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Present status with impacts and roles of miRNA on Soil Transmitted Helminthiosis control: A review

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ABSTRACT

Soil-Transmitted Helminthiasis (STH) is one of the most widespread Neglected Tropical Diseases (NTDs), and almost 1.5 billion of the global population is affected, mostly in the indigent, countryside sectors of tropics/subtropics. STH, commonly caused by various nematodes, adversely affects the hosts' growth, cognatic development, and immunity. Albendazole is most commonly used against STH (Soil-Transmitted Helminths) but resistance has already been reported in different countries. To date, no effective vaccine is present against STH. miRNAs are a unique class of small non-coding RNA, regulating various biological activities indulging host immune responses in host-pathogen interaction of STH. Dysregulation of miRNAs are being considered as one of the most important aspect of host-parasite interactions. Thus, it is the prime importance to identify and characterize parasite-specific as well as host-derived miRNAs to understand the STH infection at the molecular level. Systematic bibliometric analysis reveals a huge knowledge gap in understanding the disease by using both host and parasitic miRNAs as a potential biomarker. In this study, we addressed the present status of the STH prevalence, and therapy under the light of miRNAs. This would further help in designing new inhibitors and therapeutic strategies to control STH.

1. Introduction

Neglected tropical diseases (NTDs) are the particular category of infectious diseases that mostly influence indigent, countryside sectors of the tropical as well as subtropical areas of our world. Among these, Soil-Transmitted helminthiasis (STH) is one of the most widespread forms of NTD. The nematodes like hookworms (*Ancylostoma duodenale*, *Necator americanus*), *Ascaris lumbricoides*, whipworms (*Trichuris trichiura*) and threadworms (*Strongyloides stercoralis)*, are considered as STH. There are around 1.5 billion individuals affected worldwide by STH (Moser et al., 2017; Anisuzzaman and Tsuji, 2020, Anisuzzaman et al. 2023), in which India alone comes up with approximately 25% of the total cases. The World Health Organization (WHO) announced that in India around 220 million school-going kids, aged between 1 and 14 years are massively threatened by STH infection (WHO, 2012). They can adversely affect growth, rational development as well as immunity against other diseases (Raj et al., 1997). Albendazole is the most common medicine, given to the kids to prevent STH. Although it is reported to be a safe drug, but several cases of side effects have been reported to the people after Mass Drug Administration (MDA) (Gupta., 2017).

One of the key strategies to counter helminthic infection and probable drug resistance is to identify the roles of miRNA in modulating STH. Parasite miRNAs can utilize host miRNAs for their survival. miRNAs have a definite role in parasitic development in different modes of environmental changes in the host body (Arora et al., 2017). In the genome, the clustering of miRNAs is an interesting phenomenon that is very species-specific, and shows functional linkage (Britton et al., 2014). Comparative analysis of helminth genomes has revealed that few miRNAs are conserved whereas others are helminth specific. Many conserved miRNAs show similar sequences that are very identical to mammalian miRNAs that are considered as regulators in the immune system. Several soluble proteins or glycans are secreted from parasitic helminths that can suppress the differentiation process of M1 macrophages present in the host body (Tran et al., 2021).

In this present study, we are focusing on documenting the present status of STH infection globally. Also, through biblometric study of the

