they can penetrate the skin of a human host. Upon the penetration, they shed their forked tail, becoming schistosomulae. The schistosomulae migrate to the veins where they develop into adult worms and will then reside in the superior mesenteric veins draining the large intestine. The female adult releases about 300 eggs per day in the small venules of the portal and perivesical systems, which are then moved towards the lumen of the intestine until they are eliminated into the environment with the faeces. Thus, these helminths can infect humans through several modes: ingestion, direct contact with contaminated soil or direct contact with contaminated water (Cross, 1996).

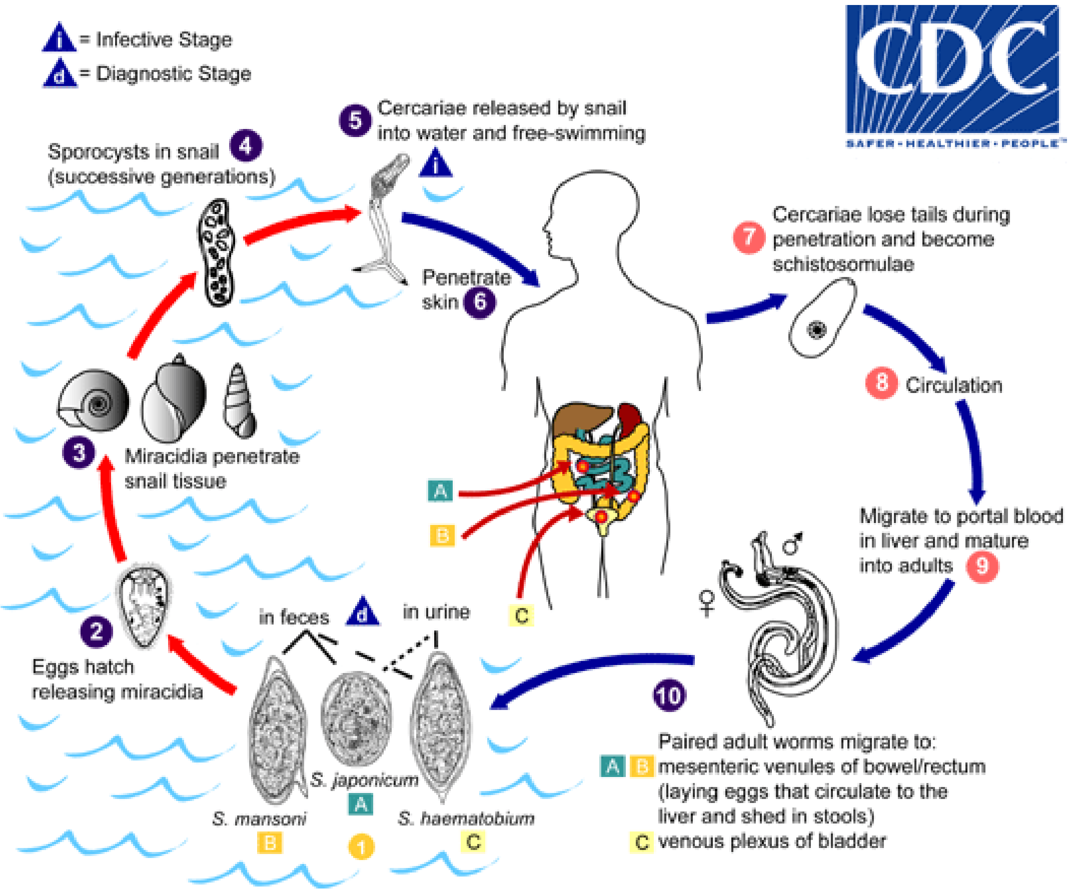

Figure 8. *S. mansoni* life cycle. Figure from CDC (www.cdc.gov).

1.1.2. Epidemiology and disease burden

Worm distribution is highly aggregated, *i.e.* most infected individuals harbour just a few worms in their intestines and a few hosts harbour a disproportionate amount of worms (Anderson and Mau, 1991). Indeed, it has been shown that about 70% of the worm population is hosted by 15% of the host population. These 15% are heavily infected, which means they are both at higher risk of disease and are the main responsible for environmental contamination (Bundy, 1998).

In 2003, it was estimated that *A. lumbricoides* infected 1221 million people, *T. trichiura* 795 million, and hookworms 740 million (de Silva *et al.*, 2003). Regarding schistosomiasis, for the same year, it was estimated that 207 million peoples were infected

(Steinmann *et al*., 2006). Over 90% of schistosomiasis cases occur in Sub-Saharan Africa (van der Werf *et al*., 2003; King and Dangerfield-Cha, 2008).

School-aged children are particularly at risk of infection with helminths and make up the group with the highest infection rate and worm burden (intensity), which can highly affect their growth and development (Tomono *et al*., 2003; Anderson *et al*., 2013). However, both their nutritional status (Stephenson *et al*., 1993; Beasley *et al*., 1999) and their cognitive ability (Drake *et al*., 2000) can be improved with treatment. Fortunately, school systems offer an ideal setting for drug administration, implementation of health education and can be of great value in the strengthening of health care messages (Montresor *et al*., 1998; Hotez *et al*., 2006).

Helminthiasis rarely cause death. However, and although most infections are asymptomatic, they are responsible for significant morbidity; they can lead to many health- and nutrition-related complications that go beyond gastrointestinal tract disturbances (Luong *et al*., 2003). Each parasite species interacts differently with the host's organism causing a wide range of health problems.

Upon skin penetration, both hookworms and *S. mansoni* often cause an erythematous reaction, *i.e.* the skin itches where the larvae entered. Secondary bacterial infections may occur at these sites. Larvae migrating across tissue may cause severe reactions. For instance, larvae migrating through the lungs can cause pneumonitis. Adult *A. lumbricoides* worms, for example, can block the intestines sometimes leading to fatal intestinal obstruction. Adult hookworms attach to the small intestine mucosa with the buccal capsule and feed on mucosal tissue and blood leaving wounds that ooze blood for several days. The loss of blood can be considerable and often results in iron deficiency anaemia. *T. trichiura* behaves similarly also leading to conditions such as anaemia (Cross, 1996).

The pathogenesis of these parasites can lead to other clinical manifestations such as loss of appetite, fatigue, fever, weight loss, nausea, vomiting, abdominal pain, diarrhoea, intestinal inflammation, malabsorption and malnutrition (Cross, 1996; King, 2005). All these conditions are associated with each other and are short-term effects of helminthiasis which, although quite worrisome, do not represent the most serious consequence of these parasitic infections. Long-term damages caused by these parasites, such as impaired growth and poor cognitive function, can be irreversible and are carried to adulthood (Brooker, 2010; Torres *et al*., 2014). This slower cognitive development has been shown to be associated with impairment of learning and poor school performance in several studies (Nokes *et al*., 1992; WHO, 2003; WHO, 2005). However, other studies failed to find a clear association between helminthic infections and school performance (Dickson *et al*., 2000; Taylor-Robinson *et al*., 2007; Ziegelbauer *et al*., 2010; Liu *et al*., 2015), suggesting that the impact of infections on learning may be variable. Conditions associated with helminthic infections, such as anaemia, reduce individuals' work capacity which is a great disadvantage for the individual as well as for his/her community (Haas and Brownlie, 2001).

The overall disease burden caused by these parasites is often measured in disability-adjusted life years (DALYs). This measurement expresses the number of years lost due to ill-health, disability, or early death (Murray, 1994). A recent review by Pullan *et al*. (2014) estimated that 1450 million people worldwide were infected with at least one STH in 2010. Globally, this results in 5.18 million DALYs and 4.98 million years lived with disability (YLDs). Out of the 4.98 million YLDs attributable to STH they found that 65% were due to hookworms, 22% to *A. lumbricoides* and 13% to *T. trichiura*. In the case of *S. mansoni*, King (2010) estimated that this parasite accounted for 24-56 million DALYs lost in 2010.

Thus, helminthic infections still constitute one of the most important public health issues, particularly in tropical and subtropical regions (Asaolu and Ofoezie, 2003; WHO, 2012). Yet, they are part of a long list of infections particularly common in the tropics which received far less attention compared to malaria, tuberculosis and HIV/AIDS and are, therefore, considered to be neglected tropical diseases (NTD).

1.2. Soil-transmitted helminths and *S. mansoni* control strategies

Regarding the prevention and control of STH and other helminthic parasites, several strategies have been tested. WHO (2005) has recommended three main strategies in order to reduce soil contamination and morbidity due to helminthiasis: regular drug administration, sanitation supported by personal hygiene, and health education.

1.2.1. Deworming

Currently, the main approach to the control of STH and *S. mansoni* is regular drug administration. The global STH control relies mainly on albendazole, usually administered orally at a single dose of 400 mg (WHO, 2006; Keiser and Utzinger, 2008). Albendazole has been shown to be quite effective at eliminating hookworms and *A. lumbricoides* (Keiser and Utzinger, 2008) but low cure rates have also been reported (Olsen *et al*., 2009; Soukhathammavong *et al.*, 2012). Against *S. mansoni*, the drug of choice is praziquantel, which has proven to be both safe and efficacious (Ojurongbe *et al*., 2014). It is usually administered as a single dose of 40 mg/kg (Wikman-Jorgensen *et al*., 2012).

Drug treatment can be administered using several approaches. One, often referred to as mass drug administration (MDA), is when treatment is offered to the entire community (all ages, genders and infection statuses). However, the treatment can also be targeted at specific population groups such as school-children only, girls only or infected individuals only (Mascarini-Serra, 2011). The fact that drug treatment does not effectively prevent reinfection is a major limitation of this approach. Thus, the combination of chemotherapy with other strategies, such as sanitation, personal hygiene improvement and health education, is considered to be essential for an effective control of helminthiasis (Evans and Stephenson, 1995).

1.2.2. Sanitation and personal hygiene

STH infections will never become a public health issue in communities where sanitation and hygiene are appropriate (Albonico *et al*., 2006). These authors also defend that, in the context of economic development, sanitation improvement is the only intervention which can virtually eliminate STH infections. Albonico *et al.* (2006) consider that sanitation is composed of two elements: a physical component (such as toilets, latrines, sewage treatments and water supply) and a more abstract component (personal hygiene and legislation). However, it has been shown that providing adequate sanitation and access to safe water does not mean they will be adequately used, in which case prevalence and intensity of infection may not decrease (Arfaa *et al*., 1977; Holland *et al*., 1988; Huttly, 1990; Coffey *et al*., 2014; Patil *et al*., 2014). Personal hygiene also plays a crucial role in controlling infections and awareness towards this subject can be raised through health education.

1.2.3. The potential of health education in the control of STH and *S. mansoni*

Some important reasons for high STH prevalence have been highlighted by Lu *et al*. (2015): (i) the lack of awareness and scepticism regarding the high prevalence of STH and (ii) local myths concerning STH and chemotherapy. These issues can only be overcome by increasing knowledge regarding these infections. Thus, the gains of chemotherapy, water supply and sanitation improvement can be consolidated through health education (Evans and Stephenson, 1995; Gazzinelli *et al*. 2012). Health education can be defined as the “multidisciplinary practice, which is concerned with designing, implementing, and evaluating educational programs that enable individuals, families, groups, organizations, and communities to play active roles in achieving, protecting, and sustaining health" (Joint Committee on Health Education Terminology, 1991). Thus, the objective is to induce change in individual behaviour to reduce the risk of infection, through an increase of knowledge and awareness (Freudenberg, 1978; Utzinger *et al*., 2005). The fundamental role of schools in health education can be complemented through health education interventions (Yuan *et al*., 2005), *i.e*. “programs that shift the distribution of health risk by addressing the underlying social, economic and environmental conditions” (Hawe and Potvin, 2009).

Few studies have explored the effect of health education interventions on STH and *S. mansoni* prevalence rates and intensities (but see: Han *et al*., 1988; Albonico *et al*., 1996; Hadidjaja *et al*., 1998; Albright and Basaric-Keys, 2006; Bieri *et al*., 2013; Gyorkos *et al*., 2013). In the Seychelles, a two-year national project used both printed and electronic media (newspapers, posters, leaflets, radio and television) to increase public awareness and knowledge concerning intestinal parasites resulting in a 44% reduction in the prevalence of infections (Albonico *et al*., 1996). In Peru, Gyorkos *et al*. (2013) found that, four months after the implementation of a school-based health hygiene education programme, there was a significant reduction of *A. lumbricoides* infection intensity in children from intervention schools compared to those from control schools. In China, Bieri *et al*. (2013) implemented a health education package which included a teacher-training workshop, a cartoon based video, leaflets, posters, and a drawing and essay competition, which resulted in a 50% decrease of *A. lumbricoides* and *T. trichiura* infections in interventions schools, when compared to control schools that only received posters.

Initially, researchers believed that informing people was enough to modify their behaviour but by the 1950s they started to become aware that health education had limited effectiveness (Schloman, 1997). Even if, in general, providing basic health information and preventive measures towards a specific health problem results in an increase of knowledge and awareness, it does not necessarily change behaviour (Asaolu and Ofoezie, 2003). This could be due to the fact that interventions often suggest solutions that are either not available or too expensive to adopt (Mascarini-Serra, 2011). Some studies reported no significant differences in the prevalence of helminthic infections between children who received health education when compared to those who did not. For example, in Indonesia, children who received heath-education over the course of five months were not less infected with *A. lumbricoides* than children in control schools. In Burma, intervention targeting hand-washing did not have a significant impact either (Han *et al*., 1988).

As mentioned earlier, health education interventions use several communication media such as radio, newspapers, leaflets and posters. Combining educational messages with entertainment through multimedia is particularly important when the target population are school-children (Bieri *et al*., 2012). It is known that observing correct behaviour induces change in behaviour (Chambers *et al*., 2006). Because videos can display correct behaviours (Chambers *et al*., 2006), they are more likely to improve behaviour than traditional teaching methods (Bandura, 1986; WHO, 1988). They are also the most attractive mean of communication because they provide action, colours and sound (WHO, 1988). There is evidence that they are more effective at convincing the viewers that they are at risk and that it is up to them to change this situation (Bandura, 1986; Glanz *et al*., 2008).

Bieri *et al*. (2012) performed a systematic review of studies conducting preventive health educational videos targeting infectious diseases in schoolchildren. Studies were excluded if they were not about infectious diseases, if they were not school-based, if they targeted adults and if the impact of the video on knowledge or infection was not evaluated. Out of the eleven selected studies, four targeted schistosomiasis and took place in China

(Yuan *et al*., 2000, 2005; Hu *et al*., 2005) and Suriname (Locketz *et al*., 1976). The only study that aimed at STH took place in the Seychelles (Albonico *et al*., 1996). The remaining six studies were on sexually transmitted infections. Out of the ten studies which assessed knowledge, eight showed a significant increase, but of six studies assessing behavioural change, only two reported a statistically significant improvement. As in other studies (Tsay and Hung, 2004; Chambers *et al*., 2006; Gysels and Higginson, 2007), some of the papers included in the review highlighted that educational videos are more effective when combined with other teaching methods such as classroom discussions, games, drawing and/or essay sessions to consolidate key messages. Interventions including more than one method are often referred to as health education packages.

Since the publication of the Bieri *et al*. (2012) review, a few studies performing video-based health education interventions in schools have been published. Two of these studies targeted STH and both resorted to health education packages. In Malaysia, the package included a half day workshop for teachers, a teacher's guide book to STH infections, posters, a comic book, a music video, a puppet show, drawing activities and an aid kit (Al-Delaimy *et al*., 2014). This package significantly increased knowledge and reduced STH intensities. In China, as referred earlier, the health education package included a cartoon-video followed by classroom discussions, poster display, pamphlet distribution and drawing and essay-writing competitions (Bieri *et al*., 2013). This intervention resulted in a significant increase in knowledge, change in behaviour and decrease of STH infection rates. One of the very few, if not the only, video-based health education intervention targeting children in Africa took place in Tanzania and focused on taeniasis (Mwidunda *et al*., 2015). The authors reported an increase in knowledge but did not investigate changes in infection.

