ORIGINAL ARTICLE

Correlation between HIV, Tuberculosis, and Malaria with COVID-19 Indices: A Global Level Ecological Study

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Abstract

Background: HIV, Tuberculosis, and Malariaare neglected due to the high pressure imposed on healthcare systems by COVID-19; however, since these diseases afflict a large number of patients globally, their effect on COVID-19, as a world pandemic, should be assessed. We aimed to assess the relationship between the prevalence of these diseases and COVID-19 indices.

Methods: In this ecological study, a data set was provided, which included the epidemiologic indices of COVID-19 for each country. The scatter plots of the social capital for the studied countries based on the epidemiologic indices of COVID-19 and HIV (human immunodeficiency virus), and Malaria were drawn.

Results: The prevalence of HIV, Tuberculosis, and Malaria were inversely correlated with the cumulative incidence rate of cases, the cumulative incidence rate of death, and COVID-19 tests performed per million, and was directly correlated with the recovery rate. No correlation was seen between case fatality rate and the prevalence of these infectious diseases.

Conclusion: However, the results of this study were in favor of people afflicted with HIV, and Further studies should be conducted on the concurrence of infectious events and their adverse consequences with future analytical protocols.

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Keywords: Coronavirus, COVID-19, Ecologic study, HIV, Tuberculosis

Introduction

Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) and Coronavirus Disease 2019 (COVID-19) were first observed in Wuhan, China, on December 8th, 2019. The World Health Organization (WHO) declared COVID-19 a pandemic on March 11th, 2020. SARS-CoV-2 was found to have a SARS-CoV-like sequence in bats.[1-3] The number of confirmed COVID-19 cases was 37,538,493 in the United States, 27,961,717 in Europe, 12,164,604 in Southeast Asia, 5,070,009 in Eastern Mediterranean, 2,047,423 in Africa, and 1,146,436 in Western Pacific. Of these, 889,076 in the United States, 610,083 in Europe, 186,337 in South East Asia, 123,725 in Eastern Mediterranean, 46,116 in Africa, and 20,750 in Western Pacific have died from COVID-19.[4]

Among these infectious diseases, Tuberculosis is one of the deadliest infectious diseases worldwide, directly related to poor living conditions, inadequate access to public healthcare services, poverty, social exclusion, and marginalization.[5, 6] As Malaria is one of the top ten causes of death in low-income countries, it is one of the most critical global health challenges,

although outbreaks of COVID-19 may not occur in endemic areas for Malaria.[7, 8] One reason is attributed to the use of drugs to treat . Chloroquine (CQ) and Hydroxychloroquine (HCQ) have long been used as anti-malarial drugs. These drugs, which have the potential antiviral and anti-inflammatory effects, can restructure the treatment of various diseases and are significantly effective in treating COVID-19.[7, 9] Acquired Immunodeficiency Syndrome (AIDS), caused by Human Immunodeficiency Virus (HIV), is one of the leading causes of immunodeficiency worldwide.[10] The risk of COVID-19 for people living with HIV is not well known. Most reported cases of COVID-19 with co-infection of HIV are those who receive antiviral therapy for a proven HIV diagnosis.[11] Although the incidence of the SARS-CoV-2 virus is expected to be lower in Asia and Europe than in Africa, with weaker healthcare systems and economies.[11]

Nevertheless, people living with HIV in many parts of the world are vulnerable to the effects of this virus. For this reason, close monitoring of the care in this population is a priority.[12] The COVID-19 epidemic has been reported by approximately 185 countries and territories, of which 45 were African. HIV, and Malaria are endemic in these areas. As of April 13th, 2020, with approximately 8767 confirmed cases and 413 deaths from the disease, the COVID-19 cases and deaths in Africa was lower than in other WHO regions.[13] The prevalence and mortality rate of COVID-19 in Africa are lower than in several Western countries, including the United States.[14] Given that COVID-19 is not yet fully understood and since there is a lack of comprehensive study on the relationship between infectious diseases and COVID-19, this study aimed to investigate the correlation between infectious diseases such as Tuberculosis, and AIDS with epidemiological indicators of COVID-19.

Methods

This survey is an ecological study, so all studied variables are aggregate from 2019 to 2020. The authors provided a data set, including the information of each country regarding the cumulative incidence rate of cases, the cumulative incidence rate of deaths, the case fatality rate, the recovery rate, and the number of performed COVID-19 tests per million. Information about COVID-19 for each country was retrieved from https://www.worldometers.info/ from the date of the first report until November 30th, 2020.[15] Also, Details about COVID-19 indices and collected data on COVID-19 indices have been previously published.[16] In this study, the relationships between COVID-19 indices, including the cumulative incidence rate of cases, the cause-specific death rate, the cumulative number of tests performed per million, the recovery rate, and the case fatality rate with AIDS, and were investigated. AIDS data were available for 117 countries, Tuberculosis for 168 countries, and Malaria for 164 countries. Statistics on Tuberculosis and AIDS were available on the World Bank website,[15, 17] and Malaria data were available on the WHO website.[18] In this study, the incidence rate of Tuberculosis (per 100,000 people) was defined as the number of new and relapsed Tuberculosis cases arising in a given year, expressed as the rate per 100,000 population.[19] Also, the total prevalence of HIV (% of the population aged 15-49) meant the estimated number of adults aged 15-49 years with HIV infection regardless of the development of AIDS symptoms, expressed as a percent of the total population age group.[20] The incidence rate of Malaria (per 1,000 population at risk) meant the number of Malaria cases per 1000 population at risk.[21] The formula of indicators mentioned the following.

