Original Article

Geographic information system and foldscope technology in detecting intestinal parasitic infections among school children of South India

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Abstract

Background: Effective and efficient use of technological advances will ease public health interventions and also help in reaching a larger population. Geographic Information System (GIS) and Foldscope are two such technologies, which have promising utilities in public health. Identifying intestinal parasitic infections early through feasible technologies will help in their effective management. With this objective, this study was conducted to assess the prevalence of intestinal parasitic infections among school children in southern districts of Karnataka, India. **Methods:** This cross-sectional study was conducted among randomly selected 10 urban, 10 rural, and 5 tribal schools of southern districts of Karnataka. A total of 1052 children studying in these schools were selected. Stool samples were collected and examined under Foldscope for parasitic infestation. The schools where children with worm infestations present were plotted in the GIS map. **Findings:** Among 1052 children included in this study, 139 (13.2%) were found to have an intestinal parasitic infestation. Among these children, 24.6% were in the age group of 5–9 years, 12.2% were males, and 14.4% were females. Urban students had higher odds (2.765) of parasitic infections compared to rural students. Mean age, height, and weight were significantly lesser among subjects with a worm infestation. **Interpretation:** Utility of Foldscope and GIS was found to be feasible and effective in the detection and mapping of parasitic infestations. The prevalence of parasitic infestation was found to be high among urban school children. Age, weight, height, and urban residence were found to be the major predictors of outcome.

Keywords: Foldscope, geographic information system, intestinal parasitic infections, public health system, school children, stool samples

Introduction

Intestinal parasitic infections are endemic worldwide and have been described as constituting the greatest single worldwide cause of illness and disease. Poverty, illiteracy, poor hygiene, lack of access to potable water, and hot and humid tropical climate are the factors associated with intestinal parasitic infections. Parasitic protozoa and helminths are responsible for some of the most devastating and prevalent diseases of humans.[1]

Intestinal parasitic infections are a serious public health problem in most of the regions of the world. Especially in developing countries, it represents a major cause of morbidity and mortality in children and among high-risk groups.[2] They represent a large and serious medical health problem in developing countries with a high prevalence rate. It is estimated that 3.5 billion

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people are affected, and 450 million are ill as a result of these infections, the majority being children. These infections cause morbidity and mortality along with other manifestations like iron deficiency anemia, growth retardation, and other physical health problems.[3] Helminthic infection is also related to protein-energy malnutrition and intrauterine growth retardation.[4] Most of these are transmitted through the soil and the route of transmission being fecally contaminated fingers or sometimes migrate through the skin to the intestine.[5] They cause detrimental effects on physical growth lead to poor cognitive performance among the affected.[6] It manifests with a range varying from asymptomatic carrier state,[7] to gastrointestinal symptoms.[8,9] To combat this situation of worm infection in India, the Indian government (Ministry of Health and Family Welfare) launched the National Deworming Day (NDD) in February 2015 as part of the National Health Mission. The aim of this program is to deworm all the children from 1 to 19 years and improve their well-being. It has emerged as the world's largest public health campaign preventing children from intestinal parasitic worms.[10-12] Limited studies determining the prevalence of intestinal parasitic infections have been published previously from South India. Therefore, it is essential to know the burden of intestinal parasitic infections in the South Indian community by using cost-effective tools like Foldscope and GIS to assess the pattern of intestinal parasitic infections among school children in different geographical areas of South Karnataka, India.

Methodology

Ethical considerations

The study was approved by Institutional Ethics Committee of the JSS Medical College, Mysuru. After explaining the purpose and procedure of the study written informed consent was obtained from students and the parents who were selected for the study. Those children who found to be positive for intestinal worm infestations were contacted back and the adequate treatment was provided along with the nutritional and hygiene advice.

Research and experiment details plan

Phase-I

The line listing of all the schools in Mysuru and Chamrajanagar District was done. 10 urban schools, 10 rural schools, and 5 tribal schools were selected randomly by lottery method and the sampling was done by probability proportional to size (PPS) for the selection of the students. The sample size was calculated with the relative precision of 7.00% and reported a prevalence of 49.38%[13] along with the 95% Confidence level to be 840 with 25% non-response rate the estimated sample size was $n = 1052$. The inclusion criteria set was the school children first to tenth standard willing to participate in the study and the exclusion criteria were the children who were not willing and have taken antihelminthic drugs in previous six months or parents not giving consent to participate in the study. The study methodology was discussed with all the principals and headmasters and the permission was obtained from the respective schools.

