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Review Article

Review Article

Dermatophytes and dermatophytosis in the eastern and southern parts of Africa

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Abstract

Dermatophytosis is currently a disease of global importance and a public health burden. It is caused by dermatophytes, which attack and grow on dead animal keratin. Dermatophytes belong to three genera, namely, *Epidermophyton, Microsporum*, and *Trichophyton*. The predominant clinical forms and causative agents vary from one region of the world to another. Poor socioeconomic status, high population densities, and poor sanitary conditions are some of the factors responsible for the high prevalence of dermatophytosis in many developing countries, which include countries in southern and eastern Africa, the focus of this review. To the best of our knowledge, there is currently no review article on published findings on dermatophytosis in the eastern and southern parts of Africa. This information will be of interest to the medical and research community since the world has become a global village. This review covers published research findings in eastern and southern regions of Africa until this date. The countries covered in the current review include Kenya, Ethiopia, Tanzania, South Africa, Mozambique, Madagascar, Malawi, Rwanda, Burundi, Uganda, Zambia, Zimbabwe, and Botswana. *T. violaceum* is the most common human etiological agent in all the countries under review with prevalence ranging from 56.7% to 95%, except for Madagascar (*M. langeronii*, reclassified as *M. audouinii*), Uganda (*M. gypseum*) and Malawi (*M. audouinii*). Tinea capitis was the most clinical type, followed by tinea corporis. Etiological agents of animal dermatophytoses were variable in the countries where they were reported. Major risk factors for dermatophytoses are age, climatic, and socioeconomic factors.

Key words: Southern Africa, Eastern Africa, Dermatophytes, Dermatophytoses, Skin infection, Keratin.

Introduction

Dermatophytosis is a major public health challenge in many parts of the world,[1–3] with tinea capitis being the most predominant dermatophytic infection affecting school children.[3–6] Apart from the poor housing conditions, high population densities, limited water supply and poor sanitary conditions that are found in developing countries, other studies suggest that the inadequate amount of fungi-inhibiting fatty acids synthesized in prepubescent children predisposed them to dermatophytic infections.[3,7–9] Premenopausal women may also be predisposed to tinea capitis due to a reduction in the synthesis of these fungistatic triglycerides in their sebum.[9,10] Low socioeconomic status, illiteracy, and sharing of fomites have also been associated with the high prevalence of dermatophytic infections in developing parts of the world.[3,11,12] Furthermore, uncontrolled access to infected animals and use of immunosuppressive drugs such as corticosteroids are also considered as risk factors of this infection.[13] Nweze (2010)[1] noted the warm humid climatic condition of Africa as a predisposing factor to the higher prevalence of dermatophytoses in this part of the world.

Dermatophytoses have been suggested to play a negative role in the academic development and performance of school children. This is because of the attached social disapproval and psychological trauma of tinea infections that may hamper the concentration and performance of the child in the class.[7] Due to its attached psychosocial discomfort and ill feeling,[14–20] these superficial mycoses may also affect the expression and self-confidence of its patients. These infections may also have economic implications in terms of the time and money spent in treating them.[21,22] Veterinary epidemiological and surveillance studies are important tools used in fighting farm animal diseases.[23] This is largely because superficial fungi infections affect the quality of animal products. Such surveys in animals are also important because of the risk of transmission of these dermatophytes to humans, with the attendant public health implications.[24]

On the other hand, epidemiological investigation of dermatophytosis in sub-Saharan Africa is hampered by the self-limiting nature of dermatophytoses cases.[7] This absence of life-threatening conditions [25] will in turn negatively affect the development of active control programs by public health agencies and hinder the prioritization of dermatophytosis-based drug research in this region. The control of any persistent infection requires the identification of the etiologic agent and its prevalence.[26,27] Due to widespread dermatophytic infection in humans and animals of different age groups, an interdisciplinary approach of dermatologists, pediatricians, primary healthcare physicians, and veterinarians can be used in curtailing this infection.[6] This review therefore aims to present published and detailed clinical picture of dermatophytosis in southern and eastern parts of Africa. This among other reasons is expected to enhance collaboration of different stakeholders involved in the management of dermatophytosis in southern and eastern regions of Africa and even beyond. Moreover, there are findings that suggest that consistent epidemiological updates are important in controlling an infection in any particular area.[1,2,28] Here we present a review of specific fungal agents of dermatophytic infections in East Africa (Kenya, Ethiopia, Tanzania, Uganda, Rwanda, Burundi, Malawi, Somalia) and Southern Africa (South Africa, Mozambique, Madagascar, Botswana, Zambia, Zimbabwe) according to published findings till date, its prevalence and the ways of combating these dermatophytic infections. The map showing all the countries covered in this review is presented in Figure 1.

Data sources

Data were collected from platforms such as Google Scholar, ScienceDirect, and Pubmed. The search strategy involved imputing the name of the target African country and dermatophytosis (or tinea) as key words. Other key words include the use of tineas (such as tinea capitis, tinea unguium, tinea pedis, etc.) and the respective countries, as well as their GDPs and climatic conditions (such as rainfall, relative humidity, etc.). This is to ensure that all published findings on dermatophytosis in Eastern and Southern parts of Africa were duly covered. The period of data search started from September 2015 to August 2016. There were no time restrictions in the selection criteria. Except where the abstracts were not available, published and relevant online articles on dermatophytosis in these parts of Africa were accessed and used in the current review. Finally, the relevance of articles used in this review was accessed based on one or more of the following conditions: (1) it examines the epidemiology of dermatophytosis especially in the regions under consideration; (2) It looks at the climatic or economic conditions of these regions; and (3) it recognizes the problems and prospects of dermatology research in these parts of the world.