$$\textbf{Total Cases Cumulative Incidence} = \frac{\textbf{Total Cases}}{\textbf{Population}} \times \textbf{1,000,000}$$

$$\textbf{cause} - \textbf{specific death rate} = \frac{\textbf{Total Deaths}}{\textbf{Population}} \times \textbf{1,000,000}$$

$$\textbf{Total Tests Cumulative Incidence} = \frac{\textbf{Total Tests}}{\textbf{Population}} \times \textbf{1,000,000}$$

$$\textbf{Recovery Rate} = \frac{\textbf{Total recovered}}{\textbf{Total cases}} \times \textbf{100}$$

$$\textbf{Case Fatality Rate} = \frac{\textbf{Total Deaths}}{\textbf{Total Cases}} \times \textbf{100}$$

Scatter plots of HIV, Tuberculosis, and Malaria for the studied countries were drawn based on the cumulative incidence rate of cases, cumulative incidence rate of death, tests performed per million, recovery rate, and case fatality rate of COVID-19. Furthermore, the Spearman correlation coefficient was also used to verify the correlation between HIV, Tuberculosis, and Malaria with indicators related to COVID-19.

Results

The results of this ecological study showed that among all countries surveyed, Montenegro (60310.56 per million) and Luxembourg (54807.89 per million) had the highest cumulative incidence rate of cases of COVID-19, when Tanzania (8.42 per million) and Vietnam (13.78 per million), had the lowest cumulative incidence rate. Also, it revealed that Belgium (1425.15 per million), followed by Spain (1118.96 per million), had the highest cumulative incidence rate of death due to COVID-19, while Burundi (0.08 per million) and Tanzania (0.35 per million), had the lowest cumulative incidence rate. Luxembourg (2180641.18 per million) and United Arab Emirates (1682880.81 per million) had the highest number of performed COVID-19 tests per million among

the studied countries. The lowest number of performed COVID-19 tests per million belonged to Yemen (560.05 per million) and Niger (1885.52 per million). The highest recovery rate was in Timor-Leste (100%) and Singapore (99.86%), while the lowest rate was in Belgium (6.48%) and France (7.28%). In addition, the highest case fatality rate of COVID-19 was in Yemen (28.34%), followed by Mexico (9.54%), while the lowest case fatality rate of COVID-19 was in Singapore (0.05%) and Burundi (0.15%). In this study, 88 countries had a population of ten million or more. In countries with a population of 10 million, the highest cumulative incidence rate of COVID-19 cases was in Belgium (49661.05 per million), followed by the Czech Republic (48493.85 per million), the lowest rate was in Tanzania (8.42 per million) and then in Vietnam (13.78 per million). The highest and lowest cumulative incidence rate of death were similar to the ones seen in all of the countries section.

The highest number of tests performed per million was in the United Kingdom (626236.72 per million), followed by the United States (579643.25 per million), and the lowest was similar to the "all countries" section. The highest recovery rate was in Ghana (97.83%), followed by Germany (97.70%), and the lowest was similar to the "all countries" part. The highest case fatality rate was in Kuwait (28.34%), followed by Mexico (9.54%), while the lowest was observed in Burundi (0.15%) and Malaysia (0.29%).

Table 1 shows the correlation coefficient between the indicators related to COVID-19 and Tuberculosis, and AIDS. This study showed that the prevalence of HIV in people aged 15-49 years has a significant inverse correlation with the cumulative incidence rate of death and tests performed per million (P<0.001).

In countries with a higher prevalence of HIV, the cumulative incidence rate of cases, the cumulative incidence rate of death, and the tests performed per million were lower. Also, the recovery rate was directly correlated with the prevalence of HIV in people aged 15-49 years; with an increasing prevalence of HIV, the recovery rate increased (P=0.01). There was no significant correlation between the prevalence of HIV in people aged 15-49 years and the case fatality rate (P=0.35). The incidence of Tuberculosis was significantly correlated with the cumulative incidence rate of the cases, the cumulative incidence rate of death, and the COVID-19 tests performed per million (P<0.001). In countries with a higher incidence of Tuberculosis, the cumulative incidence rate of cases, the cumulative incidence rate of death, and the performed tests per million were lower. Also, the recovery rate was directly correlated with the incidence of . With an increase in tTuberculosis Tuberculosis incidence, the recovery rate increased (P<0.001).