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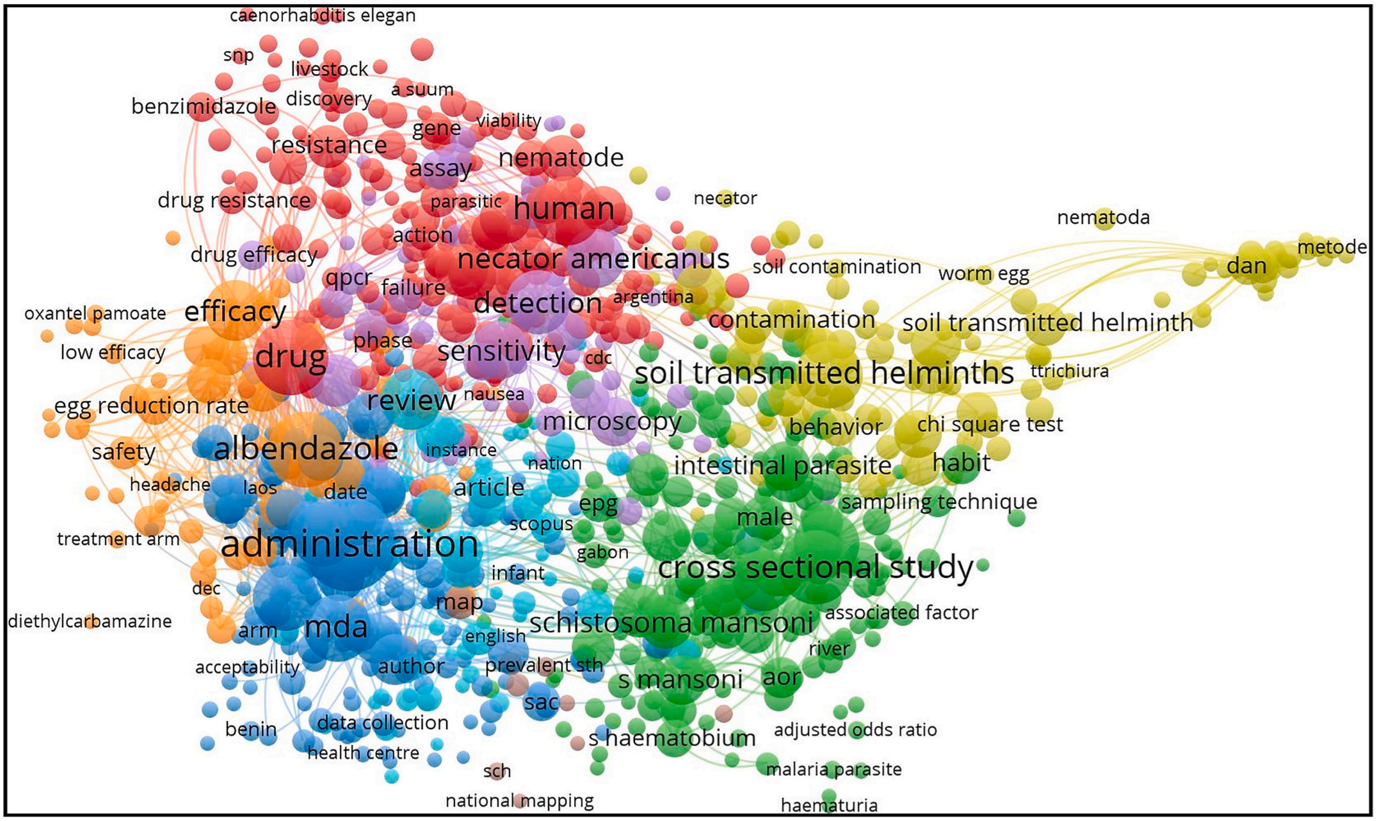

Fig. 1. The co-words network of author keywords. (A) Tabular representation of the methodology adopted for bibliographic analysis. (B) VOSviewer generated map-view for relevant terms extracted from titles and abstracts of the research articles identified by DimensionsAI. 60% of the most relevant terms are mapped on the plot with 'occurrence' as the Weightage parameter.

Table 1
Methodology of the bibliographic analysis for the Fig. 1.

Steps	Database/program/ method	Execution
1.Data collection	Pubmed database and Dimensions AI	Timespan: 2000 to 2022 with key words/terms, title, abstract. Major key words: (soil transmitted helminthes, soil transmitted diseases and school going children). Type of document: Journal article. 2743 (STH) and 754 (STH, SC) (DimensionsAI) articles appeared for further analysis.
2. Analysis and identification	VOSviewer (For Dimensions AI data)	953 terms (dimension) were automatically identified for bibliometric analysis.
3.Further analysis and map	VOSviewer (Dimensions AI data)	Descriptive analysis of Co-occurrence for key terms
4.Research topic interpretation	Qualitative interpretation (For both data sets)	The authors reviewed the titles, abstracts, and keywords and analyzed of each research topic.

available literatures, we discussed the risk factors and roles of parasitic along with host-derived miRNAs effecting STH transmission. We have also showcased efficiency of the miRNAs in developing control strategies against STH. Our study reveals that there is a considerable amount of lack of studies related to miRNA mediated regulation of STH and its preventive applications. This study would help to find out the probable gaps to facilitate the STH outbreak management using miRNAs as potential biomarkers and also could motivate the researchers and policy-makers to upgrade their prevention plans for STH control.

