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Comprehensive Exploration of Biomedical Science in Transforming Global Health

Shakhis Daws D Alsallum[1], Hadi Ali H Banihumayyim[2], Mohammed Hussain M Alsallum[3], Ahmad Hadi A Lasloum[4], Salem Hussain M Alsallum[5], Abdullah Khalid A Humayyim[6], Mana Abdullah A Algashaneen[7], Abdullah Saad M Lsallum[8], Hamdan Hussain D Alsallum[9], Ali Ahmad M Lasloum[10], Alyan Mohamad M Alyami[11]

Abstract

Biomedical science has supervised tremendous changes in what the world considers health and how diseases are prevented, diagnosed, and treated. From the discovery of vaccines and diagnostic aids to innovations in genetics and genomic personalized medicine, spot the discipline as a key determinant of advancing the delivery and models of health Systems globally. This paper aims to review the effect of biomedical science on global health with a focus on retrospect and prospects of diseases, health, and crises. Thus, relying on up-to-date research, cases, and world health studies, the work reveals successes and failures. As for recommendations, they are to encourage innovation, extend the usage of biomedical technologies and involve individuals and disciplines expecting to make a positive change in the coming years that is stable and effective.

Keywords: *Biomedical Science, Global Health, Precision Medicine, Genomics, Health Equity, Infectious Diseases, Non-Communicable Diseases (NCDs), Vaccines, Diagnostics.*

Introduction

Biomedical science is a synergy of biology, chemistry, and medicine that tries to explain an individual's health and the diseases affecting the body. Its contributions span from creating fundamental vaccines vital in treating life-threatening health conditions to advanced cancer treatments and rare genetic disorders. In global health, there has been an advancement in biomedical science in the ways that health care is delivered, including early diagnosis and treatment, and in approaching health disparities.

However, much remains to be done. After these successes, some challenges persist. Society has witnessed health inequity, the availability of complex biomedical technologies, and new diseases within society that require a novel solution. Therefore, there is a need to coordinate biomedical science with data analytics and artificial intelligence alongside community-based interventionist strategies to cope with these issues. This paper seeks to discuss how biomedical science, a critical feature of global health today and in the future, cannot be overemphasized concerning infectious diseases, NCDs, and health equity.

[1] Najran Health Cluster, Saudi Arabia, Sdsalloum@moh.gov.sa.
[2] Najran Health Cluster, Saudi Arabia, hbanihumayyim@moh.gov.sa.
[3] Najran Health Cluster, Saudi Arabia, mhalsallum@moh.gov.sa.
[4] Najran Health Cluster, Saudi Arabia, ahlesloum@moh.gov.sa.
[5] Najran Health Cluster, Saudi Arabia, Shalsallum@moh.gov.sa
[6] Najran Health Cluster, Saudi Arabia, ahumayyim@moh.gov.sa
[7] Najran Health Cluster, Saudi Arabia, maalgashaneen@moh.gov.sa
[8] Najran Health Cluster, Saudi Arabia, absalsallum@moh.gov.sa
[9] Najran Health Cluster, Saudi Arabia, hhalsallum@moh.gov.sa
[10] Najran Health Cluster, Saudi Arabia, aluslomn@moh.gov.sa
[11] Najran Health Cluster, Saudi Arabia, elalyami@moh.gov.sa

