The Effect of Schistosomiasis and Soil-Transmitted Helminths on Expressive Language Skills Among isiZulu Speaking Preschool Children

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Research article

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Abstract

Background: Schistosomiasis and soil transmitted helminths (STH) have been associated with compromised child development. We determined the effect of schistosomiasis and STH on expressive language skills among isiZulu speaking preschool children focusing on the variables: age, gender, school and stunting.

Methods: We compared, qualitatively and quantitatively the performance of a cohort of infected and non-infected children using a 2 phased approach. In phase 1 infected children were treated with praziquantel and matched with non-infected children and both groups were tested for expressive language performance. In phase 2 both groups of children were re-tested for expressive language skills using a similar but modified test. The participants were 106 preschool children between the age of 4 and 6 years,11months. The Developmental Language Test was adapted as a linguistically and culturally appropriate tool for assessing isiZulu expressive language skills.

Results: The overall performance of the children in phases 1 and 2 were statistically similar. There was significant Pearson's correlation of expressive language skills to age (0.002, $P<0.01$), schistosomiasis i.e. *vocabulary 1* (0.024, $P<0.05$) and narrative skills (0.001, $P<0.01$) and soil-transmitted helminths i.e. *vocabulary 1* (0.006, $P<0.05$), *colours* (0.029, $P<0.05$) and *narrative skills* (0.001, $P<0.01$) in phase 2 with small to high Cohen's *d* effect size for various language subtests.

Conclusion: We concluded that even mild schistosomiasis and STH may compromise the performance of preschool children on expressive language. However poor ability in following instructions may have contributed to general poor performance across the two groups tested. Diet, school effect and stunting did not influence the performance of the children on expressive language.

Background

Schistosomiasis, also known as Bilharzia, is a chronic debilitating disease, whose public health importance is second to malaria as the most common parasitic condition in Africa (National Institute of Communicable Diseases (NICD), 2018). Two main species of schistosomes infect human beings in Africa - *Schistosoma haematobium* and *Schistosoma mansoni* with each species determined by presence of a suitable snail host and its distribution. About 4 million people, mostly children, are infected with schistosomiasis in South Africa (NICD, 2018). Schistosomiasis is transmitted to humans through contact with contaminated water during bathing, swimming, fishing and domestic chores. Thus, the disease is more prevalent in coastal and rural areas of South Africa where there is no running or tap water (Global Atlas of Helminth Infections, 2017). Incidentally, the prevalence of schistosomiasis overlaps with that of soil-transmitted helminths (Global Atlas of Helminths Infections, 2017). The prevalence of soil-transmitted helminths (STH) in KwaZulu Natal is estimated at 38.8% in school aged children (Molvick et al., 2017).

Parasitic worms affect human nutrition and growth through a number of routes depending on the species, the mixture of species, the duration of infection and number of worms (Munŏz-Antoli, Parỏn, Pérez, Toledo, & Estenban, 2017). For instance, intestinal worms feed on the contents of the host's gut and tissues including blood and serum resulting in loss of iron and protein. They can cause maldigestion or malabsorption of the nutrients or induce inflammatory responses that may affect appetite and food intake thereby modifying metabolism and storage of key nutrients. Additionally, contingent responses to infection such as fever and hypertrophy of the muscles also affect behaviour, concentration levels and changes anthropometric status (Munŏz-Antoli, Parỏn, Pérez, Toledo, & Estenban, 2017). The effect of schistosomiasis and STH on cognitive function could occur as a result of one or a combination of symptoms associated with parasitic infection including iron deficiency anaemia. Since early childhood is a period of rapid growth and development of all organ sytems, particularly the brain, early life iron deficiency results in abnormal neuronal structure. Hence, schistosomiasis has been associated with negative effects on school attendance, scholastic achievement, learning and memory (Ezeamama, Bustinduy, Nkwata, Martinez, Pabalan, Boivin & King, 2018).

