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Increasing postgraduate medical mycology research dissertations at Uganda's higher institution of learning

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ABSTRACT

Objectives: Postgraduate medical mycology research may also be affected by funding. This study reports the positive impact of funding on postgraduate medical mycology research at Makerere University, Uganda.

Methods: This retrospective study was conducted on postgraduate medical microbiology dissertation topics from 2023 to 2024 using data collected between September and November 2024.

Results: A total of N = 60 postgraduate medical microbiology dissertations were analyzed for medical mycology topics, of which a total of 18 (30%) focused on medical mycology. The percentage of dissertations centered on medical mycology increased from 16% (four of 25) in 2023 to 40% (14 of 35) in 2024. Cryptococcal meningitis is the most studied fungal disease (35.7%) (five) in 2024. Notably, molecular-based polymerase chain reaction (50%, two) and semi-automated culture (35.7%, five) were the most commonly used laboratory methods in 2023 and 2024. There were 75% (four) and 71.4% (14) timely completions of the postgraduate students, and the Makerere University Fungal Group was formed to promote the "buddy system of learning" among the postgraduate medical mycology students.

Conclusion: There has been an increase in medical mycology research among postgraduate medical microbiology students at Makerere University, Uganda, which is attributable to increased funding.

Introduction

Medical mycology is an essential field in infectious disease research that focuses on the study of fungal pathogens that cause diseases in humans [1]. Despite its critical importance in the context of global public health, medical mycology has historically received limited attention, particularly, in developing countries [2]. Challenges include limited baseline epidemiological data, lack of rapid diagnostic tests, reliance on conventional microscopy and culture-based assays, and prohibitively low funding [3]. Notably, research in medical mycology received less than 3% of the total funding allocated for infectious diseases [3,4].

This neglect is particularly concerning given the substantial burden of fungal diseases, which can range from superficial [5] to subcutaneous mycoses and invasive fungal diseases (IFDs) [6]. Superficial mycoses, which affect keratinized tissues, such as the skin, hair, and nails, are the most prevalent globally, affecting approximately two billion people [7].

Subcutaneous fungal diseases often classified as neglected tropical diseases by the World Health Organization are hyperendemic in restricted geographic regions [8]. IFDs, characterized by infections of the bloodstream and/or deep-seated organs with associated high mortality rates, pose a significant public health challenge, particularly, among individuals with compromised immune systems due to conditions such as cancer, HIV/AIDS, or organ transplant [9]. The global annual incidence of IFDs is estimated to be around 6.5 million cases, with a particularly high burden observed in regions with high rates of immune suppressive conditions such as HIV/AIDS in developing countries [10,11].

In Uganda, the burden of IFDs is particularly alarming, with approximately 20% of the population (45 million) affected [12]. Among the IFDs, cryptococcal meningitis, caused by the basidiomycetous opportunist pathogenic yeast, *Cryptococcus neoformans*, stands out as the leading cause of IFD-related mortality in patients with HIV/AIDS. The survival rate of individuals diagnosed with cryptococcal meningitis remains

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critically low, with less than 50% surviving beyond 10 weeks despite receiving antiretroviral treatment and fluconazole therapy [13]. This dire situation underscores the urgent need for enhanced research efforts and funding directed toward understanding and combating IFDs in Uganda and similar contexts [14].

Previously, we showed that medical mycology comprised only 3.3% (152) of dissertations submitted by postgraduate microbiology students at the College of Health Sciences at Makerere University [14]. The low number of postgraduate medical mycology dissertations was attributed but not limited to a lack of dedicated fungal disease research funding [14]. However, funding support for medical mycology postgraduate research between 2022 and 2024 increased through the Ugandan Government's Makerere University Research and Innovation Fund, the European Union's European and Developing Countries Clinical Trials Partnership, and the National Institutes of Health/International Fogarty Centre early career grants. Therefore, this study aims to illuminate the positive impact of funding support on postgraduate medical mycology research at Makerere University. Specifically, we report an increase in the proportion of medical mycology dissertation topics, diversity of research topics, laboratory methods used in data collection, and timely student completion rates. This study is grounded in the premise that funding can significantly shape research priorities, methodologies, and outputs, particularly, in under-researched fields, such as medical mycology, in Uganda, which is a resource-limited country.

Materials and methods

Study design

A retrospective analysis of postgraduate medical microbiology dissertations was performed at the College of Health Sciences, Makerere University from 2023 to 2024.