2. Trends and gap analysis on global STH infections through a bibliometric analysis

We have done an extensive literature search on STH through systematic bibliometric analysis (Okorie et al., 2014). The initial bibliometric analysis was performed in two data-bases, DimensionsAI (https://app.dimensions.ai) and Pubmed (https://pubmed.ncbi.nlm.nih.gov/) for relevant key vocabularies (Fig. 1). We have used VOSviewer for the mapping based on some essential keywords associated with this study such as STH, School children etc. (Fig. 1 and Table 1). A total 3497 articles have been analyzed from a year span from 2000 to 2022, related to STH. Among them 754 papers are directly related with STH infection on school-going children. The mapping reveals that most of the research on STH has been clustered on the areas such as parasitic and host-specific miRNA, drug efficacy, drug resistance, MDA, STH and cross sectional study. This mapping clearly shows that not much emphasis has been given to the successful implementation of prevalence study in STH research.

3. Global distribution and prevalence of Soil-Transmitted helminths

The warm and humid climatic condition makes India a favorable habitat for most of the helminths. *Ascaris lumbricoides* is the most frequent type of worm found in India and other realms of the South- East Asia (Narkkul et al., 2022; Parikh et al., 2013). *Ascaris lumbricoides* transmission occurs through feco-oral route and reinfection is very fast even after completion of the medication (Jia et al., 2012). In children, an excessive rate of *A. lumbricoides* infections is also observed in different countries outside Southeast Asia, mostly in the African continent and also in South America and China (Jia et al., 2012; Midzi et al., 2011;

Oyebamiji et al., 2018; Sacolo-Gwebu et al., 2019; Sanchez et al., 2013; Tekalign et al., 2019). In different districts of Bihar state, India, 95% children are habituated to defecating in openly manner and 60% of them are not using soap to clean their hands (Greenland et al., 2015). In India, helminth infections are also prevalent in all the parts of the country like tea plantation areas of Darjeeling (Das et al., 2019), South Bengal (Mukherjee et al., 2013), North-East India (Ganguly et al., 2019), Uttar Pradesh (Ganguly et al., 2017) and rural parts of south India (Kaliappan et al., 2022; Mahapatra et al., 2020).

4. Transmission strategies adopted by helminths

Eggs, larvae, and adults are the three major life cycle phases of these worms. Adult worms generally infect the definitive host in which sexual reproduction and egg production occur while larval forms of STH are free-living. Mainly two routes of transmission – feco-oral as well as transdermal are being utilized by the parasites. People typically become infected with whipworms by ingesting food and/or water containing viable infective stage (eggs containing first larval stage) (Else et al., 2020). Like whipworm, pinworm infection is transmitted through the feco-oral route. Initially, the eggs appear in the perianal regions. After that, they can prevail for up to 21 days in nature and develops to the infective eggs (eggs containing L3). It may be consumed via contaminated water, food and even inheled from contaminated bed and cloths. *Ascaris lumbricoides* may enter our body by ingesting infective eggs (eggs containing L2). Children usually put their contaminated dirty fingers or hands into their mouth while playing in the field. *Ascaris* may also be transmitted by consuming raw vegetables, and fruits that are not cooked or washed properly. In the case of hookworm, the eggs hatch and go through two times of moulting in soil and then the 3rd stage larval form infects the human host by dermal penetration while walking barefoot on contaminated soil. After that, they further migrate to the lungs and finally establish themselves in the human intestines (Bharti et al., 2018).

5. Effect STH infection on nutrition and health

While most of the infections are asymptomatic and mild, moderate to severe worm infestations may delay growth, compromise nutrition and develop poor academic skills among children. Malnutrition may be developed by deficiency of micro and macronutrients. The loss of appetite and gastric enteropathy further worsen nutritional deficiencies (Stephenson et al., 2000; de Silva et al., 2003; Albonico et al., 2008).