Studies investigating effects of STH infections (Stoltzfus, Kvalsvig, Chwaya, Montressor, Albonico et al., 2001) as well as malaria and anaemia(Dellis, 2010) on neurological development have reported delayed motor and speech development. Neurological consequences are reported even in non-anaemic deficiencies where the potential for learning is reduced due to poor recognition memory and executive functions of infected learners (Luwoski, Koss, Burden, Jonides, Nelson et al., 2010). Early treatment of children with parasitic infections could potentially mitigate the memory and learning deficits in preschool children (Ezeamama, et al., 2018). There is also empirical evidence indicating cognitive and educational benefits of STH treatment (Pabalan, Singian, Tabangay et al., 2018).

Since infection with STH and schistosomiasis are confounding factors to cognitive impairment and developmental delays in communities with poor water and sanitation, there is a knowledge gap on whether STH and schistosomiasis have the same effect on expressive language skills as much as they may have on other cognitive skills. Our study aimed at determining the effect of schistosomiasis and STH on expressive language skills among isiZulu speaking pre-schoolers. We determined the profile of expressive language skills of isiZulu speaking preschool children in terms of age, gender, school, stunting and parasitic infection; and compared expressive language skills for children with and without schistosomiasis and STH.

The knowledge we have on isiZulu grammatical pattern is limited, achronological and has not yet produced developmental language norms for receptive and expressive language (Van der Merwe & Le Roux, 2014). We know that isiZulu, like Turkish and Finnish, has characteristically agglutinating morphology and in many ways isiZulu is different from English (Keet & Khumalo, 2016). Data collected from similar Nguni languages such as isiXhosa showed that trilingual and monolingual children had similar lexical development in the languages the children were exposed to (Potgieter, 2016). Expressive language builds up from nouns to verbs, adjectives, adverbs, prepositions, conjunctions and auxiliary verbs (Gonasilan, Bornman & Harty, 2013). Typical emergent skills for expressive language are memory, time-based relations, cause and effect reasoning, social script, sense of self and vocabulary which lead to learning colours, questions and narrative skills can all be achieved as early as 36 months (Phillips, 2008).

Expressive language development is usually described using the standards set in English according to the Brown's stages of syntactic and morphological development where children begin to express their thoughts in single words around 12 months and achieve full sentences and narrative skills by 5 years (Bowen, 1998). By the age of 5 years children are usually enrolled in a preschool where early identification of at-risk children and the provision of appropriate interventions and support can substantially affect future scholastic progress (Wildschut, Moodley & Aronstam, 2016). Since attendance of grade R has been found to influence literacy development, we decided to determine expressive language skills in children attending a preschool (Daws, Biersteker, Girdwood, Snelling & Tredaux, 2018).

The main risks associated with expressive language development in English speaking children has been shown to include a variety of factors such as family dynamics, interaction with parents, immediate social environment, organic hazards such as brain injury, persistent otitis media, types of food (Gurger, Vidor, Joly & Reppold, 2014), a reactive temperament and being male (Harrison & McLeod, 2010). Hence, we examined the effect of age, gender, school and status of infection with schistosomiasis and STH on expressive language skills in our sample.

Methods

Design and setting of the study

Our study area was a small rural town of Ingwavuma, located in northern KwaZulu-Natal province of South Africa, close to the borders of eSwatini (in the North) and Mozambique (in the east). Ingwavuma is under traditional authority and is regarded as the worst poverty-stricken area in KwaZulu-Natal with an estimated annual income of R32 812 (STATSSA 2015, p17). Most people in this area depend heavily on social grants estimated to R13 090 per annum (less than USD1000) as their main source of income, (General household surveys, 2018). The prevalence of *Schistosoma haematobium* in Ingwavuma is 37.5% amongst school attending children above 10 years (Kabuyaya, Chimbari, Manyangadze & Mukaratiwa, 2017) and for young children (1–5 years) it is 2% for both *S. haematobium* and *S. mansoni*. The risk factors for schistosomiasis among young children include caregiver's age, type of household head, poor sanitation, access to water source and knowledge about schistosomiasis (Sacolo-Gwebu, Chimbari, & Kalinda, 2019).