The role of climate and economic conditions of these regions

As their names suggest, the eastern region of Africa also known as the Greater Horn of Africa [29] and the southern region are respectively located in the eastern (1.9577°N, 37.2972°E) and southern horizons (24.3571°S, 19.5687°E) of Africa. The prevalence of dermatophytosis can vary from one climatic condition or lifestyle to another.[30–32] Such lifestyles include poor hygienic conditions, communal sharing of hair-care tools, close contact with animals, playing with sand among others. An important climatic feature shared by the tropical and subtropical areas of the world (where these regions of Africa belong) is their warm or hot humid weather condition. Some authors have suggested that such atmospheric weather conditions favor the growth of dermatophytosis.[1,19,33,34] This is probably because dermatophytes grow best at temperatures of 25–28°C.[35,36] Although the distribution patterns of dermatophytosis vary from one geographical region to another,[6,37,38] there are certain dermatophyte species that are restricted within a particular area.[20,31,36,39] For instance, *Microsporum ferrugineum* is mostly restricted to Africa and Asia,[40] *Trichophyton soudanense* has a partial geographic

Figure 1. Map of Eastern and Southern regions of Africa [45].

restriction within Africa,[1,36] *Trichophyton yaoundei* (in synonymy with *T. violaceum*) is endemic in central parts of Africa[41] while *Trichophyton concentricum* is found mostly in the Pacific Islands, Southeast Asia, and South America.[31]

Morrone (2008)[42] found that skin-related infections were more prevalent in developing countries with low socioeconomic status. This might be due to poor health facilities and lack of properly trained health personnel in these countries. It may also be attributed to the financial difficulties encountered by many patients in accessing quality medical care in developing countries where health insurance is virtually non-existent or ineffective where it is available. This agrees with the findings by Accorsi et al. (2009),[43] Bhatia and Sharma (2014),[34] and Chowdhry et al. (2013)[35] that suggested a strong correlation between dermatological infections and low socioeconomic conditions. Per capita gross domestic product (GDP), an indicator of the socioeconomic conditions of many nations[44] has been used to show the standard of living of people covered in areas[45] under the present review (as shown in Table 1).

Dermatophytes in Kenya

Dermatophytosis has been recognized as a major skin disease of zoonotic importance.[48,49] Animals infected with dermatophytes can easily transfer it to other animals or humans. Odongo et al. (2012)[50] carried out a retrospective study (2001–2010) on the cases of dermatophytosis

Table 1. Economic status of Eastern and Southern African countries.[46,47]

Country	Total population+	GDP per capita (current US$)+	Income level
Botswana	2,262,485	6360.6	Upper middle
Burundi	11,178,921	276.0	Low
Ethiopia	99,390,750	619.1	Low
Kenya	46,050,302	1376.7	Lower middle
Madagascar	24,235,390	411.8	Low
Malawi	17,215,232	381.4	Low
Mozambique	27,977,863	525.0	Low
Rwanda	11,609,666	697.3	Low
Somalia	10,787,104	551.9	Low
South Africa	54,956,920	5691.7	Upper middle
Tanzania	53,470,420	864.9	Low
Uganda	39032383	675.6	Low
Zambia	16,211,767	1307.8	Lower middle
Zimbabwe	15,602,751	890.4	Low

+For the year 2015.

in affected dogs and cats referred to an animal clinic located in Nairobi. They examined the relationship between the prevalence of ringworm and the age of the animal and found that there was an inverse relationship between the age of the affected animals and the occurrence of dermatophytosis. For instance, out of the 15,176 dogs that were investigated in the study, 57.1% (8,662) were dogs aged below 1 year, while 42.9% (6,514 dogs) were above 1 year. Also, out of the 405 affected cats screened by Odongo et al. (2012),[50] 18.3% were above 1 year of age, while 81.7% were below 1 year of age. Thus, the authors agreed with Cabañes et al. (1997)[51] that there is an inverse relationship between the age and occurrence of dermatophytosis in animals. Wabacha and coworkers (1998)[52] investigated a persistent ringworm infection caused by *Trichophyton verrucosum* in 20 dairy cattle housed together. They found that two attendants who worked in the dairy cattle farm were also infected, suggesting a possible transfer of ringworm infection from dairy cattle to humans in Kenya. Mwanzia and Mung'athia (1997)[53] documented an outbreak of dermatophytosis that affected free-ranging wild animals in Kenya. Skin scrapings were collected from 20 adult impalas (*Aepyceros melampus*) and 40 Grant's gazelles (*Gazella granti*). Cultural examination showed that *Microsporum gypseum* was respectively present in 90% of the samples collected from *Aepyceros melampus* and 85% of samples from *Gazella granti*. *Trichophyton schoenlenii* was also found in two Grant's gazelles and in 69.2% of the sampled camels. Though this study suggests the transmission of geophilic and anthropophilic dermatophytes to wildlife, Magwedere et al. (2012)[54] reviewed free-ranging wild animals as important sources of emerging human diseases. This is because of the difficulties in the clinical management of the wildlife species, epidemiological study of their health status as well as the problems encountered in the restriction of their access into the food chain of human beings. Since wild animals may be asymptomatic for dermatophytosis and may serve as important reservoirs for the infection,[55] an interprofessional network has been suggested as a way of reducing its spread.[56]