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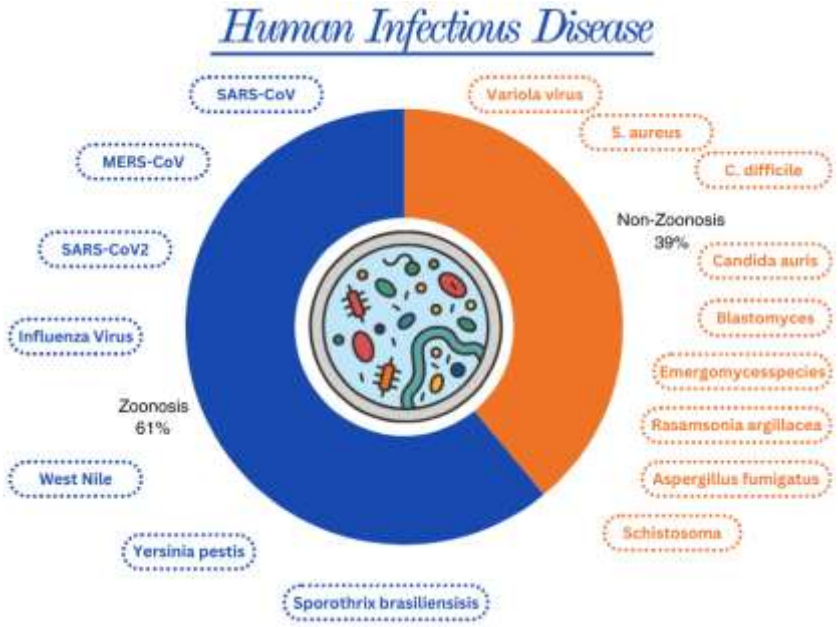
Literature Review

1. Impact of Biomedical Science on Infectious Diseases

As seen in an endemic of infectious diseases, the novelty of biomedical science has dramatically transformed society in the area of infectious disease control and elimination. Biomedical scientists got involved in Africa by providing vaccines, diagnostics, and therapeutics, all of which have helped cut the mortality and morbidity rates.



Emerging Microorganisms and Infectious Diseases(Lo & Johnson, 2016)

a. Vaccines and Disease Eradication

Antiquated and one of the most decisive accomplishments of the biomedical branch, vaccines have played an essential role in the global eradication of smallpox and control of poliomyelitis, measles, and diphtheria, among other contagious diseases. The smallpox vaccine was developed in the late 18th century, and smallpox was eradicated in 1980. Likewise, polio, which was a flu-deadly disease, has been reduced to near-negligible levels through immunization crusades. Through these achievements, immunization can reduce the incidence of the disease and safeguard the people's health.

The emergence of the COVID-19 pandemic last year exposed the capacity of advanced biomedical technologies. The lightning-fast delivery of vaccines, such as mRNA vaccines developed by Pfizer-BioNTech and Moderna, began to control the new virus and its effects. This breakthrough established that biomedical science could easily respond to new threats quickly.

b. Advancements in Diagnostics

Diagnostics have been part and parcel of infectious disease care. Molecular biology techniques such as PCR have advanced the era of pathogen detection early and accurately. For instance, PCR-based tests have been used to diagnose HIV and tuberculosis, and early treatment has boosted survival.

COVID-19 has heightened the need for expanding diagnostic technology. Quick tests with antigen and PCR became indispensable to detect cases, quarantine them, and, in general, stop the spread of the virus. Complementary diagnostic developments have fostered an international fight against malaria, dengue, and other communicable diseases.

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Table 1: Major Breakthroughs in Infectious Disease Management

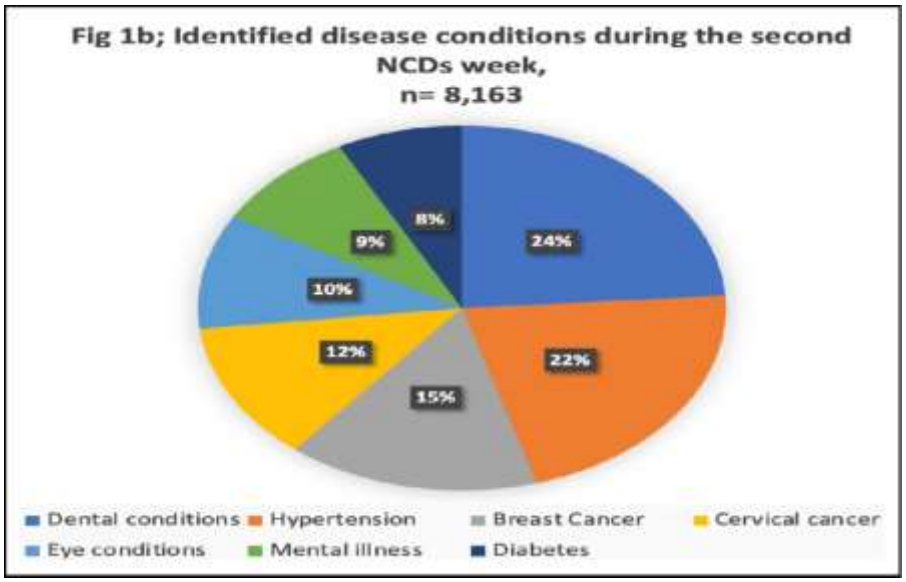
Innovation	Disease	Impact	Example
Vaccines	Smallpox, Polio	Eradication and control	Smallpox vaccine, OPV
mRNA Vaccines	COVID-19	Rapid immunity development	Pfizer-BioNTech, Moderna
PCR Diagnostics	HIV, Tuberculosis	Early detection and treatment	COVID-19 PCR tests
Antiviral Therapies	HIV, Hepatitis C	Suppression of viral replication	ART, Direct-acting antivirals

