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Fungal Infections in Plateau State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author LUE designed the study and wrote the first draft of the manuscript. Authors SJS and AAB performed the statistical analysis and wrote the protocol. Authors AHMZ and LHL managed the analyses of the study. Author IJB managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This paper describes a study carried out on people of different ages with various skin diseases who submitted themselves for examination and diagnoses at the Dermatophylosis Research Centre of the National Veterinary Research Institute, Vom, Plateau State, Nigeria. Samples of skin scrapping were collected and cultured on Sabouraud Dextrose Agar (SDA) while some were examined under the microscope for possible morphological identification of the fungi. The results showed that out of the thirty samples analyzed, nine genera of fungi were isolated comprising of *Trichophyton* 10 (33.3%), *Aspergillus* 9 (30%), *Penicillium* 4 (13.32%), *Microsporum* 2 (6.70%), *Epidermophyton* 1 (3.33%), *Trichosporum* 1 (3.33%), *Cryptococcus* 1 (3.33%), *Mucor* 1 (3.33%), and *Cephalosporium* 1 (3.33%).

The study revealed high incidence of human fungal diseases, a situation that calls for good hygiene practices in the study area to mitigate and possibly eradicate the prevalence of human skin diseases in the rural area of Plateau State.

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1. INTRODUCTION

Skin diseases are among the most common health problems worldwide and are associated with a considerable burden. The burden of skin disease is a multidimensional concept that encompasses psychological, social and financial consequences on the patients, their families and on society.

Mycoses are infections of the skin and the underlying tissues caused by fungi. They can be either superficial in the case of ringworm or deep-seated progressive infections like the invasive aspergillosis [1]. Depending on the spread of infections, it could lead to high morbidity and mortality if not adequately diagnosed and treated. Three specific genera of fungi which infect the hair, skin and nails are known as dermatophytes and include *Epidermophyton*, *Trichophyton* and *Microsporum*. They cause dermatophytoses in both man and animals and inhabit the soil [2]. Because of the benign skin lesions and self-limiting nature of dermatophytosis it is not a reportable disease in Nigeria and other tropical countries of the world [2]. Hence the actual prevalence figure for dermatophytoses in many endemic areas of Africa and the world at large is mostly unknown [2].

Human infections caused by pathogenic fungi are different from other infections in that fungi are eukaryotic organisms which have a lot of similarities with the human cells. These identities make it difficult to develop antifungal compounds and giving room for high variability of fungal tropism. Depending on the host immune status, one fungal pathogen can infect multiple tissues in the same patient, resulting in structural changes in the course of infection. The public health importance of fungal diseases is not given its due recognition by the health authorities. While bacterial, viral and protozoa diseases are recognized as important public health issues for centuries [3], invasive mycoses were only widely acknowledged as medically important pathogens in the 1980s [4].

Viral diseases of global pandemic including smallpox, influenza, dengue, Zika, Chikungunya, and currently coronavirus have affected millions of people globally with significant number of deaths in developed, developing, and less developed nations [4,5]. These have resulted in

the generation of knowledge, which has led to the eradication of smallpox [6], the production of effective vaccines [7], and development of diagnostic and preventive tools against influenza [8] and, recently, Zika [9]. The effect of bacterial infections on human health in the course of history has been overwhelming and these have led to the development of effective tools for the prevention, treatment, and diagnosis of bacterial infections [10]. In the past decades, parasitic diseases have adversely impacted on human health globally, which has resulted in the ongoing development of new drugs, vaccines, and diagnostic tests for malaria, sleeping sickness, leishmaniasis, filariasis, and Chagas disease [11]. The same cannot be said of Fungal diseases which for most part of recorded history had low impact on human health.

With the advent of Acquired Immune Deficiency Syndrome (AIDS) in the early 80s and increase in the number of other immunocompromised diseases in humans, some of whom are highly susceptible to fungal infections, the invasive fungal diseases like the systemic mycoses, have adversely impacted on human health. The Global Action Fund for Fungal Infections (GAFFI) has estimated that over one million people go blind each year from fungal keratitis and highlights the devastating impact of focal fungal diseases on individuals with intact immune systems [12]. Fungal spores have been responsible for a significant number of respiratory diseases in over 10 million individuals while about one billion individuals have skin mycoses globally. It has been estimated that over 300 million people of all ages worldwide suffer from a serious fungal infection each year [12]. Out of this number, more than 1.5 million individuals are estimated to die from their fungal disease [13].

