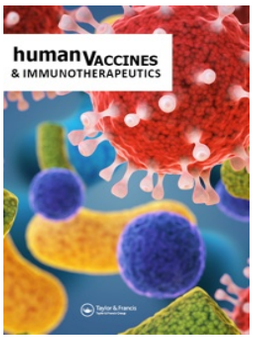

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REVIEW

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Exploring the availability and content of vaccinology courses across the globe: A scoping review

Peter S. Nyasulu[a,b], Jacques L. Tamuzi[a], Chinwe Iwu-Jaja[c], Ritika Tiwari[d], Doris Y. Sakala[a], Charles S. Wiysonge[c], Rene English[a], and Usuf Chikte[a]

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ABSTRACT

Mapping current vaccinology courses is critical for identifying educational gaps, refining program content, and increasing international cooperation to achieve a competent and well-coordinated global vaccination effort. This scoping review investigates the availability and content of vaccinology courses throughout the world, with a focus on Africa where there is a need for strengthened immunization systems and workforce capacity. Eight vaccinology courses, including short professional training and university certificate programs, were offered in Africa, including Morocco, Senegal, Uganda, Kenya, Ethiopia, Rwanda, Ghana, South Africa, and Zimbabwe. Our findings indicated that the percentages of vaccinology modules significantly vary between Africa and other continents, specifically: introduction to immunology, epidemiology, biology of pathogens, vaccine types, vaccine pharmacology, clinical research methodology, pharmacovigilance and vaccine safety, health economics, immunization programs, vaccine manufacture, the role of international organizations in vaccine development, vaccine advocacy, and vaccine cold chain management. By analyzing and comparing specific characteristics of the courses, our results also found multiple gaps and potential challenges related to target population, course objectives, method of course delivery, course contents, duration of course, training, practical sessions delivery, course costs, and funding constraints.

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KEYWORDS
Vaccinology; course content; training; Africa; world

Introduction

Vaccination is one of the most effective health interventions ever developed in the history of modern medicine. Vaccination has proven to be a safe and effective way to protect people against several infectious diseases. The evident success of vaccinations in managing and eliminating infectious diseases prompted the establishment of vaccinology as a formal, interdisciplinary scientific subject. The concept of vaccinology originated in the 1990s. It is a comprehensive discipline based on the theories and practices of multiple disciplines, mainly studying the relevant theories and technologies of vaccine development.[1] Vaccinology courses trace its history from its empirical origins to the highly specialized and interdisciplinary field nowadays. Vaccinology education is a basic strategy to promote vaccine research and practice.[1] Over the past 20 y, the education of scientists and public health professionals in vaccinology has increased dramatically. There are now many international, regional, and national courses that provide education in vaccinology.[2] The need for advanced education in vaccinology as one means to strengthen the immunization workforce around the world was recognized by a group of vaccinology experts in 1999, and materialized as the first Advanced Vaccinology Course (ADVAC) in 2000.[3,4]

The COVID-19 pandemic, recurrent Ebola outbreaks, and the emergence of Mpox have highlighted the importance of developing new vaccines and strengthening vaccinology training programs, which have become key priorities at global, regional, and national levels. Progress has also been made in knowledge areas such as vaccine ethics, vaccine allocation, vaccine rollouts, equity of access to vaccines, vaccine

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hesitancy, inequitable vaccine access, understanding the effectiveness of the vaccine, and how vaccination augments other public health preventive strategies in place.[5,6] Furthermore, there has been a rapid development of innovations and new technologies, the focus on the life-course approach to immunization and on equitable access and use of vaccines. Additionally, immunization has already received increased attention in the past years, and since the COVID-19 pandemic, there has been emphasis on the potential importance of vaccinating beyond infancy, childhood, and adolescents and reaching out to other age groups as well, including adults, elderly, and pregnant women.[7]

Education and training in vaccinology has been shown to improve immunization practices.[8,9] Effective vaccination program and well-trained health workers are crucial for attaining immunization objectives; nevertheless, their efficacy is also contingent upon broader health system characteristics, including governance, resource distribution, workforce management, and program execution.[10] Successful vaccination programs necessitate a proficient healthcare workforce. Training in vaccinology for healthcare workers (HCWs) can enhance their capacity to combat vaccine misinformation, refine patient counseling, facilitate effective vaccination administration, and foster public trust in immunization, while acknowledging that wider health-system factors also affect immunization results. Hence, vaccinology training for HCWs may help them battle misinformation, enhance patient counseling, assure effective vaccination delivery, and increase public confidence.

However, it can be argued that vaccinology is not well addressed during the training of future HCWs. Since immunization is a responsibility of all HCWs, particularly those working at the frontline, having some training and structured curriculum in vaccinology will benefit medical, nursing, or midwifery students, postgraduates, and researchers. A limited number of training programs in vaccinology and vaccine-related courses may result in a shortage of skilled professionals in the field within African countries. In many African countries, structural governance weaknesses and workforce shortages interact, preventing the health sector from expanding and employing skilled health-care workers efficiently. A study highlighted that the disconnect between health workforce unemployment and critical shortages in many countries underscores deep systemic inefficiencies and missed opportunities to strengthen health systems. Addressing this misalignment is not only urgent but also essential for achieving universal health coverage and improving population health outcomes.[11] The limited availability of vaccinology and vaccine-related training programs in Africa may contribute to gaps in specialized expertise in the field. Such gaps, together with other structural factors such as limited research infrastructure, funding constraints, and workforce development challenges, may affect the capacity of some African countries to independently engage in vaccine research, development, and production.[12] Relevant modifications should be implemented to reflect the impact of these systemic institutional defects but only if they go beyond technological fixes to address the institutional incentives, governance deficiencies, and cultural signals that drive attrition. If the underlying causes are not addressed, improvements tend to be symbolic and fail to restore the perceived value of vaccinology courses.