Informal settlements are usually illegal in many countries and are characterized by poor socioeconomic and environmental conditions.[57,58] For example, they have poor housing schemes, are usually overpopulated, and lack access to basic amenities such as water and sanitation services.[59] Children living in such urban slums are posed with a significant health risk.[60] It has been estimated that 1% of the land mass of Nairobi (the capital city of Kenya) is made up of informal settlements such as Kibera, Mathare, Korogocho, and Mukuru Kwa Njenga slums.[3] In view of this, Chepchirchir et al. (2009)[7] investigated the prevalence of dermatophytosis among primary school children in Kibera—one of the largest informal settlements in Nairobi. They examined 422 children from several primary schools located within the vicinity of Kibera and found that the prevalence of ringworm among the children was 11.2%. The etiological agents recovered in the study included *Trichophyton violaceum* (72.9%), *Trichophyton mentagrophyte* (6.25%), *T. schoenleinii* (6.25%), *Trichophyton terrestre* (4.2%), *T. concentricum* (2.1%), *Trichophyton interdigitale* (2.1%), *Microsporum canis* (2.1%), *Microsporum equinum* (2.1%), and *Epidermophyton flocossum* (2.1%). More females (55.7%) than males (42.9%) were affected, with children less than 6 years (62.5%) and between 6 and 8 years (60.6%) being the most susceptible age groups. The authors concluded the study by proposing the use of health education and public health awareness to curtail the high prevalence of dermatophytosis in urban informal settlements. In a recent study, Moto et al. (2015)[3] carried out a cross-sectional investigation to determine the prevalence of tinea capitis among school-going children from Mathare urban slum in Nairobi. Out of the 150 children who were recruited in the study and examined for tinea infections, 81.3% (122 persons) were found to have skin lesions caused by dermatophytes. Gender was a risk factor for dermatophytosis since prevalence was higher in males (45.3%) compared to females (36.7%). *Trichophyton tonsurans* was the most implicated etiological agent with a prevalence of 45.3%. Other dermatophytes recovered in the study included *E. floccosum* (7.3%), *T. mentagrophytes* (6.7%), *T. verrucosum* (4.3%), and *Trichophyton rubrum* (4.3%). These findings seem to agree with the findings made by Ndunge[38] who carried out a survey of tinea capitis among school children in this same region of Nairobi. Out of the 150 children that were included in the study, 82% were infected with tinea capitis. There was a significant difference in the prevalence of the disease among male (45.3%) and female (36.7%) participants. Of the *Trichophyton* species recovered, *T. tonsurans* had the highest prevalence (33.3%), followed by *T. mentagrophytes* (10.7%), and *T. rubrum* (8.0%). *E. floccosum* and *M. gypseum* had the same prevalence (7.3%), while *M. canis*, an important zoophilic species had the least frequency (6.0%). The authors concluded that low socioeconomic conditions and poor personal hygiene were the dominant risk factors responsible for the high prevalence of tinea capitis in this informal settlement. Ayaya et al. (2001)[61] carried out a prospective study in a primary school located at Nandi district of Kenya, to determine the epidemiology and possible ways of curtailing tinea capitis infections among children attending school there. The study population composed of 68 children who had important clinical signs of scalp dermatophytosis. Out of this number, 60.9% were males, while 39.1% were females. The prevalence of tinea capitis was 33.3%, with *T. tonsurans* being the most predominant isolate (77.8%). *T. rubrum* was isolated only in samples collected from the male participants, while *M. gypseum* was recovered in females only. These results agree with the views expressed by Aly et al. (2000)[62] that the prevalence of tinea capitis and its associated etiologic agents may vary from one gender and vicinity to another.

In a study of skin-associated fungal infections in Thika district Hospital, the most isolated dermatophyte was *T. verrucosum* (16.3%), followed by *T. soudanense* (9.3%), *T. mentagrophytes* (9.3%), with *Epidermophyton* spp. and *Microsporum* spp. each representing 2.8% of the total isolates recovered in the study.[63] Routine screening to reduce the morbidity associated with dermatophytic infections was proposed in this study. In demonstrating the economic efficiency of a single dose and intermittent griseofulvin regimens on the treatment of tinea capitis, Nyawalo and Bwire (1988)[64] recruited 3788 Kenyan school children in the intervention study and reported an incidence of 9.6%. These regimens were not only effective but also cheap. Other antifungal agents which have been considered for use in the treatment of scalp dermatophytosis include terbinafine, itraconazole and fluconazole.[65] These agents exhibit their effects rapidly and are relatively safe to handle.

It is important to note that psychiatric patients are neglected members of the society especially in the developing parts of the world. The stigma as a result of such mental conditions limits psychiatric patients' access to good quality medical care. There is also paucity of research data on the correlation between mental problems and dermatological conditions.[66] Ogutu et al. (2010)[4] carried out a study to determine the prevalence of superficial mycosis among psychiatric patients in Kenya. The prevalence of superficial mycoses was found to be 12.5%, with *Microsporum* species being the most implicated species (53%). Although the etiological agents of dermatophytosis were not identified to the species level in this study, the distribution of the three genera of dermatophytes among male and female psychiatric patients was discussed. *Microsporum* occurred more in males (47%) than in females (5%), while *Trichophyton* was isolated only in females (42%) and *Epidermophyton* only in males (5% of the total isolated species). Ogutu et al. (2010)[4] thus advocated for the regular screening of psychiatric patients for superficial mycoses and immediate commencement of treatment in confirmed positive cases. Following an observation that diabetes mellitus, a health disorder characterized by abnormal insulin secretion, can increase the susceptibility of its patients to fungal diseases, Gitau et al. (2011)[67] investigated the incidence of fungal pathogens among diabetic patients suffering from foot ulcer in Kenya. With a frequency of 3.7%, *T. schoenleinii* was the most occurring dermatophyte, followed by *T. rubrum* (3.0%) and *T. verrucosum* (2.4%). *Microsporum ferrugineum*, *Microsporum audouinii,* and *T. mentagrophytes* occurred in the same frequency (1.8% each), while the incidences of *E. floccossum* and *T. soudanense* were also similar at 1.2%. Other dermatophytes recovered in the study include both *M. gypseum* and *T. interdigitale*, with a low incidence of 0.6%, respectively. The authors emphasized the need to avoid underestimating the occurrence of superficial mycoses in diabetic and other immunocompromised patients. It is important to note that there is no general agreement among scientists on the significance of immunodeficiency as a predisposing factor in dermatophytic infections.[68] Many authors have previously postulated that patients with immunosuppressive conditions were more prone to superficial fungal infections, with immunodeficiency exacerbating the effect of dermatophytic infection leading to systemic or deep dermatophytosis.[69–76] On the other hand, a contrary position is held by some authors[76,77–80] who reported no significant correlation between the prevalence of dermatophytic infections and immunity status. Thus, further studies should be done to conclusively determine the role of immunodeficiency in dermatophytoses.

In countries where there are scarcities of dermatologists and other medical personnel, internet- based telemedical services can be used to enhance healthcare accessibility to the people. This was the view of Smith et al. (2013)[81] who demonstrated the use of telemedical tools in diagnosing dermatophytosis in Kenyan school children. Such tools enable the timely diagnosis of infections and immediate commencement of treatment. Though several workers[82–86] have advocated for an increased use of tele-dermatological tools to diagnose and treat skin infections, Eedy and Wootton (2001)[87] reviewed some limitations of this modern technology. 1) Teledermatology may be resisted by some members of the medical profession due to its tendency to erode the close contact between the doctor and the patient. 2) Poor image quality and incorrect diagnosis may also be considered as limiting factors of this technology. Finally, internet facility is not readily available in many developing countries.