Phase II

The stool or faces sample is the most common specimen used for the diagnosis of intestinal parasitic infections. Depending on the nature of the parasite, the microscopic observations include the identification of cysts, ova, trophozoites, larvae, or portions of the adult structure. The ability to detect and identify human parasite is directly linked to the quality of the clinical specimen. The participants were given containers before the day of examination and asked to collect the fresh stool samples in the morning with the instructions given. A pretested semistructured proforma, which included general profile and sociodemographic profile of the student was used. Details such as address, age, sex, education, sanitation, habits, medical history, and footwear usage were collected. Data on footwear usage during each of the following activities were captured: defecation, outdoor activities, going to school, travel outside of the village, and farming.

Collection of the specimen

In the field procedures, children were given plastic containers labeled with unique identification numbers (IDs) and invited to return the containers filled with a fresh morning stool sample (10–50 g) the following day. The specimen was collected in a wide-mouthed clean container without contamination with urine, water, or disinfectants.

It was labeled with the student's name, age, sex, and date of collection. The specimen that was kept at the warm temperature and the dried specimen were discarded.

Examination of stool

Examination of the stool sample was done by trained microbiologist with adequate knowledge and experience in the stool examination. The macroscopic examination was done for consistency, adult worms, and the color of the stool sample. The microscopic examination was done to identify intestinal protozoa and eggs and larvae of helminths by the direct smear examination. The direct smear examination was done by the saline wet mount by mixing a small quantity (about 2 mg) of faces in a drop of saline placed on a clean glass slide. The gross fibers and particles were cleared and covered with a coverslip. The air bubble was avoided by drawing one edge of coverslip slightly into the suspension and lowering it almost to the slide before letting it fall. The mount prepared was just thick enough that the newspaper print was able to read through the slide. The smear was then examined under the foldscope microscope.

Description of foldscope

"Foldscope is an ultra-affordable, paper microscope. Designed to be extremely portable, durable, and to give optical quality similar to conventional research microscopes (magnification of ×140 and 2-micron resolution). The Foldscope is an origami-based optical microscope that can be assembled from a flat sheet of paper in less than 10 min. Although it costs less than a dollar in parts, it can provide over ×2000 magnification with submicron resolution, weighs less than two nickels (8.8 g), is small enough to fit in a pocket (70 × 20 × 2 mm^3), requires no external power, and can survive being dropped from a 3-story building or stepped on by a person. The Foldscope is operated by inserting a sample mounted on a microscope slide, turning on the LED, and viewing the sample while panning and focusing with one's thumbs. The sample is viewed by holding the Foldscope with both hands and placing one's eye close enough to the micro-lens so one's eyebrow is touching the paper. Panning is achieved by placing one's thumbs on opposite ends of the top stage and moving them in unison, thus translating both optics and illumination stages while keeping the stages aligned. Focusing is achieved using the same positioning of one's thumbs, except the thumbs are pulled apart (or pushed together). This causes tension (or compression) along the optics stage, resulting in −Z (or +Z) deflection of the micro-lens due to flexure of the supporting structure of the sample-mounting stage. Unlike traditional microscopes, the Foldscope anchors the sample at a fixed location, whereas the optics and illumination stages are moved in sync."[14]

The examination was begun at one corner of the smear and systematically examined successive adjacent swaths with the microscope. When a parasite/trophozoites/cysts like objects came into view, it was more closely examined and identified.

Phase-III: Data analysis

The data collected were entered into Microsoft Excel 2013 and analyzed using SPSS software version 22 (Licensed to JSSAHER). Statistical tests were carried out at 5% significance level ($P < 0.05$) and confidence interval (CI) set at 95%. Bivariate analyses using Pearson's Chi-squared test were performed to identify the association between risk factors and the outcome. Binary logistic regression analysis was performed to build a model using predictors those statistically significant or near significant in Bivariate analysis.

Geospatial analysis

These Geographical data were analyzed in the QGIS a free and open-source geographic information system (GIS) (Version 3.8 "Zanzibar" licensed under the GNU General Public License, the QGIS is an official project of the Open Source Geospatial Foundation [OSGeo]).[15] The location of the schools was linked to prevalence data and environmental data using unique schools' identifier, separate layers were created for school location, infection data, and environmental data for the production of the map. Infection prevalence for school was classified into five groups using WHO prevalence classification system, they were (1) No infection, (2) Light infection 0.1%–9.99%, (3) Moderate infection 10%–24.9%, (4) Heavy infection, 25%–49.9%, and (5) Very heavy infection 50+% for display in GIS.

