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Barriers and enablers to the effective implementation of omics research in low- and middle-income countries

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Addressing the hurdles and opportunities associated with omics research in low- and middle-income countries may inform strategies for its effective execution, and thus increase our ability to tackle health challenges that transcend geographical boundaries.

Low- and middle-income countries (LMICs) shoulder a substantial portion of the global disease burden[1]. Communicable, maternal, neonatal and nutritional diseases collectively account for more than two-thirds of this burden in the world's most impoverished population[2]. Additionally, 86% of premature deaths due to non-communicable diseases occur in these resource-constrained settings[3]. Consequently, there is a critical need for rigorous research to deepen our comprehension of the underlying determinants and consequences of these diseases. This research is essential to develop effective interventions, elucidate why existing measures are not universally effective, and stratify populations on the basis of the specific interventions required.

Over the past decade, there has been an increasing interest in the application of omics technologies (such as genomics, transcriptomics, proteomics, metabolomics and gut microbiome metagenomics) to investigate the intricate interplay among hosts, pathogens and the environment. However, the adoption of these technologies in LMICs, particularly for the study of diseases endemic to these regions, has been relatively limited compared to higher-income countries (HICs)[4,5] – although, based on the number of papers indexed in PubMed, there is an apparent upward trajectory in recent years. This concentration of omics studies in HICs is unsurprising given that these studies demand substantial resources, funding, infrastructure and materials, and highly specialized personnel. Furthermore, omics research in LMICs encounters challenges that often surpass those encountered in HICs[6–9]. However, barriers and enablers for the effective implementation of omics research in LMICs are frequently undocumented.

We are a collective of scientists engaged in omics research within LMIC contexts, with a specific emphasis on maternal and child health, infectious diseases, and malnutrition. Here, we draw upon our collective insights and experiences in conducting omics research in a diverse range of LMICs, including Bangladesh, Burkina Faso, Ethiopia, the Gambia, Indonesia, Kenya, Malawi, Pakistan, the Philippines, Thailand, Uganda, Zambia and Zimbabwe. Our aim is to provide a current snapshot of the factors that hinder or enable omics research in LMICs. By sharing these insights, we advocate discussions among different actors (researchers, organizations or countries) on the need for capacity in omics in LMICs and finding ways to enhance their application to discovery science.

We have categorized the barriers and enablers to omics research in LMICs into four overarching themes: administrative, institutional, project-specific and community (Fig. 1). The barriers manifest early in a project's planning stages and often endure beyond its completion. In this context, we offer insights into potential facilitators and opportunities for mitigating these obstacles that draw from our cumulative experience and expertise in our respective research environments.

Administrative barriers and enablers

We define administrative barriers as hindrances and challenges that manifest at the national level. Many of these barriers are well-recognized at the project's outset; this which requires awareness among researchers, as these barriers are pertinent to all phases and types of research in LMICs. Enablers are opportunities to mitigate these barriers at the national level. Effective and timely collaboration with relevant national and local government agencies and institutions are of paramount importance to ensure the seamless execution of research initiatives.

Conducting omics studies in LMICs can encounter barriers related to high costs, intricate customs processes, lengthy approvals and complex logistics of sample shipments, which pose challenges in procurement that may surpass those encountered in HICs. Given constrained government funding in LMICs, funding for omics research predominantly comes from foreign (private or non-profit) foundations and foreign government sources. Consequently, a substantial portion of the research is conducted and/or led by scientists from HICs with or without providing training and mentorship to LMIC scientists.

The complexities and expenses associated with procurement, shipping and importation in LMICs often exert adverse effects on study timelines and research budgets. Legal procedures in certain LMICs limit direct procurement, which necessitates the use of third-party suppliers who impose additional costs. Moreover, fluctuating currency exchange rates can result in prices being higher than initially allocated when the project started.

Customs procedures for importing materials and exporting samples may lack clarity or consistency, which results in cumbersome paperwork and processes. Additionally, regulatory agencies that are responsible for approving imports or exports and other research-related matters in LMICs are frequently understaffed and underfunded, and are sometimes without omics expertise, which leads to delays in approvals. In severe instances, delays in reviews and licensing approvals result in the untimely termination of research projects.