Besides, regular updating is essential as programs face changing situations (introduction of new vaccines, inclusion of new target groups as expected in life course vaccination, changes in vaccination coverage, disease outbreaks, antimicrobial resistance, humanitarian crises), the increasingly high rate of turnover of immunization program managers in many countries, and the need to counteract misinformation from anti-vaccine organizations and individuals.[4] Similar studies assessing vaccination courses worldwide,[3,7] however, none have been compared the courses contents in Africa and examined the gaps in vaccinology course offerings, including geographical and topical deficiencies. Moreover, none have undertaken a comprehensive investigation to present vaccinology courses, conceptual framework, and curricula in Africa. This study is important as it identifies current vaccinology education opportunities, highlights gaps in training, and supports the development of more robust educational programs. This is especially critical in regions such as Africa, where building capacity in immunization and vaccine science is vital for enhancing public health outcomes.

Postgraduates and researchers need a foundation curriculum in vaccinology to deal with the challenges of new and reemerging infectious diseases across the world, especially in resource-limited areas. Hence, the need for access to advanced vaccinology courses globally, regionally, and nationally continues and is likely to grow.[4] Comprehensive training in vaccinology is often not incorporated into the curricula of medical and biological sciences programs at universities, resulting in a notable deficiency in knowledge concerning

vaccine-related topics among healthcare providers. The key question is: "What vaccinology courses are available globally with emphasize in Africa for medical, nursing, and allied health sciences students and practicing health professionals, and what are their characteristics, delivery methods, and associated challenges?"

Objective

The main objective of this scoping review was to explore the availability and content of vaccinology courses globally. This study also looks at the vaccinology courses objectives, methods of delivery, duration, language, exit qualification, and fees. Furthermore, this analysis examines the gaps and challenges associated with vaccinology courses throughout the globe and proposes a conceptual framework for incorporating vaccinology courses into African university curricula, to strengthen regional capacity for vaccine research and immunization programs. This review will inform the development of a vaccinology course tailored to medicine, nursing, and health sciences curricula in African Universities. The specific objectives included: (1) To document the objectives of existing vaccinology courses worldwide; (2) To investigate the various methods of course delivery, such as in-person, online, and hybrid formats; (3) To determine the duration and frequency of vaccinology training programs globally; (4) To identify the languages used for instruction in global vaccinology courses, noting any language barriers to access; (5) To map the types of qualifications conferred by vaccinology courses worldwide; (6) To analyze the costs and fees associated with vaccinology courses; (7) To examine the gaps in vaccinology course offerings, including geographical and topical deficiencies; (8) To map the main challenges and barriers affecting vaccinology training worldwide.

Methods

This scoping review was conducted following the Joanna Briggs Institute methodology for scoping reviews.[13] We conducted this study based on the methodological framework developed by Arksey and O'Malley,[14] which was subsequently expanded by Tricco et al.[15] To enhance transparency and uniformity of reporting, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for scoping reviews (PRISMA-ScR) was applied.[16]

Inclusion and exclusion criteria

The Population, Concept, and Context (PCC) framework was used to determine studies eligible for inclusion in this review. The population included medical, nursing, and allied health sciences students, as well as practicing health professionals who may participate in vaccinology education or training (P). The concept examined vaccinology education and training, including course content, teaching and learning strategies, delivery methods, course duration, language of instruction, exit qualifications, fees, and identified gaps and challenges in vaccinology training (C). The context included educational institutions globally that offer vaccinology courses at undergraduate and postgraduate levels (C). Furthermore, we examine the gaps and challenges related to vaccinology courses. We included published sources (peer-reviewed articles), unpublished or gray literature (such as reports, theses, policy briefs, technical documents, and policy reports), as well as preprints that had not yet undergone peer review. Exclusion criteria included editorials or comments, existing systematic reviews, conference materials without complete text, non-empirical research, courses with a limited scope or unrelated themes, and courses that have not yet been implemented. The review was limited to courses published in English from 01 January 2021 to 28 February 2026. The final choice to include reports was made based on this data extraction and whether it matched the inclusion criteria, based on an independent assessment by three authors (CJIJ, JLT, and RT), and any discrepancies were resolved by consensus.

Search strategy

The search strategy, which was designed, aimed to locate studies of both published and unpublished vaccinology courses. An initial search strategy was conducted for PubMed (**Appendix 1**) and adapted for

other databases such as Scopus, CINAHL, and Web of Science from 01 January 2021 to 28 February 2026. Furthermore, searches were conducted across Google Scholar using key words (teaching, module, course, training, and vaccinology). The collaboration's objective for the global database of vaccinology courses is to assist in the realization of a global, collaborative, and complementary vaccinology practice and educational context, better benefitting individuals who work within it and communities throughout the globe.[17] Relevant websites of institutions that offer vaccinology around the globe and portals for vaccinology courses were searched. The EndNote V.25 reference manager was used to eliminate duplication. CIJ, JLT, and RT assessed all the publications indicated by title and selected those that were possibly acceptable.

All identified records were collated after the search, and eligible studies were selected according to inclusion and exclusion criteria. This process was done by three independent reviewers (CIJ, JLT, and RT). In the event of a disagreement, the third author (PSN) was available for consultation if agreement could not be achieved.

Data charting process

Relevant information was extracted from included courses by two independent reviewers (CJIJ and JLT) using a data extraction tool developed by the reviewers. Both reviewers created an Excel form and separately examined the data items included to verify that they were consistent with the review's objectives. The data extracted included specific details about the target population (e.g., undergraduates, post-graduates, health professionals, etc.), the name and type of institutions offering the course (e.g., colleges, universities, private organizations, etc.), course duration (weeks, months, or years), the content of the courses, modes of teaching (e.g., online, offline, self-paced, etc.), exit qualification (e.g., certificate, diploma, degree, etc.), fees, course objectives, language, and any other relevant information. The course content for each identified course was summarized using thematic analysis.

