



## General review

## The estimated burden of fungal diseases in Mali

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## ABSTRACT

Mali is a developing country facing several health challenges with a high rate of tuberculosis (TB) and a moderate HIV infection burden. Little is known or done about fungal diseases, yet they represent a significant public health problem in certain populations. The aim of this study was to estimate the national burden of fungal disease, and summarize data, diagnostic and treatment gaps. We used national demographics and PubMed searches to retrieve articles on published data on these infections and at-risk populations (pulmonary TB, HIV/AIDS patients, patients receiving critical care etc.) in Mali. The estimated Malian population was 21,251,000 in 2020 (UN), of which 45% were children <14 years. Among HIV patients, we estimate an annual incidence of 611 cryptococcosis, 1393 *Pneumocystis pneumonia*, 180 histoplasmosis and >5,700 esophageal candidiasis and some microsporidiosis cases. Our prevalence estimates for tinea capitis are 2.3 million, for recurrent vulvovaginal candidiasis 272,460, ~60,000 fungal asthma and 7,290 cases of chronic pulmonary aspergillosis (often mistaken for TB). Less common acute fungal infections are probably invasive aspergillosis (n=1230), fungal keratitis (n=2820), candidaemia (>1,060) and mucormycosis (n=43). Histoplasmin was found in 6% in general population. A few cases of mycetoma are described in Mali. Many WHO Essential medicines and Diagnostics are not available in Mali. This shows a marked disparity in documented and estimated cases of fungal diseases in Mali. These infections are underestimated due to the lack of accurate diagnosis tools and lack of support for fungal diseases diagnosis and management.

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## Introduction

With an area of 1,240,190 square kilometers, Mali is the second largest country in West Africa, after Niger. Stretched out between **17 00 N and 4 00 W** from the Sudanese savannahs in the south to the Saharan desert margins in the north, Mali has little relief, consisting of plains and low plateaus rarely exceeding 350 meters.

Over the last twenty years, Mali has defined policies that have served as a reference framework for all social and health development projects and programs. The Sectoral Health Policy was adopted in 1990 and reconfirmed and enshrined in 2002. Its main objectives are: (i) improving the health of the population, (ii) extending health coverage and (iii) seeking greater sustainability and performance of the health system.

Fungal diseases are responsible for serious and mostly silent diseases. They cause significant mortality in people at risk. Nearly 2 million people die from invasive fungal infections each year in the World [1]. Invasive fungal infections have emerged worldwide as an increasingly frequent cause of opportunistic infections [2]. However, their impact is not well recognized or appreciated compared to other diseases of medical importance. In the case of fungal diseases, there is a wide disparity in access to diagnostic and treatment services in resource-limited countries, particularly in sub-Saharan Africa. [3]

Patients at greatest risk are those with underlying medical conditions, including advanced HIV disease, solid organ and hematopoietic stem cell transplantation (HSCT), chronic obstructive pulmonary disease (COPD), those taking immunosuppressive drugs for rheumatoid arthritis and other inflammatory conditions, prematurity, advanced age, major surgery, trauma, burns and cancers requiring major surgery and/or chemotherapy. In Sub Saharan Africa, HIV is one of the most important factors associated with fungal diseases. Of the estimated nearly 38 million people living with HIV (PLHIV) globally at the end of 2018, over 60% (~ 25.7 million) are found in SSA alone

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**Table 1**  
Proportion of the population according to fungal diseases