M. gypseum, a predominant geophilic species,[88,89] has been implicated in the occurrence of human infections such as tinea pedis,[90] tinea incognita,[91] onychomycosis,[92] and tinea facei.[93] Muhammed and Lalji (1978)[94] investigated the distribution of geophilic dermatophytes in Kenyan soils. They collected and analyzed 281 soil samples from different provinces of Kenya and found that *M. gypseum* and *M. cookei* represented 75.8% and 3.2% of the total isolates, respectively. These geophilic species were associated more with acidic than alkaline soils. Moreover, cultivated fertile soils[89] or moist soils rich in organic or keratinous materials[95] have been associated with the increased prevalence of geophilic dermatophytes.[89,95,96]

Dermatophytes in Ethiopia

Ethiopia has a huge livestock population and a blossoming leather industry whose main source of raw materials are farm animals.[97] Skin infections affect the quality of leather, aesthetic appeal, and the use of leather as an export product of Ethiopia. Ambilo and Melaku (2013)[98] carried out a cross-sectional study to determine the prevalence of major skin diseases such as dermatophytosis, acariasis, pediculosis, lumpy skin disease, and dermatophilosis among cattle found in Hawassa area of southern Ethiopia and its surroundings. Out of the 384 cattle that were examined, 17.19% were clinically infected with skin diseases, with dermatophytosis being the predominant skin infection (8.32%). Poor husbandry conditions and young age of the animal were regarded as risk factors for the infection. The authors advocated a stronger role by governmental organizations and tannery industries to support the fight against skin infections of cattle. In a similar development, Megersa (2014)[99] investigated the seasonal variation of major diseases affecting camel calves in Borana region of Southern Ethiopia. Dermatophytosis was found to have a higher incidence in the rainy (8.3%) than the dry season (3.2%). This seasonal variation of dermatophytosis has been reported elsewhere in Murmu et al. (2015)[100] and Nooruddin and Singh (1987).[101] Furthermore, this higher prevalence of dermatophytosis in the cold seasons of the year was attributed to the high humidity and a reduction in the intensity of solar radiation, which provides a good environment for the growth of dermatophytes.[24]

Dermatophytosis, especially tinea capitis, has been reported as the most frequent skin infection affecting primary school children in rural areas of southern Ethiopia. Using interviews and dermatological examination, Leiva-Salinas et al. (2015)[102] screened 647 students for dermatophytosis in Oromya region of southern Ethiopia. Out of this number, 236 of those examined had dermatophytosis, with more males (42.2%) than females (30.5%) being affected. Tinea capitis was observed to be the most prevalent dermatophytic infection (24.6%), followed by tinea pedis (8.7%), tinea corporis (7.7%), and tinea unguium (0.9%). One of the limitations of this study is that no laboratory-based examinations were done to determine the etiologic agents of such clinical manifestation. In a study describing the spectrum of dermatophytosis and its associated etiologic agents among patients visiting a dermatology clinic in Adidis Ababa, 54.4% and 79.3% of the 305 study participants were shown to be positive for this infection by microscopic and cultural methods, respectively.[21] Tinea unguium was the most common clinical manifestation observed in the study (51.1%), followed by tinea capitis (20%), tinea corporis (10.8%), tinea faciei (6.6%), tinea manum (5.2%), tinea pedis (4.9%), and tinea cruris (1.3%). Though *T. violaceum* (49 isolates), *T. mentagrophytes* (23 isolates), and *T. tonsurans* (21 isolates) were the major dermatophytes implicated, this study highlighted the increasing role of nondermatophyte moulds and yeasts in causing different clinical forms of dermatophytosis. The nondermatophytic fungal species that were implicated in the study include *Candida*, *Aspergillus*, *Cladosporium*, *Fusarium*, *Alternaria*, *Curvularia,* and *Penicillium*. The significance of such nondermatophytic species in skin-related infections has been highlighted in many published studies.[103–108]

The prevalence of dermatophytosis affecting children from two different schools located in Addis Ababa was investigated by Woldeamanuel et al. (2005).[109] Out of the 824 students sampled from one of the schools, 62.3% (513 students) were clinically diagnosed of dermatophytosis, with tinea capitis being the predominant dermatophytic infection that affected 90.3% (463) of the students. *T. violaceum, T. verrucosum,* and white variants of *T. violaceum* were recovered as the etiological agents of dermatophytosis in this study. In a different but related study, Ali et al. (2009)[26] screened 372 students from two elementary schools in Gondar town of Northwest Ethiopia for tinea capitis. Tinea capitis was clinically diagnosed in 47.5% (177) of the students. Microscopic and cultural examination of 174 scalp samples collected from the suspected cases gave an incidence of 65.5% and 50%, respectively. *T. violaceum* was the most implicated species and had an incidence of 86.2% in the culture-positive samples. They recommended the use of health education in schools to combat the high prevalence of tinea capitis in the area. Using conventional and molecular tools, Woldeamanuel et al. (2005)[110] identified rare white variants of *T. violaceum* in Ethiopia. This report was noted to be unique since it was the first time such white variants of *T. violaceum* were reported in the country. Woldeamanuel et al. (2005)[111] investigated the prevalence of dermatophytosis among children in Tulugudu Island of southern Ethiopia. Out of the 171 children who were screened, dermatophytosis was diagnosed in 79.5% of them, with tinea capitis being the most predominant form (76.5%). *T. violaceum* was isolated in 80.6% of the culturally positive samples, followed by *T. verrucosum* (16.3%), *T. tonsurans* (2.0%), and a white variant of *T. violaceum* (1%). Out of the 539 patients who were screened by Woldeamanuel et al. (2006)[112] for the presence of dermatophytosis in a dermatology reference center located in Addis Ababa, 29% were males while females accounted for 71% of the examined patients. In the study, more males (89%) than females (40%) were affected with tinea capitis, and 69% of the examined children had tinea capitis. Dermatophytes was isolated in 74% of the cultured samples, with *T. violaceum* being the most implicated organism (84%), followed by *T. verrucosum* (9.6%), *T. tonsurans* (1.4%), and *T. rubrum* (0.5%). It is important to note that 15 white variants of *T. violaceum* were isolated in the study. These white variants have also been reported elsewhere in Thakur and Goyal (2015).[113]

Immigrants may have different epidemiological spectrum from their host communities.[114,115] Out of 124 children of Ethiopia immigrants who were screened for tinea capitis, 36 had scalp lesions, while microscopic examination confirmed 32 cases as tinea capitis. Cultural examination implicated *T. violaceum* as the causal agent.[116] Meeus et al. (2010)[117] carried an investigation on the health status of 99 children that were adopted from Ethiopia and brought to Belgium. They noted that dermatophytosis affected 18% of the adopted children and recommended physical examination of the adopted children on their arrival to Belgium. The prevalence of skin infections in children infected with human immunodeficiency virus (HIV) living in an orphanage in Addis Ababa has been investigated by Doni et al. (2012).[70] Out of the 84 HIV-infected children who were included in the study, 79% (66 children) were reported to have at least one skin disorder, with tinea capitis being the most prevalent skin infection, affecting 39% of the children investigated. Similarly, Endayehu et al. (2013)[118] discussed the pattern of various skin or mucous membrane disorders (mucocutaneous disorders) in HIV-infected children receiving treatment in an Addis Ababa-based specialized hospital. In total, 270 HIV-infected children formed the study population, with superficial fungal infections being recognized as one of the major mucocutaneous disorders (51.8%). Among other clinical manifestations of these superficial fungal infections, tinea capitis (28%), tinea corporis (17.3%), and tinea unguium (3.5%) represented the majority.