The geographical information system was designed to map the prevalence patterns of intestinal parasites in relation to the environmental parameters. The boundaries of the study villages, water sources, taps, important landmarks and commonly used defecation fields were mapped using a hand-held global positioning system (GPS). The geographical coordinates (latitude and longitude) of the students and schools were recorded using the field Model GPS. The hotspot areas were generated and were divided into red, yellow, and green zones. The red zone indicates the clustering of more than three cases closely associated and particularly this area where the intensified management of the worm infestations should be done.

Results

Among 1052 children included in this study 139 (13.2%) were found to have an intestinal parasitic infestation. Among children with the parasitic infestation, the eggs of Ascaris lumbricoides (roundworm) and cyst of Balantidium coli were found in one student and the remaining were Ancylostoma duodenale (hookworm) eggs.

As shown in Table 1, age-wise distribution most of the study subjects were 24.6% in the age group of 5–9 years and 1% in the age group of 13–15 years tested positive for stool parasites. No students were affected in the 10–12 years age group. We found a statistically significant association between age group and the presence of the parasites. In gender, 12.2% of the males and 14.4% of the females had parasites on stool microscopy. 19.3% of students from urban schools had a positive parasite on school microscopy, whereas 1.1% of rural children were affected, which showed a significant association between the place of residence and the presence of the parasite. 17.1% of the non-vegetarians and 12.1% of the vegetarians had positive stool microscopy. There was a significant association between food intake and the presence of the parasite. Among the students exposed to animals in the last 1 week, 0.9% tested positive for stool parasite and among the students not exposed to animals 18.5% tested positive for stool parasite. There was a significant association between exposure to animals in the past 1 week and the presence of the parasite. 15% of the majority of the students who took bath daily had a parasite in stools. Among the students who took bath on alternate days and the students who took bath once a week, none had the parasite in stool. There is a significant association between intervals of bath and the presence of the parasite. 14.2% of students who did not have a history of mud ingestion and nail-biting had parasites on stool examination. 13.3% who had received medicine for intestinal parasites from school tested positive on stool microscopy. There is a significant association between medicine for parasite being given in school and the presence of the parasite. Among the students with the cat around the house, 18.5% had a positive parasite in stools and 0.5% of the students with a dog around the house tested positive on stool microscopy. There is a significant association between the presence of cat (18.5%) around the house and the presence of the parasite.

As shown in Table 2, on binary logistic regression, it was found that with one unit increase in age and weight there a slightly lesser chance of developing parasitic infection and this was found to be statistically significant. Urban students had higher odds (2.765) of parasitic infections compared to rural students; however, it

Table 1: Association between the sociodemographic profile and parasitic infections (*n*=1052)

Variable	Category	Stool microscopy		Total	*P*
		Positive	Negative		
Age group	5-9	135 (24.6)	413 (75.4)	548 (52.1)	0.001
	10-12	0	114 (100.0)	114 (10.8)	
	13-15	4 (1.0)	386 (99.0)	390 (37.1)	
Gender	Male	68 (12.2)	490 (87.8)	558 (53.0)	0.296
	Female	71 (14.4)	423 (85.6)	494 (47.0)	
Locality	Urban	135 (19.3)	563 (80.7)	698 (66.3)	0.001
	Rural	4 (1.1)	350 (98.9)	354 (33.6)	
Food preference	Vegetarian	102 (12.1)	738 (87.9)	839 (79.7)	0.041
	Nonvegetarian	37 (17.5)	423 (82.5)	212 (20.1)	
Exposure to animals	Yes	3 (0.9)	315 (99.1)	318 (30.2)	0.001
	No	136 (18.5)	598 (81.5)	734 (69.8)	
Intervals of taking bath	Daily	139 (15.0)	789 (85.0)	928 (88.2)	0.001
	Alternate days	0	123	123 (11.7)	0.001
	Once a week	0	1	1 (0.1)	
History of mud ingestion	Yes	0	72	72 (6.8)	0.001
	No	139 (14.2)	841 (85.8)	980 (93.1)	
Nail biting	Present	0	75	75 (7.1)	0.001
	Absent	139 (14.2)	838 (85.8)	977 (92.9)	
Deworming in schools	Yes	139 (13.3)	908 (86.7)	1047 (99.5)	0.0018
	No	0	2	2 (0.2)	
	Absent that day	0	3	3 (0.3)	
Cow in the family	Yes	0	125	125 (11.9)	0.001
	No	139 (15.0)	788 (85.0)	927 (88.1)	
Dog in the family	Yes	1 (0.5)	208 (99.5)	209 (19.7)	0.001
	No	138 (16.4)	705 (83.6)	843 (80.1)	
Cat in the family	Yes	136 (18.5)	598 (81.5)	734 (69.8)	0.001
	No	3 (0.9)	315 (99.1)	318 (30.2)	