Table 1: Spearman correlation of indices related to COVID-19* with HIV**, Malaria, and Tuberculosis

Variable	All countries				Countries with ≥10 million population			
	N***	Correlation coefficient	P value	Comment ****	N	Correlation coefficient	P value	Comment
The cumulative Incidence rate of Cases (per million)								
Prevalence of HIV in 15-49-year-olds (%)	117	-0.29	<0.001	Weak	67	-0.32	0.009	Weak
The incidence rate of Tuberculosis (per 100,000)	168	-0.56	<0.001	Moderate	88	-0.56	<0.001	Moderate
The incidence rate of Malaria (per 1,000 pop at risk)	164	-0.60	<0.001	Strong	88	-0.65	<0.001	Strong
The cumulative Incidence rate of Death (per million)								
Prevalence of HIV in 15-49-year-olds (%)	114	-0.33	<0.001	Weak	66	-0.40	0.001	Moderate
The incidence rate of Tuberculosis (per 100,000)	163	-0.52	<0.001	Moderate	87	-0.56	<0.001	Moderate
The incidence rate of Malaria (per 1,000 pop at risk)	160	-0.53	<0.001	Moderate	86	-0.62	<0.001	Strong
Tests performed per million								
Prevalence of HIV in 15-49-year-olds (%)	105	-0.36	<0.001	Weak	59	-0.34	0.007	Weak
The incidence rate of Tuberculosis (per 100,000)	156	-0.67	<0.001	Strong	80	-0.69	<0.001	Strong
The incidence rate of Malaria (per 1,000 pop at risk)	152	-0.73	<0.001	Strong	79	-0.77	<0.001	Strong
Recovery rate (%)								
Prevalence of HIV in 15-49-year-olds (%)	114	0.23	0.01	Weak	64	0.22	0.07	NS*****
The incidence rate of Tuberculosis (per 100,000)	163	0.29	<0.001	Weak	83	0.19	0.08	NS
The incidence rate of Malaria (per 1,000 pop at risk)	159	0.27	0.001	Weak	82	0.23	0.04	Weak
Case fatality rate (%)								
Prevalence of HIV in 15-49-year-olds (%)	114	-0.09	0.35	NS	66	-0.27	0.02	Weak
The incidence rate of Tuberculosis (per 100,000)	163	0.06	0.48	NS	87	-0.17	0.09	NS
The incidence rate of Malaria (per 1,000 pop at risk)	160	0.14	0.07	NS	86	-0.07	0.52	NS

*COVID-19: Coronavirus Disease 2019; **HIV: Human immunodeficiency virus; ***N: Number; ****00-.19 "very weak", 0.20-0.39 "weak", .40-0.59 "moderate", .60-0.79 "strong", 0.80-1.0 "very strong". *****Indicates insignificant