The study was an analytical cohort study which described and compared language skills of non-infected and infected children with schistosomiasis and STH using clinical assessments and observations to obtain data. It was an ancillary study to the *Tackling infections to benefit Africa* (TIBA SA) project (http://tiba-partnership.org/about/what-is-tiba). Over 700 preschool children were tested for STH and schistosomiasis in the TIBA study between 2017 and 2020. *Schistosoma haematobium* was diagnosed using the filtration technique on urine samples (Mott, 1983); *S. mansoni* and STH (Taenia, *Ascaris*

Lumbricoides, *Trichuris Trichiura)* were diagnosed on stool samples using the Kato Katz technique (Katz, Chaves & Pellegrino (1972).

Purposeful random sampling was used. To be eligible for the study a child had to be of age between 4.0 and 6.11 years; attend an isiZulu medium preschool or ECD in the target area, have no developmental delays, be monolingual isiZulu speaker and pass a hearing screening test. The study participants were striated based on age (4 to 6 years), gender (50% of each gender) and inclusion of infection positive participants at a ratio of 2 negative cases for every 1 positive case. The principal researcher was blinded to both status and nature of infection of the study participants. Children were tested in two phases; phase 1 was testing immediately after parasitology screening and phase 2 was testing at least 12 weeks later and after treatment of children with schistosomiasis and STH with oral Praziquantel. Some children participated in both phases while some participated only in phase1 and could not be traced for repeat testing. The data for the children who participated in both phases was treated separately because the phases were 3 months apart, affecting the children's level of maturity and the language test was adapted for phase 2 to reduce content bias.

Sample characteristics

The distribution of children in phase 1 and 2 varied in terms of age, gender and infection. The mean age was 4 years 9 months in phase 1 and 5 years 9 months in phase 2. The total number of children with schistosomiasis (17.9%) was less than the number of children with STH (31.1%) and the infections were not necessarily co-existing. The combined distribution of infections in phases 1 and 2 indicated that the largest number of STH infection was from *A. Lumbricoides* with 17 cases (16%).

Table 1
sample characteristics

Variable	Description	Phase 1	Phase 2
Gender	Boys	N = 38	N = 23
	Girls	N = 20	N = 25
	Total N	N = 58	N = 48
Age	Minimum	4.0	4.10
	Maximum	6.11	7.03
	Mean	4.9	5.7
Schistosomiasis	Positive (1)	19 (32.75%)	13 (27%)
STH & number of infections carried by 1 child	STH Total	N = 19 (32.75%)	N = 16 (33%)
	1	15.5%	7= (14,5%)
	2	12.1%	8= (16,6)
	3	5.2%	1= (2.1%)
Time Taken to Test	Mean	26.97 min	23.71 min

The 17 participating preschools had pit toilets, at least one rainwater harvest tank within the facility and provided one meal a day for the children. In our observations on all test dates, the meals did not include green leafy vegetables or meat. All the teachers met the minimum required qualification of high school education for ECD and a teaching diploma for Grade R. Although all schools had government supplied grade R books, they lacked in resources such as puzzles, board games, a computer, a television and had no internet access.

Data collection procedures

Considering the socio-economic profile of the study area, children were provided with a peanut butter sandwich and orange juice before undergoing testing to ensure they had a healthy breakfast and had energy to participate in the tests. Testing started with hearing screening which, included otoscopic examination and tympanometry in order to exclude ear infections and its contribution to poor language scores (Harrison & McLeod, 2010). A nutritionist determined the participant's anthropometric data by calculating BMI-for-age (weight in kg) and height-for-age (height and arm circumference in cm) to determine stunting (World Health Organisation, 2011). The children were classified as having mild (1), moderate (2) or severe (3) levels of stunting. The majority of the participants had adequate nutrition. The prevalence of stunting was 26% and the results showed no significant correlation of the test scores to stunting in both phases of the study.

All children were monolingual, speaking isiZulu at home and at school. The Developmental Language Test (Kvalsvig, Govender & Taylor, 2009), a non- standardised test developed for a research project, was adapted for this study following a pilot study and observations by research assistants. From these observations the test's vocabulary was adjusted to include local dialect (Northern KwaZulu-Natal coast) and the sequence of test items was formatted into 5 sections for easy scoring and interpretation (Table 2). New test illustrations were developed using pictures taken in Ingwavuma with local community members for improved clarity and to accommodate the adjusted format of the test (see appendix A for test illustrations and B for test form).

