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Climate change and onchocerciasis: Insights from an analysis of public datasets

Mudanças Climáticas e a Oncocercose: perspectivas a partir de uma análise de bancos de dados públicos

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ABSTRACT

This study investigates possible correlations between climate change and the prevalence of onchocerciasis. The reported number of individuals treated for the onchocerciasis time series from 2005–2018 was obtained from the World Health Organization Global Health Observatory data repository, whereas the global land-ocean temperature index for the same period was obtained from NASA's Goddard Institute for Space Studies. The global land-ocean temperature index was used as the independent data, whereas the reported number of individuals treated for onchocerciasis was used as dependent data on the curve fitting regression models. Brazil ($p = 0.0037$, $r2 = 51.86$) and Venezuela ($p = 0.0012$ $r2 = 59.85$) in South America and Burundi ($p = 0.0397$, $r2 = 30.7$), Cameroon ($p = 0.0001$, $r2 = 71.41$), Chad ($p = 0.0068$, $r2 = 46.93$), Congo ($p > 0.05$), The Democratic Republic of Congo ($p = 0.002$, $r2 = 56.4$), Ethiopia ($p < 0.00001$, $r2 = 77.52$), Malawi ($p = 0.0097$, $r2 = 43.96$), Nigeria ($p = 0.0055$, $r2 = 48.68$), Uganda ($p > 0.05$), and United Republic of Tanzania ($p < 0.00001$, $r2 = 76.76$) in Africa composed the study group. Overall, the patterns observed suggest that climate change may be associated with a rise in the prevalence of onchocerciasis.

Keywords: Global warming; Disease; Black flies

RESUMO

Este estudo investiga possíveis correlações entre as mudanças climáticas e a prevalência de oncocercose. O número relatado de indivíduos tratados para a série temporal de oncocercose de 2005 a 2018 foi obtido do repositório de dados do Observatório Global de Saúde da Organização Mundial da Saúde, enquanto o índice global de temperatura terrestre-oceânica para o mesmo período foi obtido do Goddard Institute for Space Studies da NASA. O índice de temperatura global terra-oceano foi usado como dados independentes, enquanto o número relatado de indivíduos tratados para oncocercose foi usado como dados dependentes nos modelos de regressão de ajuste de curva. Brasil ($p = 0{,}0037$, $r2 = 51{,}86$) e Venezuela ($p = 0{,}0012$ $r2 = 59{,}85$) na América do Sul e Burundi ($p = 0{,}0397$, $r2 = 30{,}7$), Camarões ($p = 0{,}0001$, $r2 = 71{,}41$), Chade ($p = 0{,}0068$, $r2 = 46{,}93$), Congo ($p > 0{,}05$), República Democrática do Congo ($p = 0{,}002$, $r2 = 56{,}4$), Etiópia ($p < 0{,}00001$, $r2 = 77{,}52$), Malawi ($p = 0{,}0097$, $r2 = 43{,}96$) , Nigéria ($p = 0{,}0055$, $r2 = 48{,}68$), Uganda ($p > 0{,}05$) e República Unida da Tanzânia ($p < 0{,}00001$, $r2 = 76{,}76$) na África foram o grupo de estudo. No geral, os padrões sugerem que a mudança climática pode estar associada a um aumento na oncocercose.

Palavras-chave: Aquecimento global; Doenças; Simulídeos

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INTRODUCTION

Since factors, such as climate change, biodiversity loss, deforestation, and atmospheric pollution have significantly impacted population health, the study of the relationship between anthropogenic environmental change and human health has grown significantly over the past few years (PIGNATTI, 2004; CONFALONIERI, 2007).

Addressing the impacts of climate change on environmental and human health is a major challenge of the 21st century (TOSAM AND MBIH, 2015; PAL, 2017). Climate change during the last few decades have had an increasing influence on the transmission of infectious diseases, particularly those transmitted by vectors, which are still a major cause of morbidity and mortality in Brazil and globally (CONFALONIERI, 2007; EPSTEIN, 2005; BARCELLOS et al., 2009; LAFFERTY, 2009).

Land temperature records are a fundamental indicator in analyzing climate change and, in this context, the global land-ocean temperature index is an important tool to achieve this (HANSEN et al., 2010). Increasing temperature may directly improve the potential of vector-transmitted diseases and increase the morbidity and mortality of the disease (KUTZ et al., 2005; LAL et al., 2012), especially during the duration of the infection (HAY et al., 2004).