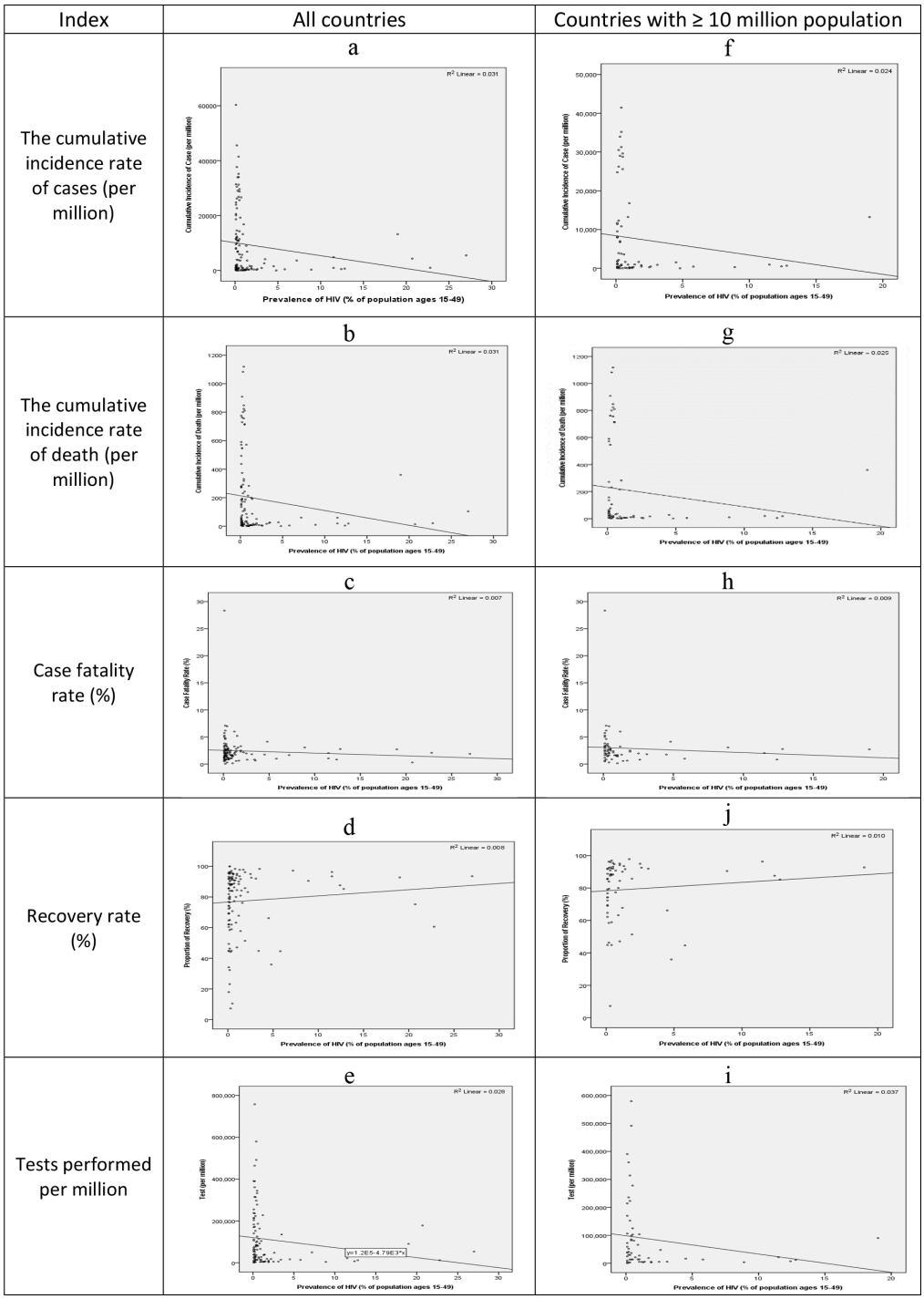


Figure 1: Scatter plot of correlation between HIV with indices related to COVID-19. a: Eswatini, Lesotho, Botswana, South Africa, Zimbabwe, Mozambique, Namibia, Zambia, Malawi, Equatorial Guinea, Uganda, Tanzania, Kenya, Gabon, Guinea-Bissau, Cameroon, Rwanda, South Sudan, Togo, the Gambia, Haiti, Angola, Ghana, Sierra Leone, Liberia, Guyana, Jamaica, Guinea, Suriname, Nigeria, Mauritius, Mali, Chad, Ukraine, Benin, Thailand, Burundi, Dominican Republic, Ethiopia, Papua New Guinea, Djibouti, Barbados, Democratic Republic of Congo, Moldova, Trinidad and Tobago, Myanmar, Burkina Faso, Cabo Verde, RB Venezuela, Brazil, Chile, Colombia, Belarus, Paraguay, Latvia, El Salvador, Cambodia, United States, Spain, Georgia, Argentina, Costa Rica, Ecuador, Malaysia, Senegal, Cuba, France, Peru, Honduras, Kazakhstan, Guatemala, Madagascar, Vietnam, Armenia, Switzerland, the Netherlands, Italy, Lithuania, Ireland, Bolivia, Libya, Kyrgyz Republic, Singapore, Philippines, Uzbekistan, Mauritania, Tajikistan, Nicaragua, Sudan, Niger, Fiji, Timor-Leste, Montenegro, Croatia, Romania, Oman, Bulgaria, Serbia, Lebanon, Albania, Azerbaijan, Iran, Morocco, Tunisia, Nepal, Algeria, Pakistan, Afghanistan, Egypt, Sri Lanka, Australia, Comoros, Syrian Arab Republic, New Zealand, Somalia, Mongolia, Republic of Yemen. b: all countries in (a) except Cambodia, Timor-Leste, and Mongolia. c: all countries in (a) except Cambodia, Timor-Leste, and Mongolia. d: all countries in (a) except Spain, the Netherlands, and the Democratic Republic of Congo. e: all countries in (a) except Comoros, Tajikistan, Burkina Faso, Chad, Somalia, Sierra Leone, Nicaragua, Algeria, Sudan, Syrian Arab Republic, Tanzania, and the Democratic Republic of Congo. f: all countries in (a) except the countries with ≤10 million population. g: all countries in (a) except Cambodia and the countries with ≤10 million population. h: all countries in (a) except Cambodia and the countries with ≤10 million population. i: all countries in (a) except Spain, the Netherlands, the Democratic Republic of Congo, and the countries with ≤10 million population. j: all countries in (a) except Burkina Faso, Chad, Somalia, Algeria, Sudan, Syrian Arab Republic, Tanzania, Democratic Republic of Congo, and the countries with ≤10 million population.

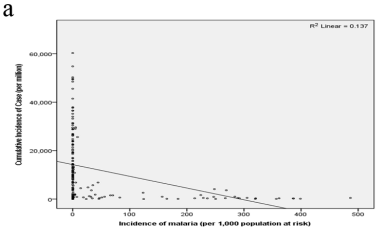
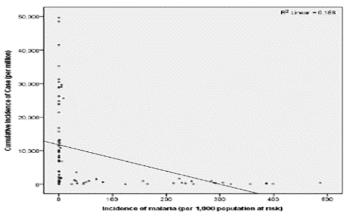
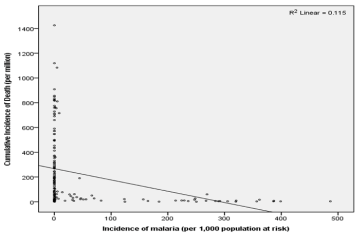
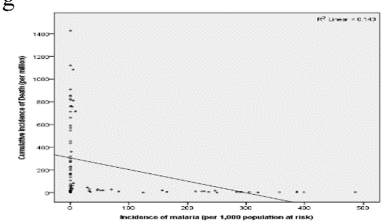
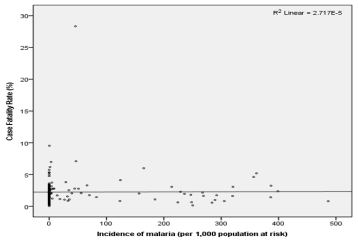
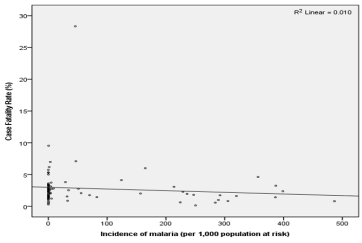
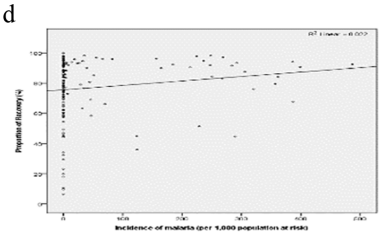
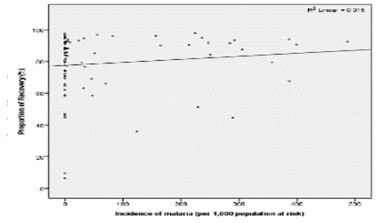
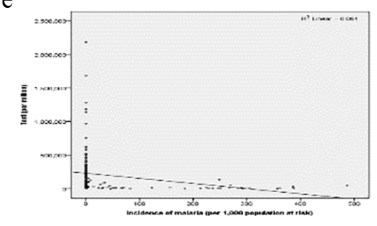
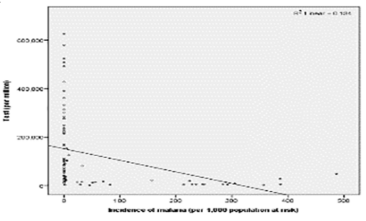
Index	All countries	Countries with ≥ 10 million population
The cumulative incidence rate of cases (per million)	a 	f 
The cumulative incidence rate of death (per million)	b 	g 
Case fatality rate (%)	c 	h 
Recovery rate (%)	d 	j 
Tests performed per million	e 	i 

