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REVIEW ARTICLE

The Environment and COVID-19 Transmission: A Perspective

Condições ambientais e transmissão de COVID-19: uma perspectiva

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Abstract

Coronavirus disease 2019 (COVID-19) has become a severe public health threat worldwide. Despite the global spread, there is an observed aberration and skewness in the geographic/regional distribution of the disease, with a high preponderance of cases and mortality occurring in the temperate regions compared to the tropics. A plausible explanation for this discrepancy could be linked to variability in environmental factors. Hence, this review discusses succinctly the possible influences of geographic location, temperature/sunlight, relative humidity and building design on the rate of transmission of COVID-19. We postulate that elevated melatonin production in a hot climate, high temperature, adequate vitamin D synthesis from sunlight exposure, high relative humidity and efficient ventilation due to housing design confers innate immunity and adaptive advantage to COVID-19 transmission for populations in the tropics over those in the temperate regions. Hence, we recommend that control studies taking into congnizance the relationship between environment and disease be prioritized. Such studies are important for predicting viral disease spread, in particular if this leads to pandemics like in the case of COVID-19, to aid decisions in public health policies at the global level.

Keywords: COVID-19. SARS-CoV-2. Tropics, Temperate. Environmental Factors. Transmission.

Resumo

A doença de Coronavirus 2019 (COVID-19) tornou-se uma grave ameaça à saúde pública em todo o mundo. Apesar da propagação global, observa-se uma aberração e fraqueza na distribuição geográfica/regional da doença, com uma elevada preponderância de casos e mortalidade nas regiões temperadas em comparação com os trópicos. Uma explicação plausível para esta discrepância pode estar ligada à variabilidade dos factores ambientais. Assim, esta revisão discute sucintamente as possíveis influências da localização geográfica, temperatura / luz solar, umidade Relativa e design de construção sobre a taxa de transmissão de COVID-19. Nós postulamos que a elevada produção de melatonina em um clima quente, alta temperatura, síntese adequada de vitamina D da exposição solar, alta umidade Relativa e ventilação eficiente devido ao Projeto de habitação confere imunidade inata e vantagem adaptativa para a transmissão COVID-19 para as populações nos trópicos sobre aqueles nas regiões temperadas. Por isso, recomendamos que sejam priorizados estudos de controle que levem em consideração a relação entre o meio ambiente e a doença. Tais estudos são importantes para prever a propagação da doença viral, em particular se esta conduzir a pandemias como no caso da COVID-19, para ajudar as decisões nas políticas de saúde pública a nível mundial.

Palavras-chave: COVID-19. SARS-CoV-2. Trópicos. Temperados. Fatores Ambientais. Transmissao.

INTRODUCTION

It is a fact that the morbidity and mortality due to nCovid-19 are rising daily with its attendant consequences on human life, economic and political affairs globally. Several pieces of researches and efforts being made by clinicians, scientists and international agencies to develop a vaccine to combat this deadly scourge still remain futility[1]. Currently, a lot of developed and developing nations are forced to relax the prolonged total lockdown initially imposed on their citizenry and economic activities despite the astronomically daily increase in the number of COVID-19 cases globally. The reason for this action, might not be far-fetched from the economic relapsed presently witness by most countries around the globe.

Just barely over a semester, COVID-19 pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) emerged from the city of Wuhan, a Hubei province in China and spread sporadically to over 213 countries around the globe and two international conveyances. COVID-19 infection is an airborne disease that could result in severe respiratory illness, similar to the severe acute respiratory syndrome coronavirus (SARS-CoV)[2,3]. The incidence of illness and infectivity of any virus that is conveyed by the airborne route in an indoor and ambient environment is dependent upon numerous factors. These include population density, temperature, exposure to Ultraviolet (UV) ray or antiviral chemicals, humidity, susceptibles number, exposure duration, ventilation rate, settling rate of an infectious particle, presence of lipid or non-lipid envelope around the virus, number of infected people producing contaminated aerosols, the presence of encompassing organic material, antibiotic resistance or antiviral therapy resistance

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by microbes, form and level of invasive procedures, spatial considerations such as seating or sleeping arrangements and contact with a carrier, pathogens persistence within hosts, immuno-epidemiology, evolution and transmission of resistance and host genetic factors role[4].