Synthesis of results

The results of this review were conveyed using narrative synthesis. ArcGIS Pro version 3.5, Stata version 19 MP, and EdrawMax version 14.2.2 were used to report map, graphs, and diagram. We described the features of the included articles using percentages, and count for categorical and continuous variables and content analysis methods for text data. CJIJ and JLT worked together to synthesize the findings. Studies were summarized based on title of course, target audience, name of institution and country, course objectives, course content, method of course delivery, duration of course, language, exit qualification, and cost. The course contents were grouped into the following themes: introduction to immunology, epidemiology, biology of pathogens, vaccine types, vaccine pharmacology, clinical research methodology, pharmacovigilance-vaccine safety, health economics, immunization programs, vaccine manufacture, role of international organizations in vaccine development, vaccine advocacy, and vaccine cold chain management. We also reported the target population audience, method of course delivery, duration of course, learning language, and exit qualification. Based on the study findings, gaps and challenges were identified, and a conceptual framework was developed. A conceptual framework was created by mapping the retrieved data to the framework's vaccinology courses and provided descriptive narrative of how the literature handles each component. We did not appraise the methodological quality or risk of bias of the included articles, as this is not required for scoping reviews.[18] However, efforts to prevent bias in a scoping review synthesis focus on clear methods, broad evidence base, and standardized scoping review processes.

Results

Results of the search

From the search conducted with databases and websites, 13212 records were identified and screened (Figure 1). After the screening of titles and abstracts, as well as full-text screening, we found only 42 records eligible for inclusion (Figure 1). Majority of the information on vaccinology courses offered worldwide were obtained from a global database of vaccinology courses.[17] This

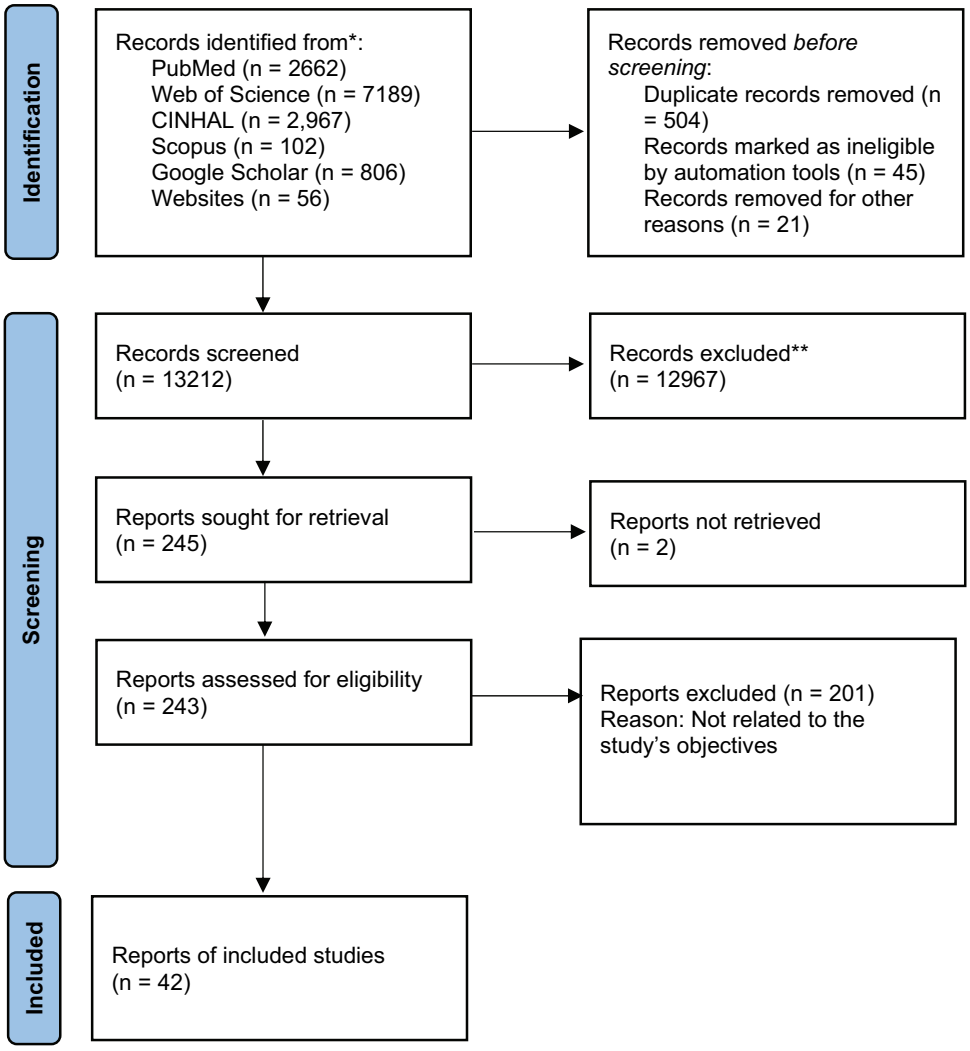

Figure 1. PRISMA flow diagram showing the process of study selection.

database is authenticated by several organizations and institutions.[17] Figure 1 describes the process used to select eligible courses included in this review. We identified a total of 42 vaccinology courses offered worldwide. These courses are available across various regions, including: (1) Europe: Belgium, France, Italy, Spain, Switzerland, Romania, and the United Kingdom; (2) Asia: Jordan, India, China, and South Korea; (3) America: Canada, the United States, Mexico, Argentina, and Chile; (4) Oceania: Australia; and Africa: Ghana, South Africa, Zimbabwe, Uganda, Senegal, Rwanda, Kenya, Ethiopia, and Morocco. These courses reflect a global commitment to advancing vaccinology education and training (Figure 2). Europe and Africa have a much larger number of countries providing vaccination courses, with 11 and 14, respectively (Figure 2). Our findings indicated that 14/42 (33%) of vaccinology courses were provided in Africa (nine countries), whereas 28/42 (67%) were offered elsewhere in the globe (Figure 2).

Summary of vaccinology courses

Course information overview

Supplemental Table 2 is comprised a table that provides comprehensive information on the courses, including the name of the institution, country/setting, course content, duration, exit qualifications, and costs. Majority of the courses identified (35/42, 83%) were offered in English. Others were conducted in Chinese, French, and Spanish.