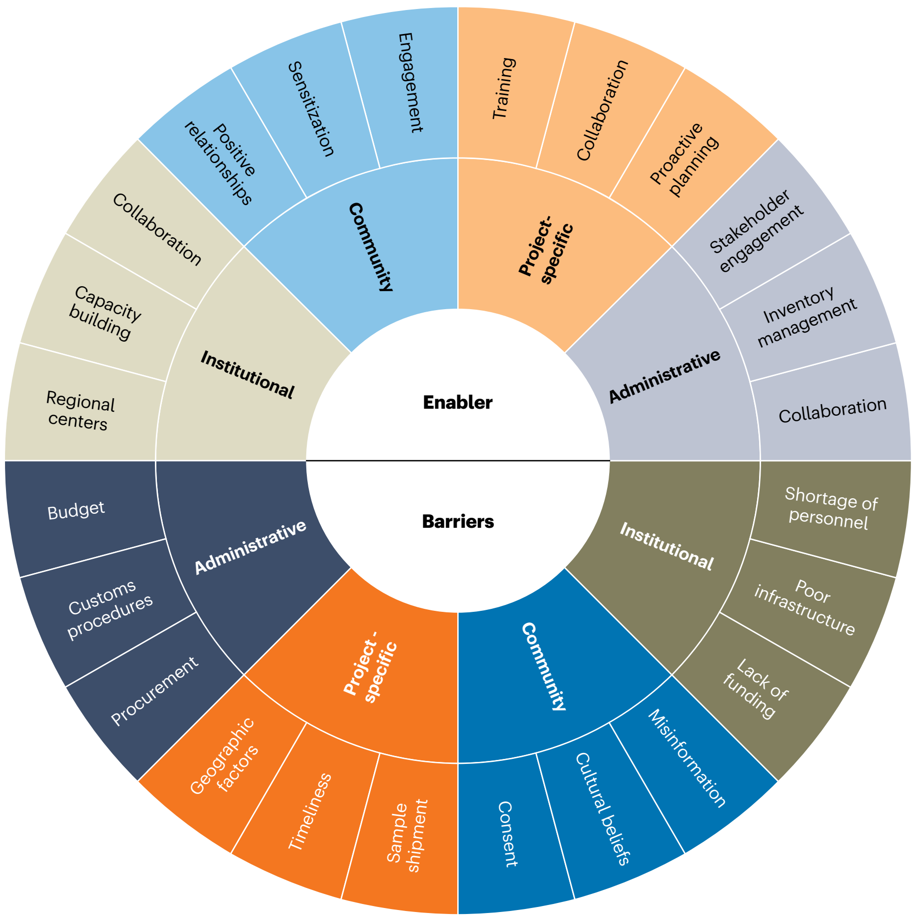

Fig. 1 | Barriers and enablers to the implementation of omics research in LMICs. Barriers and enablers can be categorized into four overarching themes: administrative, institutional, project-specific and community.

As these barriers stem from national regulations and processes, the most prudent courses of action entail proactive coordination with relevant stakeholders and meticulous planning. Principal investigators should engage early with national and local authorities to secure guidance and support. Given the challenges of importing supplies, efficient inventory management within each laboratory becomes imperative. Many of us anticipate all of the necessary research materials for the upcoming year, although this practice poses challenges and occasionally results in supply shortages or expiration. Effective coordination between researchers and with suppliers is indispensable and bulk purchasing invariably proves more cost-effective, as in any country.

The allocation of funding at the national level heavily relies on the national agenda, which prioritizes initiatives aligned with broader goals. To stimulate increased national funding for omics research in LMICs, there is a pressing need to heighten awareness and advocate for the potential of omics to address national issues with governmental bodies. For example, the COVID-19 pandemic, although devastating, underscored the potential of genomics capacity to monitor and help to prevent future health crises, which prompted LMIC governments to invest in, and benefit from, genomics infrastructure and research. Several research institutes in LMICs secured funding and equipment for in-house genetic sequencing, and thus expanded the opportunities for researchers from LMICs to extend genomics research beyond COVID-19. Effective communication regarding the potential of omics technologies with national institutions is therefore timely.