In this scenario, vector-borne diseases are particularly prone to alterations in their transmission patterns due to the largely documented impacts of global warming on arthropods (BUITRAGO-GUACANEME et al., 2018).

Vector-borne diseases comprise a group of different syndromes caused by a myriad of different pathogens, ranging from viruses to helminths that are all transmitted through the blood meal of arthropods (PAL, 2017).

The World Health Organization identifies malaria, dengue, chikungunya, yellow fever, zika, lymphatic filariasis, schistosomiasis, onchocerciasis, chagas, leishmaniasis, and Japanese encephalitis as the main vector-borne diseases (Global Vector Control Response, 2017–2030) and all of these are extremely sensitive to climate change (BRYSON et al., 2020).

Onchocerciasis is a neglected tropical disease caused by the nematode *Onchocerca volvulus* with complications that can lead to ocular lesions, which is why it is known as river blindness. This disease is a major public health problem in Africa, where it is endemic in 26 countries, but also in the Americas, where it is endemic in six countries and in the Eastern Mediterranean. Its global burden estimated in 2017 showed that its prevalence was 20.9 million infections, 1.15 million of those with vision loss (WORLD HEALTH ORGANIZATION, 2020).

Over the past decades, studies have emerged in the literature reporting the positive correlation between onchocerciasis and epilepsy on hyperendemic areas (KILIAN et al., 1994). The severity of skin lesions and the blindness caused by onchocerciasis have a direct social-economic impact on countries where it is endemic because large extensions of fertile land near vector breeding sites are often abandoned (WORLD HEALTH ORGANIZATION, 2012).

Certain species of black flies (Diptera: Simuliidae) of the genus Simulium infect human hosts with the *Onchocerca volvulus* filaria. These insects belong to a family that is widely spread worldwide, although only certain species are vectors of onchocerciasis (FIGUEIRÓ and GIL-AZEVEDO, 2010). These organisms have their immature forms breed on running waters and are locally restricted to areas with suitable microhabitats for their larvae and pupae (CURRIE and ADLER, 2008; FIGUEIRÓ et al., 2008).

In this context, black fly populations are usually regulated by the availability of suitable microhabitat (BUITRAGO-GUACANEME et al., 2018; CUADRADO et al., 2019; DOCILE et al., 2015), predation (WERNER and PONT, 2003), and parasitism (ARAÚJO-COUTINHO et al., 2004). Studies have shown that seasonality plays a crucial role in the composition of black fly species (FIGUEIRÓ et al., 2014), affecting epizootics (NASCIMENTO et al., 2007) and probably influencing other biotic factors that shape local black fly assemblages, and affecting adult biting behavior and *Onchocerca* infectivity (OFORKA et al., 2020). Additionally, studies found in the literature (CILEK and SCHAEDIGER, 2004) have reported a severe infestation of black flies associated with *El nino* events. Therefore, global warming and its impacts on seasonality will potentially affect black fly spatial and temporal patterns of distribution and consequently alter onchocerciasis prevalence and incidence.

Therefore, climate change seems to allow higher transmission rates of onchocerciasis due to higher biting rates and parasite development rates, along with black fly population growth (CHEKE et al., 2013), with impacts on public health and, thus, demanding greater vigilance and control efforts.

In this context, this article investigates possible correlations between climate change and the prevalence of the onchocerciasis and to discuss the potential implications for the control of the disease.

MATERIAL AND METHODS

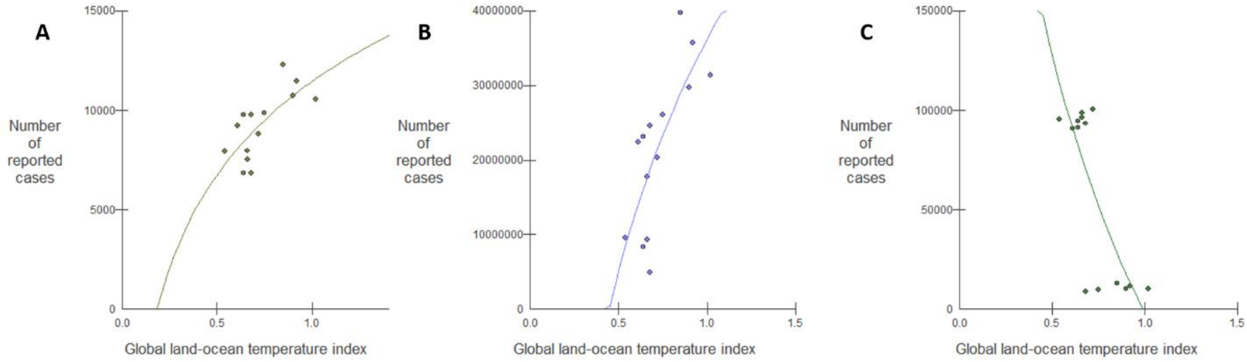
The reported number of individuals treated for onchocerciasis time series from 2005–2018 was obtained from the World Health Organization Global Health Observatory data repository (https://www.who.int/data/gho), whereas the global land-ocean temperature index for the same period was obtained from NASA's Goddard Institute for Space Studies (https://climate.nasa.gov/vital-signs/global-temperature/). Only countries that had no information gaps in their respective time series were included in the analyses. The global land-ocean temperature index was used as the independent data, while the reported number of individuals treated for onchocerciasis was used as dependent data on the curve fitting regression models using BioEstat v.5.3 (AYRES et al., 2007).