Several studies have reported that STH infections bring about morbidity by hampering nutritional conditions along with weakening logical operations, particularly among school going children (Brito et al., 2006; Crompton and Nesheim, 2002; Curtale et al., 1999; de Silva et al., 2003; Ostan et al., 2007). In several studies, it has been stated that hemoglobin levels are elevated in infected children of two-year-old due to anthelmintic medication (Stoltzfus et al. 1998, 2004), indicating STH is associated with blood loss and anemia.

6. Prevention strategies against STH transmission

In India, albendazole is considered to be a highly efficient deworming drug for hookworm and *Ascaris* infections but shows limited effect in the case of whipworm infections (Vercruysse et al., 2011). In February 2015, the Indian government initiated the National Deworming Day program to deworm every child between 1 and 19 yrs old twice a year. It is considered as special biggest governmental public health plan over the world (NHP, India, 2021). According to WHO, where the frequency of STH infection is more than 20% medication is recommended annually and when exceeds 50% then it should be twice in a year (WHO, 2012). In India, Swachh Bharat Abhiyan activity is especially focusing on the abolishment of open defecation practice to decrease the rate of STH infection. It has been suggested that, at the time of family counselling, and the major hygienic protocols need to be discussed, and more emphasis to be given on hand cleaning with disinfectant soap after bowel movement, nail cutting, use of cloths, undergarments, toys, bedding, and kitchen utensils after washing and sun drying. And, children must be counselled not to roam around barefoot in the soil. Precautionary therapy should administer to other members of family to inhibit immediate transmission (Dalal et al., 2020)

7. Present status of vaccines against STH

One of the key challenges to encounter and control STH, is to develop a vaccine against different helminthic strains distributed globally. Vaccines could play a vital tool to break the transmission cycle of worms. To date, effective vaccine against STH hasn't been found and no such component has reached up to human clinical trial against *Ascariasis* or any other helminths (Gazzinelli-Guimaraes et al., 2021). Adjuvant selection is another major problem in anti-ascariasis vaccine production because it may cause an allergic reaction in the host. So another priority is to discover functional adjuvants to design adjuvant recombinant vaccines against ascariasis.Reports suggest, a very small number of vaccine candidates against hookworm and schistosomiasis have been brought to the human trial so far. A schistosomiasis vaccine named Bilhvac has just finished phase 3 trial. Other anthelminthic vaccines like Na-APR-1, Na-GST-1, Na-ASP-2 against HW, as well as Sm-TSP-1/SmTSP-2, Sm28GST/Sh28GST, Sm14 and Sm-p80 against schistosomiasis also have been lined up for the clinical trials (Anisuzzaman and Tsuji, 2020).

Helminths always try to adopt defensive mechanisms and secret considerable amounts of bioactive molecules (BAMs) like inhibitors as well as enzymes to counter host defences and effects of anthelminthics used. These molecules can control their survivability and reproduction. (Anisuzzaman and Tsuji, 2020). Unfortunately, very few studies have been done so far to understand the host-helminth interactions. Recent studies show that all living organisms secret miRNAs, which play critical roles in the modulation of host-parasite interactions.

8. Overview of miRNA in transmission of helminthic disease

miRNAs (MicroRNAs) are a category of small non-coding RNAs that have appeared as chief regulatory component that can control the gene expression of metazoans, being involved in many different biological processes, including development. miRNAs are endogenous RNAs (~23 nt-long) that combine with target mRNAs to repress their post-transcriptional events. In the nucleus, RNA polymerase II transcribes miRNAs into pri-miRNAs (primary miRNAs) that are further processed by Drosha (an enzyme ribonuclease III) generating a small hairpin-like structure named pre-miRNA (precursor miRNA). Precursor miRNA has been transported into the cytoplasm from nucleus with the help of Exportin 5 protein. The cytoplasm of the cells contain a hairpin loop structure of precursor miRNA is then cleaved by Dicer (an RNAse III enzyme) into miRNA duplex (miRNA-miRNA*). Helicase breaks the duplex into a single-strand miRNA and is incorporated into RISC (miRNA-induced silencing complex) which is made up of a major RNA-binding protein belonging to the Argonaute family (AGO).The mature miRISC finally suppresses parasitic growth and development (Chamnanchanunt et al., 2020). It can affect gene stability and regulate gene expression after transcription through such interactions with the 3 UTR (3' untranslated regions) of target mRNAs. Generally, miRNAs can interfere in autophagy, cell signaling, cell death, cell metabolism, cell proliferation as well as differentiation during the commencement of pathogenic infection to generate inflammatory and immune responses. Different kind of miRNAs that has been identified from helminth, are also found in the plasma or serum of a helminth-infected person (Pockar et al., 2019). miRNAs that are present in the helminthes usually helps in the development of the organism from larval stages to the adult, sex determination and regulating metabolic activities (Gazzinelli-Guimaraes and Nutman, 2018). These parasitic miRNAs modulate host immune