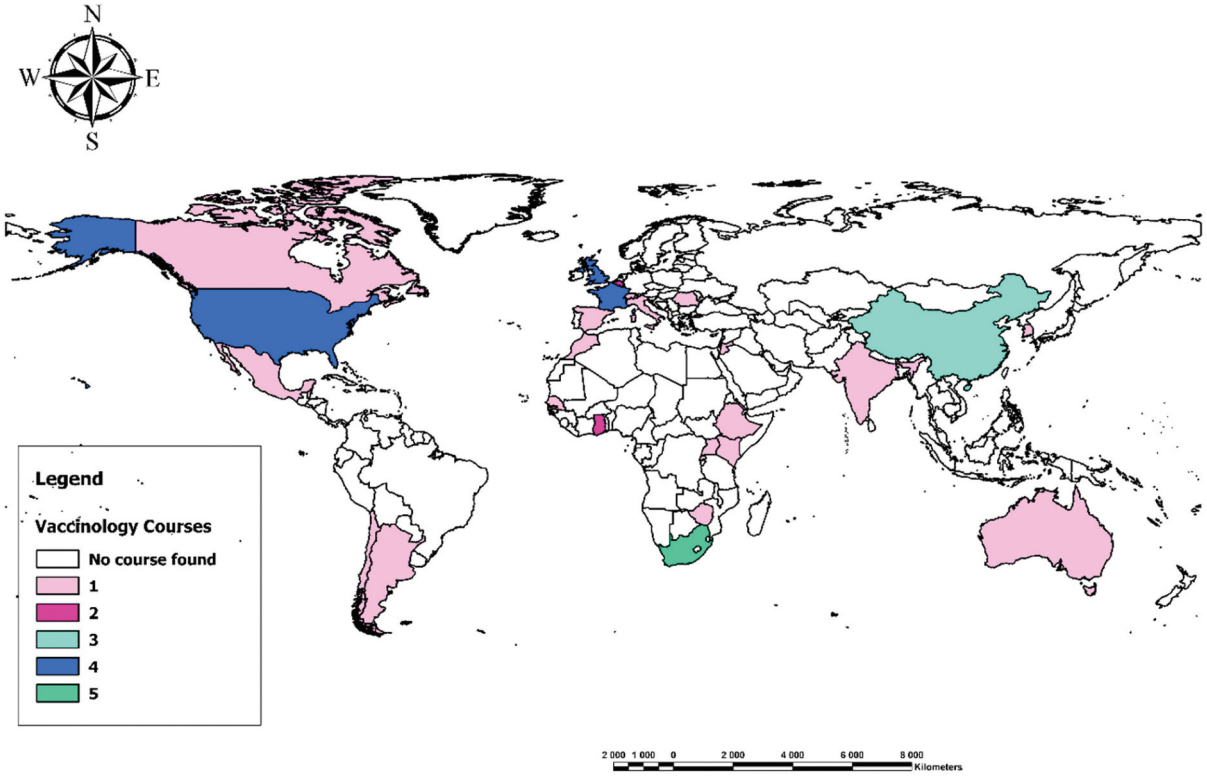

Figure 2. Global distribution of vaccinology courses, showing the number of courses offered in different countries.

Course delivery methods

Our findings revealed that 27 (64%) courses are in person, 12 (28%) are online, and the rest are blended courses (Supplemental Figure 1). Most of the vaccinology courses available at these institutions do not have specific entry requirements but largely target people working in the health sector. These include, medical doctors, nurses, pharmacists, undergraduate, and post-graduate students in (para)medical sciences.[19-32] Some institutions have different rates for students and industry delegates as well as international and local delegates.

Course cost and duration

Two courses provided in South Africa were free of cost for a week's duration.[8,17,33,34] The cost of courses lasting 1 week or less varied between USD 148.15 to USD 4000 (Table 1).[8,17,34,39] South Africa offered the cheapest course,[17,33] and the most costly course was in Australia (Supplemental Table 3).[36] For courses lasting more than 1–2 weeks, the total costs varied between USD 582.34 and USD 10948.05,[22] with France being the most reasonable and costly (Table 1).[17] In Italy and Switzerland, 1-y master's programs cost between USD1747.03 to USD 25,088.22. Similarly, 2-y master's programs in Canada, Romania, Kenya, Rwanda, and South Africa have an estimate of total fees ranging from USD 3030.40 to USD 8928.06 each year.[19,20,23,26,27] The total fees for the PhD vaccinology course offered in Canada and UK ranged between USD 8928,06 and 41739,06 per year.[20,40] Some institutions have indicated that the scholarship for the course is available, fully funded, and potential delegates may apply.[8,17,28–34,41,42] Costs are sometimes determined by academic/governmental institutions, non-governmental organizations (NGOs), business, and others. Furthermore, costs differed based on national or foreign applicants. Regarding the course duration, 38% (15/42) were in the range of 1 week or less, 33% (14/42) ranged between more than 1 week and less than 1 y, 12% (5/42) lasted 1 y and less than 2 y, 21% (9/42) were 2 y, and the rest of the courses ranged between 3 and 4 y (Supplemental Figure 2). A certificate of attendance is the exit qualification at most institutions usually to the participants who attended the full course.