In conclusion, there is evidence that health education is important to enable an environment that potentiates positive effects of both chemotherapy and sanitation (Asaolu and Ofoezie, 2003).

1.3. Objectives

Chemotherapy is currently the main strategy for the control of STH and *S. mansoni* and, as seen above, it can gain from concurrent health education activities as well as sanitation improvement. Such an integrated approach is the focus of an ongoing project carried out in Côte d'Ivoire entitled "An integrated approach to fight parasitic worms and diarrhoea" and this thesis was conducted within the framework of that project.

The present study aims at contributing to the improvement of teaching methods that can increase knowledge and health-related behaviour in school children. Authors agree that video-based interventions seem to be the most effective (Bandura, 1986; WHO, 1988). For this reason, and because there is still insufficient data to conclude on the importance of video-based health education interventions (Bieri *et al*., 2012), the present study focused on an intervention combining a video-based health education package with preventive chemotherapy. The studied package consisted on the visualisation of a cartoon-video about the transmission and prevention measures of STH and *S. mansoni* followed by a discussion and drawing session to consolidate key messages. Because the impact of video-based health education interventions has not yet been investigated in schools in West Africa, the geographical location of this study, in rural Côte d'Ivoire, is of great value. In addition, most previous studies of health education only evaluated their impact on infection rates, whereas the present study combines that with an evaluation of the knowledge gain due to the package. However, not only knowledge gained from health education interventions is important. Baseline knowledge can also be a factor minimizing infections in which case one should expect that children with more knowledge should be less infected. This issue is rarely addressed in other studies but it will be included in this one.

Thus, the specific objectives of the present study are:

1. Assess the current situation of soil-transmitted helminths and *Schistosoma mansoni* infections in schoolchildren in Western Côte d'Ivoire.
2. Test if children's knowledge level at baseline influences their probability of infection.
3. Assess if a health education package designed for schoolchildren increases knowledge and reduces parasitic infections.
4. Determine if schools' sanitary conditions and the socioeconomic status of children' households influence parasitic infection rates.

Finally, the results of this study will be used not only to assess whether the health education package has a positive effect but also to formulate recommendations on how equivalent health education packages can be improved in order to enhance the gains at the levels of knowledge, attitude and practice and, thus, reduce infection.

2. MATERIALS AND METHODS

2.1. Study site

The study took place in four regions of Western Côte d'Ivoire: Tonkpi, Cavally, Guemon and Haut Sassandra (Figure 9). The first three regions are located west of the Sassandra River in a mountainous setting with an average altitude ranging from 300 to 1000 meters above sea level. This area of Western Côte d'Ivoire receives the strongest annual rainfall in the country with a rainy season between March and October (Brou, 2005). The less mountainous region of Haut Sassandra is located east of the Sassandra River and is characterized by two rainy seasons: a long one between March and July and a short one in September and October (Utzinger *et al.*, 2000). The majority of the population is involved in agriculture and rice, coffee and cocoa crops are their main source of income. Cassava, maize, bananas and yams are produced by villagers for self-consumption (Utzinger *et al.*, 2000). Parasites such as *S. mansoni* and hookworms have been shown to be endemic in the study area (Raso *et al.*, 2005a).

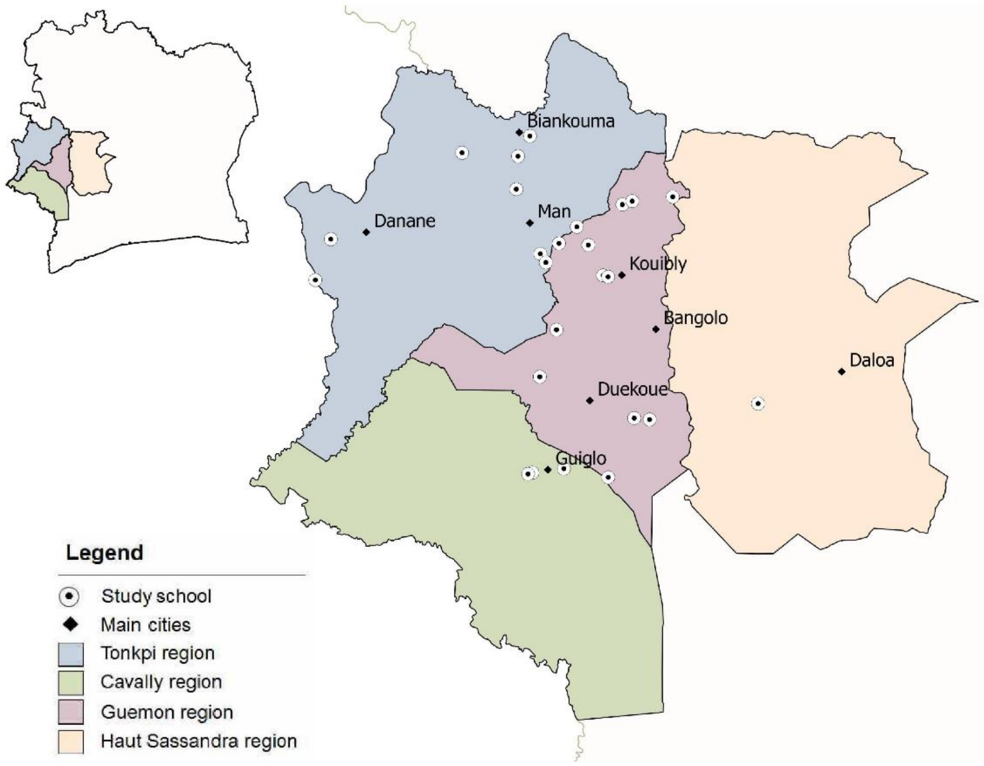

Figure 9. Map of Côte d'Ivoire with the four study regions and the 25 schools included in the study.

The choice of this study site is due to our collaboration with a project from the Schistosomiasis Consortium for Operational Research and Evaluation (SCORE). The main objective of SCORE project is to identify the most balanced preventive chemotherapy strategy to control schistosomiasis, while taking into account the cost and the reduction in prevalence and intensity of infections in school children. For this, they selected 75 schools which fulfilled the following criteria: (i) prevalence of *S. mansoni* between 10 and 24%; (ii) at least 100 students aged 9-12 in grades 2-5 and 50 children aged at least 13 in grades 4-6; (iii) village and school had not been administered with praziquantel against schistosomiasis in the previous 12 months; (iv) village is accessible in both dry and rainy season; and (v) village is safe to work in. They then randomly assigned each of the 75 schools to one of three intervention arms (25 schools in each arm) using a computer-based randomization procedure. The project had a duration of four years (2011-2015) during which each arm received the treatment differently: A) annual treatment for four years; B) treatment in the first two years and no treatment for the last two; C) treatment in years 1 and 3 and no treatment in years 2 and 4. For our study, we selected the 25 schools included in arm A because they were given praziquantel annually which is the dose recommended by WHO (2006).

2.2. Study design

Our study is a cluster-randomized trial. This type of design is often used to evaluate the effects of an intervention in the improvement of health, for example. In such studies, clusters are randomly assigned to one of the treatment conditions (Breukelen and Candel, 2012). In our study, clusters are schools and the different treatment conditions are intervention and control. We adopted this type of trial instead of an individually-randomized trial because we desire to capture the mass effect of the health education package on infection rates due to an overall decrease in transmission (Hayes and Bennet, 1998).

The overall steps of this study are illustrated in a simplified manner in Figure 10. Out of our total of 25 schools, 13 were randomly assigned to the intervention group and 12 to the control group. For all 100 participants from each of the 25 schools we performed the first parasitological survey and knowledge, attitudes, practices and beliefs (KAPB) questionnaire in May 2014, followed by the distribution of anthelminthics (albendazole and praziquantel). Then, in the 13 schools belonging to the intervention group, we implemented the health education package. In December 2014, all 25 schools underwent a second round of questionnaires and the 13 intervention schools were exposed, for the second time, to the health education package. Finally, follow-up took place in April 2015. At this point children underwent their second parasitological survey and answered the questionnaire for the third time. In this study we only include results from the first and last questionnaires (first and third).

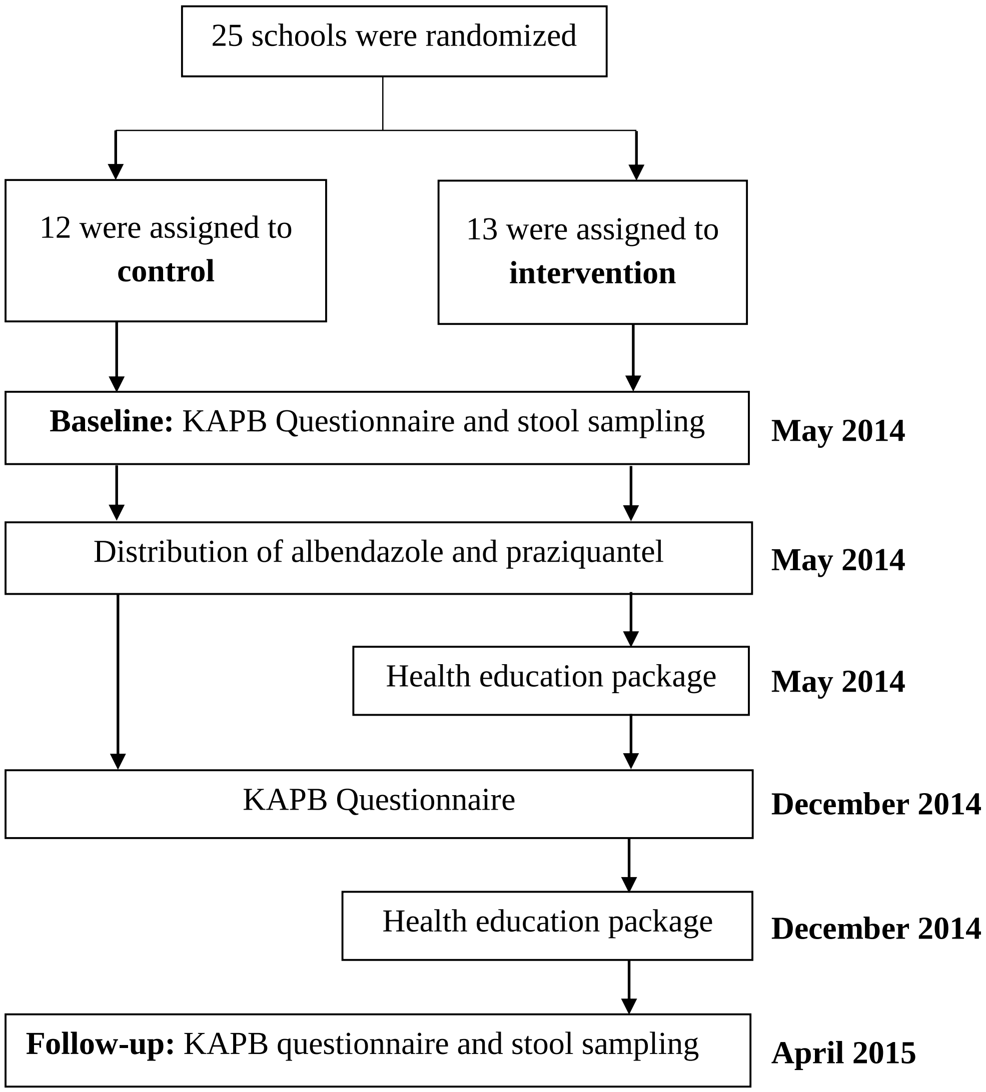

Figure 10. Study design: 25 schools in the four study regions were randomly assigned to control or intervention group. Control schools underwent an initial parasitological and questionnaire survey, a second questionnaire survey and finally, at follow-up, a second parasitological and third questionnaire survey. Intervention schools underwent the same process but, additionally, had two interventions.

2.3. Parasitological assessment / faecal samples

Each participant was provided with a plastic container (125 ml) and asked to give three stool samples over three consecutive days. Containers were labelled with the participant's identification code. Simultaneously, the participant's name, age and school grade were documented. Stool samples were then transferred to central laboratories in Man, Douékoué and Semiens where trained technicians conducted the diagnosis.

Figure 11. Coded plastic containers with feces samples.

For the diagnosis of STH and *S. mansoni* infections we opted for the Kato-Katz thick smear technique (Peters *et al*., 1980) which is recommended by WHO for surveillance and epidemiological field survey of STH infections (WHO, 1994; Montresor *et al*., 1998). It is the most common technique because it is simple to implement in the field, has a relatively low cost (Katz, 1972), and it allows the categorization of the infection into established intensity classes based on cut-offs of egg counts: light, moderate or heavy (WHO, 2002).

The Kato-Katz thick smear has a few disadvantages though. The first is that the thin shell enclosing hookworm eggs collapses shortly after it comes into contact with the glycerol used in the slide preparation, compromising its detection under a light microscope. For this reason, WHO (2004) recommends that slides should be examined within 30-60 minutes to prevent a major underestimation of this parasite's prevalence. Also, this technique is known for its low sensitivity, particularly when applied to a single thick smear (Bergquist *et al*. 2009), and its inability to detect light and recently acquired infections (Utzinger *et al*. 2001). This is a particularly important limitation in regions with regular deworming that may have reduced the prevalence and intensity of infections; in these situations the use of more sensitive diagnostic methods is a necessity. To improve diagnostic accuracy with Kato-Katz one can use multiple thick smears from a single stool sample or from multiple samples (Utzinger *et al*., 1999; Booth *et al*., 2003; Knopp *et al*., 2008).

Taking this into consideration, we collected three samples per participant from which duplicate Kato-Katz thick smears were prepared, *i.e*. we prepared two thick smears from each sample. The preparation of the smears was performed as described in the Bench Aids for the Diagnosis of Intestinal Parasites (WHO, 1994):

1. A small mound of sample was placed on a piece of aluminium foil (Figure 12).
2. Nylon screen (60 – 105 mesh) was pressed on top of the mound so that some faecal material sieved through the screen (Figure 13).
3. This sieved faecal material was then scraped off using a flat spatula.
4. A 1.5 mm thick plastic template with a hole of 6 mm (collects 41.7 mg of faeces) was placed over a clean microscope slide (75 x 25 mm).

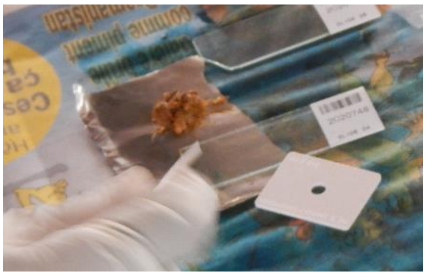

Figure 12. Step 1 of Kato-Katz thick smear.

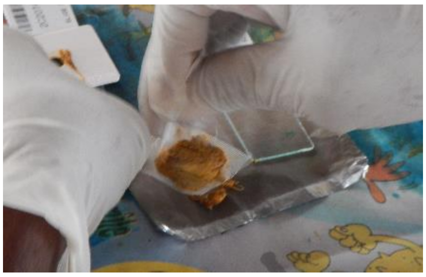

Figure 13. Step 2 of Kato-Katz thick smear.

Figure 14. Step 6 of Kato-Katz thick smear.

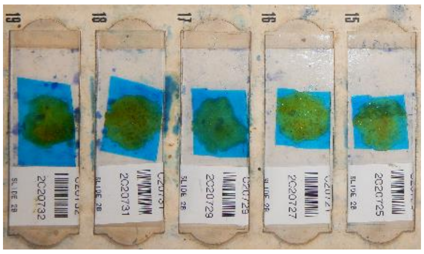

Figure 15. Kato-Katz thick smears ready for observation.

5. The hole was filled with the faeces on the spatula leaving no excess.
6. The template was then removed leaving a cylinder of faeces on the slide (Figure 14).