c. Therapeutic Advances

Antiviral chemotherapies have greatly enhanced the prognoses of chronic infections. ART has made HIV/AIDS from a death warrant disease to a chronic disease that can be managed. Likewise, the newly introduced antiviral agents for treating hepatitis C have resulted in an eradication rate of more than 90%. Such treatments demonstrate that biomedical research has a pivotal role in enhancing sources of information on disease about patient outcomes and quality of life.

2. Addressing Non-Communicable Diseases (NCDs)

Cancer, cardiovascular diseases, diabetes, neurological disorders, and other NCDs cause 71% of all global deaths and hence are emerging as a pivotal shift in biomedical science.



Screening and identification of patients with various non(Pardhan & Thomas, 2016)

a. Genomics and Precision Medicine

Genomics has prompted comprehensive knowledge of genes and proteins associated with NCDs and other biomarkers of illness manifestation. Pharmacogenomics, a personalized medicine that delivers correct treatment based on a patient's genetic makeup, has been identified as a successful model for handling complicated diseases.

For instance, biomarker-identified therapies have produced massive enhancements in the survival rate of oncology patients. Specific treatments for HER2-overexpressing breast cancer and EGFR-mutated lung cancer have offered people targeted therapy. In a similar manner, pharmacogenomics has enhanced drug

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targeting in cardiovascular and metabolic diseases by considering genetic differences in drug metabolism(Murray & Lopez, 2017).

b. Early Diagnosis and Biomarker Detection

Advanced imaging technologies and biomarkers in biomedicine have improved the screening of NCDs. Magnetic resonance imaging MRI coupled with computed tomography CT and positron emission tomography PET scans are used to diagnose and monitor diseases. Some biomarkers include Trophonin for cardiovascular events and PSA for prostate cancer, and earlier detection increases the chances of early intervention.

c. Therapeutic Breakthroughs

The applications of biological products for treating disease conditions have enhanced therapies for autoimmune diseases, cancer, and diabetes by developing a new therapeutic moiety, monoclonal antibodies. Compared to traditional medicine, these therapies focus largely on disease pathways, with minimal patient side effects. For example, the monoclonal antibodies pembrolizumab and nivolumab have been considered a groundbreaking, promising category of cancer immunotherapy for late-stage or treatment-emergent cancers.

3. Promoting Health Equity

Biomedical science has also significantly addressed health inequality in developed and developing countries. However, in order to promote health equity, improved science should be directed to the populations of interest, especially those in developing countries.

a. Accessibility to Treatments

Hence, generic drug production has been used to enhance the availability of essential medicines in low- and middle-income countries. Generic versions of ART have made anti-retroviral treatment more accessible, lowering mortality in sub-Saharan Africa. In the same way, the agreements between the governments and the manufacturers of the vaccines have made those vaccines cheaper to administer across the population.