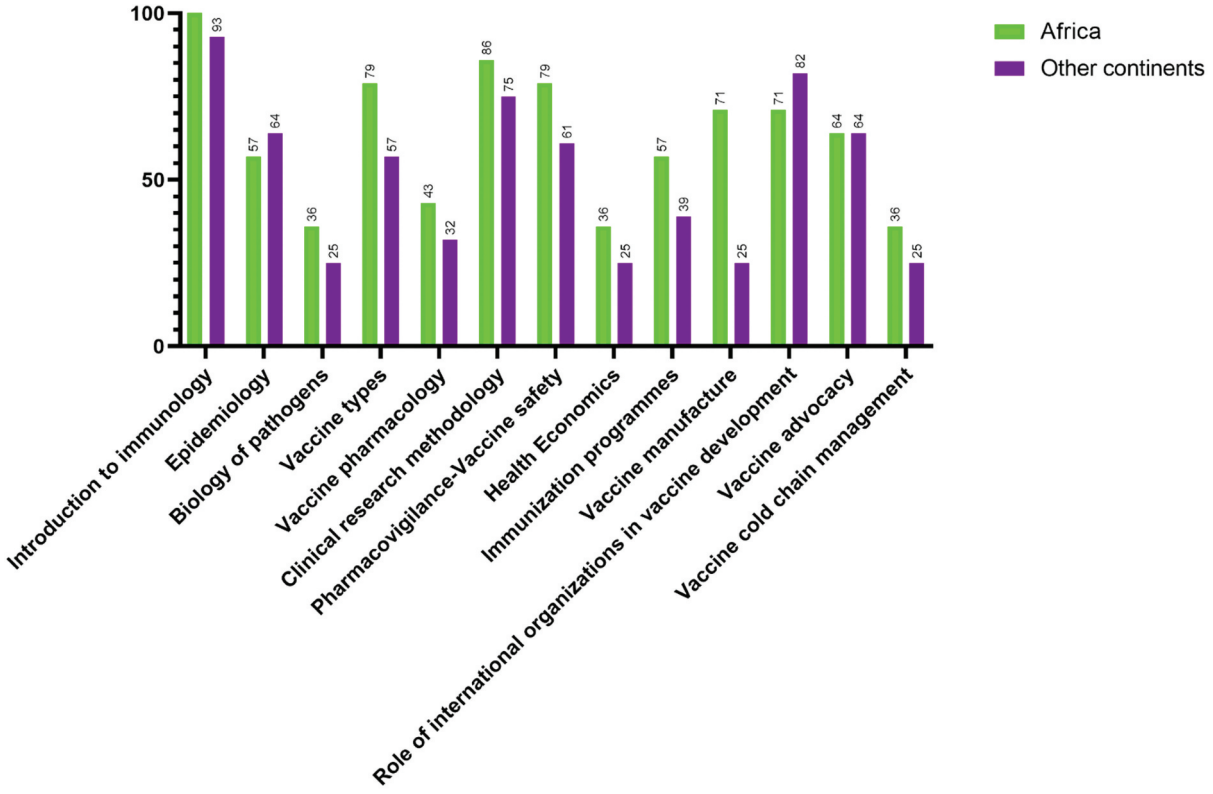

Figure 3. Comparison of vaccinology contents between Africa and other continents expressed in percentage.

Regional comparison of vaccinology courses

We summarized the courses available in Africa compared to other continents. Comparatively to other continents, Africa showed higher or equal rates of modules courses offered in vaccinology, including introduction to immunology, epidemiology, biology of pathogens, vaccine types, vaccine pharmacology, clinical research methodology, pharmacovigilance, vaccine safety, health economics, immunization programs, vaccine manufacture, role of international organizations in vaccine development, and vaccine advocacy; except the vaccine cold chain management module was lower in Africa (Figure 3).

Vaccinology courses in Africa

In Africa, most of the available courses in Africa are in South Africa (five courses). Other courses were available in Uganda, Rwanda, Kenya, Ethiopia, Zimbabwe, Senegal, Ghana, and Morocco. In South Africa, vaccinology courses are currently available in three institutions, including, Sefako Makgatho University in South Africa offers two courses: A higher certificate in vaccinology, offered online for 30 weeks, and a 1-week in-person short course.[2,4] In addition, the University of the Witwatersrand (WITS) offers the African Advanced Vaccinology course (Afro-ADVAC), a 10-d advanced vaccinology course, and also a master's degree in vaccinology.[23,35] The University of Cape Town (UCT) offers a 1-week Annual African Vaccinology Course.[8,17,43] In Zimbabwe, University of Zimbabwe offers a 2-y master of science degree in vaccinology.[21] In Uganda, The East Africa Centre for Vaccines and Immunization (ECAVI) offers a 1-week in-person certificate course.[3] In Senegal, the institution named Vaccinology in Africa offers a 4-d course[44] and in Morocco, an African University Diploma in vaccinology is offered as a 1-y course in Rabat's Medical Faculty.[22] The goal of the 1-week vaccinology course offered by Addis Continental Institute of Public Health (ACIPH) is to improve national vaccination programs and research capacity while educating researchers and healthcare professionals on immunization strategies and vaccinology principles.[42] A 2-y MSc vaccinology program offered by a University in Rwanda aims to build expertise in vaccine development, immunization systems, and vaccine supply chain management in Africa.[27] To train experts in infectious disease research and vaccine development for emerging pathogens, Jomo Kenyatta University of Agriculture and Technology in Kenya offers an MSc in Infectious Diseases and Vaccinology.[26] Both the Ghana College of Pharmacists and the University of Ghana's Noguchi Memorial Institute for Medical

Research (NMIMR) provide 4-month and 6-week vaccination courses, respectively, to train pharmacists to take part in national immunization programs, strengthen vaccine research capacity in Africa, and give researchers the tools they need to develop and evaluate vaccines[28,45] (Supplemental Table 2).

Vaccinology courses in other continents

In other continents, we found a total of nine courses available across various countries in Europe; four courses in France, three courses in the United Kingdom, two in Belgium and Romania, Spain, one course each in Italy.[19,40,46] These are mostly short courses offered between 1 and 2 weeks. There are currently four vaccinology courses available in the United Kingdom. The University of Oxford offers a 1-week course, and the London School of Hygiene and Tropical Medicine provides a 2-week course. In the same line, master's and PhD programs in vaccinology are offered exclusively by the University of Liverpool.[40] In addition, Master's degree programs in vaccinology are offered in a limited number of countries, namely Italy, Romania, and Switzerland.[17,24,37] Six vaccinology short courses were offered in four Asian countries, one course in each country, including China, India, Jordan, and Republic of Korea.[17,29,30] Their duration ranged from 1 week to 18 months[17,29,30] (Appendix 2). In America, there were four vaccinology courses in the United States, one in Canada, one in Mexico, one in Chile, and one in Argentina.[31,32,38] All of them were short courses, expected in Canada where a 2-y and 4-y master and PhD were offered by Vaccinology and Immunotherapeutics graduate program (University of Saskatchewan).[20] Furthermore, Emory and Maryland universities offered a 2–3-y certificate in vaccinology.[31,32]