7. The cylinder was covered with a strip of hydrophilic cellophane pre-soaked (for at least 24 hours) in glycerol-methylene blue solution (1 ml of 3% methylene blue was added to 100 ml of glycerol and 100 ml of distilled water) of approximately 25 x 35 mm in size.
8. The strip over the cylinder was then firmly pressed by another slide in order to spread the sample evenly (Figure 15).

Both slides were examined under a light microscope using 100x magnification as recommended by WHO (1991). The number of eggs was counted for each of the four helminths separately. For the calculation of EPG one simply multiplies the counted eggs per slide by 24 (WHO, 1994).

2.4. Construction and administration of the KAPB questionnaire

We intended to assess participants' knowledge concerning health-related hygiene with particular focus on STH and *S. mansoni* infections, their treatment, prevention, symptoms and modes of transmission. Additionally, we wanted to explore their attitudes and practices concerning hygiene as well as probe for cultural beliefs linked to these parasitic infections.

Thus, participants were administered a knowledge, attitudes, beliefs and practices (KAPB) questionnaire three times: at baseline, 6 months later and at follow-up (11 months later). In addition to the KAPB data, questionnaires also collected basic demographic information (sex, age and class) and socioeconomic information (possession of specific household assets). Socioeconomic indicators were only collected in the last questionnaire, *i.e*. at follow-up (2015).

Questionnaires were designed in a semi-structured manner, *i.e*. they included a mixture of open- and closed-ended questions (Kuzma *et al*., 2013). The use of this type of questionnaires allows for a combination of qualitative and quantitative information to be collected (Hague *et al*., 2013). Questionnaires were drafted in French which is the official language of Côte d'Ivoire and it is taught in schools. The few times we encountered non-French speaking children, we had a local interpreter with us during the interview. The pre-testing of the questionnaire took place in a primary school in Abidjan in order to assess its suitability regarding duration, content and question comprehensibility. Prior to the field work, interviewers gathered for a short meeting concerning the questionnaire and its administration.

Figure 16. Participants being interviewed individually. Photo by Issouf Issa.

All participating children were then interviewed individually (Figure 16). The administration of a questionnaire usually lasted between 15 and 30 minutes, depending mostly on the interviewee's age. The study design required that the same individuals were both sampled and interviewed at baseline and follow-up. Thus, when a student was not present we would ask their colleagues to go and look for them in the village. In some cases we had to go ourselves and interview them at home.

2.5. Observation of school sanitary conditions

As the sanitary conditions and access to safe drinking water could affect the infection rates of participants, at follow-up we took note of the following information concerning each school: whether water was available and, if yes, from what type of source (safe for drinking or not); whether latrines were available; and whether soap was available. Only water pumps (Figure 17) and taps were considered safe for consumption.

Figure 17. School girls extracting water from a water pump. Photo by Issouf Issa.

2.6. Health education package

The health education package consisted on the visualization of a short cartoon (Figure 18) followed by group work with a drawing session (Figure 19).

The video-based cartoon was created by AfrikaToon, a private audio-visual company from Côte d'Ivoire which specializes in 2D and 3D animation videos. Initially,

Figure 18. Visualisation of the cartoon in one of the intervention schools. Photo by Clémence Essé.

a KAPB survey took place in four schools in order to identify key health and hygiene messages which should be addressed in the cartoon. This was followed by the writing of the script and video production. The result was a 15 minute cartoon video named “Koko et les Lunnetes Magiques” (Koko and the Magic Glasses. The full video is available online (https://www.youtube.com/watch?v=PCNLEK5Ityw).

Once the cartoon was shown to participants in the schools belonging to the intervention group (Figure 18), the team had a brief discussion on what had been mentioned in the cartoon and challenged children to make drawings about something they had learned about these parasites (Figure 19).

Figure 19. Child making a drawing about what he learned with the cartoon. Photo by Clémence Essé.

In the intervention group the health education package was implemented twice: at baseline (April 2014) and later in December 2014. In control schools, participants also received chemotherapy but did not watch the cartoon and there were no information/discussion sessions.

2.7. Deworming treatment

All participants were administered with a single oral dose of albendazole (400 mg) against soil-transmitted helminthiasis and praziquantel (40 mg/kg) against schistosomiasis at baseline, immediately after the baseline parasitological survey.

2.8. Ethical statements

Ethical clearance for the study was obtained from the Ethics Committee of Basel (EKBB) and from the ethics committee of the Ministry of Health and Public Hygiene in Côte d'Ivoire.

Because this study involved the participation of primary school-aged children, these had to return the written informed consent signed by their parents or legal guardians at baseline.

2.9. Data management and analysis

The quantitative data collected from the questionnaire was double entered and cross-checked in Epi Info 3.5.3 (CDC, Atlanta, GA, USA). Parasitological data was first entered in smartphones and then transferred to a database in the central server (Open Data Kit) held by the SCORE secretariat at the Task Force for Global Health in Atlanta, USA. Finally, all the data were combined into a single master file used for the analysis. Statistical analyses were mostly carried out in STATA 10.1 (StataCorp. 2007. Stata Statistical Software: Release 10. College Station, TX: StataCorp LP.). A few analyses were conducted using Quantitative Parasitology 3.0 (Rózsa et al., 2000) and these are indicated in the text.

To determine the power of our data to identify differences in prevalence between treatment and control, I used the techniques described by Hemming *et al*. (2011) for randomized-control trials. For our data, a cluster trial with 80% power and an α=0.05, results in a minimum detectable difference in prevalence between intervention and control schools ranging from 2-7%, depending on the parasite species. This was deemed reasonable although it is possible that smaller differences may not be detected as significant using our samples.

Several authors agree that outliers may lead to substantial distortions of results from statistical analysis masking patters and preventing researchers from reaching the correct conclusions (Zimmerman, 1994). For this reason, our data was inspected for outliers using boxplots. The case of the school of Biele, in particular, stood out proving to be a strong outlier for infections with *S. mansoni* and was, therefore, eliminated from the sample in several analyses related to the infection by *S. mansoni*. Yepleu was also excluded from parasite related analysis because we do not have any parasitological data from this school at follow-up.

2.10. Prevalence and intensity of infection at baseline and follow-up

The number of eggs per gram (EPG) of feaces was used as an indirect measurement of intensity of infection (WHO, 2011). The prevalence was calculated as the percentage of individuals infected. Intensities, prevalence and confidence intervals were calculated with the software Quantitative Parasitology 3.0 (Rózsa *et al*., 2000). This program performs statistical analyses specific to the description of parasitic infections of a sample of hosts. According to Reiczigel (2003), the best method for calculating confidence intervals for the mean prevalence is the Stern or Wald technique (Sterne, 1954). For mean intensity, Quantitative Parasitology 3.0 calculates Bootstrap (BCa) confidence intervals whereas for the median intensity it calculates the exact confidence interval.

Intensity of infection was then graded as heavy, moderate or light according to the criteria proposed by WHO (2002) (Table 1). This method is often used to identify a child's degree of infection. All calculations related to the intensity of infections exclusively took into account infected individuals.

Table 1. Threshold of intensity (EPG) of each parasite as established by WHO (2002).

	Intensity threshold (EPG)		
Helminth	**Light**	**Moderate**	**Heavy**
S. mansoni	1 - 99	100 – 399	≥ 400
Hookworms	1 - 1999	2000 - 3999	≥ 4000
A. lumbricoides	1 - 4999	5000 - 49999	≥ 50000
T. trichiura	1 - 999	1000 - 9999	≥ 10000

The effect of sex on the infection with each parasite was tested using Generalized Estimating Equations (GEE), a general method which enables the analysis of clustered data (Liang and Zeger, 1986). This approach is one of the most popular for handling correlated response data which is common in biomedical studies (Pan and Connett 2002; Gosho, 2014). This method assumes that observations within a cluster may be correlated (which is the case of our children within a school) but that observations in different clusters are independent (children from different schools are not correlated) (Halekoh *et al.*, 2006).

To perform a GEE one must select: (i) the family of the dependent variable (binary, Gaussian, Poisson, etc.), (ii) the link function (logistic, identity, log, etc.) and (iii) the working correlation matrix which best fits the structure of the data.

The exchangeable correlation matrix was chosen because the order of sampling of children does not affect the correlation (Checkoway *et al.*, 2004). Because the data was binary (infected vs. non-infected) a logistic link function was applied.

Similarly, I tested whether children over ten years of age were more or less infected than ten year olds and younger using GEE models. The data is also binary (infected vs. non-infected) so I used a logistic link function. Again, because the order of sampling is irrelevant, an exchangeable correlation matrix was chosen.

2.11. Effect of deworming on prevalence and intensity

According to Montresor (2011) the most correct indicator to measure the difference in mean EPG counts, following an intervention, is the egg reduction rate (ERR). It was calculated as follows:

ERR = [1 – (mean post intervention EPG / mean prior intervention EPG)] x 100

To test for a significant change in intensity between years, a meta-analysis was applied. This method is mostly used for the combined analysis of the results of multiple studies on a particular subject. However, Osborne (2008) highlights its value for replicated field study designs. In the present study, the replicates are the schools and, according to this author, the replicates can be viewed as multiple studies enabling the researcher to use meta-analysis within a single project.

Change in intensity between years was assessed with a meta-analysis using mean differences of each school. It was not necessary to standardize the mean differences because the scale of measurement was the same in all schools – EPG (Higgins and Green, 2011). All parasite intensities were homogenous enough to use fixed effect models (Ried, 2006).

In order to test whether there were significant changes in prevalence from 2014 to 2015, a meta-analysis was also performed for each parasite separately. As this is binary data (presence – absence of infection), these analyses were based on the Risk Ratio (RR), which represents the probability of being infected in 2015 compared to 2014. A RR<1 indicates that the risk of becoming infected by a certain parasite decreased from 2014 to 2015; a RR>1 means the risk of becoming infected increased from 2014 to 2015. The choice of calculating the RR as opposed to odds ratio (OR) was mainly due to the fact that its interpretation is clearer and more intuitive (Higgins and Green, 2011). Furthermore, Deeks (2002) showed that the use of RR is just as consistent as odds ratio (OR). Only hookworm intensities were heterogeneous enough to be analysed using random effect models; *S. mansoni* and *T. trichiura* were both analysed using fixed effect models.

2.12. Socioeconomic situation index

Our questionnaires included a final section in which participants were asked which of the following assets/housing characteristics were present in their households: soap, electricity, radio, television, refrigerator, fan, mobile phone, bicycle, motorcycle, car, gas or coal for cooking, electricity.

While some authors argue that an asset based index is not entirely reliable (Onwujekwe *et al.*, 2006) or that ownership does not capture the quality of the asset (Falkinghan and Namazie, 2002), others believe it is reliable (Filmer and Pritchett, 2011) and highlight its advantage at minimizing the measurement error (McKenzie, 2005).

There are several alternatives for combining the collected asset data in order to measure participants' asset wealth. One can simply add up the number of assets owned by each participant in which case all assets will weigh equally (Montgomery *et al*., 2000). Even if this method is conceptually more interpretable, it may not be reasonable, for example, to consider that owning a car is equal to owning soap or a radio. An alternative method that overcomes this problem is to use the index resulting from the first axis of a factor analysis as a proxy for socioeconomic status (SES). Factor analysis was preferred over other ordination methods because it seeks to optimize the extraction of underlying latent variables in the structure of the studied variables (Osborne, 2015). Filmer and Pritchett (2011) agree that the results drawn from the asset index (first axis) are robust when using a factor analysis. This method examines and groups together variables (assets) which are correlated, in order to create a combined score which, in this case, measures SES (Chateau *et al.*, 2012). In this score, assets found to be more relevant (higher loading) are given more weight than assets found to be less relevant (lower loading). I performed a factor analysis and produced an orthogonal rotation to obtain such a score. The rotation intends to clarify the results, *i.e*. make relevant assets stand out (Osborne, 2015). This score was then used to divide participants into quintiles (five groups with approximately the same number of individuals in each) reflecting different SES: poorest, very poor, poor, less poor and least poor (Schellenberg *et al.*, 2003, Raso *et al*., 2005b). Children with incomplete questionnaires were excluded from the factor analysis.

The potential influence of SES on both parasitic infections of participants was tested using a GEE for each parasite because, as mentioned earlier, this method is appropriate for clustered data (Liang and Zeger, 1986). The dependent variable is binary (infected vs. non-infected) so a logistic link function was applied. Since the order of sampling does not affect the correlation, an exchangeable correlation matrix was chosen (Checkoway *et al*., 2004).

The influence of SES on knowledge was also tested using a GEE model with exchangeable correlation matrix, but using the identity link function because the dependent variable (score for general knowledge at follow-up) was found to have a Gaussian distribution through histogram observation.

2.13. The effect of the health education package on knowledge

The effect of the health education package on children's knowledge was evaluated using the individual questionnaires. However, questionnaires often include questions that are highly redundant or not adequate to quantify knowledge; factor analysis is a good technique to explore which questions appropriately measure knowledge (Chateau *et al*., 2012). This technique allows the researcher to, first, identify the separate underlying dimensions of the structure, and then determine to which extent each variable (questions) explains each dimension (such as knowledge) (Hair *et al*., 1998). In other words, it allows the identification of which questions are most revealing of knowledge, as well as those that should be discarded because they are uninformative, or pooled to minimize high redundancy.

Because the data is binary, the factor analysis was based on a matrix of tetrachoric correlations (Uebersax, 2000). Factor analysis loadings represent the level of association between a variable and each factor and are used in the final interpretation of the analysis. We discarded questions which had loadings lower than 0.4 on the factor representing knowledge, as recommended by Manly (1994).

Following this process of selection, one must decide whether to measure knowledge of each child using the score along this factor or to create a summated score. The summated scale only includes variables that load highly on the factor and excludes those that have little impact. In contrast, in factor scale all variables have some degree of influence which makes the interpretation of the measurement more complex. For this reason, I opted for the creation of a summated scale consisting on the combination of several variables (questions) into a single measure of knowledge.

When using a summated scale, the next step is to assess internal consistency, *i.e.* whether the questions have a strong relationship between each other. If this is the case, then their relationship with the latent variable (knowledge) is also strong. This internal consistency was diagnosed by calculating the Cronbach alpha, which is a measure of scale reliability (Tavakol and Dennick, 2011), using the acceptable Cronbach's alpha value of $\alpha \geq 0.6$ (Sim and Wright, 2000).

For this analysis the whole questionnaire was included. However, a few changes suggested by the results of the factor analysis were made. For example, in the case of the symptoms question ("what are the symptoms of intestinal worms?"), its sub-questions ("do they cause diarrhoea?", "do they cause a belly ache?", "do they cause fatigue?" etc.) were all combined into one score, *i.e.* a score was created using the results of each of the seven sub-questions. Thus, a child who replied correctly to five out of the seven sub-questions was considered knowledgeable regarding the symptoms, while a child who replied correctly to up to four questions, was considered not knowledgeable. Other questions were combined using the same methodology. In all cases, the participant was considered to be knowledgeable when he/she replied correctly to over 65% of the sub-questions.

The overall knowledge score of each participant was calculated by summing the points gained in all the questions selected by the above described methodology. I then tested whether there was a significant difference in knowledge gain (score) between intervention and control schools with a two sample t-test. To eliminate any knowledge inequalities between the two groups at baseline, *i.e.* intervention or controls schools already having higher scores at baseline, the two sample t-test was performed on the difference between the baseline and follow-up scores of each participant (Difference in score = Score at follow-up – Score at baseline; the differences had similar standard deviations and a normal distribution). Consequently, the results of the test indicate if the average change in knowledge between years was different for participants in the intervention and control schools.

Finally, a paired t-test was executed to check for a change in knowledge between baseline and follow-up. This type of t-test assumes that the differences between pairs are normally distributed (McDonald, 2015). Before performing the paired t-test the difference between scores was confirmed to be normally distributed through the visual analysis of a Q-Q plot.