The general health and living conditions of Ethiopian primary school children were shown by Murgia et al. (2010)[119] when they screened 1,104 pupils and reported 1,086 skin-related cases. Fungi was the major etiologic agent of the skin infections (36.1%), with tinea capitis, tinea corporis, and tinea unguium representing 76%, 27%, and 8% of the fungal skin infections, respectively. The authors concluded the study by advocating for the improved hygienic practices of the children and the continual presence of community-based health workers in order to ensure the effective diagnosis of skin infections and distribution of dermatological drugs. The prevalence of tinea capitis infections among school children in rural and urban communities of Illubabor district, Southwestern Ethiopia, has been reported by Figueroa et al. (1997).[120] Out of the 219 children who were included in the study, physical examination showed that 29% of the children had clinical lesions indicative of tinea capitis. Tinea favus and tinea corporis accounted for 1.4% and 2% of the examined cases, respectively. Dermatophytes were isolated in 33% of the scalp samples, with the implicated species being *T. violaceum* (97%), *T. schoenleinii* (1.4%), and *T. rubrum* (1.4%). A five -year (1996–2000) retrospective study of dermatophytosis cases handled in an Adidas Ababa–based mycology reference laboratory was carried out by Fentaw et al. (2010).[121] Out of the 2,367 specimens that were received for diagnosis in this laboratory, cultural examination showed that 85.21% (2,017) were positive for cutaneous mycoses. In the study, *Trichophyton* species was reported as the leading cause of dermatomycoses and had a high incidence of 56.81%. Also, *Aspergillus*, a nondermatophytic mould, was noted to have a relatively high incidence of 16.2%. An important limitation of this study was the absence of species-specific identification.

Dermatophytes in Tanzania

Even within a particular country, the etiologic agent of a disease as well as its prevalence may vary from one region to another.[32] This was shown by Nsanzumuhire and Masawe (1978)[122] when they investigated the predominant etiologic agents of tinea capitis in five different regions of Tanzania. While *M. ferrugineum* was found in the southern regions, *M. audouinii* and *T. violaceum* were the predominant agents in the coastal belts and high hinterlands regions of Tanzania, respectively. In this study, more males than females were affected by dermatophytosis in the ratio of 2:1. Henderson (1996)[123] investigated the prevalence of skin infections in Ndebwe rural area of Tanzania. Out of the 936 people who were included in the study, 41% (390 persons) were male, while 59% (546 persons) were female. Dermatophytosis affected 5.13% of the study population. Tinea capitis was reported in 37 persons, tinea corporis and tinea pedis in four persons each; tinea facieii in two persons and onychomycosis affected only one person. In their work on the correlation of skin infections with socioeconomic conditions in rural Tanzania, Gibbs (1996)[124] randomly sampled 254 households and reported household density as a major socioeconomic determinant of skin infections. Out of the 224 school children who participated in a study that investigated the efficacy of triclosan soap against superficial dermatomycoses in Morogoro region of Tanzania, 174 were found to have tinea versicolor, 40 had tinea capitis, while tinea pedis and tinea corporis affected 21 and 15 persons, respectively.[11] *T. tonsurans, T. violaceum,* and *T. mentagrophytes* were the implicated dermatophyte species. Triclosan soap was shown to be a cost-effective option in the treatment of dermatological infections, especially in resource-limited societies. In Dar es Salaam region of Tanzania, Komba and Mgonda (2010)[125] investigated the spectrum of skin infections among primary school children. Of the 420 children who were included in the study, 11.4% had dermatophytic infections. The rate of infection was more in males (12.6%) than females (10.1%). School children aged 6–10 years were mostly affected (21.8%), followed by those aged from 11 to 15 years (15.6%) and 16 to 19 years (3.7%). Cultural examination was positive in 88% of all the dermatophytosis cases. Out of the culture-positive dermatophytoses, tinea capitis was the most prevalent (71.4%), followed by tinea pedis (26.1%), and tinea corporis (2.3%).

Generally, there are scanty reports on the cases of bovine dermatophytosis in Africa. In a commercial dairy herd found in the Arusha region of Tanzania, Swai and Sanka (2012)[126] described a severe form of bovine dermatophytosis. Clinical examination revealed two sets of lesions that included gray-white crusty lesions and pustular scabby lesions on the animal bodies. The disease affected 33.3% of the sampled cattle with *T. verrucosum* as the only etiological agent recovered. This finding agrees with reports from other authors[127–133] on the predominance of *T. verrucosum* as the causative agent of cattle ringworm. Bovine dermatophytosis has a huge economic importance because it can affect the quality of leather produced from cattle. Thus, vaccination, regular screening and quarantine, and good sanitation practices should be used in the effective management of ringworm infections in cattle.

Mgonda and Chale (2011)[134] carried out a cross-sectional study on the prevalence of coexisting dermatological disorders among patients admitted to a national hospital in Dar es Salaam. Out of the 390 hospitalized patients who formed the study population, 59.5% had at least one of these skin disorders, with dermatophytosis representing 10% of these disorders. The most clinical manifestations of dermatophytosis were found to be tinea corporis (3.6%) and tinea unguium (3.6%), followed by tinea pedis (1.8%), tinea cruris (0.8%), and tinea capitis (0.5%). The authors advocated the need for an improved dermatological education among clinical workers in order to ensure prompt and proper treatment of these skin diseases.