Data collection

Dissertation topic review

This study conducted a comprehensive review of dissertation topics in the postgraduate microbiology and immunology departments of Makerere University. The inclusion criteria for this analysis were rigorously defined. First, only dissertations that explicitly addressed subjects pertinent to microbiology, including medical mycology, encompassing research on various types of fungal diseases, including superficial, subcutaneous, and invasive forms, were considered. The time frame for submission was constrained to dissertations submitted between January 2023 and November 2024, thereby ensuring the relevance of the findings to contemporary trends and the influence of funding sources.

Data extraction

Data extraction involved the systematic collection of specific information from each dissertation, including the title and abstract, to ascertain the topic, precise focus of the research, including laboratory methods used, and the year of submission to monitor temporal trends in research output, including completion time, to investigate the influence of funding on the timely completion rates of postgraduate studies. These processes were executed by a team of researchers proficient in data analysis, thereby ensuring consistency and accuracy throughout the data collection procedure.

Data analysis

Qualitative analysis

Qualitative analysis was performed on the abstracts and methodologies of various dissertations to discern the prevalent themes and emerging trends within the field of medical mycology. The analysis comprises several key components. First, a thematic analysis was conducted on

the abstracts to identify recurring subjects, including candidiasis, cryptococcal meningitis, and dermatophytosis, and thematic coding was used to systematically categorize these topics. Second, a comprehensive methodological review was undertaken to evaluate advancements in research techniques, focusing on the application of, in addition to conventional methods, semi-automated antimicrobial susceptibility testing (VITEK), matrix-assisted laser desorption ionization-time of flight (MALDI-TOF) mass spectrometry, polymerase chain reaction, and sequencing. Finally, an assessment of the collaborative learning environment fostered by the newly formed Makerere University Fungal Group (MUGF) was carried out, drawing on anecdotal evidence and feedback from group members. These qualitative data illuminated the effectiveness of the MUGF "buddy system of learning" in promoting student collaboration and enhancing academic performance.

Quantitative analysis

Quantitative analysis was used to examine the data using descriptive statistics to summarize the findings. The metrics calculated included the proportion of medical mycology dissertations, which was expressed as a percentage of the total dissertations for each academic year, number of diverse research topics, laboratory methods used in data collection, and, qualitatively, timely completion of the students.

Results

This section presents the findings of an analysis of postgraduate microbiology dissertation topics at Makerere University from 2023 to 2024, specifically focusing on medical mycology. The results highlighted a significant increase in research output, diversification of topics, evolution of methodologies, and the impact of funding on research completion rates.

Increase in medical mycology postgraduate research output

A comprehensive review of postgraduate medical microbiology dissertations conducted between 2023 and 2024 reveals a substantial increase in the proportion of research dedicated to medical mycology. A previous study in 2022 found that only 3.3% (five of 152) of postgraduate dissertations focused on medical mycology (Achan *et al.* [14]), which rose to 16.6% (four of 24) in 2023 and surged to 40% (14 of 36) in 2024 (Table 1). These remarkable increases illustrate the growing recognition of the importance of medical mycology in addressing public health challenges posed by fungal diseases, particularly, in Uganda, where the burden of such diseases is notably high. The data underscore not only an increase in the number of dissertations focused on medical mycology but also a shift in academic priorities toward addressing the pressing health challenges posed by fungal infections.

Diversification of research fungal pathogens

A total of 60 medical and microbiological dissertations were reviewed. Cryptococcosis remained the most studied area, with five (35.7%) dissertations highlighting its clinical significance, particularly, among immunocompromised patients with HIV/AIDS. *Candida* is the second most studied pathogen, with four (28.7%) dissertations in 2024.

Table 1

Proportion of medical mycology dissertations from 2022 to 2024 were retrieved.

Year	Number of dissertations (n)	Medical mycology, n (%)
2023	25	4 (16)
2024	36	14 (40)

The proportion of medical mycology dissertation topics was determined using descriptive statistics and expressed in percentage as shown.

Table 2
Fungal pathogens studied in 2023 and 2024.

Year and fungal pathogens	Frequency (%)
2023	
<i>Candida</i>	1 (25)
Mycetoma-causing fungi	1 (25)
Dimorphic fungi	1 (25)
Other fungi	1 (25)
2024	
<i>Candida</i>	4 (28.6)
<i>Cryptococcus</i>	5 (35.7)
Dermatophytes	1 (7.14)
Other fungi	4 (28.6)

Postgraduate medical mycology students studied different fungal pathogens as shown.

Table 3
Fungal pathogens studied in 2023 and 2024.