| Specific population at risk                                    | Estimated prevalence | Proportion estimated to have a fungal disease  | Reference   |
|--|----------------------|--|---|
| HIV infected adults  | 96,000               |  | UNAIDS, 2020 [9]  |
| ADH in adults, including an 11% ART failure or resistance rate | 11,980               | 5.1% cryptococcal meningitis<br>9% PCP<br>1.5% histoplasmosis<br>20% of ADH + 5% of those taking ARVs esophageal candidiasis | Minta, 2011 [18]<br>Traoré M et al [19]   |
| HIV infected children  | 14,000               | 6.8% PCP among children dying of pneumonia   | UNAIDS, 2020; [9] Lanaspá, 2015 [20]<br>Pneumonia deaths 12% Campbell & al [14] |
| AIDS deaths  | 4,600                | 4% with invasive aspergillosis   | Antinori, 2009 [21]   |
| Pulmonary TB   | 9,240                | 8,408 in HIV negative people and 7,820 surviving people. CPA incidence (~12.7%) and prevalence (~59%)                        | WHO, 2020 [22]<br>Denning, 2016 [23]  |
| Asthma in adults   | 1,501,700            | 12.8% of the adult population<br>ABPA, 2.5% of adult asthmatics<br>SAFS, 3.3% of adult asthmatics                            | Adeloye [16]<br>Denning 2013 [24]   |
| COPD   | 680,000              | 3.2% of the population, admission to hospital 10.5% and 1.3% with IA   | Hammond, 2020 [25]  |
| Lung cancer  | 331                  | 2.6% with IA   | Globocan, 2020 [15]<br>Yan et al, 2009 [26]                                     |
| Acute myeloid leukaemia  | 531                  | 2.5/100,000, and 13% with IA, and an equal number in all other hematological malignancy patients                             | Chen, 2019 [27]   |

[4,5]. On the African sub-continent, three countries including Mali have high rates of diabetes, as the work of the World Diabetes Foundation highlighted [6]. Pulmonary tuberculosis and other lung problems leave patients open to developing aspergilloma and chronic pulmonary aspergillosis.

Taking account of the limited availability of diagnostic tests in many low-income countries, fungal infections are often not diagnosed at all, or diagnosed very late, leading to an underestimation of the incidence and prevalence of most fungal diseases [6]. Indeed, across the World death due to fungal infections are similar to the number of people dying from TB [7]. In recent years, many African countries have estimated the burden of fungal diseases at the population level [6,8–11].

In the last three decades Mali's health system has faced considerable issues, most notably the demand for providing healthcare services for the control of HIV and associated tuberculosis (TB), endemic infections such as malaria and Neglected Tropical Diseases as well as for other diseases such as diabetes, malignancies and overuse of some drugs such as corticosteroids. From the latest WHO data published in 2018, diabetes mellitus deaths in Mali reached 2,438 or 1.49% of total deaths [6]. In Mali, the age-standardized incidence for all cancers is high compared with rates reported elsewhere in West Africa (119.6 per 1,000,000) [7] and hematological malignancies correspond to an annual mean of 33 cases per million [8]. Despite the frequency of these risk factors, fungal disease has not been prioritized. Thus, in this study, we sought to provide estimates of the burden of fungal infections by using studies published at country level.

## Methods

We searched PubMed, Embase, Web of Science, and the African Journals Online databases to select studies in English and French reporting the incidence and prevalence of fungal diseases alone or associated with other diseases. The search terms included 'fungal infections and Mali', specific underlying conditions (e.g., "chronic obstructive pulmonary disease", aspergillosis, histoplasmosis, invasive fungal diseases, yeast, dermatophytosis, mycetoma etc.), and specific fungal infections (e.g., "invasive aspergillosis"). We had considered all articles published in French and English. The time period for the search was all dates up to June 2021.

Populations at risk were also determined (Table 1). The total, children (age 0–14 years) and female in their reproductive years (15–49 years) were obtained from United Nations statistics for 2020 [9]. HIV estimates were from UNAIDS, and the population of adults assumed to be those failing antiretroviral therapy (ART) (11%) [9–13] and those not started on ART having a 7 year decline in immunity to <200 CD4 cells /mm<sup>3</sup>. All children HIV positive not on ART were deemed at risk. There are an estimated 12,560 childhood deaths from pneumonia in Mali each year [14]. Pulmonary tuberculosis (TB) data was derived from WHO for 2020 [18]. Leukaemia patient numbers were taken from the WHO estimate for acute myeloid leukaemia for low-income countries (2.5/100,000) and lung cancer from Globocan for 2020 [15]. An estimate of the prevalence of asthma in adults (12.8%) was taken from Adeloye et al [16]. Chronic Obstructive Pulmonary Disease (COPD) prevalence (3.2% of the population) was estimated from Hammond et al (2020) [17]. There are no diagnosed cystic fibrosis cases in Mali and no transplant procedures are undertaken.