RESULTS AND DISCUSSION

After excluding countries with inadequate time series, the study group comprised Brazil and Venezuela in South America and Burundi, Cameroon, Chad, Congo, Democratic Republic of the Congo, Ethiopia, Malawi, Nigeria, Uganda, and the United Republic of Tanzania in Africa.

The best models for Brazil (p = 0.0037, r2 = 51.86) (Fig 1a), the Democratic Republic of Congo (p = 0.002, r2 = 56.4) (Fig 1b), and Venezuela (p = 0.0012 r2 = 59.85) (Fig. 1c) was logarithmic regression, indicating in the first two positive correlations between the global land-ocean temperature index and the reported number of individuals treated for onchocerciasis, whereas the opposite trend was observed for Venezuela.

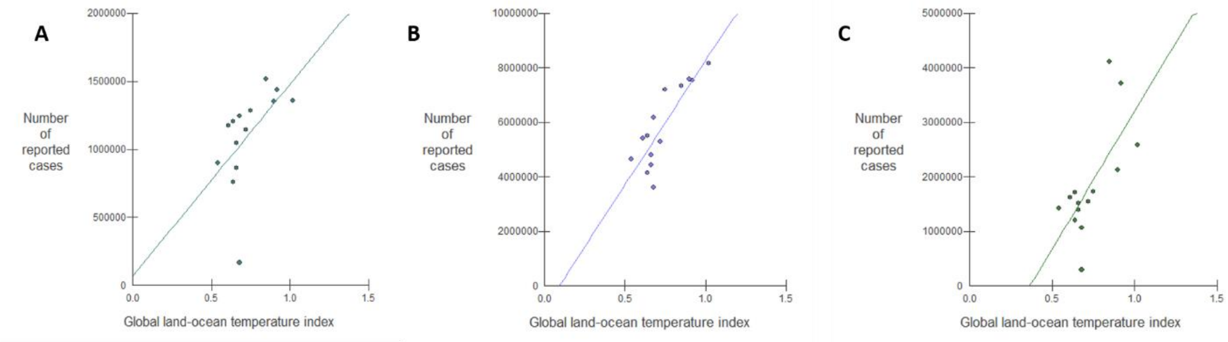
Figure 1 –(A) Logarithmic regression for data from Brazil, indicating a positive correlation between the global land-ocean temperature index and the reported number of cases treated for Onchocerciasis (p = 0.0037, r2 = 51.86) (B) Logarithmic regression for data from the Democratic Republic of Congo, indicating a positive correlation between the global land-ocean temperature index and the reported number of cases treated for Onchocerciasis (p = 0.002, r2 = 56.4).(C) Logarithmic regression for data from Venezuela, indicating the trend toward a reduction in the number of reported cases treated for Onchocerciasis under higher global land-ocean temperature index values (p = 0.0012 r2 = 59.85).



Source: Elaborated by the authors (2023)

For Burundi (*p* = 0.0397, r2 = 30.7) (Fig. 2a), Cameroon (*p* = 0.0001, r2 = 71.41) (Fig. 2b), Chad (*p* = 0.0068, r2 = 46.93) (Fig. 2c), Ethiopia (*p* < 0.00001, r2 = 77.52) (Fig. 3a), and Malawi (*p* = 0.0097, r2 = 43.96) (Fig. 3b), the best model was linear regression, also showing a positive correlation between the global land-ocean temperature index and the reported number of individuals treated for onchocerciasis.