Method	Frequency (%)
2023	
Conventional culture	1 (25)
Matrix-assisted laser desorption ionization-time of flight mass spectrometry	1 (25)
Polymerase chain reaction	2 (50)
2024	
Conventional culture	3 (21.4)
Semi-automated culture	5 (35.7)
Whole genome sequencing	2 (14.3)
Rapid cryptococcal antigen biomarker test	1 (7.1)
Enzyme-linked immunosorbent assay	2 (14.3)
Artificial Intelligence	1 (7.1)

Postgraduate medical mycology students used different laboratory methods for their projects as shown.

This underscores the need for further research on its pathogenesis, treatment, and prevention due to rising antifungal resistance, as recently reported by Musinguzi *et al.* (Therapeutic Advances in Infectious Diseases, 2024). Dermatophytosis was the least studied, with one (7.14%) dissertation (Table 2). A dissertation on dermatophytosis reflects a novel area of research among postgraduate students, indicating a growing interest in medical mycology. The laboratory methods used in medical mycology projects were also reviewed. Polymerase chain reaction and semi-automated culture are the most commonly used methods at 50% (two) and 35.7% (five) in 2023 and 2024, respectively. This was followed by MALDI-TOF mass spectrometry, followed by conventional culture at 25% and 21.4% in 2023 and 2024, respectively. In 2024, enzyme-linked immunosorbent assay, whole genome sequencing, and both, 14.3% (two), and the rapid cryptococcal antigen biomarker assay, 7.1% (one), as well as trending artificial intelligence, 7.1% (one), were used (Table 3). The integration of these advanced methodologies has not only enhanced the quality of the research conducted but also equipped students with critical skills essential for modern mycological research. This methodological advancement is indicative of the broader strength of mycological research, in which advanced technologies are increasingly utilized to address complex biological questions.

Completion rates

The availability of funding plays a crucial role in facilitating the successful and timely completion of research projects and enhancing the academic performance of postgraduate students. A notable example of the positive impact of funding is the case of our Doctor of Philosophy (PhD) and Master's graduates who completed their research projects on time (Table 4) because of the financial support provided for tuition fees, stipends, and laboratory consumables. Our findings agree with those of a previous study conducted at Makerere University, in which the de-

Table 4
Timely completion rate of medical mycology students.

Year	Timely completion, % (frequency)
2023	75% (4)
2024	71.4% (14)

Timely completion rate was calculated by subtracting the year of dissertation defense from the year of registration for the postgraduate program. The difference was multiplied by 100 and expressed as percentage as shown.

layed completion time of postgraduate students was associated with a lack of funding. Therefore, the timely completion of the research exemplifies how funding can enhance the research productivity and academic achievement of postgraduate students.

Formation of the Makerere University Fungal Group

The formation of the MUFG has further amplified the positive effects of funding on medical mycology research. This group, consisting of 25 postgraduates (two PhD, 20 master's, three undergraduate students, and four faculty members) (Figure 1), met weekly to discuss ongoing research projects, share insights, and provide constructive feedback. The collaborative environment fostered by MUFG has facilitated the buddy system of learning, where students engage in peer-to-peer critiques and discussions that extend beyond formal meetings, which, in turn, promoted a culture of research innovation and inquiry. Students are encouraged to explore novel research questions and methodologies, leading to a richer academic discourse in the field of medical mycology.

Discussion

The findings of our study revealed a significant transformation in the landscape of medical mycology research at Makerere University, particularly, in 2023 and 2024. The notable increase in the number of dissertations focused on medical mycology, the diversification of research topics, the evolution of methods, and the timely completion rate of PhD students collectively underscore the critical importance of funding in medical mycology in addressing the public health challenges posed by fungal diseases. In this discussion, we contextualize these findings within broader academic and public health frameworks and explore their implications for future research, education, and health policies.

Research output

The dramatic increase in the proportion of dissertations dedicated to medical mycology from 5% in 2022 to 40% in 2024 signals a paradigm shift in academic priorities among postgraduate microbiology students at Makerere University. This trend reflects growing awareness of the burden of fungal diseases, which have historically been underrepresented in research agendas, particularly, in sub-Saharan Africa. The rise in medical mycology research can be attributed to several factors, including the increasing incidence of fungal infections, the emergence of antifungal resistance, and a heightened focus on the intersection of fungal diseases with other health issues, such as HIV/AIDS. Fungal diseases such as candidiasis and cryptococcal meningitis pose significant health risks, particularly, in immunocompromised populations. Recognition of these health challenges has prompted researchers to prioritize investigations into the epidemiology, pathophysiology, and treatment strategies for these infections. As such, the findings of this study not only reflect an institutional shift but also align with global health priorities, emphasizing the need for enhanced research efforts in medical mycology.