The actual risk of a fungal infection in each patient group was derived from multiple sources, some from Mali, some from other African countries and others internationally (Table 1). A deterministic model was built from these data, of both annual incidence for acute and life- or sight-threatening fungal infection, or prevalence for chronic fungal disease.

## Results

Mali had an estimated population of 21,251,000 in 2020 (UN), of which 47.69% were children up to the age of 14 and an estimated 4,752,212 were women between the ages of 15 and 54 years old. The GDP per capita was \$859 in 2020 with gold and cotton is the main exports. The proportions of the population with various underlying conditions relevant to fungal disease are shown in Table 1. The estimated total fungal disease is 2,729, 670, 12.8% of the population, dominated by tinea capitis in school aged children (Table 2).

ADH = advanced HIV disease; ART = antiretroviral therapy; PCP = *Pneumocystis pneumonia*; TB = tuberculosis; ABPA = allergic bronchopulmonary aspergillosis; SAFS = severe asthma with fungal sensitization; COPD = chronic obstructive pulmonary disease.

**Table 2**  
Estimated burden of serious fungal diseases in Mali

| Infection                                      | Incidence or prevalence | Number of infections per underlying disorders per year |           |             |        |     | Rate/ 100K | Total burden |
|--|-------------------------|--|-----------|-------------|--------|-----|------------|--------------|
|  |                         | None   | HIV/ AIDS | Respiratory | Cancer | ICU |            |              |
| Cryptococcal meningitis                        | I                       | 87   | 611       | -           | -      | -   | 3.3        | 698          |
| PCP in adults                                  | I                       | -  | 539       | -           | -      | -   | 2.5        | 539          |
| PCP in children                                | I                       | -  | 854       | -           | -      | -   | 9.0        | 854          |
| Histoplasmosis                                 | I                       | -  | 180       | -           | -      | -   | 0.9        | 180          |
| Oesophageal candidiasis                        | I                       | -  | 5,736     | -           | -      | -   | 27         | 5,736        |
| Invasive aspergillosis                         | I                       | -  | 184       | 928         | 115    | -   | 5.8        | 1,227        |
| Mucormycosis                                   | I                       | -  | -         | -           | 43     | -   | 0.20       | 43           |
| Chronic pulmonary aspergillosis                | P                       | -  | -         | 7,290       | -      | -   | 34         | 7,290        |
| Allergic bronchopulmonary aspergillosis (ABPA) | P                       | -  | -         | 37,540      | -      | -   | 177        | 37,540       |
| Severe asthma with fungal sensitisation (SAFS) | P                       | -  | -         | 49,560      | -      | -   | 233        | 49,560       |
| Candidaemia                                    | I                       | -  | -         | -           | 744    | 319 | 5          | 1,063        |
| Candida peritonitis                            | I                       | -  | -         | -           | -      | 159 | 0.8        | 159          |
| Recurrent vaginal candidiasis (>4 times/year)  | P                       | 272,460  | -         | -           | -      | -   | 1282*      | 272,460      |
| Tinea capitis                                  | P                       | 2,341,670  | -         | -           | -      | -   | 11,020     | 2,341,670    |
| Fungal keratitis                               | I                       | 2,826  | -         | -           | -      | -   | 13.3       | 2,826        |
| Total burden estimated                         |                         |  |           |             |        |     |            | 2,729, 670   |

PCP = *Pneumocystis pneumonia*; \* Females only

IA= Invasive Aspergillosis, HIV= Human Immunodeficiency virus, CPA= Chronic Pulmonary Aspergillosis, ARVs= AntiRetroViral

Several epidemiological or descriptive studies were included in our analysis of which some were cited in Pubmed, AJOL database and a case report from a non-indexed online journal (Table 2).

### Cryptococcosis

Cryptococcal meningitis is a frequent opportunistic infection in AIDS patients and common in Africa. Most of the clinical presentations are meningitis forms. It is the cause of early mortality in HIV-infected patients accounting for between 13% and 44% in developing countries. WHO advises rapid diagnosis, prevention and management of cryptococcal disease in HIV-infected adults, adolescents and children in guidelines first issued in 2011, and updated since [28].