2.14. The effect of the health education package on parasitic infections

The effect of the health education package on the prevalence or intensity of each parasite can be tested using GEE models. Again, the selection of this approach lays on the fact that it assumes correlation within a cluster but not between structures, *i.e*. observations within a school are correlated but observations in different schools are independent. This method can be used when the data is binary (such as prevalence: infected vs. non-infected) or in the form of counts (such as intensity: EPG count) (Hanley *et al*., 2003).

I performed two separate GEE analysis for each parasite species, one for intensity and one for prevalence. Intervention was the fixed factor (2 levels, school with or without intervention), while prevalence and intensity were dependent variables. Each school was a cluster.

GEEs for testing an effect of intervention on the prevalence of each parasite were performed using an exchangeable correlation matrix structure (because the sampling order of the participants is irrelevant) and logistic distributions (because the dependent variable is binary). The GEEs to test the effect of the intervention on the infection intensities (EPG) also used an exchangeable correlation matrix structure, but assumed a negative binomial distribution (Anderson, 2013). This type of distribution is said to accommodate the skewed distributions of faecal egg counts better than a Poisson distribution (Alexander, 2012).

2.15. The influence of knowledge on the prevalence of infections

It is possible that children having greater knowledge does not directly translate into changes in behaviour that reduce infection rates. Thus, one objective was to test whether children who knew more about a particular parasite, were less likely to be infected by that particular parasite.

The questionnaire included a few questions which tested the interviewee's knowledge regarding a specific parasite's mode of transmission:

S. mansoni
Can you become infected if you play in dirty water?
Hookworms
Should you defecate in latrines?
T. trichiura + *A. lumbricoides*
Can you become infected if you do not wash your hands before eating?
Can you become infected if you drink water from the river?
Can you become infected if you eat unwashed fruits or vegetables?

T. trichiura and *A. lumbricoides* were pooled together since they have these three modes of transmission in common. For these two parasites, a child was considered knowledgeable if he answered correctly to two out of the three questions. In the case of *S. mansoni* and hookworms, a child was considered to be knowledgeable if he answered correctly to the only question related to each parasite.

Similarly, general knowledge may also influence the probability of being infected. Thus, the previously described general knowledge score was also included in the following analysis. A child was considered to have sufficient general knowledge when he scored at least four out of six.

To test whether knowing more about the mode of transmission of a parasite or having general knowledge meant that the children were less likely to be infected with that parasite, a meta-analysis (RR based) was performed for each species (*A. lumbricoides* and *T. trichiura* were pooled). Similar analyses were applied to test for the effect of general knowledge on the infection by any helminth.

2.16. Effect of deworming on the prevalence and intensity of infections

As referred to earlier, at baseline, participants received a single dose of albendazole and praziquantel. To verify to what extent these drugs contributed to deworming the school children I calculated the Egg Reduction Rate (ERR) for each parasite. The ERR consists on the difference in mean EPG counts following an intervention and is expressed (WHO, 2002) as a percentage of:

(1 – (mean post-deworming EPG/mean pre-deworming EPG))

Only children who were sampled in both years (the majority) were included in this calculation.

To test whether the decrease in prevalence between both years was significant, a meta-analysis (RR based) was executed using the prevalence of each parasite per school.

2.17. The importance of access to latrines and safe water

Children in schools with latrines and access to clean water may be less infected. The meta-analysis produces an intuitive way of determining whether belonging to a school with better sanitation reduces the risk of infection by calculating the RR. Thus, a meta-analysis (excluding Biele) was performed for each parasite and for all parasites pooled together (infected by any helminth).

3. RESULTS

3.1. Study compliance and general characteristics of the studied population

In 2014, a total of 2498 children were sampled for parasites and 2283 were interviewed. In 2015, a total of 1613 children were sampled and 1623 were interviewed (Figure 20). Complete data (including baseline questionnaire, baseline stool specimen, follow-up questionnaire and follow-up stool specimen) was obtained for 1393 children (55.8% of the initial participants). This loss of participants is mostly due to the fact that children were absent the days of the survey or moved to another school. The percentage of children possessing each of the assets included for the calculation of the SES, is indicated in Table 2.

At baseline there were, more boys than girls (average of boys in all schools = 56.4%, SD ± 7.1), just like at follow-up (average of boys in all schools = 57.1%, SD ± 7.1). In addition, there were more children aged ten or younger than older than ten at baseline (average of children aged ten or younger in all schools = 54.5%, SD ± 17.2), and at follow-up (average of children aged ten or younger in all schools = 30.7%, SD ± 21.9).

Table 2. Percentage of participants in each wealth quintile living in households with each of the 12 assets included in the questionnaire.

Asset variable	Total (%)	Wealth quintiles (%)				
		Poorest	Very Poor	Poor	Less poor	Least poor
Television	46.4	0.0	1.5	18.8	38.5	41.2
Refrigerator	16.3	0.0	0.4	2.7	15.7	81.2
Fan	27.7	0.0	0.7	8.4	28.2	62.8
Electricity	61.5	0.2	11.6	25.3	31.3	31.7
Motorcycle	5.2	0.0	0.0	9.6	10.8	79.5
Coal/Gas	27.2	1.2	13.8	17.2	22.9	45.0
Car	36.0	3.0	16.8	18.5	23.6	38.1
Mobile Phone	89.9	15.5	20.1	21.1	21.8	21.5
Radio	61.7	10.3	19.9	19.8	24.7	25.3
Soap	91.6	16.9	20.2	20.4	21.5	21.1
Latrines	81.2	17.3	18.9	19.1	22.1	22.6

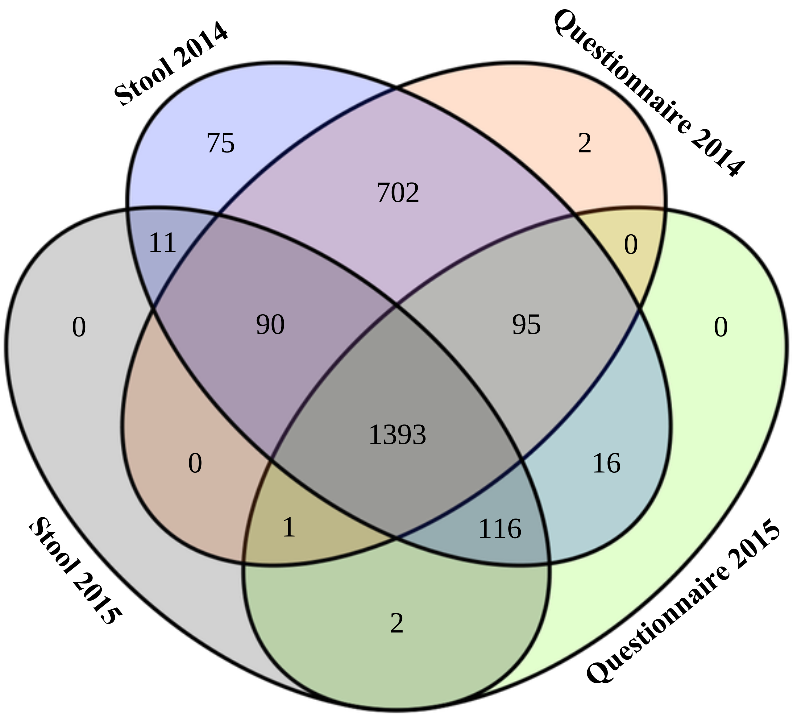

Figure 20. Diagram showing the number of participants from whom we collected each of the following: stool sample at baseline (2014), questionnaire at baseline, stool sample at follow-up (2015), questionnaire at follow-up.

3.2. Prevalence and intensity of infection at baseline and follow-up

At baseline, among the 2498 baseline participants with stool sample, 606 (24.3%) harboured at least one of the four helminths recorded: hookworms, *A. lumbricoides*, *T. trichiura* and *S. mansoni*. At follow-up, out of the 1613 sampled children, 242 (15.0%) were infected with at least one of these helminths. The prevalence and intensities of each parasite at baseline and follow-up are summarized in Table 3.

Hookworms and *S. mansoni* were the most prevalent parasites both at baseline (14.4% and 8.9%, respectively) and follow-up (6.3% and 7.3%, respectively). On the other hand, *T. trichiura* and *A. lumbricoides* were rare both at baseline (2.6% and 1.6%, respectively) and follow-up (2.6% and 0.1%, respectively) (Table 3).

Table 4 shows the prevalence of each parasite per school at baseline and follow-up. The school of Biele clearly stood out as an outlier with a *S. mansoni* prevalence of 69.0% in 2014 and 86.9% in 2015.

Table 3. Prevalence and intensity of parasitic infections at baseline and follow-up.

Parasitic Infection		**Baseline** (N = 2498)	95% CI	**Follow-up** (N = 1613)	95% CI
S. mansoni					
Prevalence [(%), n]		8.9 (221)	7.8-10.0	7.3 (118)	6.1-8.7
Intensity (AM)		82.8	62.4-108.2	118.7	86.5-169.7
Intensity (Median)		12	12-20	24	16-36
Intensity levels [(%), n]	Heavy:	0.4 (11)		0.7 (11)	
	Moderate:	1.3 (33)		1.2 (19)	
	Light :	7.1 (177)		5.5 (88)	
	None:	91.2 (2277)		92.7 (1495)	
Hookworms					
Prevalence [(%), n]		14.4 (360)	13.1-15.8	6.3 (102)	5.2-7.6
Intensity (AM)		124.1	104.8-145.4	86.2	66.0-123.1
Intensity (Median)		56	48-64	36	24-48
Intensity levels [(%), n]	Heavy:	-		5.6 (91)	
	Moderate:	-		-	
	Light:	14.4 (360)		6.3 (102)	
	None:	85.6 (2138)		88.0 (1420)	
T. trichiura					
Prevalence [(%), n]		2.6 (64)	2.0-3.3	2.6 (42)	1.9-3.5
Intensity (AM)		249.9	154.6-424.9	1279.5	544.6-2767.1
Intensity (Median)		36	16-52	34	12-132
Intensity levels [(%), n]	Heavy:	-		0.1 (2)	
	Moderate:	0.2 (4)		0.4 (6)	
	Light :	2.4 (60)		2.1 (34)	
	None:	97.4 (2434)		97.4 (1571)	
A. lumbricoides					
Prevalence [(%), n]		1.6 (39)	1.1-2.1	0.1 (1)	0.0-0.4
Intensity (AM)		270.0	58.1-950.9	132	-
Intensity (Median)		28	20-56	132	-
Intensity levels [(%), n]	Heavy:	-		-	
	Moderate:	0.04 (1)		-	
	Light :	1.5 (38)		0.1 (1)	
	None:	98.4 (2459)		99.9 (1612)	
Soil-Transmitted Helminths					
Prevalence [(%), n]		17.8 (444)	16.3-19.3	8.7 (140)	7.4-10.2
Any helminth					
Prevalence [(%), n]		24.3 (606)	22.6-26.0	15.0 (242)	13.3-16.8

Table 1. Number of examined children per year. Number of infected and prevalence of each parasite per school, at baseline and follow-up.

	School	Nº examined in 2014	Nº examined in 2015	2014 S. mansoni n (%)	2014 Hookworms n (%)	2014 *T. trichiura* n (%)	2014 *A. lumbricoides* n (%)	2015 S. mansoni n (%)	2015 Hookworms n (%)	2015 *T. trichiura* n (%)	2015 *A. lumbricoides* n (%)
With intervention	Bampleu-Kale	100	67	8 (8.0)	14 (14.0)	2 (2.0)	2 (2.0)	3 (4.5)	8 (11.9)	0 (0.0)	1 (1.5)
	Baoule Carrefour	100	65	8 (8.0)	11 (11.0)	4 (4.0)	0 (0.0)	0 (0.0)	8 (12.3)	0 (0.0)	0 (0.0)
	Batiebly Trodrou	98	79	8 (8.2)	2 (2.0)	4 (4.1)	0 (0.0)	9 (11.4)	0 (0.0)	3 (3.8)	0 (0.0)
	Biele	100	61	69 (69.0)	31 (31.0)	2 (2.0)	4 (4.0)	53 (86.9)	3 (4.9)	2 (3.3)	0 (0.0)
	Domobly	100	66	2 (2.0)	17 (17.0)	5 (5.0)	0 (0.0)	0 (0.0)	1 (1.5)	3 (4.6)	0 (0.0)
	Gbeunta	100	80	2 (2.0)	8 (8.0)	0 (0.0)	0 (0.0)	2 (2.5)	9 (11.3)	0 (0.0)	0 (0.0)
	Gregbeu	100	78	5 (5.0)	13 (13.0)	0 (0.0)	0 (0.0)	1 (1.3)	13 (16.7)	0 (0.0)	0 (0.0)
	Klangbolably	100	73	2 (2.0)	13 (13.0)	3 (3.0)	0 (0.0)	0 (0.0)	1 (1.4)	2 (2.7)	0 (0.0)
	Kpangoin	100	64	8 (8.0)	24 (24.0)	0 (0.0)	0 (0.0)	4 (6.3)	5 (7.8)	3 (4.7)	0 (0.0)
	Pona	100	66	6 (6.0)	12 (12.0)	1 (1.0)	0 (0.0)	1 (1.5)	5 (7.6)	3 (4.6)	0 (0.0)
	Seoun-Guiglo	100	64	21 (21.0)	7 (7.0)	5 (5.0)	0 (0.0)	11 (17.2)	2 (3.1)	3 (4.7)	0 (0.0)
	Taobly	100	37	2 (2.0)	19 (19.0)	0 (0.0)	0 (0.0)	1 (2.7)	4 (10.8)	1 (2.7)	0 (0.0)
	Tobly Bangolo	100	72	3 (3.0)	10 (10.0)	1 (1.0)	0 (0.0)	1 (1.4)	4 (5.6)	0 (0.0)	0 (0.0)
Without intervention	Dio	100	66	6 (6.0)	43 (43.0)	5 (5.0)	0 (0.0)	5 (7.6)	2 (3.0)	1 (1.5)	0 (0.0)
	Dompleu	100	48	7 (7.0)	0 (0.0)	2 (2.0)	29 (29.0)	5 (10.4)	0 (0.0)	0 (0.0)	0 (0.0)
	Gnoahe	100	56	5 (5.0)	3 (3.0)	1 (1.0)	2 (2.0)	2 (3.6)	3 (5.4)	0 (0.0)	0 (0.0)
	Lema-Gogouin	100	57	7 (7.0)	35 (35.0)	5 (5.0)	2 (2.0)	2 (3.5)	8 (14.0)	2 (3.5)	0 (0.0)
	Mona	100	91	2 (2.0)	9 (9.0)	7 (7.0)	0 (0.0)	1 (1.1)	2 (3.3)	3 (3.3)	0 (0.0)
	Piandrou	100	57	13 (13.0)	9 (9.0)	6 (6.0)	0 (0.0)	3 (5.3)	13 (22.8)	2 (3.5)	0 (0.0)
	Sebae-Pehai	100	51	6 (6.0)	2 (2.0)	4 (4.0)	0 (0.0)	4 (7.8)	0 (0.0)	2 (3.9)	0 (0.0)
	Siambly	100	85	1 (1.0)	15 (15.0)	1 (1.0)	0 (0.0)	2 (3.5)	4 (4.7)	3 (3.5)	0 (0.0)
	Takouaebly	100	72	10 (10.0)	8 (8.0)	0 (0.0)	0 (0.0)	5 (6.9)	1 (1.4)	0 (0.0)	0 (0.0)
	Yaoude	100	88	4 (4.0)	6 (6.0)	3 (3.0)	0 (0.0)	1 (1.1)	3 (3.4)	1 (1.1)	0 (0.0)
	Yepleu	100	-	11 (11.0)	40 (40.0)	0 (0.0)	0 (0.0)	-	-	-	-
	Ze	100	70	5 (5.0)	9 (9.0)	3 (3.0)	0 (0.0)	1 (1.4)	2 (2.9)	8 (11.4)	0 (0.0)

At baseline, single infections were more prevalent for hookworms and *S. mansoni* while *T. trichiura* and *A. lumbricoides* were rarely observed (Table 5). Double infection of *S. mansoni*-hookworms dominated. Triple or quadruple infections were not detected. At follow-up, most single infections were *S. mansoni*, followed by hookworms, then *T. trichiura* and finally only one individual was infected with *A. lumbricoides*. *S. mansoni*-hookworms double infections were still the most prevalent (Table 5). However, the patterns of co-occurrence of parasites are not the focus of this study and therefore will not be discussed further.