Fungal diseases have negatively impacted on human health and annual global new cases of cryptococcal meningitis have been put at about 220,000 resulting in 181,000 deaths mostly in sub-Saharan Africa [14]. Over 400,000 people develop *Pneumocystis* pneumonia annually and die without access to therapy [12]. The objective of the study is to describe some common fungi isolates recovered from people of different ages residing in Plateau State, Nigeria which was hitherto unknown.

2. MATERIALS AND METHODS

2.1 Sampling

People of different ages (Between 2 yrs and 100 yrs) and profession numbering thirty (n=30) including housewives, farmers, teachers, students and school pupils mostly from rural areas of Plateau State voluntarily presented themselves for clinical examination and diagnosis between January, 2019 and December, 2019 at the Dermatophylosis Research Centre, National Veterinary Research Institute, Vom, Plateau State, Nigeria. The lesions were cleaned with 70% alcohol and skin scrapings were collected into white envelopes using sterile surgical scalpel blade (one blade for each patient). Each patient skin scraping was examined by direct microscopy and culture using standard laboratory procedures [14]. The approval of Research Ethics Committee was not required, as the skin scraping was treated as routine diagnostics procedure and not as a procedure performed only for medical experiment

2.2 Direct Microscopy

A part of the skin scrapings was examined by direct microscopy using 10% potassium hydroxide (KOH) to expose the fungal structures for microscopic identification under the 40x objective for all the samples.

2.3 Culture

The remaining part of the skin scrapings were cultured on Sabouraud Dextrose Agar (SDA) and incubated at room temperature (25°C) for 1 to 30 days. Fungal growth were identified and characterized based on macroscopic, microscopic and biochemical characteristics for all the samples.

2.4 Identification and Characterization

All the cultures on SDA plates were examined for identification macroscopically by observing the surface topography, colour, texture and edge of the fungus, while the reverse was examined for pigmentation, colour and growth of mycelia into the medium. The microscopic morphological examination, biochemical and physiological characteristics were observed according to [14] for all the samples.

3. RESULTS

Clinical history: The patient (20 years old female student) experienced pruritis of the

feet and palms a year prior to presentation, the affected parts turned black. She treated with flucazole and ketoconazole and the rashes cleared but after some months the rashes reappeared. She has also used local herbs.

Dx: Epidermophyton floccosum isolated from the culture.



Plate 1. Microscopic view of *Epidermophyton floccosum* with ramified and septate hyphae, partly bulb-shaped and thickening at the end and *Epidermophyton floccosum* on SDA

History: The patient (100 years old female house wife) has skin rashes on both legs and hands and parts of the body. It started four years ago and the patient was treated with unspecified drugs and there was relief but the rashes resurfaced after sometime. Clinical history: The skin rashes started four years ago with lesions below the eyes, head and some parts of the body of 26 years old female house wife. She did not institute any kind of treatment. The skin rashes itches her always.

Dx: Aspergillus flavus was isolated from the culture (SDA)

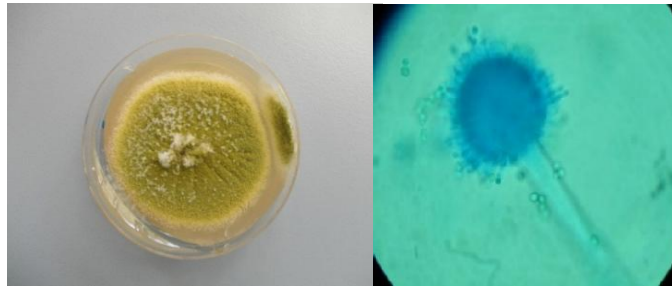


Plate 2. *Aspergillus flavus* on SDA and microscopic view of *Aspergillus flavus*

Clinical History: The patient (14 years old male student) has skin rashes on the face and part of the body which started about ten (10 yrs) years ago. The skin rashes itches him sometimes. The patient treated with gentamycin ointment, ampiclox capsules, 3-G cream and sulphur ointment. The rashes subsided but later resurfaced.