Table 2
Adapted Developmental Language Test Score form (Kvalsvig, Govender, & Taylor, 2009)

Subtest	**Task**	**Notes**	**Sum Score**				
			4	3	2	1	0
1.Vocabulary 1(nouns)	Sing a song						
	Identify people & names						
2.Colours	Recognition						
	Naming						
3.Answering WH-Questions	Who						
	What						
	Where						
	Why						
4. Vocabulary (Verbs and Object function)	Counting1-15						
	Object naming						
	Object function						
	Meanings						
	Categorisation						
5.Narrative skills	Inferencing						
	Story retelling						
TOTAL	WHOLE TEST						

The adapted Developmental Language Test showed a sensitivity of 89.7% in phase 1 and 81.3% in phase 2 reflecting that children who tested positively were true positives while specificity was 10.3 and 18.8% respectively. The Cronbach's Alpha was determined to be 0.869 (SD = 5.1) in phase 1 and 0.813 (SD = 7.7) in phase 2 demonstrating adequate internal consistency and suggesting that all items measured the same construct.

The test was administered to one child at a time by the principal researcher who is a speech-language therapist and an isiZulu speaker, familiar with dialect and culture of the area. Scoring points varied from 0 to 4 points per target, depending on the extent of the answer as described in the test form (APPENDIX B). Scoring was immediate and automated via an adapted kobo collect app, an open source platform used for collecting and analysing data (Palla, LeBel & Chavernac, 2016).

Data analysis

Quantitative data analysis for both phases comprised of descriptive frequency analysis, Independent Samples t Tests, ANOVA and Bivariate correlations on the SPSS 25 program. Post hoc tests were conducted using Bonferroni corrections to measure the specific contribution of variables such as age, gender, school and infection on language categories and time taken to complete the test. The overall error rate was controlled by the use of adjusted significance levels ($\alpha = 0.05$). Information processing model for cognitive skills (Malmberg, Raaijmakers & Shiffrin, 2019) and Vygotsky's sociocultural theory for development and learning guided data analysis and interpretation of scores (Vygotsky, 1978/ 1995).

Results

The results showed no significant differences in language scores due to STH or schistosomiasis infections in the pre-treatment Phase 1. However, in Phase 2, there was correlation of schistosomiasis to two language subtests i.e. *vocabulary 1* (0.024, $P < 0.05$) and narrative skills (0.001, $P < 0.01$).There was medium correlation effect size for correlation of schistosomiasis to *vocabulary 1* (Cohen's d= -0.67), a medium effect size for *colours* (Cohen's d= -0.53) and a high effect size for correlation of schistosomiasis to *narrative skills* subtest (Cohen's d= -0.99). The correlation was negative for all three subtests indicating that schistosomiasis may have contributed to the reduction of the mean. There was also correlation of expressive language scores to STH for three subtests i.e. *vocabulary 1* (0.006, $P < 0.05$), *colours* (0.029, $P < 0.05$) and *narrative skills* (0.001, $P < 0.01$). The correlation effect size of STH on *vocabulary 1* was negative (Cohen's d= -1.84), while for *vocabulary 2* it was small and positive (Cohen's d = 0.28). The effect size for *colours* (Cohen's d=-1.53) and *narratives* (Cohen's d=-2.16) was negative. Statistically, there was no correlation between the test scores and the school factor.

There were significant differences in performance by age for four subtests in phase 1 (excluding *WH-Questions*) and three subtests in phase 2 (excluding *narrative skills* and *vocabulary 2*) were established ($P = 0.028$; $P < 0.05$). The analysis of the correlation effect size indicated that the effect was mainly negative, with a moderate effect size for v*ocabulary 1* (Cohen's d = -0.84); and a small effect size for *vocabulary 2* (Cohen's d= -0.21).

Boys performed better than girls in *vocabulary subtests 1 and 2* respectively (0.022, $P < 0.05$) in phase 1 and in phase 2 (0.023, $P < 0.05$). Similar observations were made in the *colours, WH-questions and* *narratives* tests. The correlation effect size for gender was below minimal (Cohen's $d = 0.024$ for boys and 0.022 for boys). The mean time taken to complete the test (TTT) was 26.97 minutes in phase 1 and 23.71 minutes in phase 2 and positively correlated to age but not gender (0.002, $P < 0.01$) for phase 1 and phase 2 (0.28, $P < 0.05$).