Table 5. Proportion of single and double infections at baseline and follow-up.

	Baseline (%), n	**Follow-up** (%), n
Single parasite infections		
S. mansoni	30.7 (163)	46.6 (104)
Hookworms	55.9 (297)	39.0 (87)
T. trichiura	8.1 (43)	13.9 (31)
A. lumbricoides	5.3 (28)	0.5 (1)
Total	100 (531)	
Double parasite infections		
S. mansoni + Hookworms	61.1 (44)	47.1 (8)
S. mansoni + *T. trichiura*	8.3 (6)	23.5 (4)
S. mansoni + *A. lumbricoides*	6.9 (5)	0.0 (0)
Hookworms + *T. trichiura*	16.7 (12)	29.4 (5)
Hookworms + *A. lumbricoides*	5.6 (4)	0.0 (0)
A. lumbricoides + *T. trichiura*	1.4 (1)	0.0 (0)
Total	100 (72)	

Both at baseline and follow-up boys were significantly more infected with hookworms (17.8% prevalence in boys and 10% in girls at baseline; 7.7% in boys and 4.6% in girls at follow-up) (GEE, $P < 0.001$). The same was observed at baseline for *S. mansoni* (10.8% prevalence in boys and 6.4% in girls) (GEE, $P = 0.003$) and *T. trichiura* (3.1% prevalence in boys and 1.8% in girls) (GEE, $P = 0.038$) but differences at follow-up were not significant (Table 6).

At baseline children over ten years of age were significantly more infected with hookworms than those aged ten or less (17.4% vs 12%, GEE, $P < 0.001$). No other significant associations were detected between age groups and parasitic infections (Table 6).

Table 6. Number and proportion of participants infected by each species of parasite in control and interventions in both years by gender and age group.

	Baseline (2014)		Follow-up (2015)	
	Intervention n (%)	**Control** n (%)	**Intervention** n (%)	**Control** n (%)
Any helminth				
Girls	94 (30.6)	98 (32.8)	53 (34.2)	34 (39.5)
Boys	213 (69.4)	201 (67.2)	102 (65.8)	52 (60.5)
Older than 10	178 (30.5)	144 (26.1)	112 (19.8)	72 (13.8)
Younger than 10	406 (69.5)	407 (73.9)	454 (80.2)	450 (86.2)
All	307 (23.7)	299 (24.9)	156 (17.69)	86 (11.6)
Any STH				
Girls	64 (31.2)	73 (30.5)	24 (29.6)	24 (40.7)
Boys	141 (68.8)	166 (69.5)	57 (70.4)	35 (59.3)
Older than 10	120 (20.6)	112 (20.3)	513 (90.6)	52 (10.0)
Younger than 10	464 (79.4)	439 (79.7)	53 (9.4)	470 (90.0)
All	205 (15.8)	239 (19.9)	81 (9.29)	59 (7.96)
S. mansoni				
Girls	42 (29.2)	27 (35.1)	30 (35.3)	11 (34.4)
Boys	102 (70.8)	50 (64.9)	55 (64.7)	21 (65.6)
Older than 10	89 (15.2)	39 (7.1)	67 (11.8)	25 (4.8)
Younger than 10	495 (84.8)	513 (92.9)	499 (88.2)	497 (95.2)
All	144 (11.1)	77 (6.42)	86 (9.9)	32 (4.3)
Hookworms				
Girls	57 (31.5)	52 (29.0)	19 (30.2)	15 (38.5)
Boys	124 (68.5)	127 (71.0)	44 (69.8)	24 (61.5)
Older than 10	107 (18.3)	90 (16.3)	39 (6.9)	36 (6.9)
Younger than 10	477 (81.7)	461 (83.7)	527 (93.1)	486 (93.1)
All	181 (13.9)	179 (14.9)	63 (7.2)	39 (5.3)
T. trichiura				
Girls	9 (33.3)	11 (29.7)	5 (25.0)	9 (40.9)
Boys	18 (66.7)	26 (70.3)	15 (75.0)	13 (59.1)
Older than 10	13 (2.2)	22 (4.0)	14 (2.5)	18 (3.5)
Younger than 10	571 (91.8)	529 (96.0)	552 (97.5)	504 (96.5)
All	27 (2.1)	37 (3.1)	20 (2.3)	22 (3.0)
A. lumbricoides				
Girls	1 (16.7)	11 (33.3)	1 (100)	0 (0.0)
Boys	5 (83.3)	22 (66.7)	0 (0.0)	0 (0.0)
Older than 10	4 (0.7)	8 (1.5)	1 (0.2)	0 (0.0)
Younger than 10	580 (99.3)	543 (98.5)	565 (99.8)	0 (0.0)
All	6 (0.5)	33 (2.8)	1 (0.1)	0 (0.0)

3.3. Socioeconomic status

Socioeconomic indicators were only assessed in the follow-up questionnaire, which means this information was collected from 1602 participants.

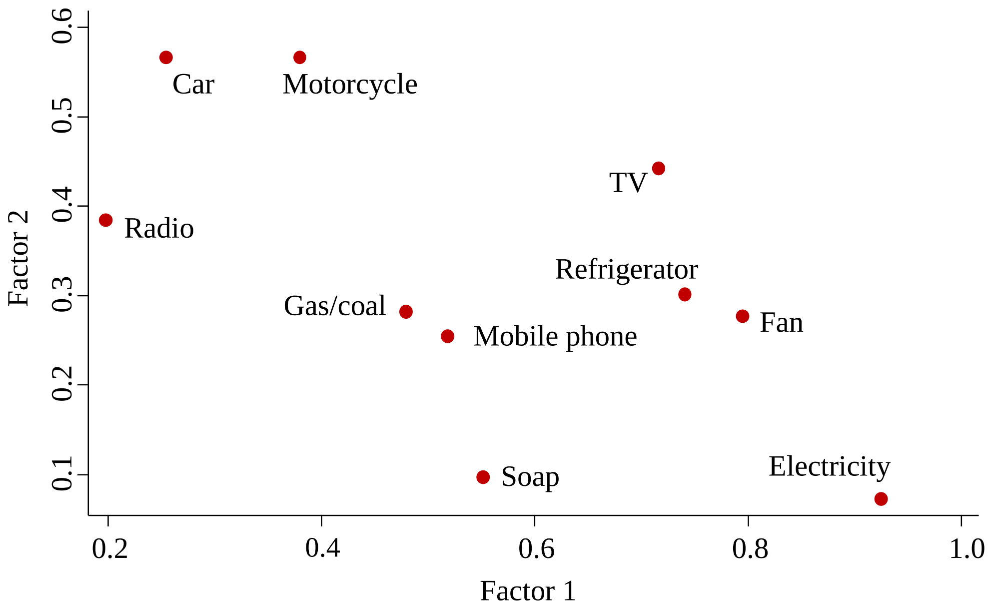

Figure 21. Loading plot resulting from the factor analysis of household assets. Higher scores along factor 1 indicate a wealthier household.

The first axis resulting from the factor analysis of the questions concerning the socioeconomic status accounts for 88.1% (eigenvalue = 4.41). Loadings varied among the assets included in the analysis: electricity (0.9), fan (0.8), refrigerator (0.7), television (0.7), motorcycle (0.4), mobile phone (0.5), soap (0.6), use of coal or gas for cooking (0.5), car (0.3) and radio (0.2) (Figure 21).

One could expect to find that poorer children would be more infected. However, this was not the case in our study for any of the helminths (GEE, $P > 0.05$). On the other hand, children with higher SES had a significantly greater general knowledge (GEE, $P = 0.003$) as illustrated in Figure 22.

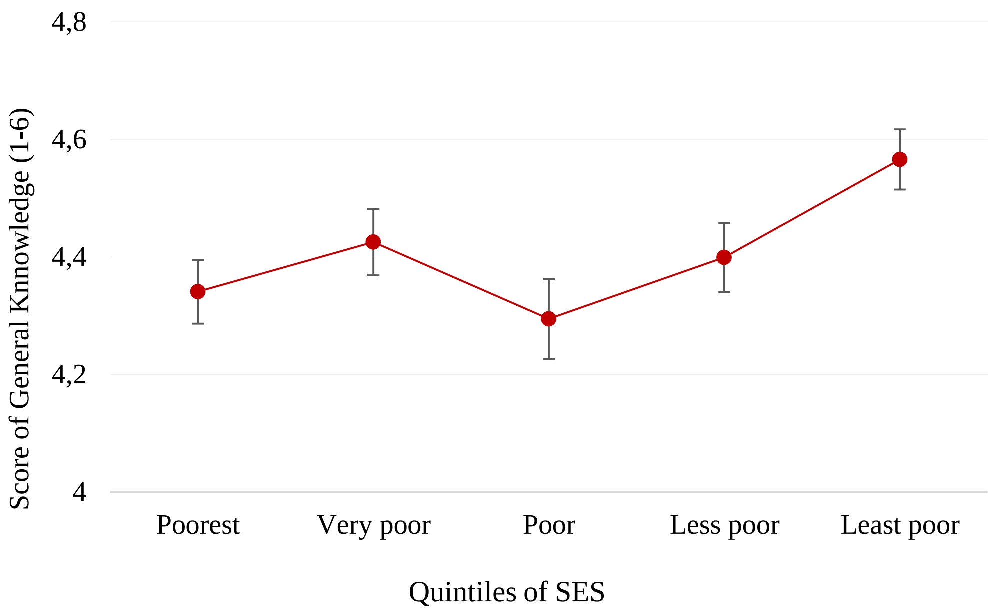

Figure 22. Growth of the mean general knowledge score and respective standard errors along wealth quintiles.

3.4. What is the effect of the health education package?

3.4.1. Effect on knowledge

The factor analysis resulted in the selection of the six variables that were best at revealing the latent variable (knowledge), *i.e.* the six questions which best measured children's knowledge. The consistency among the six variables was assessed using the Cronbach alpha which was $\alpha = 0.6192$. Table 7 lists these questions: the first three result from a combination of several sub-questions, as mentioned earlier, whereas the last three were single questions.

A score for general knowledge was calculated using these six questions; the score ranges from zero to six.

Table 7. Questions selected with factor analysis to be included in the score of general knowledge. The first three questions are the result of the combination of several sub-questions**.**

1. Child knows the symptoms/consequences
Fatigue
Hard time thinking
Hard time concentrating
Diarrhoea
Belly ache

Lack of appetite
Slower growth
2. Child knows how he can become infected
If you do not wash your hands before eating
If you drink water from the river
If you play in dirty water
If you play with/near waste
If you don't wear shoes
If you play in the soil/sand
If you do not wash fruit/vegetables before eating
3. Child believes in myth modes of transmission
If you eat too many sweet things
If you eat too many/too ripe mangoes
If you eat rotten food
4. Child knows he should defecate in latrines
5. Child believes he should defecate in the bush
6. Child who knows you should not drink river water

Figure 23 illustrates the mean difference between baseline and follow-up scores for each child in intervention and control groups. It shows that the intervention had a

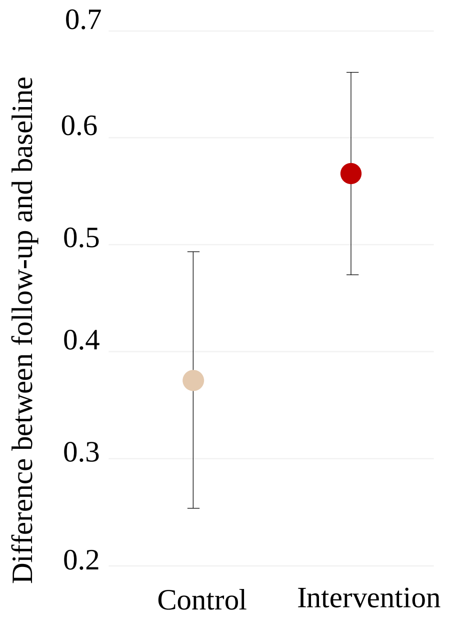

Figure 23. Difference in score between follow-up and baseline in control and intervention schools.

significant impact on knowledge; children exposed to the education package gained more knowledge than those in the control group, *i.e*. they learned more (two sample t-test, P = 0.0002).

Additionally, the question related to modes of transmission allowed for spontaneous answers in the section “others”, *i.e*. the respondents could indicate modes of transmission that had not yet been mentioned by the interviewer. Table 8 shows the number of children mentioning the four most common spontaneous answers along with other less common correct and incorrect answers. The first three answers (which are correct) are mostly mentioned by children in intervention schools: not covering food (20 vs. 5), not washing hands after defecating (11 vs. 0), open defecation (12 vs. 1). Concerning the other spontaneous answers, note that in control schools the number of correct and incorrect answers was approximately the same whereas in intervention schools there were almost twice as many correct as incorrect answers.

Finally, the results suggest that children who were exposed to the health education package may be more aware of less obvious symptoms of these parasites than children in the control group. The following questions were answered correctly more often in intervention than control schools: having a hard time thinking (61.1 vs 53.3%) and concentrating (74.8 vs 69.1%) and growing less than healthy children (76.5 vs 70.7%). However, there was no statistical significance between the proportion of correct answers in the two groups (GEE, $P > 0.05$).

We also found a significant increase in general knowledge score between 2014 and 2015, both in intervention and control schools (paired t-test, $P < 0.001$).

Table 8. Number of children in intervention and control schools mentioning the three most common spontaneous answers. Also indicated are the number other less common correct and incorrect spontaneous answers.

Spontaneous answers to the question: **How can we get infected?**		**Control** (# children)	**Intervention** (# children)
If we do not cover our food (flies will land on it).		5	20
If we do not wash our hands after defecating.		0	11
If we defecate in the bush/river (open defecation).		1	12
Other spontaneous answers	Correct	10	24
	Incorrect	16	19

3.4.2. Effect on parasitic infections

The GEEs performed to verify whether children in intervention schools were more or less infected than those in control schools did not reveal any differences. No significance was obtained in prevalence or intensity of *S. mansoni* (P = 0.762 and P =

0.759, respectively), hookworms and (P = 0.431 and P = 0.332, respectively) *T. trichiura* (P = 0.560 and P = 0.641, respectively). No GEE was performed for infections with *A. lumbricoides* since the data does not fulfil all the assumptions of the method.