In Mali in 2003, Minta & al reported 14 HIV patients suffering for *Cryptococcus neoformans* infection, 85.7% (n=12) of cases were HIV positive for the first time in Mali [29]. The clinical presentation was dominated by headache in 85.7% of cases, altered consciousness in 50% and nausea/vomiting in 35.7%. From 2004 to 2008 the prevalence of cryptococcosis in Malian studies increased from 3.1% to 30.9% [30]. These diagnoses were based on presence of encapsulated yeast of *Cryptococcus* in the direct exam by China ink and culture from cerebrospinal fluid (CSF), pleural effusion or aspirated fluid from an acromio-clavicular abscess [31,32,33]. One case was reported in a 32-year-old female patient, without any known immunosuppressive factor and without a notable medical history who died despite 16 days of fluconazole [34].

We estimate that nearly 700 people in Mali suffer from cryptococcal meningitis annually, mostly in HIV-infected individuals (3.3/100,000) (Table 2).

### Histoplasmosis

The first case of histoplasmosis in Mali was described by Catanei and Kervran (1945) and attributed to *H. capsulatum var. duboisii* [35]. Histoplasmin skin test was positive in almost 6% of the general population in 1960s [36]. Since then, there are limited incidence cohort data on histoplasmosis in Mali. *H. capsulatum var. duboisii* is the most frequent variety described through limited studies in adult patients, mostly cutaneous or mucosal forms [37–41]. No disseminated cases in AIDS or pulmonary histoplasmosis have been described, and no cases attributable to *H. capsulatum var. capsulatum*. We have

provisionally estimated the incidence of histoplasmosis in HIV patients to be 180 patients annually (Table 2), but this needs corroboration with clinico-epidemiology study.

### *Pneumocystosis*

*Pneumocystis jirovecii* (previously *Pneumocystis carinii*) is most commonly associated with AIDS. No cases are published from Mali yet. However, we have conservatively estimated that 539 adults and 854 babies and children (Table 2) develop *Pneumocystis pneumonia* annually, much of which is unrecognized and contributes to the overall HIV deaths of 4,600 per year.

### *Invasive aspergillosis and mucormycosis, chronic pulmonary aspergillosis and fungal asthma*

Invasive aspergillosis (IA) is probably uncommon in most of sub-Saharan Africa because of the general lack of high intensity cancer treatments, transplantation and less aggressive immunomodulatory treatment for immunological disorders. We described *Aspergillus* spp. exposure in an oncohematological ward with the major species circulating in the air being *A. fumigatus* followed by *A. niger* [42]. Recently one case has been described in a HIV patient who developed both tuberculosis and aspergillosis, based on antigen positivity in association with a cavitary lesion containing a nodular opacity in an immunocompromised HIV patient [43].

Mali estimate for invasive aspergillosis reflects several at risk groups: leukaemia (100+ cases), lung cancer (9 cases), as a cause of AIDS deaths (184 cases) and in those with a COPD exacerbation admitted to hospital (928 cases). The estimated total annual incidence is 1227 (5.3/100,000) (Table 2). Based on an annual incidence in other countries we tentatively estimate 43 cases of mucormycosis annually, which may be an under-estimate given the high prevalence of diabetes in Mali (1.28%), which is often poorly controlled. [44]

Our annual incidence estimate of chronic pulmonary aspergillosis is 1,177 cases comprising incorrectly diagnosed cases of TB, dual TB and aspergillosis infections and CPA emerging during or immediately after TB therapy. Probably about 20% of these patients die (121), although more work is needed nationally and internationally to confirm this. Over the preceding five years, an estimated additional 4,426 cases probably arise primarily in those with a cavity left after completion of anti-tuberculous therapy, and that 7.5% die annually in the second to fifth year after developing CPA (50% over 5 years).

Furthermore, we have assumed that CPA related to TB comprises 67% of the total prevalence, so the total CPA prevalence is estimated to be 7,291 cases (35/100,000) (Table 2).