At the present, the global total number of confirmed cases is estimated at 7,939,988 with 433,904 deaths, and 4,078,668 recovered from the coronavirus COVID-19 outbreaks to date, June 14, 2020, 17:41 GMT (source: https://www.worldometers.info/coronavirus). Despite the global spread, there is an empirical aberration and skewness in the geographic/regional distribution of the disease, with a high preponderance of cases and mortality witnessed by the western nations and countries in temperate regions of the world. The most probable explanation or hypothesis for this discrepancy in the epidemiologic distribution of the pandemic between the temperate and tropical countries of the world is variability in environmental factors. However, this lacuna has been underestimated or overlooked by key players (scientists, policymakers, international agencies etc.) in the COVID-19 battle. It is therefore reasonable that this review discusses succinctly the possible influences of various environmental parameters vis geographic location, temperature/sunlight, relative humidity and building design on the rate of transmission of COVID-19.

INFLUENCE OF ENVIRONMENTAL VARIABLES ON COVID-19 TRANSMISSION

Geographic Location

It has come to the erudition of humans that climatic variables influence epidemic diseases long before the role of infectious agents was unraveled, late in the nineteenth century. Roman aristocrats retreated to hill resorts every summer to prevent malaria, and also south Asians realized early that, in high summer, strongly curried foods were less likely to cause diarrhea[5]. Climatic conditions affect microbial viability and virulence; and consequently microbes (virus, bacteria, fungi, parasites etc.) show variability in their pathogenicity from one region to the other.

Several workers described investigations of the possible relationships between climate and respiratory viruses such as SARS, influenza, and respiratory syncytial virus (RSV) which causes mild, cold-like symptoms in adults and older healthy juveniles[6-8]. Several studies have established variability in the vital role play by latitude in viral conveyance and seasonality[9-11]. As evident in **Table 1**, temperate regions have a higher number of cases than tropical regions. Thus, it can be surmised that the harsh conditions in the tropics have an inimical effect on the survival and transmission rate of SARS-CoV-2. Viral transmission as a consequence of seasonal variation has been ascribed to at least three factors. Firstly, Dowell[12] opine extrinsically driven cycles in host resistance to infection may be linked to seasonal fluctuations in melatonin. Secondly, Cannell et al[13] suggest that circulating vitamin D metabolites or a deficiency of vitamin D may compromise human immunity. Thirdly, Shaman and Kohn[14] propose external discrepancies such as ambient temperature and relative humidity (RH) in viral survival.

Table 1. Case comparison of COVID-19 by regions as at 10:19am CEST, 13 June, 2020 (Source: WHO)[15]

WHO Regions	Total Confirmed Cases
Americas	3,638,525
Europe	2,358,953
Eastern Mediterranean	737,641
South-East Asia	439,348
Western Pacific	196,715
Africa	161,254

In this sub-section, we shall limit our discussion to the influence of geographic location in melatonin production and its role in body defense mechanism; and discuss the other two points in subsequent sub-headings. Melatonin (MLT) is an amine hormone produced primarily by the pineal gland. The physiological function of MLT is mainly to control the circadian rhythm. There is also conflicting evidence about the action of melatonin on mammalian epidermal melanocytes[16]. Melanocytes are involved in the production of melanin, which is responsible for the pigmentation of the skin; with pigmentation greatest in the tropics and reduce in temperate zones[17]. Thus it is expected that melatonin production will be higher among those in the tropics compare to those in the temperate. Also, darkness promotes MLT production while light (fluorescent source) decreases it. Most countries in the tropics especially Africans do not have access to uninterrupted electricity hence spent most of their time in the dark. This might be a contributing factor to the high production of melatonin among Africans compare to their counterparts in the western worlds.