Analysis of the total cohort performance on each subtest indicated the following trends which are relevant for clinical language norms: In the *Vocabulary 1* subtest which, included tasks to recall character names, pointing to characters and objects on picture A, few children achieved above the mean (total score was 12) on the task. For the second subtest which required identification and naming of colours, the majority of children did not know all their primary colour names and achieved the mean score of 3 in both phases. The third subtest required answering WH- questions in isiZulu where the majority of the children could not obtain the full score in this section mainly because they could not answer the Why question. The *Vocabulary 2* subtest various aspects of vocabulary including verbs, numbers and categorisation of items. There was minimal variability in the children's performance (Table 3).

Table 3
Expressive language profile comparison between Phase 1 & 2

Subtest	**Mean Raw score**		**S.D.**		**Sig.**	**Sig (2-tailed)**	
	Phase1	**Phase 2**	**Phase1**	**Phase2**		**Phase 1**	**Phase 2**
1. Vocab1	8.2	9.0	2.21	2.23	.093	.098	.105
2. Colours	3.1	3.9	1.8	1.3	.002	.012	.009
3. Wh- Questions	2.4	3.5	0.84	0.89	.539	.000	.000
4. Vocab 2	13.1	20.3	3.2	2.3	.015	.000	.000
5. Narratives	8.2	6.9	2.5	2.2	.411	.005	.004
Test Total Sum	**35.2**	**43.8**	**8.3**	**7.7**	**.349**	**.000**	**.000**

Overall, the results showed similar trends in both phases as there was no significant difference between the means of different language subtests in both phases for the cohorts. The age specific results indicate that age contributed to variation of the total scores with the older children performing better in language subtests (Table 4).

Table 4
Mean Raw score per subtest and age band

Age band	N	Mean Voc 1	Mean Colours	Mean Q&A	Mean Voc 2	Mean Narratives	Mean Total
4.0-4.5	8	8	1.8	2.6	12	7.5	32
4.6–4.11	6	7.6	1.5	2.3	12.5	6.6	30.2
5.0-5.5	20	8.25	3.25	2.4	12.45	8.7	34
5.6–5.11	12	9.25	3.17	2.25	13.3	8.4	36.3
6.0-6.5	4	9.75	5	3	16.7	10.5	44.7
6.6–6.11	7	9.4	4.7	3	16.3	11	43.3

Comparing the five subtest's medians to the 25th and the 75th percentiles, the medians were equidistant from the quartiles indicating normal distribution of data. There was minimal variability in the children's performance considering the percentile ranks and narrow interquartile range (Table 5).

Table 5
Percentiles

Subtest	25th P	50th P	75th P
Vocab 1	47	51	52
Colours	43	46	51
Wh Questions	45	48.5	51
Vocab 2	49	52	52
Narratives	39.5	45	46

Discussion

The children came from similar backgrounds and comparable schooling contexts hence, no significant differences were noted between the schools and all differentiating variables analysed. The comparison of language scores from the pre-treatment and post treatment phases indicate that the means were higher in phase two. Since we had controlled for content bias by adapting the language test and changing the test pictures in phase 2, the results imply that the older the children the higher the scores in all test areas. The gender comparison in this study shows that boys performed better in vocabulary subtests. This is an unusual finding as many studies report girls as having stronger expressive or oral language skills and boys at a higher risk of speech and language impairment (Prathanee, Thinkhamrop, & Dechongkit, 2007; Harrison & McLeod, 2010; Tsai et al., 2017). Since gender related differences in language acquisition have been attributed to cortical sex differences, thought to be acquired or enlarged through different stages of development and attributed to different cognitive strategies between sexes, we recommend further investigation into the factors that may have contributed to the trends in our study, considering its rural setting and specific to isiZulu language.