In Mali few studies were carried out to explore asthma in the population level. From December 1997 to November 1998, a prospective study in adults showed 14.9% of asthma in-patient whose lung function was assessed by measurement of peak expiratory flow [45]. Most of them were female (55.7%). Based on peak expiratory flow measurements, intermittent asthma was the most frequent type of asthma observed (37.8%), followed by moderate persistent asthma (34.4%), mild persistent asthma (18%) and severe persistent asthma (9.8%) [45]. In 2006, the frequency of asthma was 8.24% (131/1595 consulting patients) and men were exposed to women. The antecedent of family asthma was found in 46.6% of the cases, and tobacco smoking in 13% of the cases. Mean age in both studies was 31 years old [45,46].

There are no allergy skin test studies from Mali with respect to airborne fungal allergens. However, using proportions of affected people from other countries, we estimate about 37,500 patients with ABPA, 49,500 with severe asthma with fungal sensitization (Table 2). There is probably some overlap between these groups (ie ~30%), so perhaps the total affected adult population by fungal asthma is more likely to be about 60,000. We have not estimated the number of affected children, due to a global lack of data.

### Candidiasis

Oral candidiasis occurs frequently in HIV-infected patients. It has been described in HIV patients in Mali in many studies. The point prevalence of oral candidiasis varies from 24% to 53%, along with a few other oral pathologies [47,48,49]. In recent years in patients living with HIV, a meta-analysis showed a significant decline in oral candidiasis between 1996 and 2015 (from >65% to as low as <10%) in Sub Saharan Africa (SSA). We have not estimated oral candidiasis in HIV, but the more serious esophageal candidiasis probably affects in excess of 5,700 affected patients annually (27/100,000) (Table 2). In Mali from the HIV patient, mycotic esophagitis was associated with 12% of the deaths due to opportunistic infections. [19]

### Vulvovaginal candidiasis

Using a conservative international estimate of 6% of women in their fertile years developing recurrent VVC, we estimate the annual prevalence to be ~272,500 affected (1281/100,000 females) (Table 2). VVC is underestimated in Mali. Some medical theses showed a high prevalence of the VVC in 1989 to 1992, 1993 and 2009 respectively 58.8%, 56.5% and 34% [50,51,52]

### Microsporidiosis

In Mali, from 1993-1996 Maiga and al described microsporidiosis in 32% in HIV patients and 27% in HIV negative patients [53]. Two years later, 3 more case were described in HIV negative patient [54]. Immunofluorescent-antibody test (IFAT) using monoclonal probes specific for *Enterocytozoon bienersi* or *Encephalitozoon intestinalis* showed the presence of *Microsporidia* in stools from 8 of 61 patients (13.1%) seropositive for HIV. A single species, *E. bienersi*, was identified [55].

### Mycetoma and others subcutaneous fungal infections

A few cases of mycetoma have been reported from Mali [56]. We have not been able to estimate the prevalence of mycetoma based on these data. We found no data on other subcutaneous fungal infections (i.e., chromoblastomycosis, blastomycosis, sporotrichosis, conidiobolosis) despite likely environmental exposure in Mali.

### Tinea capitis, ringworm and other superficial cutaneous fungal infections

Cutaneous fungal infections are common in tropical areas and the main cause of medical visits in Mali. Studies were mainly conducted in dermatological center. Thus in 1998 Mahé et al showed that 13.6% (1477/10575) superficial infections were due to fungi [57]. In 2010, intertrigo represented 21% (29/41) of patients presenting with clinical signs; superficial mycosis was 31.7% distributed between ringworm, dermatophyte of the glabrous skin, seborrheic dermatitis, candidiasis and pityriasis versicolor [58,59].

Regarding tinea capitis, Coulibaly et al showed an overall clinical prevalence of 39.3% among 590 children (average age 9.7 years). Tinea capitis was the main clinical presentation of these children with a prevalence of 59.5% in the Sudano-Guinean zone, 41.6% in the Sudanian zone and 17% in the Sahelian eco-climatic zone. The two main causative species were *Microsporum audouinii* was primarily isolated from microsporic lesions and *Trichophyton soudanense* isolated from large and/or trichophytic lesions [60]. An important risk factor was high levels of contamination of hairdressing tools with dermatophyte propagules [61].