**P* Value was found to be statistically significant

Table 2: Predictive variables for worm infestation among study subjects

Variable	Adjusted odds ratio (95%CI)	*P*
Age	0.726 (0.556-0.947)	<0.018*
Urban (reference-rural)	2.765 (0.841-9.091)	<0.094
Height	1.029 (0.995-1.065)	<0.093
Weight	0.917 (0.843-0.998)	<0.045*

Binary logistic regression **P* Value was found to be significant

was not statistically significant. The model explains the variation in the dependent variable to the extent of 24.5%.

As shown in Table 3, it can be observed that mean age, height, and weight among subjects with worm infestations were significantly lesser compared to their counterparts without worm infestations.

In Figure 1, the GIS map shows the location of schools selected randomly by lottery method.

In Figure 2, the GIS map shows the location of schools with positive cases and the clustering of the cases is seen in the urban schools compared to rural and tribal schools.

In Figure 3, the GIS map shows the positive cases and the hotspot areas, which were divided into red, yellow, and green zones. The red zone indicates the presence of more than three cases closely associated and particularly this area where the intensified management of the worm infestations should be done.

Discussion

One of the major barriers in prevention and control of worm infestation are lack of simple and cost-effective screening tools that are be used at the community level. Fold scope bridges this barrier being simple, user friendly, and portable. The device can be used effectively at the basic field as well as basic levels of health care delivery by primary care physicians.

This study provided essential information on the prevalence and distribution of intestinal parasitic infections among the urban, rural, and tribal school children. Yet over the last decade, increasing evidence links the major neglected tropical diseases (NTDs) to a significant adverse impact on both human and economic development, especially for the major helminth infections, that is, hookworm and the intestinal helminth infections, schistosomiasis, and lymphatic filariasis, these helminth infections rank among the leading NTDs in terms of disability-adjusted life years (DALYs), accounting for approximately 10 million DALYs.

Table 3: Comparison of age and anthropometric parameters among subjects with and without worm infestations

Parameters	Negative	Positive	*t*	*P*
Age	10.71±3.1	7.61±1.4	.103	0.001
Height	131.62±19.0	115.43±11.3	.631	0.001
Weight	28.92±11.1	19.23±4.1	.369	0.001

In this study, among 1052 school students, it was found that 13.2% had a parasite on stool microscopy. Chiranjay *et al.*, in his study in Nepal, reported a prevalence of 11% and 20.5% among school-going children visiting the hospital and from community, respectively.[16] The prevalence of intestinal helminthic infection varies across India. In a study by Chhotray *et al.* in Bhubaneshwar the prevalence of helminthic infection was 15.82% which is almost similar to our study.[17] Wani *et al.* reported a higher prevalence of 71.15% in 4-15-year-old children in Kashmir which could be due to the difference in sanitation and hygiene.[18]

It was found that 24.6% of the students in the age group of 5–9 years had a positive parasite in stool, whereas only 1% of the students in the higher age group were affected. Singh *et al.* in a study among 5–10-year-old schoolchildren reported a similar prevalence of 24.5%.[19] Higher prevalence of parasitic infections (83.33%) was found in the age group of 0–9 years in a study by Kumar *et al.* which can be attributed to habits like playing in the mud followed by ingestion of food without proper handwashing among young children.[20]

Among the 1052 students, 14.4% of the females had the parasite in stool, whereas only 12.2% of the males were affected. Adolescent girls are at a higher risk of parasitic infections leading to anemia.[21] Jyoti *et al.* reported a higher prevalence of parasitosis among rural women (18.5%) compared to males (16.9%) and similar were the findings in a study by Virk *et al.* who reported a prevalence of 33.59% in females, slightly higher than that in males (28.18%).[22,23] This could probably be because of a lack of awareness of personal hygiene among rural women.