Clinical history: The patient (3 years old female pupil) has generalized skin rashes all over her body and it started one year ago. She was treated with 3K-cream and the rashes subsided only to resurface after sometime. Clinical history: He has pimple like skin rashes on his face and parts of the body which started three weeks ago. The skin rashes itches him sometimes. The patient (22 years old male student) was treated with 3 K cream, vitamin C and other drugs but the skin rashes continued. Clinical history: She has skin rashes on both legs and parts of the body which started four years ago. The skin

rashes itches her always. The patient (18 years old female student) had treated with funbact A cream, black soap, and ampiclox capsules but the skin rashes continued.

DX: *Penicillium* spp was isolated from the culture.

Clinical history: Clinical history: The patient (25 years old male civil servant) has skin rashes on the groin part of the body which itches him a lot. It all started about one year ago. The patient treated with local herbs and cream. The rashes will subside only to resurface. The patient (50 years old female house wife) has skin lesions on her face and parts of her body. It started itching her about two years ago. The patient treated the lesions with Dermacur 3m soap and ointment but the lesions persisted.

Dx: *Aspergillus fumigatus* was isolated from the culture.

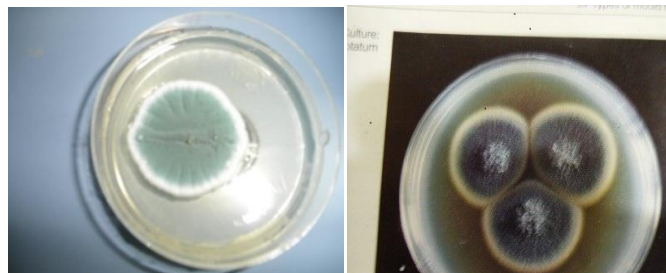


Plate 3. *Penicillium* spp. on SDA

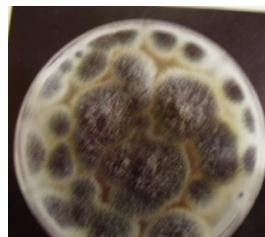


Plate 4. *Aspergillus fumigatus* on SDA

Clinical history: It all started with tiny skin rashes on the stomach and parts of the body of a 7 years old female pupil since childhood and it does not itch her. The patient was treated with various drugs including Demacur 3 m soap and ointment, fulcin syrup and funbact cream. The skin rashes subsided only to resurface after sometime. Clinical history: The patient (42 years old female business woman) has skin rashes all over her body and it has been there for the past three weeks. The rashes itch her always. The patient treated with various drugs including epiderm cream, conenole, cetrazine, hydrocortizone tablets, metdzine and betametal. The rashes will subside only to resurface. Clinical history: It started one year ago with skin rashes on his private part (groin) and face. The itching sensation comes from time to time. The patient (53 years old male civil servant) had treated with various drugs including skin gel, funbact A cream, and skineal cream. The skin rashes will subside but after sometime it will resurface.

Dx: *Aspergillus niger* was isolated from the culture

Clinical history: Clinical history: It started eight months ago with dandruff like skin rashes on the head, neck, chest, back, both legs and parts of the body. The patient (42 years old female

teacher) had treated with skineal cream, lodretidine tablets, etc. The skin rashes will subside but after sometime it will resurface. The patient (48 years old male civil servant) started observing skin lesions on the body and at the back of his neck since two years. He treated with Demacur 3 m soap and ointment but the skin lesions persisted.

Dx: *Trichophyton* spp was isolated from the culture at room temperature.

Clinical history: She is a thirteen years old student. She observed some rashes with black spots on the skin of the fingers of both legs. Though painful, but it does not itch her and it all started three months ago. The patient was treated with different drugs without improvement.

Dx: *Trichophyton mentagrophytes* was isolated.

Clinical history: Forty-five years old female teacher. She has skin rashes all over her body and it has been there for the past ten years. The rashes does not itch her. The patient treated with various drugs including fulcin tab. Ketrax. funbactA cream etc. the rashes will subside only to resurface.

Dx: *Trichophyton rubrum* was isolated from the culture at room temperature.