Diversification of research topics

The diversification of research topics within medical mycology, as evidenced by the range of fungal pathogens and diseases explored in

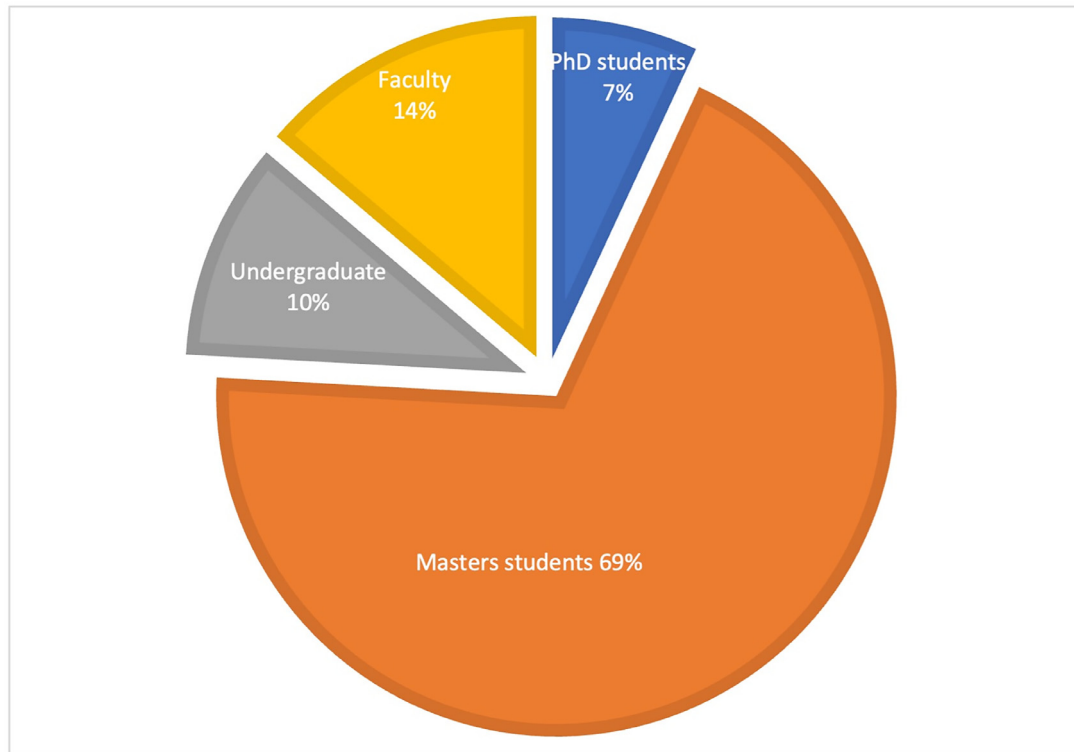


Figure 1. The Makerere University Fungal Group. The Makerere University Fungal Group is composed of postgraduate (PhD and Master's) and undergraduate students and faculty.

the dissertations, is particularly noteworthy. The focus on the various aspects of candidiasis, cryptococcal meningitis, and dermatophytosis highlights a comprehensive approach to understanding fungal diseases. This breadth of research is crucial because it indicates a recognition of the multifaceted nature of fungal infections, including their epidemiology, treatment challenges, and socioeconomic factors that contribute to their prevalence.

Increasing interest in specific pathogens and diseases reflects a more nuanced understanding of the complexities of fungal infections. For instance, the exploration of resistance patterns in *Candida* species is critical given the rising incidence of antifungal resistance worldwide. Research on cryptococcal meningitis is particularly relevant in Uganda, where the prevalence of HIV remains high. By addressing these areas, researchers have provided valuable insights that can inform clinical practice and public health interventions.

Improved methodologies

The methodologies used in the dissertations from 2023 to 2024 underwent significant evolution, reflecting a transition toward more advanced and sophisticated techniques. Notably, automated antimicrobial susceptibility testing has emerged as a prominent approach, facilitating the rapid and accurate determination of the susceptibility profiles of various fungal pathogens, thereby enabling more effective treatment strategies. In addition, the implementation of MALDI-TOF mass spectrometry has markedly enhanced the precision of fungal species identification, resulting in improved diagnostic accuracy compared with traditional methodologies. Furthermore, several students have incorporated sequencing into their research endeavors, allowing comprehensive investigations of genetic diversity, resistance mechanisms, and epidemiological patterns among fungal pathogens. The integration of these advanced methodologies not only elevates the overall quality of the research conducted but also equips students with the essential skills requisite for contemporary mycological investigations. This methodologi-

cal advancement is emblematic of a broader trend in microbiological research, wherein sophisticated technologies are increasingly used to tackle complex biological inquiries.