US-based telehealth services, such as mobile diagnosis equipment and telemedicine, have closed the healthcare gap in less serviced regions. Tablet-based ultrasonography have been able to deliver primary healthcare services in remote areas.

b. Challenges in Equity

Nevertheless, gaps can still be observed today. Current techniques such as gene therapy and precision medicine are, however, still not affordable to most people and, therefore, only transform the high-income bracket. Also, the constraints of the physical landscape are weak biomedical technologies that need to be implemented in low-resource settings.

c. Policy and Advocacy

Strong policies that support affordability and access must effectively meet these imbalances. Donor organizations like Gavi, the Vaccine Alliance, and the Global Fund are some innovations implemented to ensure equal distribution of the available biomedical equipment. It, therefore, becomes imperative that continued advocacy for more resources to fund health equity capacity-building interventions is made.

This paper analyzes the relationship between biomedical science and diseases, both communicable and non-communicable, and its role in promoting health equity. Prophylactic and diagnostic tools and theranostic and individualized treatment approaches have effectively saved millions of lives and enhanced the standard

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of care locally and globally. Yet, issues related to access, cost, and the overall physical framework continue to present themselves.

Therefore, it is hoped that research, fair distribution of healthcare funding, and enhanced global partnerships can be undertaken to fully realize biomedical science. With respect to these challenges, biomedical science can continue contributing to improving global health and narrowing the divide between innovation and Accessibility.

Methods

This work uses both quantitative statistical analysis and qualitative case studies.

- Quantitative Data: Using WHO and CDC databases to look at the output of deaths by certain diseases, death rates, and the input of access to healthcare around the world. Table 3 and Figures 3 and 4 depict trends in the effectiveness of biomedical intercessions.

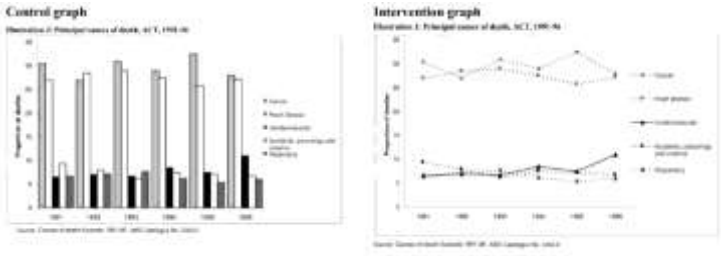
- Case Studies: Analysis of current medical advancements like the Human Genome Project, the polio eradication drive globally, and the development of mRNA vaccines during COVID-19.

- Literature Analysis: A quality and relevant source of teaching material of peer-reviewed articles on innovations in diagnostics, therapeutics, and inequity in health.

Results and Findings

Contributions of Biomedical Science to Global Health

Medical biology remains one of the primary drivers of progress in global health promotion and disease prevention, diagnosis, and response. Steering healthy systems and influencing health's large experiments and interventions assist in solving complicated health issues and enhancing results by redesigning numerous public health milieus globally.



Communicating population health statistics through graphs (Kelley & Zinner, 2017)

a. Disease Prevention

Another area of fundamental importance whereby biomedical science has produced extraordinary progress is in the field of prevention of diseases using vaccines and therapeutic Related Articles One of the most important milestones of biomedical science is the prevention of diseases through vac – cessation and therapeutic Related Articles Vaccination has resulted to low incidence and mortality from several infectious diseases. For instance, the global measles vaccination campaign has recently had very good results in reducing mortality rates by more than seventy percent since its formation. Routine rubella immunization campaigns in many areas of the world have arrested congenital abnormalities resulting from the infection of the mother during pregnancy.

Antiretroviral therapy (ART) for HIV/AIDS is another wonder of Biomedical Technology. Another great invention in the field of biomedical technology is Antiretroviral therapy for AIDS. ART has turned