Plate 5a. *Aspergillus niger* on SDA. b. Microscopic view of *Aspergillus niger*



Plate 6a. *Trichophyton* sp on SDA. b. Microscopic view of *Trichophyton* spp



Plate 7. *Trichophyton mentagrophytes* on SDA



Plate 8. *Trichophyton rubrum* on SDA

Clinical history: The skin rashes started three years ago with lesions all over his body (32 years old male farmer). The rashes itches him from time to time. He treated with

piriton tablet, cream etc. The skin rashes will subside but after sometime it will resurface. Clinical history: He has skin lesion on his abdomen and back parts of the body which started a year ago. The skin rashes does not itch him. The patient (19 years old male student) had treated with dermacur soap and Dettol soap and cream but the rashes skin rashes will subside but after sometime it will resurface.

Dx: Microsporum spp was isolated from the culture.

Clinical history: It started two years ago with skin rashes on both legs and parts of the body. She always have itching sensation. The patient (18 years old female tailor) had treated with various drugs without improvement. The skin rashes will subside but after sometime it will resurface.

Dx: Trichophyton megninii was isolated from the culture.

Clinical history: It started one and half years ago with skin rashes on his private part (groin). The itching sensation comes from time to time. The patient (28 years old male student) was treated with various drugs including ketocornazole tablet and cream, clindamycin tablets and flagyl. The skin rashes will subside but after sometime it will resurface.

Dx: Trichophyton schoenleinii was isolated from the culture.



Plate 9. *Microsporum* spp



Plate 10. *Trichophyton megninii* on SDA

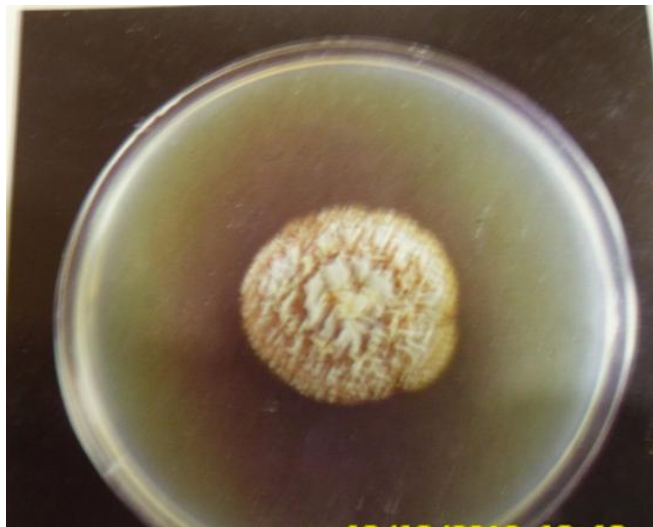


Plate 11. *Trichophyton schoenleinii* on SDA



Plate 12. *Trichophyton equinum* on SDA

Clinical history: Five months ago, she started observing some skin rashes on her right leg and parts of her body. The skin rashes is always itching her. The patient (70 years old female house wife) had treated with ciprofloxacin and ketazole tablets. The skin rashes will subside but after sometime it will resurface.

Dx: Trichophyton equinum. was isolated from the culture.

Clinical history: He has skin lesion on both hands and legs and parts of the body which started two years ago. The skin rashes does itch him from time to time. The patient (56 years old

male public servant) had treated with various drugs but the rashes will subside but after sometime it will resurface.

Dx: *Trichophyton verrucosum* was isolated from the culture.



Plate 13. *Trichophyton verrucosum*

Clinical history: The patient (27 years old female poultry farmer) has skin lesions all over her body which started one and half years ago. The skin rashes does itch hem always. The patient had treated with various drugs but the rashes skin rashes will subside but after sometime it will resurface.

Dx: *Cryptococcus neoformans* was isolated from the culture.



Plate 14. *Cryptococcus neoformans*

Clinical history: He has pimple like skin rashes on the face and skin patches on his head and the rest of his body which started six months ago.

The skin rashes does itch him always. The patient (28years old male applicant) had treated with ketoconazole cream and tablets and the skin rashes will subside but after sometime it will resurface.

Dx: *Trichosporon cutaneum* was isolated from the culture.



Plate 15. *Trichosporon cutaneum*

Clinical history: She has skin rashes on both legs and parts of the body which started four years ago. . The skin rashes itches her always. The patient (18 years old female student) had treated with funbact A cream, black soap, and ampiclox capsules but the skin rashes continued.