Figure 2: Scatter plot of correlation between Malaria with indices related to COVID-19. a: Rwanda, Burkina Faso, Mali, Benin, Liberia, Niger, Sierra Leone, Democratic Republic of Congo, Mozambique, Nigeria, Uganda, Guinea, Equatorial Guinea, Togo, Burundi, Gabon, Cameroon, South Sudan, Angola, Ghana, Malawi, Papua New Guinea, Chad, Zambia, Tanzania, Guinea-Bissau, Madagascar, Kenya, the Gambia, Senegal, Zimbabwe, Sudan, Republic of Yemen, Guyana, Mauritania, Djibouti, Somalia, RB Venezuela, Ethiopia, Afghanistan, Namibia, Cambodia, Comoros, Sao Tome and Principe, Colombia, Nicaragua, India, Brazil, Peru, Indonesia, Myanmar, Pakistan, Ecuador, South Africa, Haiti, Bolivia, Eswatini, Bangladesh, Botswana, Nepal, Thailand, Suriname, Mexico, Guatemala, Panama, Philippines, Korean Republic, Honduras, Dominican Republic, Vietnam, Iran, Malaysia, Costa Rica, Timor-Leste, Saudi Arabia, Cabo Verde, Belize, Bhutan, El Salvador, Lesotho, Jamaica, Mauritius, Ukraine, Barbados, Moldova, Trinidad and Tobago, Chile, Belarus, Paraguay, Latvia, United States, Spain, Georgia, Argentina, Cuba, Kazakhstan, Armenia, Switzerland, the Netherlands, Italy, Lithuania, Ireland, Libya, Kyrgyz Republic, Singapore, Uzbekistan, Tajikistan, Fiji, Montenegro, Croatia, Romania, Oman, Bulgaria, Serbia, Lebanon, Albania, Azerbaijan, Morocco, Tunisia, Algeria, Egypt, Sri Lanka, Australia, Syrian Arab Republic, New Zealand, Mongolia, Luxembourg, Bahrain, Belgium, Qatar, Czech Republic, Israel, Slovenia, Kuwait, Austria, North Macedonia, Portugal, Bosnia and Herzegovina, Poland, Sweden, Maldives, United kingdom, Hungary, Malta, Jordan, Slovak Republic, the Bahamas, United Arab Emirates, Iceland, Russia, Denmark, Iraq, Germany, Greece, Canada, Estonia, Cyprus, Turkey, Norway, Finland, Uruguay, Japan, Brunei Darussalam, China. b: all countries in (a) except Cambodia, Timor-Leste, Mongolia, and Bhutan. c: all countries in (a) except Cambodia, Timor-Leste, Mongolia, and Bhutan. d: all countries in (a) except Spain, the Netherlands, Sweden, and the Democratic Republic of Congo. e: all countries in (a) except Comoros, Tajikistan, Burkina Faso, Chad, Somalia, Sierra Leone, Nicaragua, Algeria, Sudan, Syrian Arab Republic, Tanzania, and the Democratic Republic of Congo. f: all countries in (a) except the countries with ≤10 million population. g: all countries in (a) except Cambodia and the countries with ≤10 million population. h: all countries in (a) except Cambodia and the countries with ≤10 million population. i: all countries in (a) except Spain, the Netherlands, United Kingdom, Sweden, Democratic Republic of Congo, and the countries with ≤10 million population. j: all countries in (a) except Burkina Faso, Chad, Somalia, Algeria, Sudan, Syrian Arab Republic, Tanzania, Democratic Republic of Congo, and the countries with ≤10 million population.