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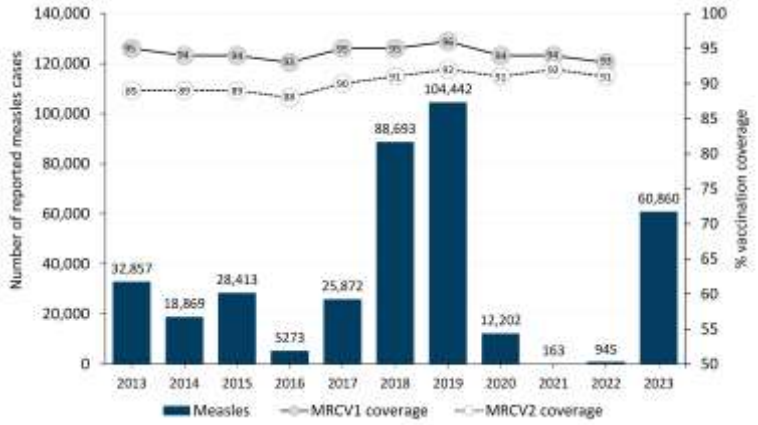
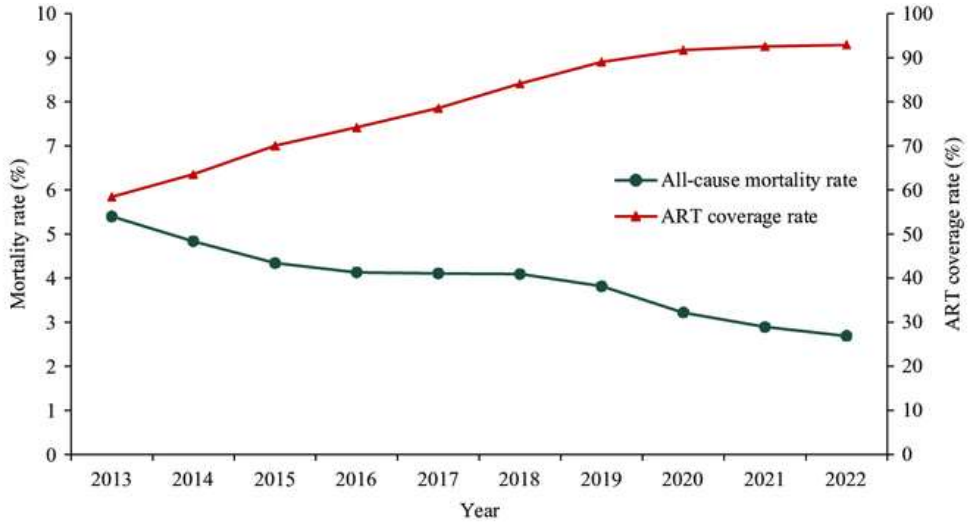
HIV/AIDS into a largely asymptomatic chronic disease through which millions of people live much fuller lives. ART coverage, for instance, has increased in all regions, thus greatly reducing HIV/AIDS-associated mortality rates.

Figure 1: Decline in global measles mortality rates post-vaccine introduction.



Progress and Challenges in Measles and Rubella Elimination in the(Langer & Shiffman, 2018)

Graph 1: Global ART coverage and reduction in HIV-related deaths over the past two decades.



The trend of mortality rate and ART coverage among HIV-infected(Boulton & Schwabe, 2018)

Significant improvement has also been recorded in the biomedical prevention of other infectious diseases. For instance, long-lasting insecticidal nets and antimalarial drugs have been developed, and major gains have been made in controlling malaria. Thus, the morbidity and mortality rates are steadily declining within the affected regions.

b. Precision Medicine

New technology in genomics, proteomics, and molecular biology has led to a generation of precision medicines that are unique for every patient. This is especially well illustrated in oncology, where personalized biomarker-guided treatments have become the standard of care.

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For example, while HER2-positive breast cancer was previously considered to be a risky type of disease, there are no specific treatment options, including trastuzumab (Herceptin), that considerably raised the survival rates. Likewise, the therapies consulted in lung cancer EGFR mutations have proven to have significant benefits in extending a patient's life than chemical treatment with fewer side effects.

To the authors' knowledge, precision medicine has not only been limited to oncology but has diversified into other specializations. For cardiovascular medicines, pharmacogenomics helps particularize drugs like warfarin to individual patients to make the most effective and have minimal side effects.