Recent studies have demonstrated that MLT could influence the immune system through several ways to regulate the function of the immune system. In infectious diseases, MLT can regulate the number of immune cells and the expression of cytokines. Moreover, MLT may enhance the function of the immune system by reducing the secretion of inflammatory factors, down-regulating the adhesion of leukocytes and anti-oxidation, which may reduce the pathology caused by inflammation damage[18]. Hence, we postulate that, MLT could play a role against pathogens infection by directly inhibiting the replication and proliferation of pathogens. Thus, it is reasonable to surmise that higher melatonin production among people in the tropics (especially Africans, Latinos, and some Asians) confer natural immunity on them against COVID-19 disease. Therefore, MLT may be considered as a novel target and a new method for the clinical treatment of infectious diseases.

Temperature/Sunlight

Some pundits believe that temperature is one of the vital parameters influencing virus survival, as it can impact the virus RNA or DNA and the viral proteins state. Viruses having

DNA has its nuclei composition exhibit greater stability than RNA viruses. Generally, virus survival is inversely proportional to temperature. Maintaining temperatures greater than 60°C (140°F) above 1 hour will usually inactivate most viruses, though this can differ depending on the presence of organic material (e.g. feces, saliva, blood, mucus, etc.) that may encircle the exhaled viral particles and insulate the virus against extreme environmental variations. Elevated temperatures for a shorter duration can be effective in viral inactivation[8].

Another plausible explanation for the discrepancy in the number of cases and rate of transmission of COVID-19 in the tropics and temperate region [**Table 2**] is the temperature difference. The tropics are characterized by high temperature (hot weather) with an annual mean temperature between 70°F to 85°F (21°C to 30°C). Temperate climates of the Earth are characterized by relatively moderate mean annual temperatures, with average monthly temperatures above 10°C in their warmest months and above −3°C in their colder months[19]. The SARS-CoV-2 and SARS-CoV genomes show strong identity; and the transmission of SARS-CoV is temperature-dependent. Thus, SARS-CoV-2 is suspected, like other coronaviruses, to have a weather-dependent virulence[20,21]. The variations in weather singly would not necessarily decline numbers of confirmed cases during the whole epidemic, but warm and humid weather could make SARS-CoV-2 less vulnerable and less stable, instigating a break in the transmission chain, and hence decreasing the contagious potency of the disease[22].

Table 2. Comparison of the total number of cases and deaths among some temperate and tropical countries of the world to date June 14, 2020 (17:41GMT). Source: https://www.worldometers.info/coronavirus/#countries

S/N	Temperate Countries	Total Cases	Total Death	S/N	Tropical Countries	Total Cases	Total Death
1	USA	2,151,730	117,649	1	Brazil	852,758	42,837
2	Russia	528,964	6,948	2	Peru	225,132	6,498
3	India	332,739	9,514	3	Mexico	142,690	16,872
4	United Kingdom	295,889	41,698	4	Dominican Republic	22,962	592
5	Spain	290,685	27,136	5	Nigeria	15,682	407
6	Italy	236,989	34,345	6	Haiti	4,165	70
7	Iran	187,427	8,837	7	Kenya	3,594	103
8	Turkey	178,239	4,807	8	Gabon	3,463	23
9	France	156,813	29,398	9	Nicaragua	1,464	55
10	Canada	98,735	8,146	10	Myanmar	261	6

Therefore, we postulate that SARS-CoV-2 being an RNA virus has its proteins being easily denatured by high temperature and ultraviolet (UV) ray, thus consequently affect its viability and survival in the tropics than in the temperate. Based on the aforementioned proposition, we deduce that these factors (high temperature and UV light) might be responsible for its low transmission rate in the tropics. However, high numbers of confirmed cases in some tropical regions such as Southern America (Brazil, Peru); Mexico, Dominican Republic etc. might be attributed to poor public health measures such as overcrowding, environmental pollution, poor housing conditions, nutritional disorder etc., which exacerbate the vulnerability of the subjects to the disease. We also predict that number of COVID-19 cases will reduce in the summer and fall compared to the winter and spring seasons in countries with temperate climates. This is because that hot climate improve the efficiency of "ciliary" cells, these are tiny hair protecting the upper respiratory airway (from nose to bronchioles)[23].