Comparison of vaccinology modules between Africa and other continents

Modules of the course provided were tagged "Yes" whereas modules not included in the course were classified "No." Our findings indicated that the percentage of vaccinology modules varies between Africa and other continents. Specifically, introduction to immunology was at 100% (14/14) for Africa compared to 93% (26/28) for other continents; epidemiology was at 57% (8/14) for Africa vs. 64% (19/28) for other continents; biology of pathogens was at 36% (5/14) for Africa vs. 25% (7/28) for other continents; vaccine types were at 79% (11/14) for Africa vs. 57% (16/28) for other continents; vaccine pharmacology was at 43% (6/14) for Africa vs. 32% (9/28) for other continents; clinical research methodology was at 86% (12/14) for Africa vs. 75% (21/28) for other continents; and pharmacovigilance and safety was estimated at 79% (11/14) for Africa vs. 61% (17/28) for other continents. Our results also revealed that health economics was estimated at 36% (5/14) for Africa vs. 25% (7/28) for other continents, immunization programs with 57% (8/14) for Africa vs. 39% (9/28) for other continents, vaccine manufacture 71% (10/14) for Africa vs. 25% (7/28) for other continents, role of international organizations in vaccine development with 71% (10/14) for Africa vs. 82% (23/28) for other continents, vaccine advocacy with 64% (9/14) vs 64% 19/28) for other continents, and vaccine cold chain management with 36% (5/14) vs. 25% (7/28) for other continents (Figure 3, Supplemental Tables 1 and 2).

Gaps and challenges

Table 1 summarizes gaps, challenges, and ways forwards in vaccinology courses in Africa

Conceptualization of vaccinology course in African universities

Based on the review findings, a proposed structured vaccinology course was designed to address Africa's existing vaccinology issues and gaps. Blended courses bridge the gap between online and in-person classes, providing flexibility and personalization while also encouraging collaboration and accessibility, possibly leading to increased student motivation, engagement, and academic success. Vaccinology students should take blended courses. Most vaccination courses are brief in length. Given the relevance of this course, as stated in the introduction, a vaccinology course should be organized at the undergraduate, bachelor, and postgraduate levels. Modules are organized into basic, special, and research levels, as seen in Figure 4. Most courses do not offer practical or laboratory instruction. This mind map proposes that each level should be linked to training in at least one fundamental subject.

Table 1. Gaps, challenges, and ways forward in vaccinology courses in Africa.

Domains	Gaps	Challenges	Ways forward
Target audience	Most courses do not have appropriate quotas for health workers and students.[17,33]	The demands of nations or areas in terms of vaccination concerns may be biased.	Before organizing vaccination courses, assess the requirements of each group of health professionals and establish quotas.
Course objectives	Most of the objectives are general without considering contextual and regional parameters.[35]	Challenges in vaccinology are associated with modern technologies and emerging diseases.	Vaccinology courses should be designed to meet the country's and area's specific demands in terms of current vaccination gaps and challenges.
Course contents	Less courses included important modules such as vaccine cold chain management, health economics, vaccine hesitancy, and biology of pathogens.[17,19,33]	Participants' ability to completely comprehend the course may be hampered by a lack of fundamental knowledge of vaccinology (Biology).	Improve the vaccinology course by including fundamental and specialized sections.
Method of course delivery	Less courses included blended methods.[17,21,23,25]	Weaknesses associated with online or in-person interactions.	Blended vaccination courses will provide greater benefits than traditional in-person or online courses.
Duration of course	Most courses are short of duration.[8,17,24,35–38]	Not enough depth, little chances for professional growth, and the possibility of uneven quality given the present situation in vaccinology.	Well-structured vaccinology courses at the undergraduate, bachelors, and postgraduate levels are increasingly required.
Training and practical	Insufficient or lack of information on practical and training.[8,17,19,24,35,36]	challenges in accessing vaccines, delivering them effectively, and building capacity for vaccinology expertise.	Incorporate effective training and practical applications within the vaccinology course curriculum.
Course costs and research funding constraints	Lack of financial support in most of the trainings.[17,20,21,25]	High course costs and lack of scholarships.[17,20,35]	More scholarships and research funding are needed.