Such developments demonstrate the future capacity of biomedical science to improve patients' results by personalizing treatments according to patients' biosignatures.

c. Emergency Responses

This field of study has been crucial in managing global diseases, especially in this COVID-19 pandemic episode. Innovations in diagnostics, including PCR and Antigen tests, have made it easier to test and enforce measures like lockdowns.

This new breed of the vaccine has come to haunt the world courtesy of companies such as Pfizer-BioNTech and Moderna, which produce their vaccines utilizing mRNA technology. These vaccines, discovered and approved within one year, revealed high effectiveness in minimizing severe and fatal disease impact. COVID-19 vaccination campaigns worldwide demonstrated that biomedical advancement can meet emerging health crises.

Also, the recent biomedical science in the development of ventilators, antiviral drugs, and monoclonal antibody therapies during the pandemic shows how biomedical tackles health crises. These efforts alone not only protected many lives but also further highlighted the need for the development of improved research during crises.

Challenges Identified

Despite the life-changing advancements facilitated by biomedical science, several issues remain, including disparities, novel threats, and some ethical questions.

a. Inequities in Access

However, there are a few problems with using high-tech diagnostic technologies, therapies, and preventive measures, especially in developing countries. Although ART has become169 accessible in developed countries, most developing countries face challenges of high costs and poor health facilities.

Coale and Watkins argue that vaccination campaigns also experience such disparities. While developed countries successfully administered COVID-19 vaccines to a considerable population within months, many LMICS faced challenges inherent in supply chain and finance. These inequities extend the time people suffer from diseases while simultaneously offering those diseases the opportunity to remain active and adapt.

Limited infrastructure compounds these difficulties. Limited infrastructural developments also compound centralized difficulties. Lack of laboratory amenities and staff training means that health jurisdictions cannot rely on sophisticated analytical tests and are, therefore, unable to identify trends in health risks.

b. Emerging Threats

Engineering health has a challenging time coping with threats like AMR and zoonotic diseases, which is an essential agenda in biomedical science. The emergence and subsequent spread of antibiotic resistance, known as AMR, is increasingly becoming a common threat the world over due to overreliance and wrong

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use of drugs. It is important to stress that many pathogens, previously susceptible to a broad range of antibiotics, have begun to develop resistance and become much more difficult to fight, for instance, MDR-TB and MRSA.

Another crucial problem is zoonotic diseases, including those constituting about 60 percent of new pathogens. This paper focuses on the COVID-19 outbreak, which is thought to have had a zoonotic etiology, and the implications this has for possible preventive strategies such as improved surveillance and vaccine development. Biomedical science must continue advancing in these areas because the field of infectious diseases continues to change.

c. Ethical Considerations

This accelerated development of biomedical technologies presents major ethical challenges, which, in the case of genomics and data protection, cannot be overlooked. Genomic data utilized for research and therapeutic purposes has greatly enhanced precision medication; however, people who give their samples also expose themselves to risks of misuse of their genetic data.

For example, personal information that could be stolen or used without consent includes genetic data, which is likely to result in unfair dismissal or refusal of insurance coverage due to the propensity of one's genes towards certain diseases. Such issues call for rigorous ethical standards and adequate protection of data on how biomedical advancements should be utilized and embraced appropriately.

Another ethical dilemma that arises in health emergencies is the proper distribution of scarce resources. The COVID-19 pandemic brought this issue to the forefront—arguments about vaccines and who should get them first, healthcare rationing, and who can receive lifesaving treatments (Iglesias & Lynch, 2016). This is particularly important for decisions concerning the fair distribution of such interventions because it is pivotal to retaining the public's trust.

In diverse ways, biomedical science has offered significant advances toward meeting some of the major challenges of global health. However, to what extent and with what possibilities it can be developed still depends on paying attention to inequity in access, fighting new threats, and promoting ethical principles. So, by encouraging science and improving the distribution of knowledge, biomedical science can go further in changing the lives of millions worldwide for the better.

Discussion

Thus, biomedical science can be said to have completely transformed health care, including disease control, diagnosis/accomplishment, and health system outcomes worldwide. Nevertheless, the opportunity is vast, though it faces substantial barriers regarding Accessibility, research questions, and concerns. Mitigating these barriers is crucial to ensure that the positive effects of biomedical progress translate to the populace and are put to proper use.