Dermatophytes in South Africa

In a cross-sectional study of 100 patients suspected of having dermatophytosis in Kwa-Zulu Natal area of South Africa, Morar et al. (2004)[5] isolated *T. violaceum* from 90% of the culturally positive samples and concluded that this species was the major cause of tinea capitis in South Africa. A similar finding was made by Neil and coworkers (1987)[135] who collected scalp scrapings from 651 children in the Cape Peninsula and Western Cape Coast and identified *T. violaceum* as the predominant cause of tinea capitis (90.5%), followed by *T. yaoundei* (currently revised as *T. violaceum*) (2.4%), *T. verrucosum* (2.0%), *M. canis* (1.7%), *M. audouinii* (1.5%), *T. mentagrophytes* (1.5%), and *T. tonsurans* (0.5%). The high rate of isolation of dermatophytes in subjects with no symptoms (isolated in 16% of carriers) highlights the important role played by carriers in the spread of dermatophytic infection. In another study, Vismer and Findlay (1988)[136] collated an 8-year clinical data of patients who came to hospital clinics in Pretoria due to dermatophytic infections. From a total of 496 dermatophyte cultures that were examined, *T. rubrum* was the predominant etiological agent (27%), followed by *T. mentagrophyte* (23%), *M. canis* (19%), *T. violaceum* (18%), *E. floccosum* (12%), and *M. gypseum* (1%). Though *M. audouinii*, *T. schoenleinii*, and *T. yaoundei* (reclassified as *T. violaceum*) were recovered in the study, the authors did not report their prevalence in this population. However, the clinical forms observed were tinea pedis, tinea corporis, tinea unguium, tinea manuum, tinea capitis, and tinea barbae.

In the Durban region of South Africa, Raboobee and his group (1998)[137] carried out a cross-sectional study to determine the prevalence of tinea pedis et unguium among the adult Muslim male population and non-Muslim males. Skin scrapings and nail clippings were collected from 78 adult Muslim males that were chosen randomly from five mosques, with 72 adult non-Muslim males serving as the control group. The prevalence of tinea pedis et unguium among the Muslim group and the control population were found to be 85% and 41%, respectively. The higher prevalence observed among the Muslim group was attributed to the role of the prayer carpets and communal ablution areas in transmitting the dermatophytic infections. This finding ignites the call for the development of strategies for controlling the spread of infections in community-used facilities such as hotels, public bathrooms, gymnasiums, swimming pools, and so forth. In the study of scalp dermatophytosis affecting 153 children selected from the Transvaal region of South Africa, Young (1976)[138] reported that *T. violaceum* was the predominant etiological agent, followed by *T. yaoundei* (renamed *T. violaceum*), which was recovered in five infections; *M. audouinii* was also implicated in four children and *M. canis* in just one infection. Young (1976) [138] further noted that this was the first documented report of *T. yaoundei* (or *T. violaceum*) as the causative agent of endothrix tinea capitis in South Africa. Though *T. yaoundei* (or *T. violaceum*) is an endemic dermatophytic species in Africa,[139] it has also been reported elsewhere in Europe[140] and Asia.[141] In a 1970–1973 survey of dermatophytosis carried out in Bloemfontein, South Africa, Scott and Scott (1973)[142] found that tinea capitis affected children mostly from the Bantu tribe (blacks), while tinea corporis was more prevalent in white children. Also, tinea pedis and tinea cruris was more prevalent in the white adult population. These variations in the predominance of certain dermatophyte infections among different tribes may be explained by the peculiar lifestyles and cultural practices of such people. For instance, the spread of tinea pedis has been associated with the wearing of shoes instead of open sandals,[35,143–145] sharing of shoes, socks, and communal bathing places.[12] Long-term wearing of shoes and socks provide moist environment favorable for the development of tinea pedis and tinea unguium.[34] Thus, tinea pedis was more prevalent among the white adult population perhaps due to the fact that they wear shoes for a longer time when compared to the black people.

In a classical study of dermatophytosis affecting porcupines in South Africa, Marais and Olivier (1965)[146] isolated *T. mentagrophytes* in one of the animals that showed clinical signs of dermatophytosis. In a bid to emphasis the need for caution in handling domesticated birds, an intentional contact with the infected porcupine resulted in the development of clinical lesions typical of dermatophytosis after 3 weeks of handling the animal. Also, in order to highlight the health implications of close contact with farm animals, Gummow (2003)[147] investigated the occurrence of zoonoses among veterinarians in South Africa. Out of the 88 veterinarians who were included in the study, 63.6% had suffered from one form of zoonotic diseases or another, with dermatophytosis representing 44% of these cases. Thus, this work further highlights the importance of dermatophytosis as an occupational hazard for people whose work requires regular close contact with animals.[148–150] Adequate publicity and regular screening programs can also be used in curtailing the transmission of dermatophytosis in such occupation groups.[151]

Dermatophytes in Mozambique and Madagascar, Somalia

The spectrum of dermatophytic infections in Lourenço Marques city of Mozambique was investigated by Neves et al. (1963).[152] *M. audouinii* and *T. violaceum* were reported as the major etiologic agents of tinea capitis with an incidence of 69% and 21%, respectively. Tinea pedis and tinea cruris were also found to be more common among white adult participants. The most common etiologic agents of tinea pedis were *T. mentagrophyte* (66%), *T. rubrum* (22%), and *E. floccosum* (6%). On the other hand, the most occurring dermatophytes responsible for tinea cruris infection were *T. rubrum* (55%), *E. floccosum* (39%), and *T. mentagrophytes* (5%). Among the isolated dermatophytic agents causing tinea corporis, *T. tonsurans* and *Trichophyton mengninii* were mostly contracted from Europe. The authors noted that *T. tonsurans* and *T. mengninii* were not indigenous species in Mozambique. In a study involving two primary schools located in Maputo province of Mozambique, Sidat et al. (2006)[153] observed that tinea capitis had a prevalence of 11.6% and 6.8%, respectively, in each school, with *M. audouinii* being the most isolated dermatophyte.

Drouhet and Campos (1966)[154] collected 106 soil samples from six different regions of Mozambique and investigated the incidence of geophilic dermatophytes and other keratinophilic fungi in the soil. *M. gypseum* was isolated from 15 soil samples, *Microsporum fulvum* from five samples, and *Microsporum cookie* from two soil samples. There are documentations on the use of hair-baiting techniques in the recovery of geophilic dermatophytes from soil samples collected in Egypt,[155] New Zealand,[156] Brazil,[157] Italy,[158] Austrialia,[159] Romania,[160] Norway,[161] and the United Kingdom[162] among others. The etiologic role of *M. cookei* in cases of dermatophytosis has also been highlighted in literature.[163–168] While traditional methods of microscopy and morphological tools have led to the misdiagnosis of *M. fulvum* with *M. gypseum*, Nouripour-Sisakht et al. (2013)[169] vividly showed the use of sequence-based methods in the proper diagnosis and identification of *M. fulvum* as an ignored pathogenic species.