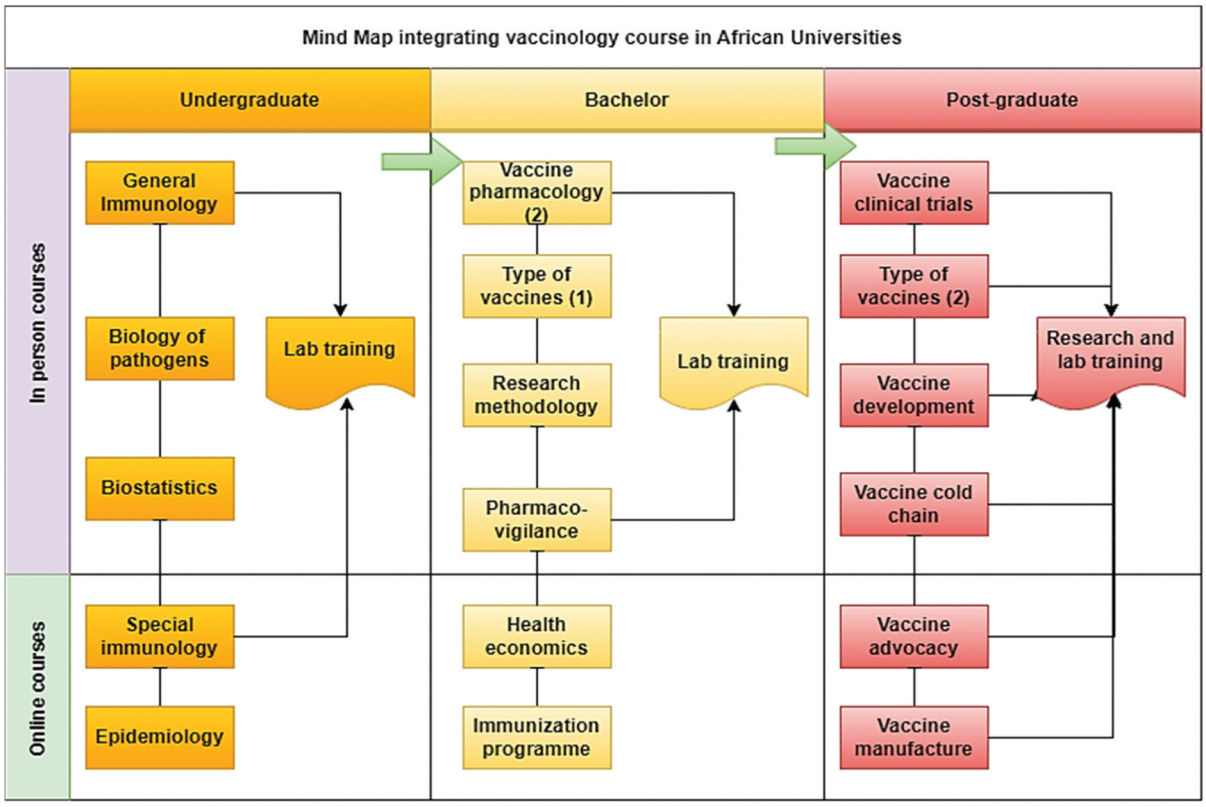

Figure 4. Mind map integrating vaccinology course in African universities.

Discussion

This scoping review provides a global overview of vaccinology courses, with particular emphasis on Africa. The review identified variations in course content across regions. Common modules included introduction to immunology, epidemiology, biology of pathogens, vaccine types, vaccine pharmacology, clinical research methodology, pharmacovigilance-vaccine safety, health economics, immunization programs, vaccine manufacture, role of international organizations in vaccine development, vaccine advocacy, and vaccine cold chain management. Overall, African courses covered most of these modules more frequently than courses in other regions, with the exception of the module on the role of international organizations in vaccine development and epidemiology. Despite this relatively broad coverage of modules, Africa remains heavily dependent on external organizations and companies for vaccine supply. Historically, less than 1% of vaccines used across the continent were produced locally, highlighting the limited local capacity for vaccine research, development, and manufacturing.[47–49] Some countries have successfully established or upgraded vaccine manufacturing facilities, allowing for local production of specific vaccines, such as COVID-19 vaccines in South Africa.[50] Despite this progress, overall vaccine production remains limited, and Africa continues to depend largely on imports to meet its population's needs. These developments demonstrate initial advancements but also emphasize the ongoing need for capacity building, skilled workforce development, and sustained investment.[51,52]

Most accessible courses in Africa are in South Africa (five courses). Other courses were offered in Uganda, Rwanda, Ghana, Ethiopia, Kenya, Zimbabwe, Senegal, and Morocco. In view of this, there is a need to expand the vaccinology course on national immunization programs and universities within the African continent.[8] Regarding delivery methods, most courses were conducted in person, followed by online, and while a smaller proportion used blended learning formats. Similarly, just a few courses were offered for free. The cheapest short course was offered in South Africa, while the most expensive course was in Australia. Master's courses were available in Italy, Switzerland, Canada, and South Africa. Furthermore, PhDs were exclusively offered in Canada. The master's total fees vary greatly depending on the country. Furthermore, fewer scholarships were available in vaccinology studies. The limited availability of Master's and PhD

programs, together with subsidies for vaccinology courses, leads to a shortage of skilled professionals, hence hindering independent vaccine research, development, and production.[12,53] In fact, The Master of Science degree employs a framework that integrates essential theoretical knowledge with the practical and laboratory competencies required for conducting immunology and vaccinology research.[53] The shortage of skilled vaccinology professionals in Africa is further exacerbated by structural challenges within the health workforce, such as unemployment among trained health professionals and recruitment practices affected by nepotism or corruption. Even when individuals receive appropriate training, limited job opportunities and inequitable hiring practices hinder their ability to contribute effectively to vaccine research and development. As a result, the shortage is not solely due to insufficient training programs, but also to broader systemic barriers in workforce deployment and governance.

The review also identified gaps in the content of several courses. Modules on biology of pathogens, health economics, and vaccine cold chain management were included less frequently. Participants' understanding of vaccinology courses may be limited by insufficient foundational knowledge in basic sciences, particularly biology. Moreover, the observed prevalence of good vaccine cold chain management practices in Africa remains below expected standards, highlighting gaps in both knowledge and practical competencies.[54,55] Beyond course content, our findings also revealed multiple gaps in vaccinology courses in terms of target population audience, course objectives, method of course delivery, duration of course, training practical delivery, course costs, and research funding constraints. These gaps and challenges in vaccinology courses are contextualized by the need for a competent and well-prepared workforce to address ongoing, emerging, and reemerging infectious disease threats.[19,56] A shortage of skilled vaccinologists, particularly in Africa, creates dependencies that hinder autonomous vaccine research, development, and production aligned with specific regional needs. However, corruption in higher education can greatly hinder the development of a competent vaccinology workforce in Africa.[57,58] When recruitment, promotion, and funding decisions are driven by nepotism or personal connections instead of merit, qualified individuals may be overlooked, research initiatives may lack adequate funding, and academic standards can deteriorate.[57,59,60] This not only limits the ability to train skilled vaccinologists but also impedes innovation and independent vaccine research. In response to these gaps, this review proposes a conceptual framework for integrating vaccinology courses in undergraduate, bachelor, and post-graduate level. Our concepts were in line with studies that advocate for the integration of specialized vaccinology courses at advanced stages of medical education.[2,19] It is hoped that the information gathered can inform the development of a vaccinology course in African universities, which can be tailored to our target audience; the undergraduate clinical students and post-graduate students interested in vaccinology. This conceptual framework tackles the shortage by integrating vaccinology training throughout various educational levels, from undergraduate to postgraduate programs. By introducing students to vaccinology theory and practice early and progressively, the framework helps build a pipeline of skilled professionals, strengthens competencies, and encourages the retention of expertise within the region. Although it may not completely resolve systemic challenges related to employment and governance, it offers a structured approach for developing a sustainable and skilled workforce. To address the challenges posed by corruption in higher education in Africa, a study suggests that influential actors in the corrupt relationship need to be explored holistically by employing other qualitative methods such as document analysis and focus groups.[58] In addition, interventions beyond curriculum design – such as implementing transparent, merit-based recruitment and promotion policies, establishing targeted scholarships and funding to prioritize merit and capacity-building, fostering partnerships with international institutions to enhance training and mentorship, and supporting continuous professional development[61]–are essential, and when combined with the proposed conceptual framework, they increase the likelihood of developing and sustaining a competent vaccinology workforce even in difficult governance environments.