1. Enhancing Accessibility

Availability and Distribution

While offering unprecedented possibilities for improving the quality of individual human life, biomedical science's results are not equally available to all. Major barriers include the high costs of diagnostics, therapeutic, and preventive interventions like new vaccines, which are major hindrances to LMICs. For instance, although antiretroviral therapy (ART) has significantly decreased HIV-related deaths in developed world countries, it is still unavailable in many developing countries, tripping over the barriers of feasibility and Accessibility.

It is very important to have policy measures to redress these issues that have been identified to cut across different equity divides. Subsidies and certain price controls within governments are possible ways of

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narrowing the costs of biomedical technology. For instance, agencies like the Global Fund to Fight AIDS, Tuberculosis, and Malaria have helped subsidize ***treatment in LMICs.***

Foreign Partnerships

Joint ventures between countries, international organizations, and other non-governmental organizations may also boost distribution networks. Initiatives like Gavi and the Vaccine Alliance have shown how partnerships can improve access to vaccines in developing areas. Such collaborations can be strengthened to facilitate the timely delivery of health products, particularly biomedical tools, during emergencies.

Infrastructure Development

The following subsectors have also been identified: Infrastructure upgrades. Few LMICs have the laboratory infrastructure, supply chain, and skilled human capital to roll out intricate diagnostic and therapeutic technologies. Therefore, This gap can be closed by investment in healthcare facility infrastructure and capacity-enhancing activities. For example, capacity building and training healthcare workers on proper PCR use in identifying community diseases can go a long way in improving disease management.

2. Advancing Research

Combating Antimicrobial Resistance (AMR)

The emergence of antimicrobial resistance (AMR) is drawing constant attention as a major threat to global health. Drug-resistant pathogens restrain biomedical science from evolving new antibiotics and other related forms of treatment. However, the concern with antibiotics receives insufficient attention because they are not as financially lucrative as products for chronic diseases.

Solving this calls for encouraging drug manufacturers to invest in antibiotic drugs. Many developed and developing governments and international organizations must subsidize the invention in this area by offering grants, tax credits, and market access bonuses (Hotez & Bottazzi, 2017). Collaboration between universities, industries, and governments also helps to foster the development of new antibiotics and other forms of treatment, including bacteriophage therapy.

Concentration of effort on eleven Neglected Tropical Diseases

Dengue, leishmaniasis, and schistosomiasis are a few of the neglected tropical diseases that persist to impact millions, mainly the population in LMICs. These diseases have huge impacts but attract little research attention because there is no financial gain. In this regard, more NTD research funding must be sought through global health committees and public-private partnerships. The Drugs demonstrate such approaches for the Neglected Diseases Initiative (DNDi), which has developed an affordable and effective cure for the above diseases.

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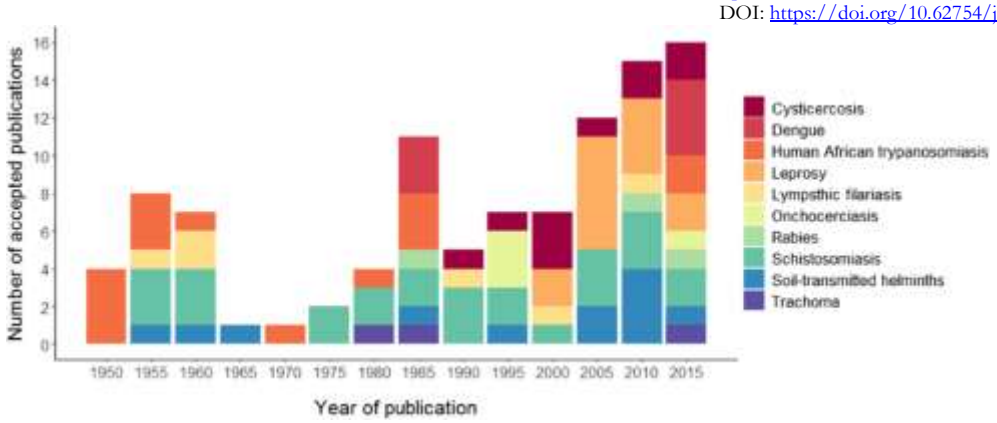