Using the local estimate of 24.6% of school age children with tinea capitis, our estimate for Mali is 2.3 million affected (11,200/100,000) (Table 2). We have not estimated the burden of other superficial fungal diseases such as ringworm, tinea pedis or onychomycosis.

### Fungal keratitis

To our knowledge, no case of fungal keratitis has been diagnosed in Mali. Based on other African studies, we estimate that 2826 eyes will be affected annually (Table 2), most of which will go blind, or the eye will be lost.

### Candidaemia and invasive candidiasis

There are no studies published on candidaemia or invasive candidiasis in Mali. Blood cultures are only done in the private sector. However, assuming that the rate is similar to other countries, at 5/100,000, we suggest there may be as many as 1063 mostly undiagnosed cases of bloodstream *Candida* infection each year (Table 2). Invasive candidiasis is about 2.5 times as frequent (blood cultures are only 40% sensitive), so the affected numbers are probably substantial. An additional number of ~160 intraabdominal (peritoneal) candidiasis cases are also likely in patients who have had pancreatitis or major abdominal surgery (Table 2).

## Discussion

Mali is a landlocked country in West Africa with a population estimated at 20.2 million inhabitants. It is one of the poorest countries in the world with security challenges in its northern regions. In Mali, the HIV epidemic has been overall stable since the early 2000s. Indeed, HIV prevalence in the general population first decreased from 1.7% in 2001 to 1.1% in 2012 but more recent data estimates suggest an increase to 1.4% in 2018 [62].

The burden of fungal disease is difficult to estimate because many fungal diseases go undiagnosed. The incidence of fungal infections may be underestimated, as there are a lack of non-culture diagnostics such as antigen testing for cryptococcal, *Histoplasma* and *Aspergillus* infections (Table 3) which limits clinical experience and prevents high quality epidemiology studies in the country. There is no public health surveillance in Mali for common or lethal fungal infections. However, skin diseases are major reason for consultation in the dermatological center in Bamako in immunocompetent patients.

Histoplasmosis is a neglected disease in Africa. The main challenge is recognition and diagnosis given the lack of antigen testing and its slow rate of growth and the low sensitivity of culture. Several

**Table 3**  
Current provision of WHO-listed Essential diagnostics and antifungal agents in Mali.

| Diagnostics  |                           | Antifungal agents          |              |
|--|---------------------------|----------------------------|--------------|
| Test   | Status                    | Antifungal                 | Availability |
| Direct microscopy of superficial samples                         | Frequently done           | Griseofulvin               | Available    |
| Direct microscopy of respiratory samples for <i>Pneumocystis</i> | Rarely done               | Fluconazole                | Available    |
| Fungal culture   | University hospitals only | Itraconazole               | Unavailable  |
| Blood culture  | Private hospitals only    | Voriconazole               | Unavailable  |
| Histopathology (including fungal stains)                         | University hospitals only | Intravenous amphotericin B | Unavailable  |
| Cryptococcal antigen   | Not done                  | Liposomal amphotericin B   | Unavailable  |
| <i>Histoplasma</i> antigen                                       | Not done                  | Flucytosine                | Unavailable  |
| <i>Aspergillus</i> antigen                                       | Not done                  | Natamycin 5% eye drops     | Unavailable  |
| <i>Aspergillus</i> IgG antibody                                  | Not done                  | Micafungin                 | Unavailable  |
| <i>Pneumocystis</i> PCR  | Not done                  | Caspofungin                | Unavailable  |
|  |                           | Anidulafungin              | Unavailable  |

studies in Africa have shown exposure to *H. capsulatum* using skin reactions to histoplasmin in the population [63,64]. The 6% exposure documented in the population in Mali, indicates that disseminated histoplasmosis is being continually missed and could account for a significant proportion of HIV deaths. Our estimate could be low, due to the difficulty of clinical diagnosis and the cultures requiring prolonged incubation and confirmation of species identity in a BSL3 laboratory – not frequent in West Africa.

Time to diagnosis is a major factor determining outcome. In addition, both amphotericin and itraconazole antifungal agents are required for the successful treatment of histoplasmosis as ketoconazole and fluconazole are not effective in severe disease (and inferior in milder disease) [65,66]. The active agents are not currently available in Mali. Thus, many efforts are required to address training of physicians and laboratory personnel to improve the management of patients suffering from histoplasmosis in Mali.