3.5. Does knowledge influence the prevalence of infections?

Figure 24 illustrates the effect of knowledge about modes of transmission on the probability of infection. We observe that answering correctly to questions associated to *S. mansoni* at baseline did not influence its prevalence (meta-analysis, P = 0.884), *i.e.* children who knew that playing in dirty water could infect them, were not less infected

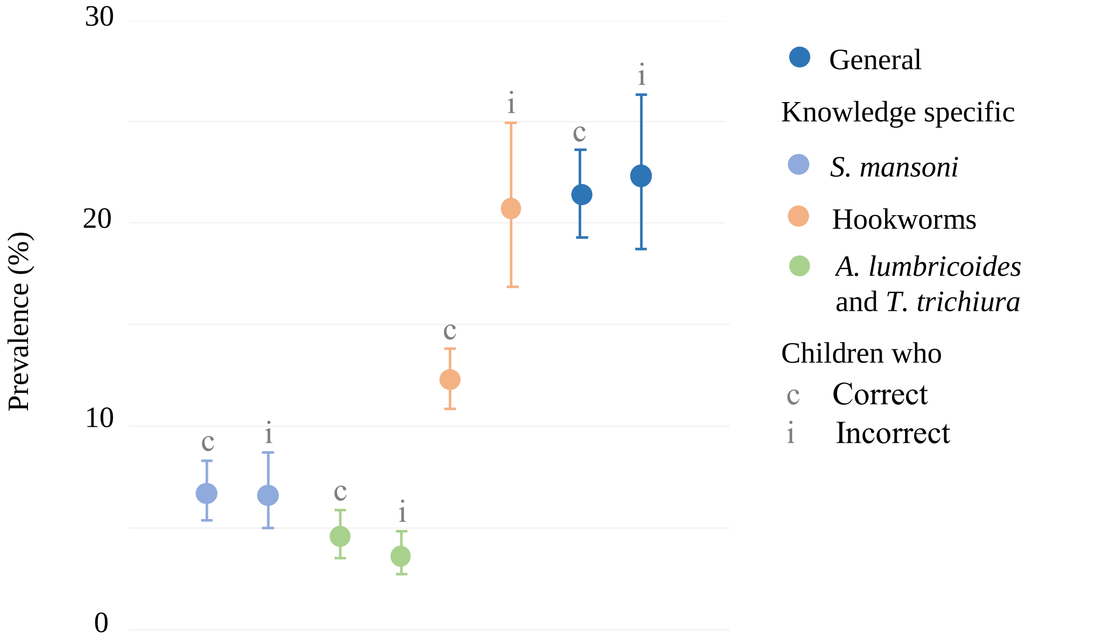

Figure 24. Parasite prevalence in children with (c) and without (i) knowledge of the modes of transmission of each parasite. Colours represent different parasites. Dark blue compares prevalence of any species of helminth in children with low or high general knowledge about parasites.

than those who did not know. The same applied for questions related to *A. lumbricoides* and *T. trichiura* (meta-analysis, P = 0.265); children who knew more about these two parasites were not found to be less infected by them. However, the results indicate that knowing that the correct place to defecate is in the latrines, significantly reduced the probability of infection with hookworms (meta-analysis, P = 0.034).

We also tested the importance of general knowledge on infection, *i.e.* knowledge related to these parasites, such as their treatment and their symptoms. Again, there was no significant influence of general knowledge on the infection rates (meta-analysis, P = 0.839).

3.6. Effect of deworming 11 months post-treatment

As referred to earlier, following the baseline interviews and stool sampling, all participants received one dose of albendazole and one doze of praziquantel. For the analyses in this section, we include the 1610 children who were sampled in both years. Figure 25 shows the effect of the drugs on the prevalence of each parasite (excluding

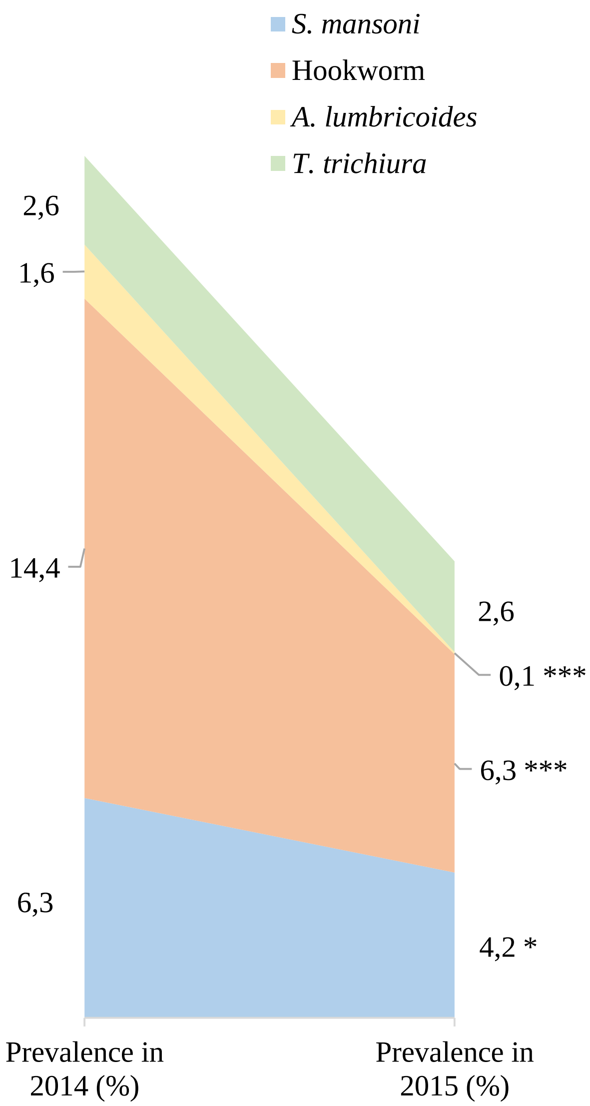

Figure 25. Change in prevalence of each parasite between baseline (2014) and follow-up (2015). Asterisks indicate significant difference between the two time-points: * P ≤ 0.05, *** P ≤ 0.001.

Biele, which was considered an outlier). There was a clear decrease in the prevalence of overall helminth infections from 2014 to 2015. The prevalence of hookworms decreased from 14.4% to 6.3% which represents a reduction of 53.3% (meta-analysis, P = 0.001). In the case of *A. lumbricoides*, the prevalence went from 1.6% to 0.1%, a reduction of 93.8% (meta-analysis, P = 0.001). However, the same did not occur in the case of *T. trichiura* infections which prevalence did not suffer any significant changes (meta-analysis, P = 0.975). In the case of *S. mansoni*, the decrease was significant (33.3% reduction) (meta-analysis, P = 0.019) when we removed its outlier (Biele) from the meta-analysis but not when it was included (17.3% reduction) (meta-analysis, P = 0.203).

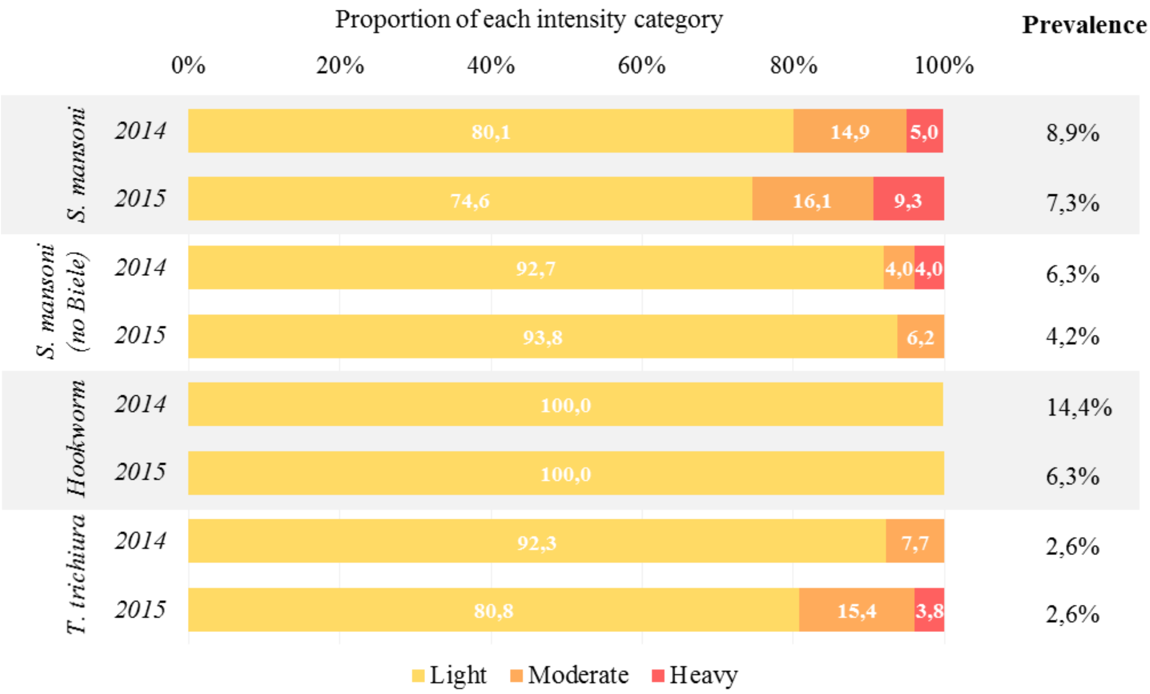

Figure 26. Percentage of light, moderate and heavy infections with each parasite at baseline and follow-up along with the respective prevalence.

Regarding intensity of infection, several indicators such as the mean and median intensities (Table 3) and the ERR can be analysed. Figure 26 shows the proportion of heavy, moderate and light infections in both years, using the criteria indicated by WHO (2002). *A. lumbricoides* was not included in Figure 26 because only one child was found infected in 2015.

In our sample, we observed more heavy infections with *S. mansoni* (including Biele) at follow-up than at baseline (ERR = -43.4). However, when excluding Biele, all heavy infections at baseline disappeared and we observed an improvement in EPG of *S. mansoni* (ERR = 36.3%), although not significant (meta-analysis with EPG, P = 0.601). In the case of hookworms, all infections were and remained light after treatment, with a significant ERR of 30.5% (meta-analysis, P < 0.001). *T. trichiura* prevalence suffered no change and we observed an increase in the proportion of moderate infections and some new heavy infections (ERR = -499.6%) but no significance was detected (meta-analysis, P = 0.406). Because at follow-up only one participant was found to be positive for *A. lumbricoides*, the meta-analysis for this parasite could not be performed.

3.7. Do access to safe water and latrines at school alone influence the prevalence of infections?

In total, only 3 schools out of the 25 schools had soap available to students, 17 had latrines (8 intervention and 9 control schools) and 10 had access to safe water from a pump (4 intervention and 6 control schools).

The forest plot (Figure 27), shows the decrease of infection by any helminth between 2014 and 2015 in schools with and without access to clean water and latrines. This meta-analysis did not include Yepleu (no parasitological data in 2015) and Biele (outlier). There was no difference in the decline of RR between schools with or without access to safe water and latrines. The same result was achieved from meta-analyses performed for each of the four parasites separately, suggesting that access to safe water and latrines at school do not influence infection rates.

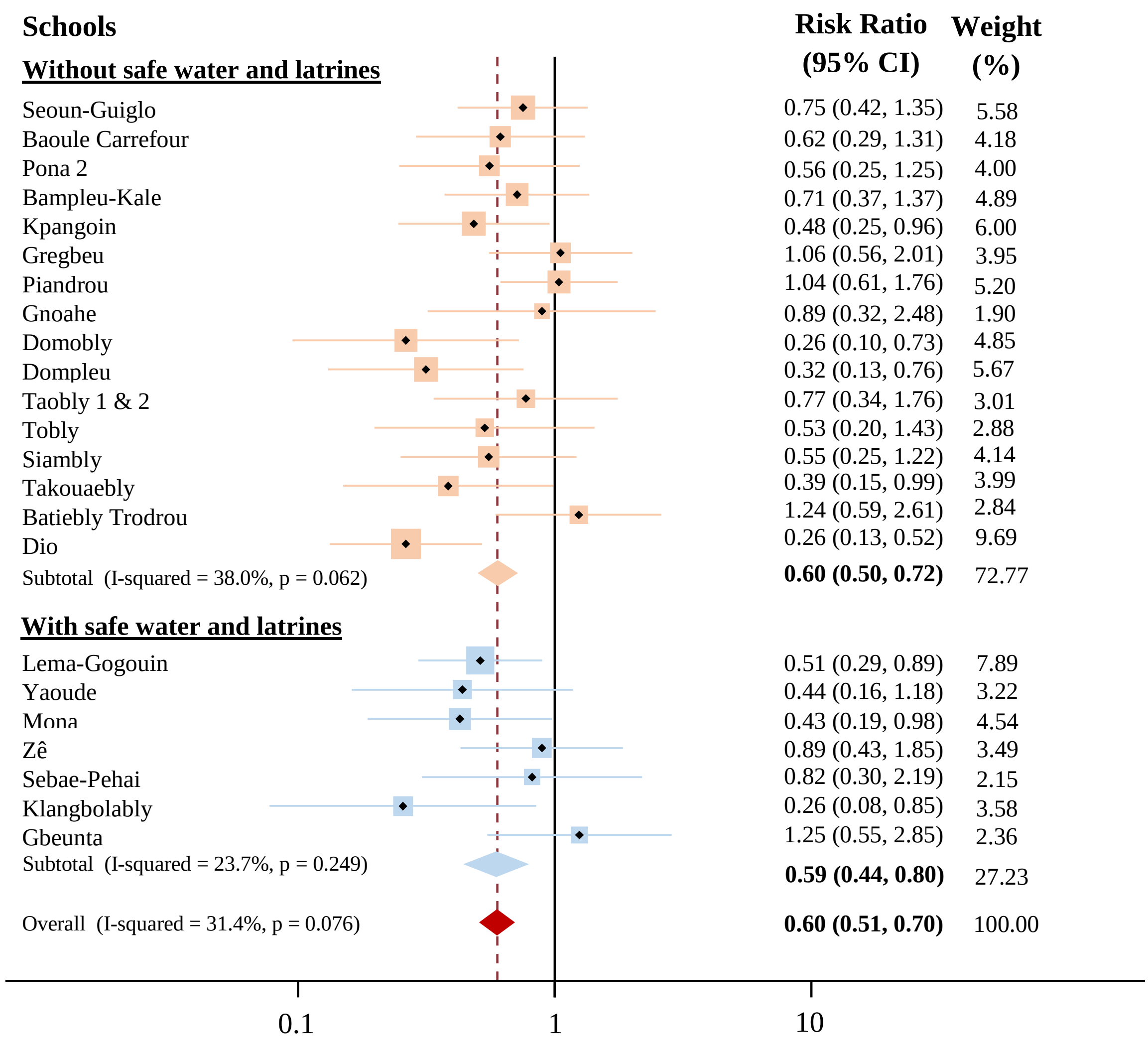

Figure 27. Forest plot with the change in risk of infection with any helminth between 2014 and 2015 (RR) separated into two groups: schools with and without access to safe water and latrines.

4. DISCUSSION AND CONCLUSIONS

4.1. Prevalence and intensity of infection at baseline were relatively low

Biele was identified as a clear outlier for *S. mansoni* infections; its prevalence was over 69 and 87% in 2014 and 2015, respectively. In fact, prevalence increased between baseline and follow-up, despite the annual treatment with deworming medication. This very high infection may be due to the presence of a relatively large water body approximately 70 meters away from the village, which is visible on aerial imagery from the area (Google Earth Pro version 7.1.2.2041, 2013) (Figure 28). In fact, a study done in the same region (Matthys *et al*., 2007) found that proximity to a river was a significant risk factor for a *S. mansoni* infection; populations closer to rivers were more infected because frequency of contact with infected water bodies depends on distance to the source (Brooker *et al.*, 2001) which translates into a focal distribution of this parasite (Woolhouse *et al*., 1998). Zhang *et al.* (2007) observed that, even after two rounds of treatment, prevalence and intensity of *S. mansoni* in schools closer to lakes remained relatively high. The transmission of this parasite in Biele is most likely very high and

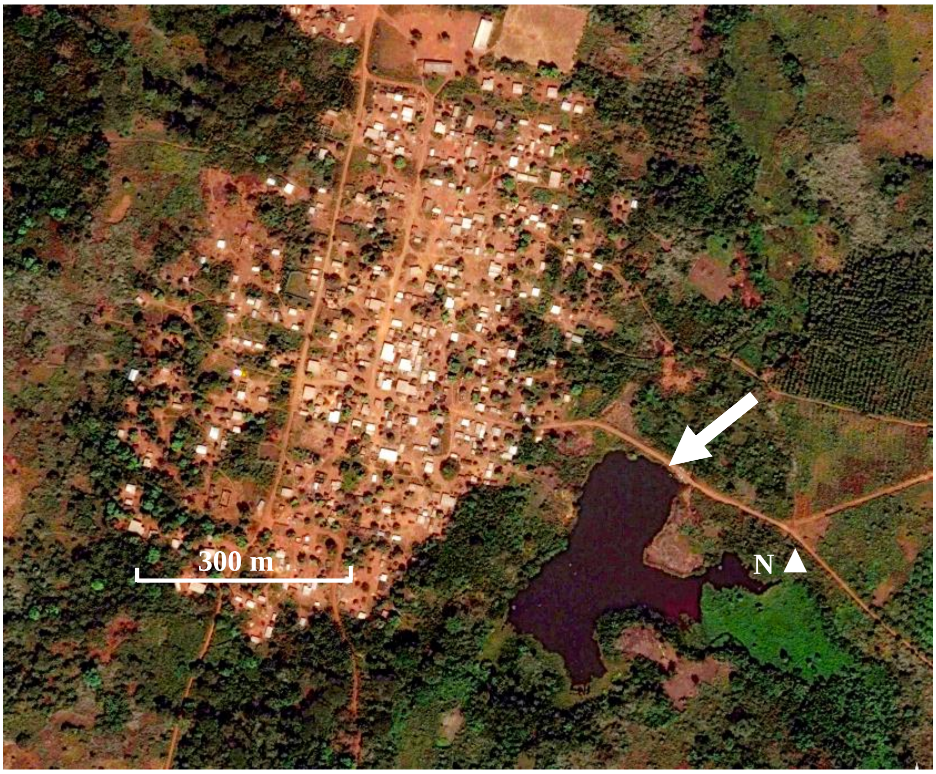

Figure 28. Aerial view of the village of Biele showing the presence of a large body of water in its proximity.

chemotherapy does not seem to solve the problem, which means special attention should be given to this village in order to reduce infection rates.