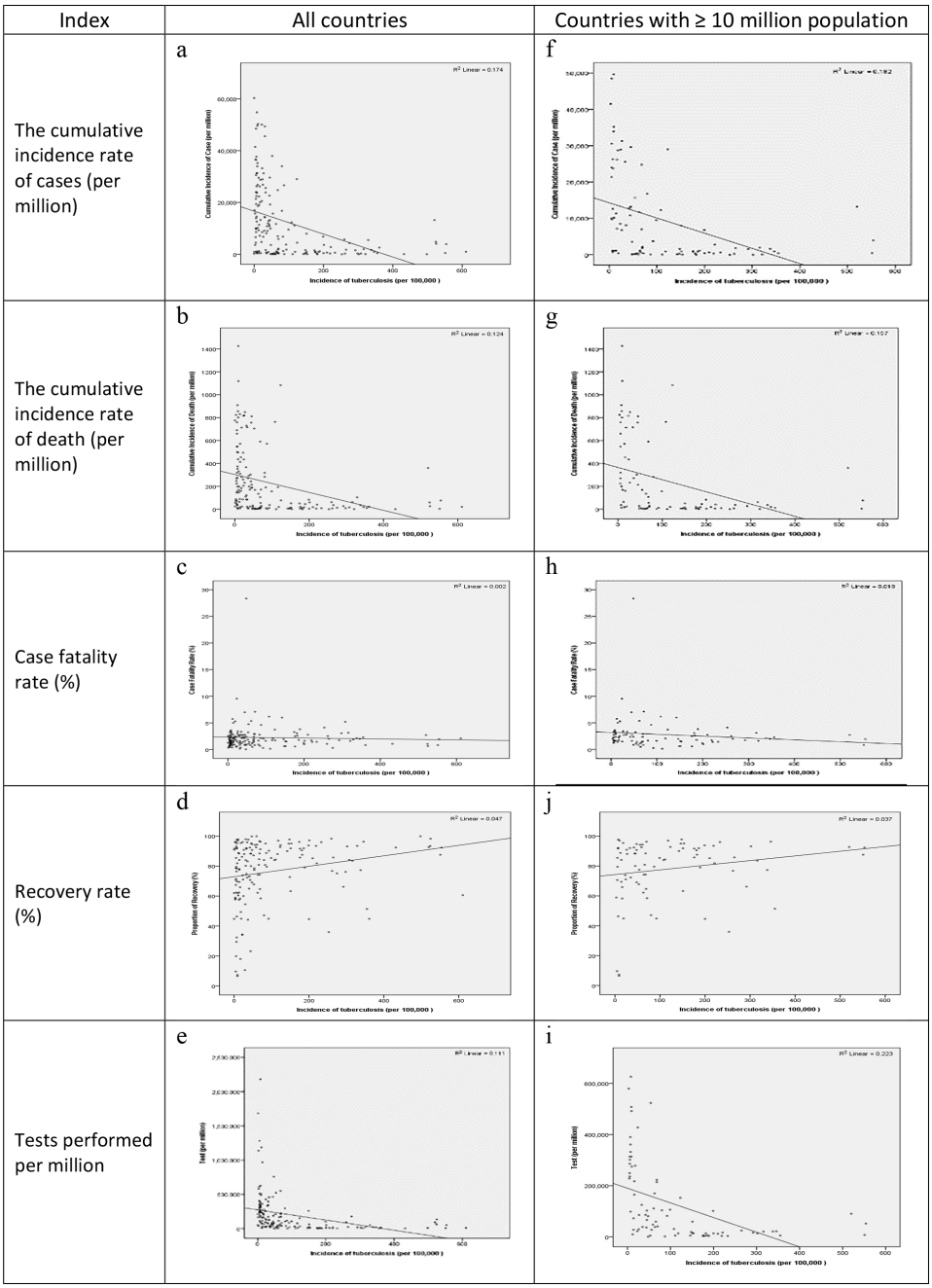


Figure 3: Scatter plot of correlation between Tuberculosis with indices related to COVID-19. a: Lesotho, Philippines, Mozambique, Gabon, Namibia, South Africa, Timor-Leste, Papua New Guinea, Guinea-Bissau, Angola, Zambia, Myanmar, Eswatini, Democratic Republic of Congo, Indonesia, Liberia, Cambodia, Sierra Leone, Kenya, Botswana, Pakistan, Somalia, Djibouti, Tanzania, Madagascar, Bangladesh, Nigeria, Zimbabwe, Equatorial Guinea, Uganda, India, Afghanistan, Cameroon, Vietnam, Malawi, Guinea, Haiti, the Gambia, Thailand, Ethiopia, Nepal, Bhutan, Ghana, South Sudan, Chad, Sao Tome and Principe, Peru, Senegal, Kyrgyz Republic, Burundi, Bolivia, Morocco, Mauritania, Malaysia, Niger, Moldova, Tajikistan, Guyana, Ukraine, Georgia, Sudan, El Salvador, Uzbekistan, Algeria, Kazakhstan, Romania, Brunei Darussalam, Hong Kong, Korean Republic, Sri Lanka, Azerbaijan, China, Macao, Rwanda, Benin, Fiji, Russia, Mali, Panama, Burkina Faso, Republic of Yemen, RB Venezuela, Singapore, Cabo Verde, Brazil, Dominican Republic, Ecuador, Lithuania, Paraguay, Iraq, Nicaragua, Libya, Suriname, Honduras, Togo, Comoros, Tunisia, Colombia, Maldives, Uruguay, Belarus, Armenia, Qatar, Belize, Latvia, Argentina, Guatemala, Bosnia and Herzegovina, Portugal, Mexico, Kuwait, Bulgaria, French Polynesia, Trinidad and Tobago, Syrian Arab Republic, Chile, Albania, Serbia, Poland, Turkey, Iran, Malta, the Bahamas, Japan, Mauritius, North Macedonia, Estonia, Egypt, Lebanon, Bahrain, Costa Rica, Saudi Arabia, Spain, Belgium, France, Croatia, Luxembourg, United Kingdom, New Zealand, Germany, Cuba, Austria, Italy, Ireland, Australia, Switzerland, Hungary, Oman, Slovak Republic, Canada, Sweden, Czech Republic, Denmark, Cyprus, the Netherlands, Slovenia, Jordan, Finland, Greece, Norway, Israel, United States, Jamaica, Iceland, United Arab Emirates, Barbados, Montenegro, Mongolia. b: all countries in (a) except Cambodia, Timor-Leste, Mongolia, Bhutan, and Macao. c: all countries in (a) except Cambodia, Timor-Leste, Mongolia, Bhutan, and Macao. d: all countries in (a) except Spain, the Netherlands, and the Democratic Republic of Congo. e: all countries in (a) except Spain, United Kingdom, Sweden, the Netherlands, and the Democratic Republic of Congo. f: all countries in (a) except the countries with ≤ 10 million population. g: all countries in (a) except Cambodia and the countries with ≤10 million population. h: all countries in (a) except Cambodia and the countries with ≤10 million population. i: all countries in (a) except Spain, United Kingdom, Sweden, the Netherlands, Democratic Republic of Congo, and the countries with ≤10 million population. j: all countries in (a) except Burkina Faso, Chad, Somalia, Algeria, Sudan, Syrian Arab Republic, Tanzania, Democratic Republic of Congo, and the countries with ≤10 million population.

There was no significant correlation between Tuberculosis incidence and case fatality rate (P=0.48). The incidence of Malaria was significantly and inversely correlated with the cumulative incidence rate of cases, the cumulative incidence rate of death, and performed tests per million (P<0.001). In countries with a higher incidence of the cumulative incidence rate of cases, the cumulative incidence rate of death, and the performed tests per million were lower. Also, the recovery rate was directly correlated with Malaria incidence; with an increase in Malaria incidence, the recovery rate increased (P<0.001). No significant correlation was observed between Malaria incidence and case fatality rate (P=0.07).