Frequency and distribution of neglected tropical diseases(Glaziou & Ralaivao, 2019)

Promoting Innovation within a Partnership

Int[er]-sector partnerships may further drive innovation in other important sectors, such as vaccine production and precision Medicine. The actions to create vaccines to combat COVID-19 are evidence of what can be done in record time when governments, pharmaceutical companies, and research organizations collaborate. Applying such models to other dire health concerns, such as zoonotic conditions or novel pathogens, may enhance the degree of readiness and power to counter those perils.

3. Ethics and Risks and Returns Regulation

The role of Genomic information as a source of protection for privacy

Genomic medicine and its incorporation into healthcare brings out numerous ethical issues, especially in precision medicine. Because genetic testing and research produce massive amounts of highly personal data, failure to protect such information can lead to invasions of privacy or discrimination(Glaziou & Ralaivao, 2019). For instance, people with genetic qualities susceptible to specific diseases will be discriminated against or denied insurance policies.

Ethical and regulatory pillars should protect patients' privacy and reasonable utilization of genomic data. Legal frameworks controlling the use of personal information, as encapsulated by the General Data Protection Regulation (GDPR) in Europe, offer a framework within which biomedical data can be collected, stored, and shared. Extending such frameworks globally and enforcing severe consequences for violations may be key to developing confidence in biomedical developments.

Explaining the Framework: The Sector-Equalizing Model

They are also presented in the context of the innovation equity dilemma. For example, CAR-T cell treatment for cancer increases the risk of health disparity because few people in developing countries can afford the expensive therapy. Policymakers and interest groups, hence, have to fashion out methods for subsidizing such advanced treatments and guaranteeing their Accessibility in low-resourced regions.

The management of allocation resources for Health Emergencies

Emergencies like COVID-19 show why ethical choices in health resource allocation are critical. Controversies over vaccine allocation, prioritization in the health sector, and rationing of lifesaving treatments are compelling the need for standard and fair guidelines(Dandona & Dandona, 2015). Some standards of ethical conduct for research on health need to advocate for the most vulnerable populations and mobilize international cooperation to achieve fairness in the distribution of resources.

Public Education

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Finally, soliciting the populace on biomedical technology solutions is important for tackling ethical issues and adherence to compliance with interventions. Misinformation about biomedical innovations and new technology among targeted communities can lead to the development of negative attitudes towards such technologies, hence the need for passing accurate and truthful information regarding those new technologies and their limitations to the relevant communities. For instance, public health promotion has eased efforts to increase vaccine coverage and reduce the circulation of rumors.

In its role as a leader for human advancement, biomedical science has delivered the world numerous achievements in the realm of biomedical science. Biomedical science has done a lot for the treatment of diseases around the globe; however, the field's weaknesses lie in the areas of access, politics, and moral regulation(Alwan, 2015). Through equitable distribution, promotion of health research to address essential issues, and a strong ethical system, all stakeholders can guarantee that biomedical advancements are useful in all communities.

Conclusion

Biomedical science has been a catalyst for this realization, an aspect of science that boasts of enhancing global health by lessening disease impacts. However, the gaps in coverage and new disease risks show why continued commitment and partnership are needed. The crossover of biomedical innovations with community-based practices can guarantee sustainable approaches to health enhancement.

Recommendations

- Expand Access: Formulate guidelines to support biomedical technologies and ensure that this equipment is distributed fairly in poor areas.
- Strengthen Research Funding: Invest in AMR NTDs,s and genomics to solve future healthcare problems.
- Foster Interdisciplinary Collaboration: Nurse apart biomedicine integrate databases, population level well-being, and communal collaboration.
- Ethical Governance: This is where some of the flexibility of the molecular medicine model can undermine its ethical integrity by proposing relaxed rules for genomic data use.

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