Although we recorded relatively low prevalences of *A. lumbricoides* (1.6%) and *T. trichiura* (2.6%), our results were not surprising when compared to other studies done in the Man region, in western Côte d'Ivoire. Raso *et al.* (2004) recorded 6.0% of *A. lumbricoides* and 2.0% of *T. trichiura*; Raso *et al*. (2005b) found 2.2% of *A. lumbricoides* and 1.3% of *T. trichiura*; Matthys *et al*. (2007) found 3.2% of *A. lumbricoides* and 1.2% of *T. trichiura*. In a nation-wide study, Yapi *et al*. (2014) found 1.9% of *A. lumbricoides* and 1.3% of *T. trichiura*.

In contrast, in the case of *S. mansoni* (8.9% including Biele and 6.3% excluding Biele) and hookworms (14.4%), our participants were considerably less infected than those in the studies mentioned above: Raso *et al.* (2004) recorded 39.8% of *S. mansoni* and 45.0% of hookworms; Raso *et al*. (2005b) found 38.7% of *S. mansoni* and 30.5% of hookworms; Matthys *et al*. (2007) found 51.4% of *S. mansoni* and 24.7% of hookworms.

In the case of *S. mansoni*, two potential explanations for this lower prevalence were identified. As explained before we used a subset of the schools selected by the SCORE project, which only targeted schools with *S. mansoni* prevalences between 10 and 24%. This excluded schools with high prevalences, which have been sampled by other authors working in this region (Raso *et al.*, 2014; Raso *et al.*, 2005b; Matthys *et al.*, 2007). Secondly, prior to our parasitological survey, our participants had been given, praziquantel for three consecutive years. This probably explains why the prevalence of this parasite went all the way down to 8.9% and 6.3%, with and without Biele respectively.

In the case of hookworms, it is particularly likely that there was an underestimation of its infection rate; not only because all infections are light and therefore more easily undetected, but also because the shell involving the eggs dissolves rapidly after the slides are prepared.

Regarding intensity, infections were predominantly light for all four parasites. A relatively small proportion of moderate and heavy infections were found in all parasites except for hookworms, which only had light infections (Table 3 and Figure 26). Similar results were reported by Yapi *et al*. (2014).

We found that male students were significantly more infected with *S. mansoni* and hookworms than females, which is in agreement with several studies (Albonico *et al*., 1997; Cundill *et al.*, 2011; Hotez *et al.*, 2003). This could be related to a gender specific water contact patterns, *i.e.* boys are more likely to help their parents with agricultural work than girls (Watts *et al*., 1998; Hu *et al.*, 2005). Indeed, a study which analyzed separately farming households and non-farming households, found that males were only more infected with *S. mansoni* in farming-households (Matthys *et al*., 2007).

We found that, at baseline, children over ten years of age were more infected with hookworms than those aged ten or less which is in accordance with other studies (Matthys *et al.*, 2007; Sanchez *et al*., 2013; Alelign *et al*., 2015; Greenland *et al*., 2015). It could be that, since hookworms tend to be more of an occupational infection, children who are older and physically stronger will more likely help their parents in the fields and thus become more infected (Alelign *et al.*, 2015).

In brief, whereas *A. lumbricoides* and *T. trichiura* do not seem to constitute a major health problem in this region, hookworms and *S. mansoni* infections are still quite high in spite of the ongoing chemotherapy programme, suggesting that changes in the current parasite control strategy may be desirable.

4.2. The health education package increases knowledge

Our results suggest the health education package increased children's knowledge about parasites. In fact, the gain in score between baseline and follow-up was significantly greater in intervention schools, in which the students were exposed to the package. However, the difference in mean score between intervention and control schools was quite modest ($\overline{X} = 4.0$ vs. $\overline{X} = 4.4$ out of 6 points) when compared to results of a very similar study in China where, at follow-up, children which underwent a similar health education package knew over twice as much as those who did not (Bieri *et al.*, 2013). Other studies investigating children's knowledge concerning schistosomiasis in China have also found great increase in knowledge following health education. For instance, Yuan *et al*. (2005) found that 99.8% of children in intervention schools reached the passing score of the questionnaire, whereas in control only 16.7% passed. Another example is a study by Hu *et al*. (2005) which found that 94.4% in intervention schools passed in contrast with 8.6% in control.

There is some evidence that in our study region the level of knowledge about parasites is actually quite high, even at baseline. For example, in China Bieri *et al*. (2013) found that at baseline only around 50% of participants had heard of intestinal worms whereas in our case 85% had heard of them. An even greater contrast is evident in other issues such as the number of children that mention stomach ache as a symptom of these worms (9.5% versus 80%) and knowledge about the need to wash hands before eating to avoid contamination (16.1% versus 65%). In China, Hu *et al*. (2005) also found children had very low scores at baseline, only 7.5% reached the passing score.

Thus, it could be that the increase in knowledge with the administration of the package was not great in our study (a 10% increase in the final score) because children were already quite well informed at baseline. There may be two explanations for this. The first is that all our schools have been a part of the SCORE project since 2011. As this project aims at the control of schistosomiasis it could be that people have become more informed throughout the project. In fact, in a study in Côte d'Ivoire, participants mentioned that research and control activities were their main source of information (Acka *et al*., 2010). A second explanation for a somewhat high baseline knowledge is that the study programme of all primary school years in Côte d'Ivoire includes the discussion of issues such as body and food hygiene, the importance of clean water, the importance of a balanced diet, treatment of waste and where to go when one is sick (hospital and pharmacy) (Ministry of Education of Côte d'Ivoire). Consequently, at baseline, children had already learned about several of the issues mentioned in the health education package and, therefore, did not acquire as much new information with it. However, children in intervention schools were capable of adding correct and relevant information spontaneously between 4 and 12 times more often than those in control schools. This suggests that, although they already knew part of the information provided in the cartoon and group work, there was additional information in the package that they were not aware of and learned with the intervention. Also, awareness towards less obvious symptoms and consequences of intestinal parasites (stunting, difficulty concentrating and thinking) was higher in intervention schools. It may have been this additional and less intuitive facts that made children in intervention schools score higher at follow-up.

We also detected a significant increase in average knowledge score of all children between 2014 and 2015. Other studies have found similar increases in knowledge from baseline to follow-up (Bieri *et al*., 2013; Al-Delaimy *et al*., 2014). Mwidunda *et al*. (2015) suggested that this general increase, in schools with and without intervention, is most likely due to an educational effect of the questionnaire survey itself. In our study, at follow-up participants had already replied twice to the same questionnaire so it is not surprising that they had learned from it or even memorized questions. If this intervention was being implemented in a non-study setting, children would not undergo questionnaires; they would simply be exposed to the health-intervention package. Therefore, the knowledge gained with the questionnaire is an artefact that presumably masks part of the potential increase in knowledge that the intervention on its own would have produced. The overlap between knowledge gained due to the questionnaire and the knowledge gained due to the health education package cannot be easily measured, but it is likely that the gain estimated in our study underestimates the gain in an operational setting.

In conclusion, our health education package had a positive effect on children's knowledge and the reason why it was not more evident may be because participants were originally already quite informed. Thus, there is a need to not only reinforce the basics, but also emphasize issues which are not taught in schools. Longer-term education packages and/or more frequency exposure to the packages may further increase knowledge. Finally, it follows from our results that, to better evaluate education packages, questionnaires should be sufficiently challenging.

4.3. Knowledge and the health education package did not significantly influence infection

Studies show that the success of health education packages in reducing infections can be highly variable. In China, Bieri *et al.*, (2013) reported that, not only did children become more knowledgeable with the STH-related health education intervention, but this translated into a 50 % decrease of infections due to behavioural changes. Also in China, Hu *et al.*, (2015) reported that an increase in schistosome-related knowledge led to a behavioural change which decreased infection. In contrast, a study in Peru (Gyorkos *et al.*, 2013) found that more knowledgeable children were not significantly less infected with hookworms or *T. trichiura*, although infections with *A. lumbricoides* declined. In Indonesia, Hadidjaja *et al*. (1998) also did not detect any additional effect of an intervention with chemotherapy and health education when compared to chemotherapy alone.

Our study, did not detect any significant difference in intensity or prevalence of infection between intervention and control schools. Additionally, at baseline, children who scored higher in general knowledge were not less infected and knowing more about the transmission of *A. lumbricoides*, *T. trichiura* and *S. mansoni* did not decrease infection by these parasites (Figure 24). Finally, wealthier children were slightly more knowledgeable, but not less infected. This set of evidence suggests that the health education package was not effective at inducing changes in behaviour and health-related practices that minimized infection, *i.e*. even when they knew how to, they did not change their hygiene and health-related practices to reduce the risk of infection. Other authors have also concluded that acquiring knowledge does not necessarily translate into behavioural changes (Schall *et al.*, 1998; Acka *et al*., 2010). The fact that children did not change their behaviour even if they knew how to avoid infections may have several explanations (see below), which are not mutually exclusive.

One could be that children underestimate the risk associated to parasitic infections, because they are not fully aware of their potential severity or of the long term consequences. In fact, our questionnaires show that the majority of children (85%) believed that efficient treatment is available and that of those most believe that, once treated, they cannot get re-infected (86%). Such a misconception lowers the perception of risk associated to parasitic infections and risky behaviours will persist. Therefore, they may not consider it to be truly important to apply their knowledge by improving their behaviour.

It is also possible that children do not change their behaviour in response to more knowledge about parasites because of the absence of conditions to assume better behaviours. For instance, even if children know the risks of coming into contact with contaminated water sites, they will continue to do so until there is a readily available alternative. Our results suggest that this is the case: having more knowledge about the modes of infection by *S. mansoni*, *A. lumbricoides* and *T. trichiura* did not translate into a lower probability of infection by these parasites (Figure 24). In fact, in Brazil, Schall (1998) found that populations continue their activities in contaminated water and drinking unsafe water when there is no easy alternative. Children are not likely to give up a swim in the river on a hot day just because someone told them they may become sick. In a village in Ghana, a study by Kosinski *et al*., (2012) built a swimming pool. One year later, the prevalence of infection with *Schistosoma haematobium* in children had decreased significantly, illustrating the importance of providing alternatives, in addition to knowledge.

Finally, although there was an effort to take the participants' living conditions into account during the design of the cartoon, it is possible that some of its recommendations were not easy to implement in all villages which may have somewhat decreased the influence of the health education on children's behaviour. Some more acceptable messages have been more assimilated than others. Wearing shoes to avoid hookworm infections in soil contaminated with faeces is a good example of a simple solution most children can easily assimilate and implement. And indeed, we found that children who knew that open defecation was associated to infection, were less infected with hookworms. Interestingly, this was the only significant relationship between knowledge and decline in infection that we found in our study.

But how to explain that knowledge has been so successful at altering hygiene-related practices of children in China (Bieri *et al*., 2013; Hu *et al*., 2015) but not in Peru (Gyorkos *et al*., 2013) or in Côte d'Ivoire (present study)? While local sanitary conditions and package characteristics may play a part (they varied among the mentioned studies), the response to new knowledge seems to be influenced by cultural and demographic differences among regions. As Gu (2013) stated "one word could summarize Chinese education over thousands of years: obedience". Chinese children live in a culture with a long tradition of unconditional obedience to authority (Liu, 1998), so they are likely to implement advice received in school. Furthermore, China has been mostly under a one-child policy since 1979 (Hesketh and Zhu, 1997), so most parents can focus all their attention on their only-child. In contrast, Peruvian and Ivorian mothers have, on average, 2.18 and 3.54 children (CIA, 2015), respectively, and children often wander freely and unattended. This could mean that, compared to Chinese children, Peruvian and Ivorian children have more opportunities to misbehave (*i.e*. not put in practice what they have learned) without being censured by an adult.

In summary, although our health education package took into account several cultural issues and it improved participants' knowledge, no reduction of parasitic infections was detected. A successful health education package should increase knowledge and awareness, stress the risk of these parasitic infections and be realistic enough to induce critical changes in behaviour. One of the possible shortcomings of our experiment was that it was not long-term and the messages were repeated only twice. In an operational scenario it is not practical or cost-effective to have external teams repeatedly visiting schools to implement health education packages. Thus, as done by Gyorkos *et al*. (2013), it would also be of great value to strengthen the role of teachers in the health education package because they have the huge advantage of interacting with children almost daily, allowing them to reinforce the key messages of the package.

4.4. The impact of deworming on prevalence and intensity of infections is significant

Since the decrease in prevalence between 2014 and 2015 was similar in control and intervention schools, we can assume this reduction is at least partly due to the chemotherapy that was administered at baseline. Chemotherapy has been said to be an effective short-term solution for reducing prevalence and intensity of helminth infections (Alum *et al*., 2009).

To our knowledge, albendazole (single dose of 400 mg) was administered for the first time to the children in our study in May 2014, after collecting the baseline stools samples, and this drug seems to have been relatively effective against *A. lumbricoides* and hookworms but not *T. trichiura* infections. Comparable results have been obtained in other studies done in Africa. In Uganda, Zhang *et al.* (2007) one year after the first administration of albendazole had a 75.2% ERR of hookworms, which in our study was 36.3%; after two doses of albendazole (one per year), they achieved a 92.9% ERR. For *A. lumbricoides* they observed a 79.1% ERR after one year and an 83% ERR after two years. We also had a major reduction in prevalence but, since we only had one positive case of *A. lumbricoides* at follow-up, its ERR was not calculated. In the case of *T. trichiura* Zhang *et al.* (2007) found very little improvement one year post-treatment while Njenga *et al.* (2014), also in Uganda, even observed an increase in intensity. In our study intensity was also higher 11 months after the treatment, but this difference was not statistically significant.

Praziquantel has been distributed annually in this region since June 2011, and once after the baseline collection of stool samples. Zhang *et al*. (2007), found a 63% reduction in prevalence of *S. mansoni* one year post-treatment. One year after the second round of annual treatment, they found an additional 66% reduction in prevalence. Our analysis shows that at follow-up the prevalence of *S. mansoni* was still significantly lower than at baseline (33.3% reduction). Our sample also indicated a reduction in intensity but it was not significant. Thus in our study, praziquantel did not perform as well as it could have.