Another effect is the high production of vitamin D by exposure to UV light in the tropics region due to high sunlight intensity. Vitamin D is primarily obtained through exposure to sunlight, and thus, the modern lifestyle in many western countries has resulted in many people being perpetually deficient. Vitamin D synthesis decreases from age 70yrs and above of life, due to a decline in solar exposure and cutaneous synthesis[24]. It is low among the westernized population, 75% of them being severely vitamin D deficient (serum 25(OH)D < 25 nmol/L)[25]. Vitamin D helps to bolster the immune system which inhibits infection and also acts as a powerful anti-inflammatory agent. Vitamin D may help to modulate the response of white blood cells to the virus, preventing them from secreting excessive inflammatory cytokines. Also, it is a fact that high temperature/hot weather increase retinoic acid (vitamin A) metabolism in the body to retinol (performed vitamin A) which is the active and utilizable form in the body. Vitamin A helps to regulate the immune system, acts as an antioxidant and promotes the growth and health of body cells and tissues, particularly in the lungs. The ACE2 gene encodes the angiotensin-converting enzyme-2, has been proved to be the receptor for both the SARS-coronavirus (SARS-CoV) and the human respiratory coronavirus NL63. New researches and analyses show that ACE2 (angiotensin-converting enzyme) could be the host receptor for the novel coronavirus 2019-nCoV/SARS-CoV-2[26,27]. Calcitriol (1,25-dihydroxyvitamin D3) exerted significant impact on the Renin-Angiotensin System, by suppressing the renin gene expression and thereby impeding the ACE2 receptor of COVID-19 and it also modulates macrophages' response, preventing them from secreting excessive inflammatory cytokines and chemokines[28-30].

Thus we postulate that high production of vitamin D and increase rate of retinoic acid (vitamin A) metabolism among Africans confers them with innate immunity advantage against COVID-19 compared to their counterparts in Europe and Americas, who are usually vitamin D deficient and have lesser rate of vitamin A metabolism, hence serving as a contributing factor to the low transmission and mortality rate of the disease in the tropics. This assertion is corroborated by other studies, which depicted an inverse correlation between serum 25-hydroxyvitamin D (25-h D) levels and upper respiratory tract infection (URTI)[13,31,32]. Also, the Southern European countries have declined levels of vitamin D due to low exposure (prefer the shade in strong sun)[24] and also as skin pigmentation reduces vitamin D synthesis[33]. This might be responsible for the high number of cases and mortality witnessed in countries such as Spain and Italy, as shown in **Table 2**; with the aging people being the highest risk group[25]. Also, it is important to note that it is difficult to obtain sufficient quantities of this micronutrient through diet alone. Exposure to sunlight remains the primary source of vitamin D production from provitamin in the body. This assertion is validated by the high mortality episode of black people in America from COVID-19 due to low vitamin D deficiency; since dark-skinned people usually need more sunlight exposure compared to light-skinned people to generate a commensurate quantity of vitamin D. However, it is imperative to state that public health measures, individual lifestyle, age distribution, and presence of underlying ailments play a key role in this innate defense mechanism.

Relative Humidity

Numerous researchers, including Shephard and Shek,[34] Schaffer et al.,[35] Harper[36] and Hemmes et al[37], proposed three potential mechanisms to elucidate the observed impact of relative humidity (RH) on microbial transmission. Firstly, RH may act at the host level. Breathing dry air could lead to the desiccation of the nasal mucosal, resulting in epithelial damage and/or declined mucociliary clearance, which consequently increases the host susceptibility to respiratory virus infections. The mucociliary clearance apparatus is an important defense mechanism for clearing the lung of invasive particulate matter[38]. Microbial (viral or bacterial) infections and pollutants may cause derangement of mucociliary clearance[39] and likewise influence the innate rheological features vis the adhesiveness of nasal mucus and/or slowing of ciliary beating according to Salah et al.[40] The second mechanism is that RH may act at the viral particle level. The stability of influenza virions in an aerosol has been reported to vary significantly through a range of RH. The third mechanism is when RH acts at the level of the respiratory droplet. At low RH, water evaporation from exhaled bio-aerosols occurs rapidly, resulting in droplet nuclei formation. Conversely, at high RH, small respiratory droplets adhere to water, enlarge in size and precipitate quickly out of the air. Similar to most theories of aerosol transmission, a conglomeration of these factors is probably involved.