Multidisciplinary vaccinology courses are an important priority particularly for scientists from developing countries where vaccines have significantly contributed to the dramatic decrease in the number of deaths, due to infectious diseases, particularly in children below 5 y.[2,25] The rapidly evolving field of vaccinology, with new technologies and immunization models, calls for the establishment of regular updates and refresher opportunities, which could be effectively shared across courses.[7] Vaccine research is rapidly evolving, emerging technologies, and new immunization models offer public health new tools and large potential to fight vaccines preventable diseases, with promising new platforms and broadened target populations.[62] The poor equity in training

distribution is indicative of the requirement for vaccinology courses in the developing world, where high-quality immunization services are severely needed to fill the largest gap in global vaccine coverage.[63]

Even though the value of short-term training courses has been well recognized globally, more advanced vaccinology courses are emerging around the world each year.[63] This review highlighted the importance of integrated advanced vaccinology courses in universities for scientists from developing countries should include classes on vaccinology core and elective modules. Given the challenges associated with such extensive vaccinology training, identification of suitable candidates and quota for the training activities is really key in developing countries.[2]

Without a robust workforce trained in vaccinology, African countries may continue to face challenges in conducting essential research on vaccinology, navigating regulatory processes, and establishing the infrastructure necessary for vaccine production as shown in case of COVID-19, Ebola, and Mpox vaccines. Consequently, the reliance on external expertise and resources from other regions may hinder the autonomy and decision-making capacity of African countries in the development and production of vaccines tailored to their specific health needs and priorities.[12] Vaccinology course is essential for pandemic preparation because it provides a varied workforce with the scientific knowledge, practical skills, and collaborative mind-set required to react successfully to a public health emergency.[2] Thus, the availability of access to comprehensive training programs in vaccinology are crucial factors that can influence the ability of African nations to pursue self-sufficiency in vaccine production and effectively address public health challenges.[12] Geographically, access to vaccinology courses is very uneven, with large gaps in several parts of the world, particularly African countries. Most courses were designed for public health personnel at the graduate, post-graduate, or continuing education levels.[4]

Besides, this review highlights that most of the vaccinology courses' objectives are general without considering contextual and regional parameters. A study highlighted that future research should aim to track the impact of educational interventions over time, assess the causality between specific curriculum components and vaccination rates, and explore the applicability of our findings across different cultural and health system contexts.[19] This study has multiple implications, including the need for improved monitoring of the effect of vaccination training programs and assessment of both participants and instructors. Based on the results of this research, it would be useful to examine the role of continuing professional development in preserving and updating healthcare personnel' vaccinology knowledge after graduation. Furthermore, it is critical to incorporate an integrated vaccinology course in African institutions, as proposed in this review conceptual framework. In the same line, there is a need of incorporating effective vaccine cold chain and stock management module and trainings in vaccinology courses. It is also imperative that every educational curriculum be modified to address both global and national challenges pertaining to vaccine access and distribution, unless such considerations have already been adequately integrated.[64,65] An online module in vaccinology based on existing undergraduate and post-graduate modules, tailored to meet adult learners' knowledge and content needs within the African context against the backdrop of the COVID-19 pandemic, would address such a necessity in this moment and for the future. A blended learning format for students is ideal for a vaccinology course because it provides the flexibility and immersive experiences needed to cover the field's breadth, from technical science to policy and public engagement.[66] The approach combines the structured knowledge delivery of online coursework with the practical application and networking of in-person, hands-on training.[66]

This study has several limitations. Some vaccinology courses may have been missed because they were not publicly available or were not identified during the literature search, language restriction, vaccinology as rapidly evolving field, and contextual factors. Language and scope restrictions were necessary to ensure feasibility, consistency, and reliability in data extraction and analysis. However, these restrictions may limit generalizability and exclude relevant courses in other languages or emerging areas, which should be acknowledged as a limitation. Limiting study inclusion on the basis of language of publication is a common practice in systematic reviews.[67] Some online courses may not have been detected via gray literature coverage due to poor indexing or limited access to institutional websites. Given that vaccinology is a rapidly changing topic, courses introduced after the search period may be excluded. Similarly, contextual characteristics between Africa and the rest of the globe, as well as systemic hurdles such as employment prospects, funding, and governance across regions, were not directly studied, but they may have an impact on course efficacy and workforce outcomes.

Conclusion

In conclusion, the main vaccinology modules offered in Africa and other continents included introduction to immunology, epidemiology, pathogen biology, vaccine types, vaccine pharmacology, clinical research methodology, pharmacovigilance and vaccine safety, health economics, immunization programs, vaccine manufacturing, the role of international organizations in vaccine development, vaccine advocacy, and vaccine cold chain management. This review indicates that vaccinology courses offered globally and particularly in Africa are subject to multiple gaps and challenges related to target population audience, course objectives, method of course delivery, course contents, duration of course, training and practical delivery, courses follow-up, course costs, and research funding constraints. In research, there is a need for longitudinal studies that assess the impact of vaccinology training on workforce competency and vaccine outcomes, with attention to region-specific curricula. In policy, policymakers should invest in structured and contextually relevant vaccinology programs at all educational levels to develop a sustainable and skilled workforce. In practice, educational institutions and public health agencies should introduce curricula that combine theoretical knowledge with practical skills, specifically tailored to local health system requirements. Furthermore, linking these approaches will ensure a comprehensive strategy for strengthening vaccinology capacity.

Author contributions

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Data availability statement

All relevant data for the research are provided in the publication or supplied as additional material.

Acronyms and Abbreviations

ADVAC	Advanced Vaccinology Course;
ECAVI	East Africa Centre for Vaccines and Immunization;
HCWs	Health Care Workers;
NGOs	Non-Governmental Organisations;
PCC	Population, Concept, and Context;
PRISMA-ScR	Reviews and Meta-Analyses for scoping reviews;
UCT	University of Cape Town;
WITS	University of the Witwatersrand

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