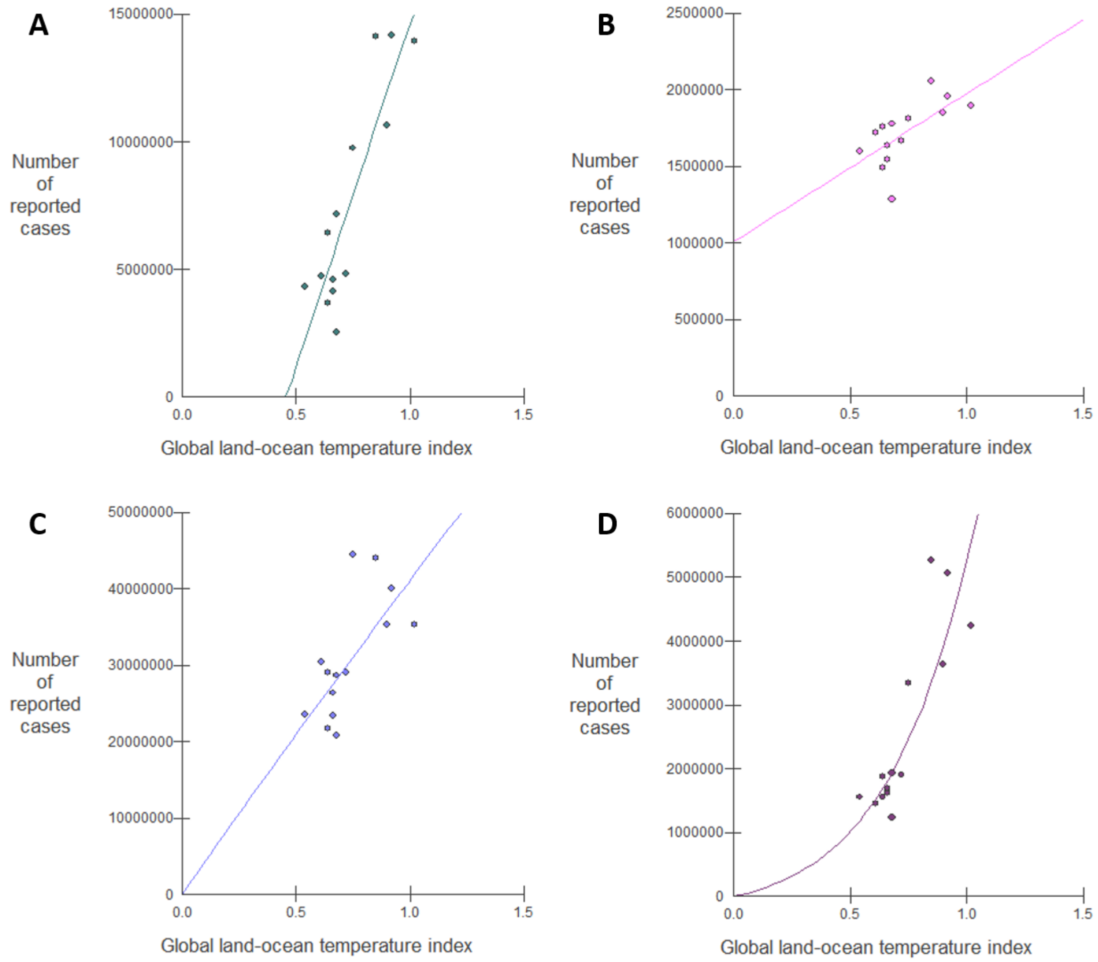
**Figure 2 - ** (A) Linear regression for data from Burundi, indicating a positive correlation between the global land-ocean temperature index and the reported number of treated cases for onchocerciasis (p = 0.0387, r2 = 30.7). (B) Linear regression for data from Cameroon, indicating a positive correlation between the global land-ocean temperature index and the reported number of cases treated for onchocerciasis (p = 0.0001, r2 = 71.41). (C) Linear regression for data from Chad, indicating a positive correlation between the global land-ocean temperature index and the reported number of cases treated for onchocerciasis (p = 0.0068, r2 = 46.93).



Source: Elaborated by the authors (2023)

The best model for the Nigerian data was geometric regression (p = 0.0055, r2 = 48.68) (Fig. 3c) and for Tanzania, it was an exponential regression (p < 0.00001, r2 = 76.76) (Fig. 3d), both of which also showed a positive correlation between global land-ocean temperature index values and the reported number of cases treated for onchocerciasis. Congo and Uganda did not show significant correlations.