Out of the 42 school-going children who were included by Carod et al. (2011)[170] in their study of dermatophytosis in Antananarivo, Madagascar, 64% were infected with tinea capitis, while 76% were presented with tinea corporis. Gray patches were the main clinical features observed in children affected with tinea capitis, with *Microsporum langeronii* (reclassified as *M. audouinii*) being the only implicated species. They further reported that 62% and 31% of the tinea capitis-infected children had regular contact with two important reservoirs of *Microsporum,* which were dogs and cats, respectively. In this study, chronic malnutrition, poor hygienic conditions, and limited access to water were also regarded as predisposing factors to these dermatophytic infections. In contrast, Contet-Audonneau et al. (2006)[171] reported the absence of gray-patch ringworm in 210 primary school children examined for tinea capitis in Antsirabe, a town located at the high central regions of Madagascar. *T. tonsurans*, *Microsporum boullardii,* and *Trichophyton terrestre* were the dermatophytes implicated in this study. In a retrospective investigation of tinea capitis in Antananarivo, Razanakolona et al. (2009)[172] indicated that the rarity of public health information and poor socioeconomic conditions are factors responsible for the high prevalence of this disease in Madagascar.

In an investigation of scalp dermatophytosis affecting schoolchildren in Somalia, *T. violaceum* was the most implicated species (112 isolates), followed by *T. soudanense* (44 isolates), *M. canis* (2 isolates), and an isolate of *E. floccosum*.[173]

Dermatophytes in Malawi, Rwanda, Burundi and Uganda

In Karonga district of Malawi, Pónnighausi et al. (1995)[174] reported the rare occurrence of *M. nanum* in a sample of skin scrapings obtained from a patient involved in pig rearing. This was the first report of the isolation of this dermatophyte variant in Africa. It is important to note that Ajello et al. (1964)[175] had earlier described this variant of *M. nanum* as a geophilic dermatophyte that commonly affects pigs but had a rare occurrence in humans. From 1987 to 1989, Pönnighaus et al. (1996)[176] carried out a survey of tinea infections affecting the Karonga population of Northern Malawi. They found out that tinea faciei, tinea corporis, tinea inguinalis, or tinea cruris affected 1.5% to 2.5% of the population. *M. audouinii* was the predominant isolate (57%), while *T. rubrum* had the least incidence of around 1%.

In Butare region of Rwanda, Buginco (1983)[177] reported the isolation of different strains of dermatophytes from 60 hair samples taken from children who showed clinical signs typical with tinea capitis. *T. violaceum* was the predominant species (34 strains), followed by *M. langeronii* (or *M. audouinii*) (19 strains), and *T. verrucosum* (2 strains). This report was the first to implicate *T. verrucosum* as a causative agent of ringworm in this region of Rwanda. In this same region of Rwanda, Bugingo (1993)[178] collected 100 samples from children who were suspected of having tinea capitis infections. Their data showed that 65% of cultured samples were positive with *T. violaceum* and *M. langeronii* (or *M. audouinii*) and were recovered in 42 and 26 cases of the cultured samples, respectively. As early as 1961, Vanbreuseghem and Rosenthal (1961)[179] described the novel isolation of *Trichophyton kuryangei* from tinea capitis cases in Ruanda Burundi. This organism was found to exhibit rapid growth rate with colonies having a bright yellow periphery in the culture medium. In another study of dermatophytoses in Ruanda-Urundi, 282 children out of 1,421 and 42 out of 1,061 adults were clinically diagnosed with these superficial fungal infections.[180] While dermatophytic infections due to *M. langeroni* was reported only in the littoral zones of Lake Tanganyika, infections due to *Trichophyton* species (*T. violaceum, T. ferrugineum, T. kuryangei*) were found only in the mountainous regions of Ruanda-Urundi. This observation on the different geographical distribution of dermatophyte agrees with the work of Nsanzumuhire and Masawe (1978)[122] as already described in this review. In an important epidemiological study involving 15,000 people, *M. langeronii* (renamed *M. audouinii*) (41.8%) and *T. violaceum* (32.3%) were reported as the major causative agents of tinea capitis in the Congo, Rwanda, and Burundi.[181] An interesting finding of this work was the high frequency (almost 100%) of dermatophytosis in children suffering from kwashiorkor. Following an observation that one out of every four children in dispensaries located in Rwanda and Burundi had scalp dermatophytosis, Dockx (1969)[182] proposed malnutrition as a contributing factor in the incidence of dermatophytosis.

In Uganda, a rare infection of tinea circinata manus affecting a 15-year old boy who was diagnosed with HIV infection has been reported by Nenoff et al. (2007).[183] An important clinical feature found in the Ugandan boy was the presence of scaly, circinated, and dry hyperkeratosis at some parts of his body. *M. gypseum* was the only implicated dermatophyte.

Dermatophytes in Zambia, Zimbabwe and Botswana

Out of the 704 primary school children in Harare area of Zimbabwe who were examined by Robertson and Wright (1990)[184] for the presence of ringworm infections, 29% showed features diagnostic of tinea capitis, with dermatophytes being isolated from 69% of the samples collected. Predominant isolates in the study were *T. violaceum* (78%) and *M. audouinii* (9%). Other isolated species were *T. mentagrophytes*, *T. yaoundei* (or *T. violaceum*), and *M. canis*. In a study of tinea capitis involving physically challenged children living in a boarding school in Harare, Wright and Robertson (1986)[185] reported a high prevalence of 39% of fungal infections in the 7–12 age group. *T. violaceum* (88%) and *M. audouinii* (38%) were the isolated dermatophytes. In an investigation on the occurrence of tinea capitis in rural and urban schools of Lusaka, Zambia, Simpanya (1989)[186] noted that there was a higher incidence (18.0%) of tinea capitis in boys compared to girls (14.7%). *T. violaceum* was the only dermatophyte species recovered from samples obtained from school children in rural schools of Lusaka, while *M. langeronii* (*M. audouinii*) and *T. violaceum* were both isolated from samples collected from children in urban schools.