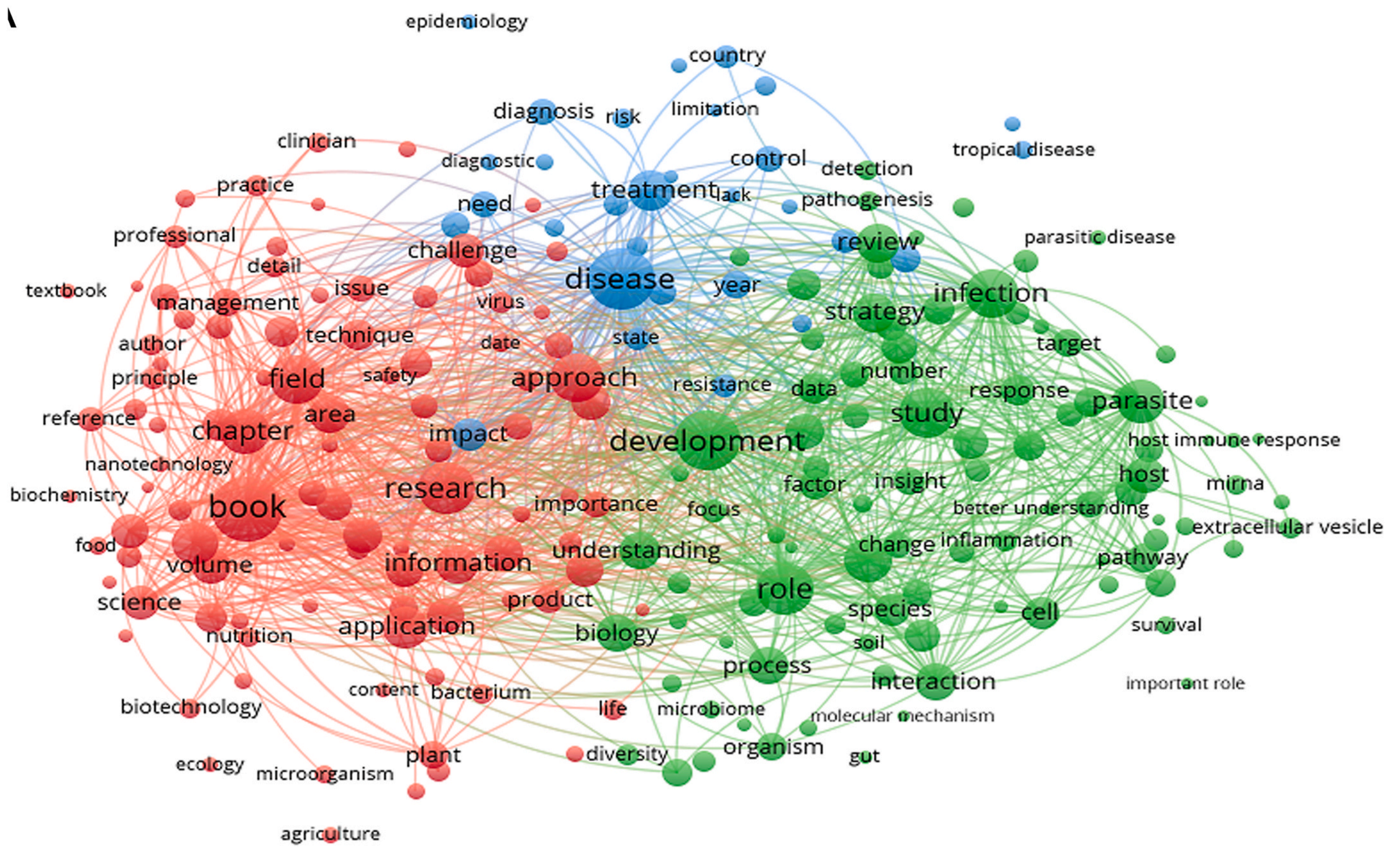

Fig. 2. The co-words network the miRNA involved in STH based on author keywords. (A) Tabular representation of the methodology adopted for bibliographic analysis. (B) VOSviewer generated map-view for relevant terms extracted from titles and abstracts of the research articles identified by DimensionsAI. 60% of the most relevant terms are mapped on the plot with 'occurrence' as the Weightage parameter.