Figure 3 - (A) Linear regression for data from Ethiopia, indicating a positive correlation between the global land-ocean temperature index and the reported number of cases treated for onchocerciasis ($p < 0.00001$, $r2 = 77.52$). (B) Linear regression for data from Malawi, indicating a positive correlation between the global land-ocean temperature index and the reported number of cases treated for onchocerciasis ($p = 0.0097$, $r2 = 43.96$).(C) Geometric regression for data from Nigeria, indicating tendency toward a larger number of reported cases treated for onchocerciasis under higher global land-ocean temperature index values ($p = 0.0055$, $r2 = 48.68$). (D) Exponential regression for data from Tanzania, indicating tendency toward a larger number of reported cases treated for the onchocerciasis under higher global land-ocean temperature index values ($p < 0.00001$, $r2 = 76.76$).



Source: Elaborated by the authors (2023).

Overall, nine countries showed a positive correlation between the land-ocean temperature index and the number of reported cases of onchocerciasis. However, only Venezuela showed a negative correlation.

The patterns observed in this study suggest that onchocerciasis prevalence may be rising because of climate change. This corroborates a study on *Onchocerca volvulus* in

Liberia and Ghana, which showed that the optimal temperature range for the black fly occurrence was between 3 and 7°C above the monthly means in each country (CHEKE et al., 2013), suggesting that global warming may impact the growth of the black fly population. However, studies with Phlebotomus adapted to the savanna, which benefits from higher temperatures, may substitute the forest adapted species as global warming increases (CHEKE et al., 2013), a pattern that possibly applies to black flies too. In this scenario, there would be a black fly species turnover, which could result in vector species distribution expansions or displacements, thus influencing the onchocerciasis dynamics.

Climate change has been one of the most discussed topics recently, as a global concern. According to the latest IPCC report, climate change has been accelerated by anthropogenic activities, due to the emission of greenhouse gases, especially carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from fossil fuel combustion and changes in land use (INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, 2014). In the last century, global mean land and ocean temperatures have increased beyond any period in the last 40 million years (INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, 2014). A recent report modeled estimated species extinction of about 33%–58% of the current biodiversity under scenarios of maximum-expected climate change, which could result in the loss of potentially competing and predatory species that could regulate vectors (THOMAS et al., 2004). Additionally, projections estimated that climate change will influence the distribution and expansion of tropical diseases in the temperate region, especially those transmitted by vectors such as schistosomiasis, onchocerciasis, dengue, lymphatic filariasis, African and American trypanosomiasis, yellow fever, and other diseases transmitted by mosquitos and ticks (LAFFERTY et al., 2009; EPSTEIN, 2000).

From this perspective, the World Health Organization (WHO) considers climate change to be the greatest threat to world health in the 21st century. According to the WHO, global warming may cause up to 250,000 deaths by 2030 (BARCELLOS et al., 2009). There are predictions that human health will be an area that will suffer the most from the effects of climate change (CAMPBELL-LENDRUM et al., 2015). Barcellos et al. (2009) highlighted that such effects can be direct, such as diseases and deaths caused by heat waves and extreme events, or indirect, such as those caused by modifications in the ecosystem and biogeochemical cycles, which may provoke an increase in the transmission of infectious diseases and on those not infectious such as subnutrition.

Climate change plays an important role in the indirect effects of vector-transmitted diseases. In some cases, prolonged draught may reduce the vector activity, reducing its life cycle and hindering its reproduction, while on the other hand it increases the number of nonimmune hosts since heat waves can reduce skin immunity on part of the population, making it more susceptible to contagion by viruses, fungi, etc., allowing the proliferation of diseases transmitted by hematophagus insect (CAMPBELL-LENDRUM et al., 2015). These factors, associated with poor sanitary conditions, increase the geographic range and seasonal abundance of vector diseases.

The WHO advocated that health protection is possible and must be a priority to the investment funds of climate change adaptations: further than the immediate impact on human quality of life, these investments must enhance long-term resilience to the impacts of global warming (BARCELLOS et al., 2009). These investments will benefit global efforts to control or eliminate human helminthiasis through mass administration of drugs, vector control and state-of-the-art biotechnological solutions. In this race against the effects of global warming, it may be imperative to accelerate the efforts on the elimination of the onchocerciasis by prioritizing the development of vaccines (LUSTIGMAN et al., 2018).

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