Impact of funding on research completion rates

Funding's role in facilitating research completion and enhancing academic performance should not be overlooked. The financial support provided by various funding agencies has alleviated many traditional barriers faced by postgraduate students in developing countries. By reducing financial burden, funding enables students to concentrate on their research, leading to higher completion rates and improved academic outcomes.

Timely completion serves as an example of how targeted funding can catalyze academic success made possible by financial support, thus underscoring the importance of sustained investment in research. Such funding initiatives not only support individual students but also contribute to the overall growth and development of the research community at Makerere University.

Furthermore, the establishment of collaborative research groups, such as the MUFU, has amplified the positive impact of funding on research productivity. The collaborative environment fostered by MUFU encourages peer-to-peer learning, innovation, and sharing of ideas, which are essential components of a thriving academic community. This collaborative approach not only enhances individual research projects but also contributes to a culture of inquiry and excellence within the field of medical mycology.

Implications for future research and policy

The findings have significant implications for future research and health policies. The substantial increase in medical mycology research at Makerere University highlights the need for continued investment in this area, particularly, considering the growing burden of fungal dis-

eases. Policymakers and funding agencies must recognize the importance of supporting research initiatives that address the challenges posed by fungal infections, especially in regions where these diseases disproportionately affect vulnerable populations.

Second, the diversification of research topics suggests a critical need for interdisciplinary approaches to understand and address fungal diseases. Collaborative efforts by researchers from various fields, such as microbiology, immunology, epidemiology, and public health, can lead to more comprehensive strategies for combating fungal infections. Such interdisciplinary collaborations can foster innovative research questions and methodologies that will ultimately enhance our understanding of fungal diseases and their impact on public health.

Finally, the evolution of methodologies used in medical mycology research underscores the importance of training and capacity building for students and researchers. Institutions must prioritize the development of training programs that equip students with the skills necessary to use advanced techniques. By investing in capacity building, institutions can ensure that the next generation of researchers is well-prepared to tackle the challenges posed by fungal diseases.

Future directions

The findings of this study highlight a significant transformation in the field of medical mycology at Makerere University, driven by increased funding, institutional support, and growing recognition of the importance of this area of research. The substantial rise in the number of dissertations focused on medical mycology, diversification of research topics, adoption of advanced methodologies, and the positive impact on research completion rates underscore the critical need for continued investment in this under-researched area of infectious diseases. As the field of medical mycology continues to evolve, an ongoing commitment to research funding, interdisciplinary collaboration, and capacity building is essential for addressing the pressing challenges posed by fungal diseases in Uganda and beyond. The future of medical mycology holds promise contingent upon sustained efforts to prioritize this vital area of research and its implications for public health. The methodologies used in these dissertations have also evolved, showcasing a shift toward more advanced and sophisticated techniques.

Limitations of the study

This study has several limitations that may have affected the interpretation of the findings. First, the focus on dissertations from a single institution potentially constrains the generalizability of the results, suggesting that future research should encompass multiple institutions to achieve a more comprehensive understanding of trends in medical mycology. Second, the reliance on students to accurately report their funding sources introduces the possibility of self-reporting bias. Nevertheless, efforts were undertaken to cross-verify these funding acknowledgments with official records whenever feasible. Third, the temporal scope of the study was limited to a 2-year period, which may not adequately capture long-term trends in medical mycology research; thus, longitudinal studies of a longer duration are recommended to evaluate sustained growth and variations over time. Finally, the completion time in 2023 was 3 years (instead of the expected 2-year post-graduate duration). This was done to provide allowances for the 1 year lost to the COVID-19-induced lockdown when the university was closed.

Conclusion

This study revealed a notable transformation in medical mycology at Makerere University, largely due to enhanced funding and institutional backing. These findings emphasize the necessity for further investment in this underexplored field of mycology.

Declarations of competing interest

The authors have no competing interests to declare.

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Ethical approval and consent

Because the data were collected from publicly available dissertation records, no individual participant consent was required; therefore, we did not seek ethical approval to conduct this study.

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Author contributions

BA: conceptualization, resources, investigation, writing the original draft; BM: data collection, writing review, analysis, and editing; OJS: writing, review, and editing. All the authors have read and approved the manuscript.

Availability of data and materials

The analyzed data sets are available from the corresponding author upon reasonable request.

Consent for publication

Not applicable.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.ijregi.2024.100562](https://doi.org/10.1016/j.ijregi.2024.100562).

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