The prevalence of tinea capitis among different age groups in Botswana was investigated by Thakur (2013)[9] who collected hair samples from 30 children and 12 adults who were attending a dermatology clinic in Gaborone. Tinea capitis was more prevalent in children aged 1–15 years (81%). The prevalence in those aged 16–60 years was 14%, while that in those aged 61–67 years was 5%. *T. violaceum* was the most common etiologic agent in the study (95%) followed by *T. tonsurans* (5%). Thakur (2013)[9] then advocated the use of several control strategies to prevent the spread of tinea capitis among the local population of Botswana. These control measures include the disinfection of hair accessories before use and avoiding the sharing of hats, towels, and bed linens. The spread of different forms of dermatophytosis in Botswana has also been determined by Thakur (2015).[187] Out of the 450 patients who had clinical features suggestive of dermatophytosis, dermatophytes were isolated from 120 patients. The most prevalent isolate was *T. violaceum* (80%), followed by *T. interdigitale* (13.33%), *T. tonsurans* (4.16%), *E. floccosum* (1.66%), and *M. ferrugineum* (0.83%). The predominant clinical manifestation of dermatophytosis was tinea unguium (27.5%), followed by tinea corporis (20%), tinea capitis (17.50%), tinea faciei (15.83%), tinea pedis (12.50%), tinea manuum (3.33%), and tinea cruris (3.33%). A case report of tinea capitis affecting a 7-year old child in Botswana was presented by Thakur and Goyal (2015).[113] Initial cultural examination of collected hair samples gave white variants of *T. violaceum*. Interestingly, only violet strains of *T. violaceum* were isolated after the child was placed on treatment with griseofulvin for 6 weeks. The isolation of two variants of *T. violaceum* from a single case is rare but may be due, among other factors, to a mixed infection of the two strains.

Table 2. Etiologic agents of animal dermatophytosis in Eastern and Southern Africa.

Animal	Etiologic agent	References
Cattle	*T. verrucosum*	52,126
Impalas	*M. gypseum and T. schoenleinii*	53
Camels	*T. schoenleinii*	53
Porcupines	*T. mentagrophytes*	146

Challenges and prospects

The regions of Africa covered under this review have important exotic animals of tourist attraction. Many of these animals are important reservoirs of dermatophytes and can contribute to infection transmission to tourists. There are few reports of such transmissions in Africa. The role of these animals in the transfer of dermatophytes to zookeepers, hunters, butcher, and tourists needs further investigation.[55] As shown in Table 2, there are few reports of animal dermatophytosis in these regions of the world. More work in these regions of the world should focus on the characterization of dermatophytes in domestic animals such as poultry, swine, and so forth. Dermatophytosis, though recalcitrant in its infection, is commonly controlled by drugs and agents that inhibit the production of ergosterol in the etiologic fungi, a membrane lipid similar to cholesterol in mammals.[22] Africa, blessed with rich herbs, needs to be explored on the development of pharmaceutical products that would counter dermatophytosis.

The use of microscopic and cultural methods as conventional diagnostic tools in the identification of dermatophytosis in eastern and southern parts, the focus of the current review, is symbolic mainly because of inadequate manpower and equipment. The atypical morphology of some of the species poses a serious problem in diagnosis. Molecular diagnostic methods employing conserved genetic areas such as the ITS (Internal transcribed spacer) regions

Table 3. Predominant etiologic agents of tinea capitis and other dermatophytic infections in Eastern and Southern Africa.

Country	Predominant isolate (%)	References
Botswana	*T. violaceum* (80–95%)	9,187
Burundi and Rwanda	*T. violaceum* (34 strains),	177
	M. langeronii (or *M. audouinii*) (41.8%)	181
Ethiopia	*T. violaceum* (80.6–97%)	26,111,112,120
Kenya	*T. violaceum* (72.9%)	7
	T. tonsurans (33.3–77.8%)	3,38,61
	T. verrucosum (16.3%)	63
	T. schoenleinii (3.7%)	67
Madagascar	*M. langeronii* (or *M. audouinii*) (100%)	170
Malawi	*M. audouinii* (57%)	176
Mozambique	*M. audouinii* (69%)	152,153
Somalia	*T. violaceum* (112 isolates)	173
South Africa	*T. violaceum* (90–90.5%)	5,135
	T. rubrum (27%)	136
Tanzania	*M. ferrugineum, M. audouinii, and T. violaceum*	122
Uganda	*M. gypseum*	183
Zambia	*T. violaceum and M. langeronii* (or *M. audouinii)*	186
Zimbabwe	*T. violaceum* (78–88%)	184–185

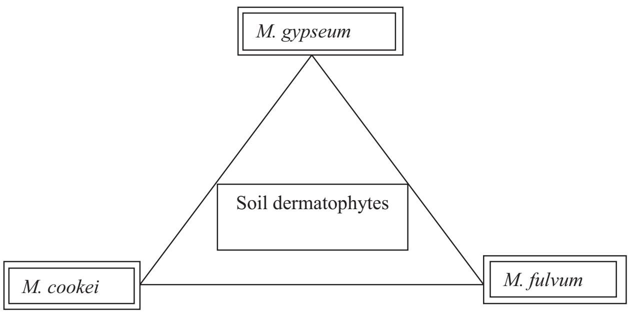

Figure 2. Geophilic dermatophytes isolated from Eastern and Southern African soils.

can be used to prevent the wrong diagnosis of dermatophytic infections.[22,188,189] Table 3 is a summary of predominant etiologic agent of dermatophytosis in these parts of the world. Future studies should also focus on the characterization of geophilic dermatophytes in different parts of Africa. This will help in monitoring and preventing the transmission of geophlic dermatophytes to children who may contact these pathogens through playing with sand. Figure 2 shows three major geophilic dermatophytes found in these regions.

The unwillingness of some parents and guardians to allow their children or wards to participate in some of the epidemiological surveys poses a serious challenge in these parts of the world.[7] Cultural practices such as the braiding of hair may contribute to the incidence of the disease especially among the female population.[120] Additionally, there are not many well-trained dermatologists in the developing parts of the world.[190] Training of medical personnel in the treatment and prevention of dermatological infections may also help in curtailing the spread of dermatophytosis in many these parts of Africa[191] and even beyond.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and the writing of the paper.

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