Lastly, collaborative efforts between LMICs and HICs contribute to the success and sustainability of omics research in LMICs. International cooperation expands the capacity to address research questions initially hindered by limited local resources and is often essential for securing substantial funding. However, it is imperative to ensure equitable sharing of research opportunities and responsibilities, which offers researchers from LMICs ample opportunities to learn and to lead projects and thus fosters the sustainable advancement of omics research in LMICs.

Institutional barriers and enablers

Institutional barriers encompass the structural, policy and operational constraints embedded within research institutions that are engaged in omics research within LMICs. Effective mitigation of such barriers necessitates systemic alterations within these institutions. Enablers are opportunities to mitigate these barriers at the institutional level.

The main institutional challenges that confront omics research in LMICs are limited infrastructure and a scarcity of trained personnel. Omics research necessitates substantial investments in data collection, sample transportation, sustainable storage at precise temperatures, and laboratory analyses. Unfortunately, numerous LMIC institutions lack the requisite infrastructure, including physical space, high-speed internet connectivity and critical equipment such as −80 °C freezers, mass spectrometers, sequencers or temperature-controlled transporters. Frequent power outages in some LMICs necessitate the use of diesel generators. Consequently, many omics studies are led by institutions in HICs, and LMIC partners primarily provide biological samples. This scenario sometimes transforms scientists from LMICs into 'glorified data collectors': the intellectual center of gravity remains with HIC institutions, and capacity-building efforts often fail to empower scientists from LMICs to independently design competitive studies or secure autonomous grant funding[10].

We have achieved success in addressing some of these challenges by training young scientists from LMICs through PhD programs, especially sandwich PhD or external PhD formats. These initiatives permit scientists from LMICs to earn degrees from HIC universities while conducting research in their home countries under the guidance of supervisors from both HICs and LMICs. However, our experience reveals that numerous PhD graduates and postdoctoral researchers focused on omics research who secure funding or enrolment in HIC universities face difficulties when contemplating reintegration into LMICs, owing to a paucity of opportunities. This issue needs to be addressed by LMIC institutions for them to fully benefit from the increased research personnel capacities achieved through these initiatives.

Given the current challenges associated with equipment acquisition, training in bioinformatics, statistics and data science equips scientists from LMICs to contribute meaningfully to omics research beyond sample collection and laboratory analysis. Thus, training in these fields within LMICs creates opportunities for scientists from LMICs and represents a pivotal step towards fostering equitable research partnerships. Nonetheless, having regional centers of excellence in LMICs that could serve a cluster of countries will be more ideal in the long term. Moreover, training young scientists from LMICs in omics now will result in more local trainers in omics in the future, which will enable LMIC universities to award PhDs in topics related to omics. This constitutes a more sustainable capacity-building strategy.

Project-specific barriers and enablers

Project-specific barriers are challenges that are specific to individual research projects, which can be mitigated through stringent and well-designed study protocols. Enablers are opportunities to mitigate these barriers at the project level.

The primary barriers that impede omics research in LMICs mostly revolve around sample collection in terms of geographical location, distances from sample collection sites and transportation logistics. Many LMIC omics studies target particular vulnerable populations and/or other endemic issues, and thus often get conducted in remote or widely dispersed locations. Consequently, researchers in LMICs contend with unpredictable factors such as flooding and typhoons during rainy seasons, which can disrupt transportation and power supply. Additional challenges to efficient sample storage include humidity, temperature fluctuations and time lags among sample collection, processing and storage. Although these are also typical challenges in HICs, most LMICs lie in tropical or subtropical zones, which makes the addressing these issues more challenging.