Studies have investigated the survival of the artificially aerosolized virus in a wide range of RH from 15% to 90% with results showing the extreme discrepancy in infectivity and survival. It is widely acknowledged that viruses with lipid envelopes such as influenza, RSV, and herpes viruses, are more stable at lower RH while other studies demonstrate that non-lipid enveloped viruses such as respiratory adenoviruses and rhinoviruses survive longer at higher RHs[41-44]. Human coronaviruses are enveloped viruses and usually have a low survival rate in high humidity. Thus, it will be reasonable to opine that SARS-CoV-2 the causative agent of COVID-19 is usually inactivated in tropical climate due to its high humidity and consequently exhibit low survival rate. This statement aligns with the experimental finding of Casanova et al[45]. The authors study the relationship between inactivation of SARS-CoV and RH, and observed that the survival rate of the virus was greater only at low relative humidity. Our proposition is also strengthened by the observed high transmission rate among air travelers who were responsible for the global spread of the disease at the early stage of the pandemic. The relative humidity in airplanes particularly during the in-flight time usually ranges from 3% to 15%. Hence one can conclude that this extremely low relative humidity and closed environment contribute immensely to the disease contagion. In addition, breathing at low humidity leads to a loss in mucosal water which consequently influences the rate of mucosal clearance.

Building Structure – Ventilation

Room airflow is dependent on an agglomeration of air movements initiated by temperature variations, ventilation, and mobile bodies and facilities. These ambiguous air movements make the path and suspension time of an infectious substance very arduous to predict once it migrates from the infectious host. The primary origins of infectious airborne pathogens in enclosed vicinities are respiratory droplets produced when an infected person coughs, sneezes, breathes, or talks. An extensive literature review depicts that there have been very limited studies on the association between exhalation flows and room ventilation systems. A recent systematic review conducted by Li et al[46]. illustrated that a poor ventilation system escalates the transmission of airborne disease, while an efficient ventilation system can assist in mitigating the spread of infectious particles and subsequently reduce disease transmission. Also, a study by Drinka et al[47]. of a long term care facility reported relationship between influenza infection and ventilation system design in different monuments. Generally, the more the percentage of ambient air circulating in the buildings, the decline in the proportion of patients infected.

Most buildings in the western world are tightly sealed energy-conserving buildings with reduced fresh air ventilation rates compared with buildings in the tropics which are usually designed for adequate ventilation because of warm weather. In most settings where ventilation is copious, the transmission of airborne disease such as COVID-19 is greatly impaired vis-à-vis buildings with a low ventilation system which exacerbate indoor airborne pathogen transmission. Hence, we postulate that the discrepancy in ventilation rate, arising from variations in building design in the tropics and temperate regions; possibly contributes to the high transmission rate of the pandemic in the latter. However, it is essential to clarify that overcrowding even in a well-ventilated room can predispose occupants to airborne infection. This might be responsible for some high number of cases witnessed in some tropical countries etc.

CONCLUSIONS

There is no established proof that any single parameter, whether it be a specific temperature, relative humidity, or geographic location can be universally applied to the diverse infectious viruses to decrease airborne or contact transmission, but there is a convincing fact in the literature that viruses and other infectious agents survival depends partially on environmental conditions.

From the foregoing discussion, it can be concluded that variations in environmental factors such as geographic location, climatic factors or housing design offer a plausible explanation for the discrepancy in the transmission and mortality rate of COVID-19 pandemic experienced in the tropics (especially Africa) and temperate (Europe and Americas) regions. It is worthwhile to note that numerous airborne infectious organisms and even strains of the same pathogen will have diverse conditions under which they may be optimally suppressed or even annihilated. Hence, we recommend that control studies taking into cognizance the relationship between environment and disease be prioritized. Such studies are consequential in the prediction of viral disease transmission, particularly if this results in pandemics like in the case of COVID-19, in order to aid decisions in public health policies at the global level.

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