In this study, we found that 19.3% of the students from urban schools had a parasite on stool microscopy, whereas only 1.1% from rural schools were affected. Mustafa *et al.* in a study among urban and rural school going children found a higher prevalence in an urban area (77.1%) compared to the rural area (53.1%) which was attributed to insufficient water supply and poor hygienic habits.[24] A study from Vellore district by Deepthi *et al.* reported a prevalence of 9% in rural areas and 4.8% for soil-transmitted helminths in urban areas. Hookworm infestation was more in rural areas, whereas Ascaris and Trichuris were more prevalent in urban areas which are probably due to the overcrowding and improper sanitation.[25]

17.5% and 12.1% of the nonvegetarians and vegetarians had a parasite on stool microscopy and it was statistically significant. Some studies suggest that consuming raw vegetables can lead

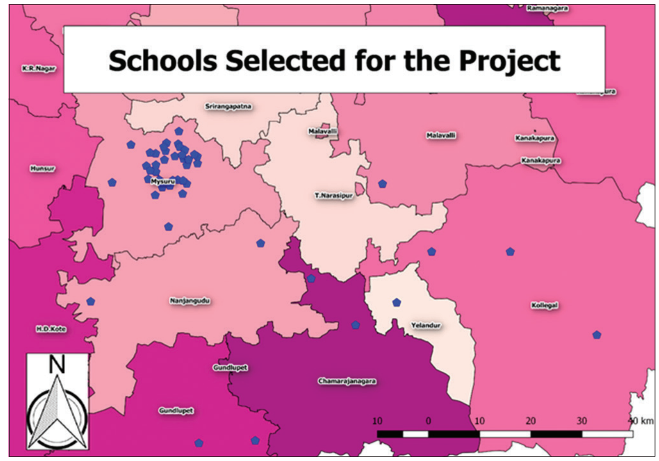

Figure 1: GIS map showing the location of schools selected for the study

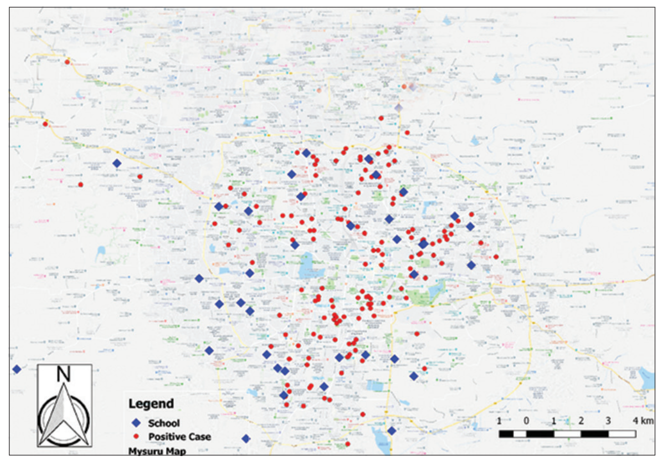

Figure 2: GIS map showing the location of schools and the positive cases

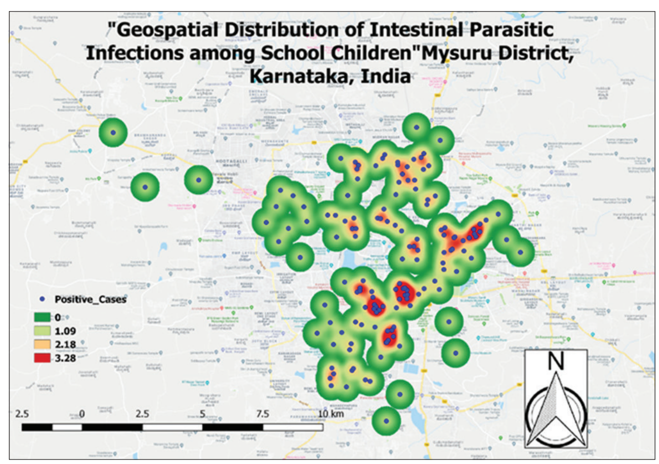

Figure 3: GIS map showing the positive cases and the Hotspot areas for the management

to parasitic infections however there is a paucity of information on the association between food preference and development of parasitic infections.[26] 18.5% of the students who had a cat around the house had a positive parasite. Saravanakumar *et al.*

reported that people with a pet cat has higher odds (1.55) of developing soil-transmitted helminthiasis and it was found to be significant.[27]

This study showed that the mean height and weight of the students with worm infestation are lower than the students without worm infestation and this was found to be statistically significant. Chronic worm infestation is associated with impaired growth and development. Peiling *et al.* in his study among school children in China found that children with Trichuris infection had lower height and weight. However, this was not statistically significant.[28]

Conclusion

In this study, the prevalence of intestinal parasitic infestation was found to be 36.1%, commonly affecting lower age group and females with urban preponderance. Mean height and weight of the children with worm infestation were lower than the children without worm infestation. Foldscope and GIS were found to be feasible, practical, and effective methods for assessing the burden and distribution of worm infestation at the community setting. We recommend the wider use of these technologies in enhancing the detection and surveillance of various other infections and infestations at a different part of the country.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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