Dx: *Mucor spp.* was isolated from the culture.



Plate 16. Microscopic view of *Mucor spp*

Clinical history: He has pimple like skin rashes on his face and parts of the body which started a year ago. The skin rashes itches him sometimes. The patient (24 years old male student) had treated with ampiclox capsules, acneoway cream and other drugs but the skin rashes continued.

Dx: Cephalosporium spp. was isolated from the culture.



Plate 17. Cephalosporium spp.

Clinical history: Generalized skin infection which started two months ago. The affected area itches her always. The patient (2 years old female child) was treated for chicken pox without improvement.

Dx: Trichophyton tonsurans was isolated from the culture.

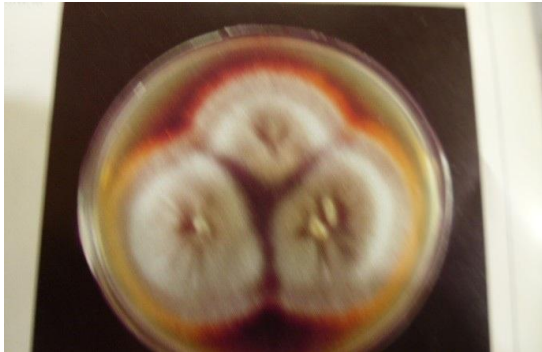


Plate 18. Trichophyton tonsurans

4. DISCUSSION

The effect of environmental factors and the activities of public health managers to a greater extent determine the health status of the people. Fungal diseases are always associated with unhygienic environment which is characteristic of rural areas where people are denied access to basic social amenities. This is why fungal diseases and other infectious diseases are endemic mostly in underdeveloped and developing tropical countries. In spite of the devastating impact on human health, fungal diseases have not received the desired attention

globally. The people examined in this study are from the rural area with poor hygiene, inadequate medical facility, poor environmental sanitation and poor or non-existent water supply. Therefore, the isolation of different genera of fungi from these patients is in tandem with the submission of Molyneux [15] who reported that neglected tropical diseases have particular characteristics, affecting the poorest people without access to safe drinking water, sanitation, and basic health services.

Table 1. Genus distribution of fungi isolates

Genus	Number of isolates	Frequency (%)
Trichophyton	10	33.30
Epidermophyton	1	3.33
Microsporum	2	6.70
Aspergillus	9	30.03
Penicillium	4	13.32
Cephalosporium	1	3.33
Trichosporium	1	3.33
Mucor	1	3.33
Cryptococcus	1	3.33
Total	30	100

The results from this study showed mixed isolates of dermatophytes and non-dermatophytes. While the superficial mycoses observed among the patients may have resulted from their interaction with the domesticated animals in their homes which are either infected or carriers. This is in agreement with the findings of Chukwu [16] who reported that superficial fungal infections are among the commonest infectious diseases and constitute the bulk of mycotic infections. Females are the most affected, because in this part of the world females are mostly involved in farming and domestic works and interact closely with the domestic animals. *Trichophyton* and *Aspergillus* are the most prevalent dermatophytes and non-dermatophytes respectively probably because dermatophytes are more keratinophilic in nature than non-dermatophytes. Fungal infections develop gradually and are usually chronic, becoming progressively worse if not treated. The damage these diseases cause can be irreversible. Again, neglected tropical diseases can cause severe pain and disability throughout life, with long-term consequences for patients and families of the affected person. People with neglected tropical diseases are often stigmatized and socially excluded, which can affect their mental health. High-income groups are rarely affected.