In countries with a population of 10 million and more, a significant inverse correlation was observed between the prevalence of HIV in people aged 15-49 years, the incidence of Tuberculosis and Malaria with the cumulative incidence rate of cases, the cumulative incidence rate of death, and tests performed per million. Malaria incidence had a significant direct correlation with recovery rate. The correlation between HIV prevalence in 15-49-year-olds and the case fatality rate was significant and inverse. Figures 1-3 shows the scatter plot of the prevalence of HIV in people aged 15-49 years, Tuberculosis, and Malaria by cumulative incidence rate of cases, the cumulative incidence rate of death, tests performed per million, recovery rate, and case fatality rate in all countries and countries with a population of 10 million or more. For HIV prevalence in people aged 15-49 years in all countries, the highest R^2 was seen with a cumulative incidence rate of cases and cumulative incidence rate of death (R^2=0.031), and in countries with a population of 10 million and more, the highest R^2 was observed for performed tests per million (R^2=0.037). For the Tuberculosis index, the highest R^2 in all countries and countries with a population of 10 million and more was for the cumulative incidence rate of cases (R^2=0.137 and 0.158, respectively). For Tuberculosis incidence index in all countries and countries with a population of 10 million and more, R^2 for the cumulative incidence rate of cases were 0.174 and 0.182, respectively.

Discussion

This ecological study was performed to investigate the correlation between infectious diseases and the incidence of COVID-19. The results showed that with increased HIV prevalence, the cumulative incidence rate of cases and the incidence rate of death due to COVID-19 decreases. The incidence of Tuberculosis increased, so did the cumulative incidence and mortality of COVID-19. Also, with the increase in Malaria incidence, both the cumulative incidence and the mortality of COVID-19 decreased. The recovery rate of COVID-19 patients showed a significant direct correlation with the prevalence of HIV, Tuberculosis, and Malaria, so the recovery rate of these patients increased with the prevalence and incidence of these diseases. The present study results showed that countries with a higher prevalence of HIV have a lower cumulative incidence rate of COVID-19. A study in Wuhan, China, showed that the cumulative incidence rate of COVID-19 in HIV patients was 0.58%. In this study, the risk of COVID-19 in people with HIV was the same as in the general population.[22] A review study also reported that the clinical course and incidence of COVID-19 in HIV-positive individuals did not differ from the general population.[23] Collins et al. Showed that out of 533 patients with COVID-19 in the hospital, only 20 were infected with HIV.[24] As expected, the most vulnerable populations are most affected in any crisis or catastrophe. So, in this crisis, HIV people feel more at risk. If they become infected with a more deadly virus such as SARS-CoV-2, they will be reluctant to seek care, and this fear will even make these patients go to pharmacies for medication due to overcrowding in medical centers.[25] Based on these findings, the lower incidence of COVID-19 in HIV patients is related to less care and follow-up of these patients, so health policymakers should consider HIV-positive people as a high-risk group to manage this pandemic. HIV-positive individuals are at high risk for COVID-19 manifestations despite antiretroviral therapy, and those with weakened immune systems are at risk for worse outcomes during the epidemic.[22] Prabhu et al. Showed that people living with HIV had a higher risk of dying from COVID-19 than healthy people.[23] Results showed that people living with HIV were at increased risk of COVID-19 mortality.[24, 26] Suwanwongse et al. showed that HIV-related lymphopenia delays the elimination of the virus for a long time and, as a result, it increases the severity of the disease and its adverse consequences. However, our study presents contradictory results. Due to the ecological nature of the present study, the existence of ecological fallacy is probably the cause of this contradiction, although we still need more analytical studies on AIDS. We have shown that with the increased prevalence of HIV, the rate of recovery increases. Wu et al. showed that HIV patients with COVID-19 showed satisfactory clinical outcomes after medical care.[27, 28] Studies have shown that approximately 85% of HIV patients recover from COVID-19.[26, 29, 30] Clinical manifestations in COVID-19 patients are still unclear, so we need further studies in this area.