Several approaches to increase the efficiency of anthelmintic drugs have been studied, including increasing the dose. In the case of albendazole, it has been shown (Adams *et al*., 2014) that the cure rates for 800 mg were significantly better than those of 400 mg but not any different from 1200 mg (administered every four months for 12 months). For praziquantel, a review by Liu *et al.* (2011) concluded that dosages of 60-100 mg/kg (60/(40 x 2 doses)/(30 x 2 doses + 40) mg/kg) provide better efficacies than a single dose at 40 mg/kg, which is the dose we used. Others, consider a single praziquantel dose of 40 mg/kg sufficient (Zwang and Olliaro, 2014).

A second approach consists of increasing the frequency of drug distribution. A study by Steinmann *et al.* (2011) showed that CRs and ERRs with a triple-dose albendazole treatment are significantly higher than a single-dose in the cases of hookworms and *T. trichiura* infections, although there is no difference for *A. lumbricoides*. Adegnika *et al.* (2014) concluded that multiple doses of albendazole were necessary to reach an adequate cure rate against these three major STH. For *S. mansoni*, Nalugwa *et al.* (2015) reported the ERR is significantly better with a double- than a single dose of praziquantel.

A third strategy to increase the elimination of STH through chemotherapy, is to combine them with other drugs. Some substances, such as ivermectin and diethylcarbamazine, in combination with albendazole, have proven to be more effective than albendazole alone (Ismail and Jayakody, 1999; Belizario *et al.*, 2003), particularly in the elimination of *T. trichiura*. Praziquantel combined with artemisinin derivatives, such as artemether and artesunate, has been shown to be better than praziquantel alone against schistosome infections (Liu *et al.*, 2011). These combinations may be particularly suitable for the treatment of patients who are consistently in contact with infected water sources (Liu *et al.*, 2011). In reality, combining drugs is not only important to improve their efficacy. It has been shown that after years of using the same anthelminthics in livestock, their worms developed high levels of resistance (Waller, 1994). These combinations should also take into account the possibility of creating resistant strains of other parasites (Wikman-Jorgensen *et al.*, 2012). For instance, in areas where schistosomiasis and malaria coexist, combining praziquantel and artemisinin derivates (known for their power against malaria) can lead to the emergence of resistant strains of *Plasmodium* spp (White, 1999) To prevent this from happening with human parasitic worms, it is imperative that MDA programs are monitored in order to recognize any changes in therapeutic efficacy. Identification of these cases, which can result from the selection of worms who carry mutations conferring resistance to the drugs, is important so that chemotherapy strategies can be adapted before resistant worms become widespread (Albonico *et al*., 2006).

Finally, a forth approach to control STH has been evaluated by Guo *et al.* (2005) who coupled health education with what they called "passive chemotherapy", *i.e.* treat residents in schistosome-endemic areas with praziquantel only upon their request. They reported similar results when comparing MDA to this new strategy. Such "passive chemotherapy", along with health education, may thus be useful, particularly in the maintenance and consolidation phase of control (*i.e.* when prevalence is relatively low).

Overall, the effect of deworming in our study, 11 months after administration, was somewhat as expected: albendazole was relatively effective against *A. lumbricoides* and hookworms but very ineffective against *T. trichiura*; praziquantel decreased *S. mansoni* prevalence significantly but not the intensity of the infections. In summary, increasing the dosage, the frequency or combining albendazole and praziquantel with other drugs should be considered in order to improve the efficacy of current chemotherapy.

Yet, a few important questions remain about the long term adequacy of a strategy based on chemotherapy alone. It is well known that reinfections are inevitable and thus strategies to minimize them are highly desirable. According to Utzinger *et al.* (2003) chemotherapy alone is not sustainable. It is an effective short-term tool that should be viewed as a first step for the implementation of an integrated approach towards the control and elimination of these parasites.

4.5. Access to safe water and latrines did not reduce of parasitic infections

The transmission of helminths is extremely difficult to eliminate in undeveloped countries where inadequate sanitation and access to clean water are a reality (Brooker *et al*., 2004). Yet two and a half billion people worldwide and 69% of the population in Sub-Saharan Africa lack access to improved sanitation. This lack of access to sanitation costs the world every year about US$ 260 billion (World Bank, 2013). One billion people worldwide still practice open defecation (World Bank, 2013). In rural Côte d'Ivoire 31% of the population drinks unimproved water (a 2% drop since 1990), only 22% have access to improved sanitation (7% better than in 1990) and 51% practice open defecation.

Among our 25 schools, seven had access to both safe water (pump) and latrines but our meta-analysis did not find a significant difference in infection between these schools and those with lower sanitation. Our results are in contrast with some systematic reviews that have reported significant improvements in the health of rural communities due to sanitation interventions (Clasen *et al*., 2010; Ziegelbauer *et al*., 2012; Engell and Lim *et al.*, 2013; Strunz *et al*., 2014; Wolf *et al*., 2014). However, they are in line with studies that found that presence of latrines and clean water does not always mean they will be used and, therefore, does not always lower infection rates (Arfaa *et al*., 1977; Holland *et al*., 1988; Huttly, 1990; Coffey *et al*., 2014; Patil *et al*., 2014). Where the facilities are available, the level of contamination will depend on their use (Asaolu and Ofoezie, 2003). In fact, we noticed that many children often did not use the schools' latrines either because they were locked, or because they were too dirty. Similar observations have been made in India, where despite the efforts of the government to build latrines, 48% of households with a working latrine have at least one family member who practices open defecation (Coffey *et al*., 2014). Thys *et al*. (2015) investigated the reasons behind the same problem in Zambia and concluded that seeking privacy (latrines may be too close to the village) and taboos were both key factors influencing the use of sanitation facilities. In addition they found that bad smell, attraction of flies, complicated maintenance and waste disposal helped explaining this preference for open defecation.

According to Archana Patkar, program manager at Water Supply & Sanitation Collaborative Council (WSSCC), referring to insufficient use of latrines in India, "The problem is that germs are invisible, and so understanding the threat of open defecation is far removed from reality until they are sick and dying. And even then, they don't really understand" (Bloomberg, 2014). Thus if people were truly informed and aware of the real dangers of the infections caused by open defecation and drinking unsafe water, for example, they would probably change their behaviour. As mentioned earlier, even though our health education package emphasized the dangers of these infections, this lack of risk perception was found in our study.

A case of outstanding success at eliminating the practice of open defecation was Bangladesh where from 1990 to 2015 the amount of people practicing open defecation dropped from 40% to 2%; in Côte d'Ivoire, during the same period, it dropped from 56 to 51% (WHO, 2015). Bangladesh based this revolution on sanitation marketing: they developed slogans such as "if we defecate openly, you will be eating other people's faeces" causing shame and disgust which according to some are just as important as health messages. Although communities were included in all parts of planning and action, CLTS was just one of the implemented strategies. Incentives were given for small businesses selling concrete parts of latrines, and school children monitored their parents' and neighbours' defecation practices. With these interventions, social norms changed and latrines became a symbol of a dignified lifestyle (Hanchett *et al.,* 2011). Nevertheless, more can be done in Bangladesh and latrine cleanness and maintenance are issues that need more attention in the future (Hanchett *et al.*, 2011).

In conclusion, our results corroborate those of studies that concluded that, while it is necessary to ensure that people have access to clean water and good quality sanitation, it is also essential to promote their usage and correct maintenance.

4.6. Conclusions and recommendations

Although the prevalence of STH and *S. mansoni* is not particularly high in this region, it remains a major health issue both in Côte d'Ivoire and other parts of the developing world (Kattula *et al.*, 2014). Globally, the current control strategy is based on anthelminthic drugs which have proved to be quite effective in this study. However, because reinfection is inevitable (Jia *et al.*, 2012), it has never completely eliminated STH or schistosomiasis infections without simultaneous economic development (Medley and Hollingsworth, 2015). Also, the risk of creating drug resistant parasites is a major concern with MDA (Albonico *et al*., 2006) which highlights the importance of developing alternative control strategies.

Health education packages are increasingly recognized as a potentially important tool to help control parasitic infections. Our results demonstrate that, even though children already receive some useful knowledge in school, specific health education packages can further increase knowledge. However, greater knowledge did not seem to minimize the chances of infection. In fact, neither children with more knowledge at baseline nor participants in intervention schools were less infected. This demonstrates that, in the context where we developed our study, increasing knowledge is not enough.

It follows from these results that, while it is important to increase knowledge it is also essential to create conditions for children to take full advantage of what they know about preventive measures. This necessarily includes providing easy access to clean sanitation infrastructure and water for hand washing with soap. If these facilities are too basic or not properly maintained they may be underused, failing to fulfil their role. As in other studies where facilities were poor, we did not detect a difference in infection between schools with and without basic facilities. Health education packages can have an important role in counteracting this problem. They can explicitly reinforce the importance of maintaining sanitation facilities in adequate conditions so that they remain an attractive alternative to open defecation. In addition, packages can include practical and realistic recommendations for children to decrease the risk of infection by taking the best possible advantage of the existing facilities.

Behaviours that protect children from infection will only be assumed if children have a proper perception of risk. However, our study suggests that this is not the case. Thus, health education packages should emphasize the dangers of these infections and demystify the idea that, because these diseases are treatable, they do not have consequences, particularly in the long term.

Our results indicate that students already have a fair amount of hygiene-related knowledge probably because they have been exposed to the SCORE project and because these topics are included in the school programme. Thus, it is important that a health education package is well articulated with the school programme in order to, not only reinforce key messages, but also complement it with additional vital knowledge. In this context, health education packages can also aim at encouraging teachers to assume a greater role in the minimization of infections throughout the school year. Not only can they keep reinforcing key messages, but they also hold the authority to ensure that there is always easily available water and soap in their schools, and that latrines are clean and being used correctly.

This study has shown that health education packages have a good potential to increase knowledge, and identified topics that may be added to improve their success. However, the study also demonstrated that, in our context, there are issues that may prevent knowledge to effectively change behaviours that reduce infection. Teaching how to overcome these issues is a critical element to release the full potential of knowledge and health education packages.

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6. LIST OF FIGURES AND TABLES

7. ANNEX

Questionnaire **adressé aux élèves du primaire**

A remplir par l'équipe de recherche:
Date______________________ (J/M/A) Enseignant________________________
ID:
Sous-préfecture **Village** **Ecole**
|__| |__|__| |__|__|
Maison **Individu**
|__|__|__|__| |__|__|__|__|

A remplir par les élèves:

S'il te plaît remplis ce questionnaire honnêtement avec l'aide de ton enseignant. Toutes les réponses resteront confidentielles et ne seront utilisées contre toi en aucune façon. L'information sera utilisée à des fins de recherche uniquement.

Informations personnelles

Nom____

Sexe (1) Masculin (2) Féminin

Age |__|__|__|__|/|__|__|/|__|__| J/M/A

Connaissances

S'il te plaît écris ce que tu as entendu et ce que tu sais des vers qui vous rendent malade. Tu peux également écrire: "Je ne sais pas."

1. Connais-tu l**es** vers qui vous rendent malade?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

2. Que sais-tu **des** vers **du ventre** (**termes locaux)?**

……………………………………………………………………………………………………

……………………………………………………………………………………………………

3. Où as-tu entendu parler des vers du ventre**?**

(1) Ami (2) Affiche (3) TV (4) Radio (5) Livre

(6) Brochure (7) Ecole (8) parents/famille

(9) Autres:…………………………………………….

4. **Comment aimerais-tu être enseigné sur les** vers du ventre**?**

(1) Ami (2) Affiche (3) TV (4) Radio (5) Livre

(6) Brochure (7) Ecole (8) parents/famille

(9) Autres:…………………………………………….

Transmission, Symptômes & Traitements

5. Comment et où peut-on être infecté par les vers du ventre**?**

(1) Manger de la nourriture avariée (2) Manger sans se laver les mains
(3) Boire de l'eau du marigot/rivière (4) Jouer dans l'eau sale
(5) Etre en contact avec les poubelles (6) Marcher sans chaussures
(7) Jouer dans le sable (8) Manger beaucoup de fruits
(9) Manger des aliments sucrés (10) Manger cru, fruits et légumes non lavés
(11) Ne sait pas
(11) Autres (A préciser): ....

6. Penses-tu que les vers du ventre peuvent provoquer des maladies graves**?**
(1) Oui (2) Non (3) Ne sais pas

7. Que se passe-t-il lorsque les gens sont infectés par les vers du ventre**?** (Tu peux choisir plus d'une réponse**)**
(1)Se sentir fatigué (2) Ne pas pouvoir se concentrer à l'école
(3)Faire la Diarrhée (4) Avoir un retard de croissance
(5)Avoir des maux de ventre (6) Ne pas avoir l'appétit
(7) Le malade ne peut pas bien réfléchir (8) Ne sait pas
(9)Autres (A préciser): ……………………………

8. Penses-tu que l'infection **par les vers du ventre** peut être traitée**?**
(1)Oui (2) Non (3)Ne sait pas

9. **Où doit-on se rendre pour ce faire soigner lorsqu'on a les vers dans le ventre ?**
(1) Chez les vendeuses de médicaments (2) Au dispensaire
(3) Chez le guérisseur (4) Ecole
(5) Autre (s'il vous plaît préciser)……………………………………………

10**. Penses-tu guérir pour toujours si tu prends** un médicament contre les vers du ventre ?
(1) Oui (2) Non (3) Ne sait pas

Attitudes

Dans les prochaines questions s'il te plaît dis-nous ce que tu penses des vers du ventre.

11. Je crois que je cours un risque de contracter **l**es vers du ventre.
(1) Oui (2) Non

11a. Si oui pourquoi, si non pourquoi ?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………...

12. Je serais-tu inquiet si tu avais des vers dans le ventre ?
(1) Oui (2) Non

12a. Si oui pourquoi, si non pourquoi?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

13. Où doit-on faire les selles ?

(1) Latrines (2) Brousse (3) Rivière (4) Autre……………………………

14. Que doit-on faire après avoir fait les selles ?
(1) Rien (2) Se laver les mains avec de l'eau
(3) Se laver les mains avec de l'eau et du savon (4) Autre……………………………

15. Que doit-on faire avant de manger?
(1) Rien (2) Se laver les mains avec de l'eau
(3) Se laver les mains avec de l'eau et du savon (4) Autre……………………………

16. Que doit-on faire des fruits avant de les manger?
(1) Rien (2) Les laver avec de l'eau (3) Autre……………………………

17. Quel type d'eau doit-on consommer?
(1) toute sorte (2) L'eau de source propre (3) Autre……………………………

18. Pourquoi doit-on toujours couvrir la nourriture?
(1) Pour ne pas qu'elle se refroidisse (2) Pour éviter que les mouches la contamine
(3) Autre……………………………

19. Pourquoi ne doit-on pas marcher ou jouer dehors sans chaussures?
(1) Pour ne pas se blesser (2) Pour ne pas être infecter par les vers
(3) Pour ne pas marcher dans les saletés (4) Autre……………………………

20. Pourquoi ne doit-on pas **se baigner dans l'eau de rivière, ruisseau, lac, marigot, etc.**?
(1) Pour ne pas avoir froid (2) Pour ne pas être infecter par la bilharziose
(3) Parce que l'eau est sale (4) Autre……………………………

<u>Situation Socioéconomique</u>

Maison en briques		Voiture	
Maison électrifiée		Téléphone mobile	
Radio		Cuisinière à gaz ('grand bouteille')	
Télévision		Gaz faitout ('petite bouteille')	
Réfrigérateur		Cuisine avec du charbon	
Ventilateur		Latrine traditionnelle	
Bicyclette/Vélo		Toilette ou Latrine avec chasse d'eau	
Motocycle		Savon	

<u>Comportements de risque</u>

Port de chaussures ?	
Tu ronge les ongles ?	

<u>Eau à boire (à la maison)</u>

Eau de robinet/Eau courante	
Eau de puits	
Eau de marigot / rivière / étang / barrage / bas fond	
Eau de pompe	

<u>Eau à boire (aux champs)</u>

Eau de robinet/Eau courante	
Eau de puits	
Eau de marigot / rivière / étang / barrage / bas fond	
Eau de pompe	