Table 2. Genus distribution of fungi isolates based on age groups and sex

Genus	Age groups (YEARS)					Sex	Isolates	Frequency (%)
	2-20	21-40	41-60	61-80	81-100			
<i>Epidermophyton</i>	1					F	<i>Epidermophyton floccosum</i>	3.33
<i>Microsporum</i>	1	1				M	<i>Microsporum spp</i>	6.66
<i>Trichophyton</i>	1					F	<i>T. tonsurans</i>	3.33
	1		1			F	<i>T. mentagrophytes</i>	6.66
			1			M	<i>T. mentagrophytes</i>	3.33
		1				F	<i>T. rubrum</i>	3.33
			1			F	<i>T. rubrum</i>	3.33
	1					F	<i>T. megninii</i>	3.33
		1				M	<i>T. schoenleinii</i>	3.33
				1		F	<i>T. equinum</i>	3.33
			1			M	<i>T. verrucosum</i>	3.33
<i>Aspergillus</i>	1					F	<i>A.flavus</i>	3.33
		1				F	<i>A. flavus</i>	3.33
			1			F	<i>A. flavus</i>	3.33
			1			M	<i>A. flavus</i>	3.33
		1				M	<i>A. fumigatus</i>	3.33
			1			F	<i>A. fumigatus</i>	3.33
	1					F	<i>A. niger</i>	3.33
			1			F	<i>A. niger</i>	3.33
			1			M	<i>A. niger</i>	3.33
<i>Penicillium ssp.</i>	2					F	<i>Penicillium sp</i>	6.66
	1					M	<i>Penicillium sp</i>	3.33
<i>Penicillium sp</i>	1					M	<i>Penicillium sp</i>	3.33
<i>Cryptococcus sp.</i>		1				F	<i>Cryptococcus neoformans</i>	3.33
<i>Trichosporon sp.</i>		1				M	<i>Trichosporon cutaneum</i>	3.33
<i>Mucor sp.</i>	1					F	<i>Mucor sp.</i>	3.33
<i>Cephalosporium sp.</i>		1				M	<i>Cephalosporium sp.</i>	3.33

There is no clear recognition of the importance of fungal diseases by international health agencies. For example, the World Health Organization (WHO) has recently included mycetoma, chromoblastomycosis, and “other deep mycoses” in the list of neglected tropical diseases [16] but specific information on WHO plans to combat fungal diseases is not yet available. [17]. Although these diseases are associated with high rates of mortality, generation of conditions that hinder the performance of professional functions and social integration [14], none of them has been formally recognized as neglected diseases by WHO.

According to Morel [18], neglected diseases persist due to failures in science, market, and public health. Science failures occur when there is insufficient knowledge on the pathophysiology of infectious agents and the host response. Market failures are usually observed in diseases

against which medicines or vaccines exist but at a prohibitive cost. Finally, public health failures occur in syndromes against which low cost or even free prophylactic tools and medicines are available but their use is limited by poor logistics and lack of governmental support.

Fungal diseases are clearly affected by the 3 types of failures described above. In this field, there has been a significant failure in science compared to diseases of medical importance recognized for decades or centuries, as previously mentioned. Of course, significant gaps in knowledge generation rates exist. Fungal infections consist of pathogenic processes triggered by eukaryotic microorganisms, which hinders the development of drugs that are toxic to the pathogen without affecting host tissues.

The fact that there are no licensed antifungal vaccines underscores another clear failure in

science. Similarly, reliable diagnostic methods are available for a very limited number of mycoses [19], and therapeutic options are restricted to a few classes of drugs that too frequently are associated to both intrinsic and acquired resistance [20], toxic, and expensive [21]. In fact, innovative tools to combat invasive mycoses are rare and of slow development. For illustration, the most recently developed antifungals (echinocandins) were approved for clinical use in 2002 [22], reinforcing a major science failure in the area. It is noteworthy that this class of drugs is ineffective against various high-mortality mycoses [21].

Market failures have a profound impact on the control of fungal diseases. The deadliest fungal infections affect neglected populations, which results in a reduced market for drug commercialization and lack of interest from the pharmaceutical sector in the development of medicines, vaccines, and diagnostic tests for human mycoses. The main drug historically used for the treatment of severe disseminated mycoses is amphotericin B (AmB), whose discovery dates to 1955 [23], and it remains the standard first-line medication for certain fungal infections, such as cryptococcal meningitis. AmB formulations used for invasive fungal infections vary greatly in efficacy, safety, and cost. Conventional formulations are usually affordable but include significant side effects. The most effective and least toxic formulation is liposomal AmB, which can generate costs of up to US\$100,000 per patient in different parts of the globe, including developing countries [24].