Our study showed that in countries where the incidence of Tuberculosis is high, the cumulative incidence rate of COVID-19 is low. Conflicting results exist regarding the association between the incidence of Tuberculosis and the incidence of COVID-19. Sala et al. showed in their study that BCG vaccination and exposure to Tuberculosis provide nonspecific protection against COVID-19 infection.[31] Moreover, another review study showed that exposure to Tuberculosis imposes a high risk

of developing COVID-19, so that Tuberculosis was an important risk factor for COVID-19 in terms of disease severity and mortality, which may cause severe lung disease in the future. So, more studies are needed on people with COVID-19.[28, 32] Khurana et al. Suggested that Tuberculosis should be suspected and adequately managed in controlling and combating the COVID-19 epidemic, as it is still one of the leading causes of death from infectious diseases.[33] Patients with Tuberculosis are more likely to develop COVID-19 and have a higher risk of mortality and adverse outcomes after infection.[34, 35] Liu et al. Showed that *Mycobacterium Tuberculosis* infection increases susceptibility to SARS-CoV-2 and the severity of this disease.[36] Another study showed that concomitant Tuberculosis increases mortality in patients with COVID-19.[32, 37] Our results were not in line with these findings. Our study's results showed a direct correlation between the rate of recovery and the incidence of Tuberculosis. So, with the increase in the incidence of Tuberculosis, the recovery rate caused by COVID-19 has increased. Tamuzi et al. Showed that the recovery rate was lower in people with both Tuberculosis and COVID-19 than in those with COVID-19 alone.[28, 32] Another study showed that the probability of recovery in COVID-19 patients with Tuberculosis was 25% lower than in patients without Tuberculosis. Also, the recovery time was significantly longer in patients with Tuberculosis.[26, 32] Due to severe lung involvement in patients with Tuberculosis and concomitant coronavirus infection, the recovery of these patients is delayed. These findings contradict our results. The role of ecological fallacy in these studies can be significant.

Our study found that countries with a higher incidence of Malaria had a lower incidence of COVID-19. Hussein et al. believe that the use of HCQ and CQ in countries endemic for Malaria may be related to this issue. T-cell activation changes the cellular pH and prevents virus replication and CQ antiretroviral activity in infected cells. Malaria patients also produce anti-Gpi antibodies that can detect SARS-CoV-2 glycoproteins and thus Have a protective role against COVID-19, although the potential role of health infrastructure and health systems in countries should also be considered.[38] The results of another study showed that chronic *Plasmodium Malaria* infection causes the production of interferons and neutralizing antibodies, which are effective against infection by coronaviruses, responsible for SARS, MERS, and COVID-19. Extensive exposure to Malaria infections could make a natural immunity to SARS-CoV-2 infection.[39, 40] The relationship between CD-147, a common Malaria receptor, and COVID-19 may play a role in creating this immunity. In addition, due to the generation of gene polymorphisms by, it may develop a type of polymorphism that has a protective role against the pathogenicity and mortality of COVID-19.[36, 41] Another study showed that COVID-19 mortality has decreased in Malaria-endemic countries.[37, 42] The relationship between Malaria and COVID-19 is complex due to the common symptoms, so further analytical studies should examine these results. We also showed that the incidence of COVID-19 increases with the increased incidence of Malaria. A clinical trial in China showed that hydroxychloroquine used in Malaria treatment could help patients with COVID-19 recover faster. These patients reported reduced fever and cough during the day and improved pneumonia.[38]

Conclusion

This ecological study showed that with increased HIV prevalence, the incidence and mortality of COVID-19 decreased. The results also showed that with increasing Tuberculosis and Malaria, the incidence and mortality of COVID-19 disease decreases. In this study, the recovery rate of COVID-19 patients was directly correlated with the prevalence of HIV, Tuberculosis, and Malaria, so with an increase in HIV prevalence and the incidence of Tuberculosis and Malaria, the cure rate of COVID-19 patients increased. Due to the limitations of ecological studies and the possibility of ecological fallacy, health policymakers, and planners should use the results of these studies as hypotheses. Further studies on the concurrence of infectious events and their adverse consequences with future analytical protocols should be performed.

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