Omics research heavily relies on computing and bioinformatics tools for data capturing, processing and reporting, and thus generates a substantial volume of omics data. This, however, results in data transfer and storage being prohibitively expensive. Despite advancements in mobile telecommunications, many LMICs still grapple with limited connectivity.

Finally, research partnerships are typically governed by material transfer agreements but concerns often linger regarding ultimate control over transported samples. Apprehensions about 'parachute research' — in which researchers from HICs work in LMICs to enrich their own careers, but deprive their LMIC-based collaborators of fair and equitable partnership and merit — are quite common among omics researchers in LMICs. This practice is unacceptable, and measures need to be taken against parachute research practices by institutions, ethical review boards and funders.

Community barriers and enablers

At the community level, recruiting study participants for omics research poses a common challenge, particularly when participants perceive no direct benefit and especially among vulnerable individuals with low socioeconomic status and education levels. Effectively communicating omics results to communities, particularly in LMICs, remains a persistent challenge. Concerns also arise that omics analyses may reveal information with implications for participants' current or future health. For instance, there is uncertainty in some LMIC communities regarding the goals of genomics, which is often misinterpreted as paternity testing. Additionally, apprehensions persist that researchers may target specific stigmatized diseases, such as HIV. Moreover, samples such as blood, stool or hair carry specific cultural implications in many LMIC communities, which leads to suspicions that researchers might misuse samples for witchcraft or sorcery.

As with any research conducted in LMICs, effective coordination with local authorities and community representatives is of paramount importance. Sensitization campaigns and community information drives conducted before research implementation foster trust between researchers and participants, especially when most participants are unfamiliar with omics research. Our experience reveals that in areas in which research activity is already established, communities tend to be more receptive to new research initiatives. Thus, building positive community relationships not only benefits current research but also extends to future endeavors.

Ethics, intellectual property and international collaborations for omics

With the growing prominence of omics research worldwide, collaborative frameworks for HIC–LMIC omics research are still nascent but rapidly evolving. This evolution stems from a shared desire among researchers from HICs and LMICs to ensure equitable and fair research practices. Consequently, conducting omics studies in HICs using LMIC-derived samples is becoming increasingly challenging. Several countries (for example, Bangladesh and India) have strict rules that prohibit the export of biological samples. Moreover, ethics committees in many regions are adopting stricter regulations for exporting biological materials. Stool samples for metagenomics analyses, which contain genetic material, fall under the Nagoya Protocol, which necessitates additional regulatory compliance before sample sharing between countries.

These developments underscore the urgency of building omics research capacity in LMICs, which necessitates initiatives akin to Human Heredity and Health in Africa (H3Africa); this initiative has successfully focused on capacity-building and empowering African researchers in genomics. H3Africa's experience can serve as a model for expanding omics research to other LMICs beyond Africa.

Ultimately, the question of ownership of research results — especially in omics studies that are funded by or analyzed in HICs, but conducted with LMIC samples — remains unresolved. In some cases, the primary sponsor (which is often an HIC institution) retains the intellectual property, even though the study was conducted in or samples were from an LMIC setting. Moreover, disproportionate sharing of indirect costs often occurs, in which HIC institutions are able to retain more indirect costs than are the LMIC collaborators; this leads to fragility of research ecosystems in the absence of core funding. These policies weaken the partnership between researchers from HICs and LMICs, and need to be revisited. Equitable research efforts should be championed by all stakeholders, which requires funders and researchers from both HICs and LMICs to align with this principle.

Conclusions

The evolving economic, demographic and nutritional landscape in LMICs renders these countries uniquely vulnerable to both established and emerging diseases. Conditions that have traditionally been associated with HICs (such as obesity, cancer and noncommunicable diseases) are on the rise in LMICs, which continue to grapple with a disproportionate burden of infectious diseases, child mortality and undernutrition across all age groups. Consequently, these is a compelling case to invest in omics technologies in LMICs to better understand the diseases that affect these regions. By identifying research barriers and sharing our strategies for effective omics research in LMIC settings, we hope to assist future researchers in planning and executing omics studies in LMIC contexts.

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Competing interests

The authors declare no competing interests.