Liposomal AmB is highly effective when used in combination with other drugs. This pharmaceutical preparation was recommended by WHO as the preferred treatment for cryptococcal meningitis [25]. However, the high prices and unavailability of liposomal AmB in several countries have created major barriers to access to the most recommended treatment—as recognized by WHO itself in developing countries. Liposomal AmB is registered and available for use (at high cost) in only 6 of 116 developing countries where fungal meningitis is a public health problem [12]. Prices are impeditive in many countries, revealing an unquestionable market failure.

Public health failures also impact fungal diseases negatively. According to GAFFI [12], several major antifungals are not available or registered in various regions where fungal diseases are

most lethal. 5-Fluorocytosine, a low-cost antimetabolite that is beneficial to a number of patients with systemic mycoses when used in combination with other antifungal drugs, is not available and/or registered in many countries, including those highly affected by systemic mycoses [12]. Given the intrinsic difficulties and high costs of drug development and the evident market and public health failures in this field, it is more realistic and impactful to make rational use of the diagnostic and antifungal tests already available to minimize the number of deaths caused by fungal diseases. In a recent study, Denning [26] proposed actions to reduce deaths from fungal diseases on the basis of currently available diagnostic tests and generic antifungals. Assuming that diagnostic tests would be properly applied and that antifungal therapy would be administered promptly and following current international guidelines, it was estimated that by 2020 annual deaths from cryptococcal meningitis could fall from 180,000 to 70,000. Deaths due to *Pneumocystis* pneumonia would fall from 400,000 annually to 162,500. The 80,000 annual deaths attributable to disseminated histoplasmosis could be reduced by 60%. Annual deaths due to chronic pulmonary aspergillosis (56,288) could fall by 33,500. These actions would thus result in a total of 1 million lives saved over 5 years. Of course, the effective implementation of AIDS control and prevention campaigns in areas lacking such programs would also positively impact the reduction in deaths caused by fungal infections. Such actions have the potential to minimize a clear public health failure on the basis of the use of existing tools for diagnosing and treating invasive mycoses.

There are ongoing initiatives to develop antifungal vaccines and drugs with the potential to control invasive mycoses [27]. However, the distance between promising laboratory results and the translation of knowledge into benefits to the general population is unquestionably long. In fungal diseases, this distance is apparently longer, considering the lack of investment in science and technology in association with the science, market, and public health failures discussed here. The situation is even more complex if one considers the emergence of multiresistant and still largely unknown pathogens such as *Candida auris*. The impact of emerging infections of this nature on human health is still hard to predict, but, as *C. auris* is now spread across the globe, the reality is that such infections can lead to significant morbidity and mortality as well as have vast economic

consequences. Thus, it seems clear that public health authorities and decision-makers need to more thoughtfully and closely consider invasive fungal diseases as a real and contemporary problem to avoid disasters historically observed in other models of infectious diseases. The fact that fungal diseases are not spread at the same rate as other microbial transmissible diseases causing epidemics does not mean they are less relevant in terms of the number of attained individuals. Furthermore, the fact that they are less studied represents an enormous risk given the new potential threats as a consequence of environmental deterioration and global warming.

Realistic discussions about how prevention, diagnosis, and control of fungal diseases will improve outcomes demand a separation between concrete actions using currently available tools and future preventive actions. Of course, prophylactic actions against as yet unknown conditions are complex and difficult to develop, but the recent history of emerging fungal diseases reveals a clear need for knowledge generation on fungal pathogens. The attention to emerging fungal pathogens is important because even in the case they do not cause disease to humans due to new and as yet unknown zoonosis, they can affect animal health with an impact in the economy. Also, they can affect wild animals with an unpredictable ecological impact on biodiversity. Stimulating basic science and innovative activities in the area is therefore essential to reduce the impact of poorly known or yet unknown fungal diseases on human health.

On the basis of currently available therapeutic and diagnostic tools, short- and medium-term impact actions also need to be implemented.

5. CONCLUSION

Support for basic research and technological development is obviously important, but making health professionals and decision-makers aware of the profound and ongoing impact of fungal diseases on human health is essential. The current situation, however, raises serious concerns, considering the funding limitations in the area and lack of public programs for prevention and control of fungal diseases. The high incidence of invasive mycoses in AIDS patients and the recent examples of *C. auris* and *E. rostratum* demonstrate that, without game-changing actions, the perspective on how fungal

diseases will impact human health in the coming decades is extremely negative.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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