Table 2
Methodology for the bibliographic analysis for the Fig. 2.

Steps	Database/program/method	Execution
1.Data collection	Pubmed database and Dimensions AI	Timespan: 2000 to 2022 with key words/terms, title, abstract. Major key words: (soil transmitted helminthes and miRNA). Type of document: Journal article. 956 (DimensionsAI) articles appeared for further analysis.
2. Analysis and identification	VOSviewer (For Dimensions AI data)	224 terms (dimension) were automatically identified for bibliometric analysis.
3.Further analysis and map	VOSviewer (Dimensions AI data)	Descriptive analysis of Co-occurrence for key terms
4.Research topic interpretation	Qualitative interpretation (For both data sets)	The authors reviewed the titles, abstracts, and keywords and analyzed of each research topic.

system by releasing extracellular vesicles loaded with miRNAs helping in zoonosis and cross-species interactions (Mu et al., 2021; Sotillo et al., 2020) In helminth infected persons or animals, most of the host-specific miRNAs are performing a common function; i.e helping in the survival of the parasites by suppressing or inhibiting host-specific immune responses (Gazzinelli-Guimaraes and Nutman, 2018). So, in STH program miRNA can be used as a potential diagnostic biomarker (Cai et al., 2016a; Cucher et al., 2015; Ghalehnoei et al., 2020).

We have done an extensive literature search on miRNA regulation on STH through systematic bibliometric analysis (Okorie et al., 2014). The initial bibliometric analysis was performed in two databases, DimensionsAI (https://app. dimensions.ai) and Pubmed (https://pubmed.ncbi.nlm.nih.gov/) for relevant key miRNAs (Fig. 2). We have used VOSviewer for the mapping based on some essential keywords associated with this study such as different miRNA involved with the infection of multiple strains associated with STH, etc. (Fig. 2 and Table 2). A total 956 articles have been analyzed from a year span from 2000 to 2022, related to miRNA regulation in STH. Among them 224 papers are directly related with miRNA mediated regulation on STH infection. The mapping reveals that most of the research on STH has been clustered on the areas such as parasitic and host-specific miRNA, host immune response, extracellular vesicle etc. This mapping clearly shows that not much emphasis has been given to the successful implementation of miRNA based study in STH research.

9. miRNA mediated regulation in STH infection

miRNAs are an important class of non-coding RNA, regulating the host response in many different parasitic infection, including STH (Cai et al., 2016a). Studies related to miRNA regulation in parasitic helminth infection started only 10–12 years back with the advancement in helminth genetics (Ghedin et al., 2007; International Helminth Genomes, 2019; Schistosoma japonicum Genome and Functional Analysis, 2009; Zheng et al., 2013). It has been found out that, many of these miRNAs are not only regulating the host response, but also inhibiting these parasites at the different stages of their development (Cai et al. 2011, 2013).

Many helminth-derived miRNAs such as miR-146, miR155, miR-223, miR-134, miR-199, let-7, and fhe-mir-125a, etc. are are reported to, show a vital role in immune modulation. The presence of such miRNA in host body suppresses the T-cells, B-cells, macrophages, and monocytes as indicated by their lower expressions in host. (Zakeri et al., 2018).

Table 3
List of miRNAs identified in various helminthic infection in human.