There was a positive effect of age on TTT, implying that with the increasing children's age, the speed to complete the test also increased. We regard the effect size minimal as it fell 1 point below the recommended 0.25 (Geata & Brydges, 2020). This was an expected finding and in line with the information processing model and cognitive theories of language development such as Luria's neurological learning theory (Clark, 2004). We did not find significant correlation between children with and without schistosomiasis and STH in TTT. Uniform processing time was observed for candidates with and without schistosomiasis in learning and memory tests in similar studies (Ezeamama et al., 2018). Similarly, when STH was associated with learning, memory and intelligence, there was no significant correlation of testing time with infection (Pabalan et al., 2018).

The results showed a negative effect of infection to language subtests where the correlation was significant in the post treatment phase 2 suggesting that children with history of parasitic infections performed lower than their peers and thus explaining the reduction of the mean of the relevant tests. This negative effect size was medium for *vocabulary* and *colours* subtests but high for *narratives skills*. Narrative tasks required the ability to follow commands and retell a story in sequence, skills that require application of short term (ability to retain information for a short time) and working memory (the ability to maintain activated knowledge in the focus of attention) (Engle, Tuholski, Laughlin & Conway, 1999). There is evidence of a relationship between linguistic knowledge and verbal working memory (vWM) in that linguistic knowledge impact on vWM (Kowialiewski & Majerus, 2019) and that vWM depends on long term representations and processes that are involved in speech production (Acheson, Hamidi, Binder & Postle, 2011). Therefore, we are intrigued by our results which imply a causal relationship between schistosomiasis and weaker narrative skills in the light of a known relationship between parasitic infection and memory deficits. Furthermore, the findings reveal the possibility of long term deficits in executive functions and memory after the parasitic worm infection and iron deficiencies have resolved (Luwoski et al., 2010).

The prevalence of STH and Schistosomiasis in our study was similar to that of other studies conducted in KwaZulu-Natal (Zulu, Ekjetland, Gundersen, & Taylor, 2020) but less than the prevalence in other low- and middle-income countries (Welsch, Hossain, Ghogamu et.al., 2019). The intensity of infection with both STH and schistosomiasis was mild and the majority of the participants were found to have adequate nourishment. We regard this as an important finding as the participants in this study area were from a typical low socio-economic rural context and their school diet was not particularly rich in recommended nutrients such as omega 3 polyunsaturated fatty acids (Spencer, Karosi, Laye, Shukitt-Hale & Barrientos, 2017). Further investigation of the children's home nutrition and other possible contributing contextual factors would have provided more conclusive results. Thus, one may conclude that the consequences of moderate to severe infection with Schistosomiasis and STH such as malnutrition do not apply to this study population (Gwetu, Taylor, Chhagan, Kauchali & Craib, 2019). This finding has positive implications for the accuracy of the profile of language skills reflected by the findings.We recommend involvement of parents through a direct questionnare and to obtain more data on the socio-economic factors impacting on the children's health related quality of life and specific information on language acquisition.

Conclusion

Schistosomiasis mainly negatively impacted on language scores, with a medium effect for *vocabulary* and *colours* and a high effect for the *narrative* subtest. Our findings illustrate the contribution of verbal working memory on expressive language abilities. Our findings also showed correlations of expressive language performance to age as well as correlations of vocabulary subtests to gender (boys), STH and schistosomiasis. Socio-economic factors such as diet, preschool and stunting did not contribute to the scores. The adapted Developmental Language Test offered valuable information towards our understanding of the profile of abilities of isiZulu speaking preschool children. The findings of this study are relevant for all professionals involved in the education and rehabilitation of preschool children with infectious diseases and emphasise the need for treatment of mild STH and Schistosomiasis.

Declarations

Ethics Approval:

The study was approved by the University of KwaZulu-Natal BRICS committee (Reference BE 252/19) and parental consent forms were signed for all participants.

Consent for publication:

All consents were obtained. The NIRH had no interest in writing or submitting the article for publication.

Availability of supporting data:

Data sets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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Author's Contributions:

Author1 conducted the investigations, adapted the language test, contributed to the design of the methodology and wrote the original draft of this article.

Author 2 was responsible for conceptualization of the study, was involved in the writing of this article through reviews and editing and sought the funding for the project.

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