Pulmonary aspergillosis is also underestimated in Mali. Several investigations are ongoing in patients who have recovered from TB to estimate the incidence of chronic pulmonary aspergillosis using antigen, culture and fungus identification with MALDI-TOF. In neighboring Senegal, Ade et al. described a series of 22 cases with aspergilloma in 2011 [67]. The COPD prevalence was 22.9% of adults diagnosed with pulmonary problems other than TB attending hospital [68]. We estimate that over 7000 patients have CPA in Mali, and there are currently no licensed or available antifungal agents for treatment.

In Mali, the lack of description of *Pneumocystis jirovecii*, one of the fungal diseases most commonly associated with AIDS, is likely due to two main factors: first no bronchial wash or aspiration is performed in the sole department of pneumology of the country and second there is a lack of microscopy stains and *Pneumocystis* PCR for diagnosis. Even at the major hospital in Bamako, there is no well-equipped mycology lab and none other in the country.

Tinea capitis is a huge problem in Mali with over 2 million school aged children affected. Different agents are described associated with Tinea capitis infections in Mali mostly the anthropophilic dermatophytes [60] including *Trichophyton soudanense*. In Nigeria, the same species is the most prevalent followed by *M. ferugineum* and *M. audouinii* [69,70]. While in Ghana *T. soudanense* is most often associated with dermatophytosis followed by *T. tonsurans* and *M. audouinii*

[71]. In northern Nigeria, Nweze and al showed (in 2001) that *T. schoenleinii* was followed *T. verrucosum*, *M. gallinae*, *T. mentagrophytes*, *T. tonsurans*, *T. yaoundei* and *M. gypseum* [72]. In Conakry, Guinea and Burkina Faso *T. violaceum*, *T. rubrum* and *T. soudanense* are the predominant etiological agents of dermatophytosis [73,74] while in Senegal, *T. soudanense* followed by *T. rubrum* and *M. langeroni* were closely associated with tinea of the scalp [75]. These dermatophytes are encountered in children living in poor hygienic conditions with variable prevalence in different regions [76,77,78]. Nevertheless, more investigations should be carried out in Mali to update the epidemiology of tinea capitis. There are also no data on antifungal resistance in dermatophytes, which is likely given substantial self-medication in Mali.

Oral candidiasis is in decline in HIV patients, at least partly due to improved ART coverage. The introduction and the widespread use of ART across SSA, mainly supported by the President's Emergency Plan for AIDS Relief (PEPFAR) initiative launched in 2004 has been welcome and important. Few studies have been conducted in Mali, esophageal or invasive candidiasis and so our estimates remain tentative.

Substantiation of our estimates is needed. Before this is realistically possible, improved fungal diagnosis is required. This will require, at a minimum, creation and long term funding of at least one well equipped mycology laboratory, roll out of lateral flow antigen and antibody tests that are listed on the WHO's Essential Diagnostic List to clinics and hospitals treating HIV and TB patients, and a major clinical training program addressing primary care and different specialties.

We can attest at the end of this review that in Mali, fungal infections remain underestimated. This challenges us in setting up diagnostic and research laboratories in order to update the epidemiology of these infections and more particular in people at risk.

## Conclusion

Our review confirms previous reports from other countries in West Africa showing that fungal disease are substantially underestimated. Thus laboratory diagnostics including advanced high throughput techniques are urgently needed. To raise public awareness and seek support from the authorities for fungal diseases, scientific evidence remains necessary to ensure adequate care of the sick or exposed population in Mali

## Author's contributions

Safiathou Niaré Doumbo, Yacouba Cissoko, Souleymane Dama, Amadou Niangaly, David W. Denning, conceived the paper, analyzed the data, and wrote the manuscript. Adam Garango, Ahmed Konaté, Abdoulaye Koné, Boubacar Traoré, Mahamadou Thera, Abdoulaye Djimde, read and completed national data in fungal diseases.

## Patient consent for publication

Not required

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## Declaration of Competing Interest

The authors declare no conflict of interest

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