Type of Helmith	Name of the miRNAs	Role of miRNAs	Reference
Schistosoma mansoni	Bantam, miR-2c-3p, miR-3488 and miR-2a-5p	Development and sex determination of parasitic helminth	(Sotillo et al., 2020)
Schistosoma mansoni	miR-10 and other extracellular vesicle -enclosed miRNAs.	Targets MAP3K7 and consequently downmodulates NF-κB activity to decline type 2 helper T-cell (Th2) immune response	(Meningher et al., 2020; Samoil et al., 2018)
Schistosoma japonicum	sja-miR-125b, sja-miR-190,sja-bantam,sja-miR-36,sja-miR-124,sja-miR-36	Parasitic miRNAs help in development morphogenesis and reproduction	(Arora et al., 2017)
	miR-155,miR-146a/b,miR-122,miR-21,miR-34a	Human miRNAs help to Supress the role of Toll-like receptor and cytokine signaling	
	miRNA-33	this novel miRNA from egg-derived exosomes of *S. japonicum* can promote liver fibrosis in the host in a cross-species manner, and the degree of fibrosis can be decreased by inhibiting the expression of this miRNA.	(Wang et al., 2022)
Schistosoma japonicum	sja-let-7	Stimulate larva to grow in the human liver	(Unnasch et al., 2018)
Schistosoma japonicum	sja-miR-7	Regulate cercariae development	(Hao et al., 2010)
Schistosoma japonicum	sja-miR-223	Stimulate development of the parasite in the Kupffer cells	(He et al., 2013)
Schistosoma japonicum	miR-2c-3p miR-3488	Regulate cercariae development	(Meningher et al., 2017)
Fasciola hepatica	fhe-mir-71a, fhemir190, fhe-mir-1, fhe-mir-125a (in parasite)	Regulate helminth infection in human	(N.Arora et al.,2017)
	fhe-miR-71-P1b, fhe-miR-71-P2, fhe-miR-1-P1, fhe-miR-1-P2, fhe-miR-96 and fhe-miR-7-P1)	might be regulating the formation and release of vesicles.	(Fontenla et al., 2021)
Ascaris suum	asu-miR-391,asu-miR-404	Immune modulation	(Arora et al., 2017)
Taenia solium	miR-12071, miR- 2b, miR-7a, miR-3479b miRs, bantam-3p, let-7-5p, miR-10-5p, miR-71-5p, and miR- 4989-3p	Regulate helminth infection by decreasing IL6	(Basika et al., 2016; Landa et al., 2019)
	miR-10-5p and let-7-5p	decrease the expression of interleukin 16 (*Il6*), tumor necrosis factor (TNF) and IL-12 secretion.	(Landa et al., 2019)
Echinococcus multilocularis	emu-miR-10, emu-miR-227, miRNAs, miR-71-5p & miR-4989-3p	Regulate gene expression	(Guo and Zheng, 2020; Ancarola et al., 2020)
	mmu-miR-155-5p	downregulate the expression of *IKBKE,* to elicite immunoregulatory effect on macrophages	(Guo and Zheng, 2020)
Ascaris lumbricoides	alu-miR-novel-053, alu-miR-novel-021, alu-miR-novel-064	Change and regulate parasitic environment	(Guo and Zheng, 2020; Ancarola et al., 2020)
Necator americanus	nam-miR-8308,nam-miR-1175-3p nam-miR-25	Regulate protein translation of parasite, maintain cell architecture as well as worm development	(Guo and Zheng, 2020; Ancarola et al., 2020)
Strongyloides stercoralis	STR-MIR-34A-3P, STR-MIR-8397-3P, STR-MIR-34B-3P, STR-MIR-34C-3P, STR-MIR-7880H-5P & STR-MIR-7880M-5P	Involve in metabolic and enzymatic transition of different stages.	(Pomari et al., 2022)
Enterobius vermicularis	let-7	Temporal development of the parasite	(Bracht et al., 2004)

Among patients with NTDs, the miRNAs test could be used as a monitoring tool, but there is some barrier due to limited knowledge regarding clinical application (Chamnanchanunt et al., 2020). Roles of few miRNAs in regulating STH in human have been identified, but still a lot of research need to be done in this aspect, which could provide strong platform to discover newer drug targets and markers for STH diagnosis. A number of miRNAs involved in the STH infection have been listed in Table 3.

10. miRNA based antihelminthic therapy and vaccines

For, mant decades, two different classes of antihelminthic drugs are being used to control STH based on their mode of action: A) Beta tubulin binders, which includes benzimidazole class. Mebendazole and albendazole are widely used drugs in this group. In nematodes, it generally binds to the beta tubulin and hinders microtubule formation, and ruptures the cytoskeleton. It also influences poor glucose uptake in the intestine of worms accelerating starvation. Remarkably, albendazole has both larvicidal along with ovicidal effects in human ascariasis. B) Spastic paralytic agents. levamisole and pyrantel pamoate belong to this class, which initiate physiological responses after binding to the acetylcholine receptors. C) Flaccid paralytic agents including piperazine drug, which reversibly hampers transmission in neuromuscular junction and acts as GABA agonist. It is administered along with some laxatives that can facilitate the exclusion of living paralyzed worms by the peristaltic movement of the human gut (Gonzalez-Moreno et al., 2011). But, few recent evidences suggested that use of benzimidazole over a prolonged period could give rise to new multi-drug resistance in different species of helminths (Dunn et al., 2019; Kitchen et al., 2019; Orr et al., 2019). Although researchers were unable to find SNPs (Single Nucleotide Polymorphism) related to benzimidazole resistance in adult of *T. trichiura* and *A. lumbricoides*, but they never eliminated the chance of its occurrence (Matamoros et al., 2019). A study revealed that there more chances of benzimidazole resistance that would be terrible for mankind, so systematic monitoring and further analysis are required for chemotherapy programs (Krucken et al., 2017).To date, the specific role of miRNAs and the mechanism of its reduced level after antihelmintic administration in STH are not very clear (Paul et al., 2020). In 2014 Shao et al. identified 97 miRNAs in feces of individuals infected with *A. lumbricoides* infection. Among them alu-miR-novel-021, alu-miR-novel-053, and alu-miR- novel-064 are some candidate miRNAs found to be associated with the survival of parasites by maintaining parasite NADH dehydrogenase and electron carrier functions (Shao et al., 2014). So, drugs or inhibitory molecules that specifically inhibit or decrease the activity of the above mentioned parasitic enzymes could used as potential antihelminthic. In 2016 Kulkarni and Mittal noted that miRNAs like nam-miR-1175-3p, nam-miR-8308, and nam-miR-254 are over-expressed in *Necator americana* helping in their survival in the host (Kulkarni and Mittal, 2016). So, they proposed that these miRNAs could be targeted as potenial drug tragets against hookworms.A significant correlation was also found between miR-2c-3p and praziquantel dose in the case of parasite eradication (Meningher et al., 2017). One specific report has been published stating that some miRNAs in schistosomes interfere in sex-biased gene expression that can be used as novel vaccine targets to develop new vaccines (Cai et al., 2016b). So, more research need to be conducted to discover new miRNA based antihelminthic drugs and vaccines.

11. Conclusion

This study highlights the potential of microRNAs (miRNAs) as molecular tools and biomarkers for Soil-Transmitted Helminthiasis (STH). STH present significant challenges in terms of treatment and control, particularly in Africa, South America, China and in Indian subcontinents etc. The unrelenting and erratic nature of these diseases, along with genetic variations in pathogens and the emergence of drug-resistant strains, necessitate the urge of developing of new drugs against these diseases. Early disease monitoring is crucial, and the detection of miRNAs presents a promising avenue (Hao et al., 2010; Unnasch et al., 2018). Studies have demonstrated the use of candidate miRNAs in predicting treatment outcomes in diseases like C. trachomatis. WHO (World Health Organization) recognizes the importance of innovative tools in addressing various neglected tropical diseases including STH, which includes understanding the underlying molecular mechanistic pathway of poor health and early detection (Ackley et al., 2021). miRNAs are attractive candidates for biomarkers as they are stable molecules found in various body fluids. They exhibit disease-specific expression profiles and have specific biological functions. However, a very few studies were conducted on patient samples, and more ground works are necessary to establish reliability and applicability in real-world settings. Overall, miRNAs hold promise as molecular tools for the diagnosis, monitoring, and treatment of neglected parasitic diseases. Continued research, development, and investment in this field are essential to advance our understanding and improve future interventions for STHs.

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Ethics

No approval of the institutional review committee was needed.

CRediT authorship contribution statement

Imon Mitra: Methodology, Writing – original draft, Revision. **Arijit Bhattacharya:** Methodology, Writing – review & editing, revision. **Joydeep Paul:** Methodology, Conceptualization, Writing – original draft, revision, Writing – review & editing. **Anisuzzaman:** Methodology, Conceptualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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