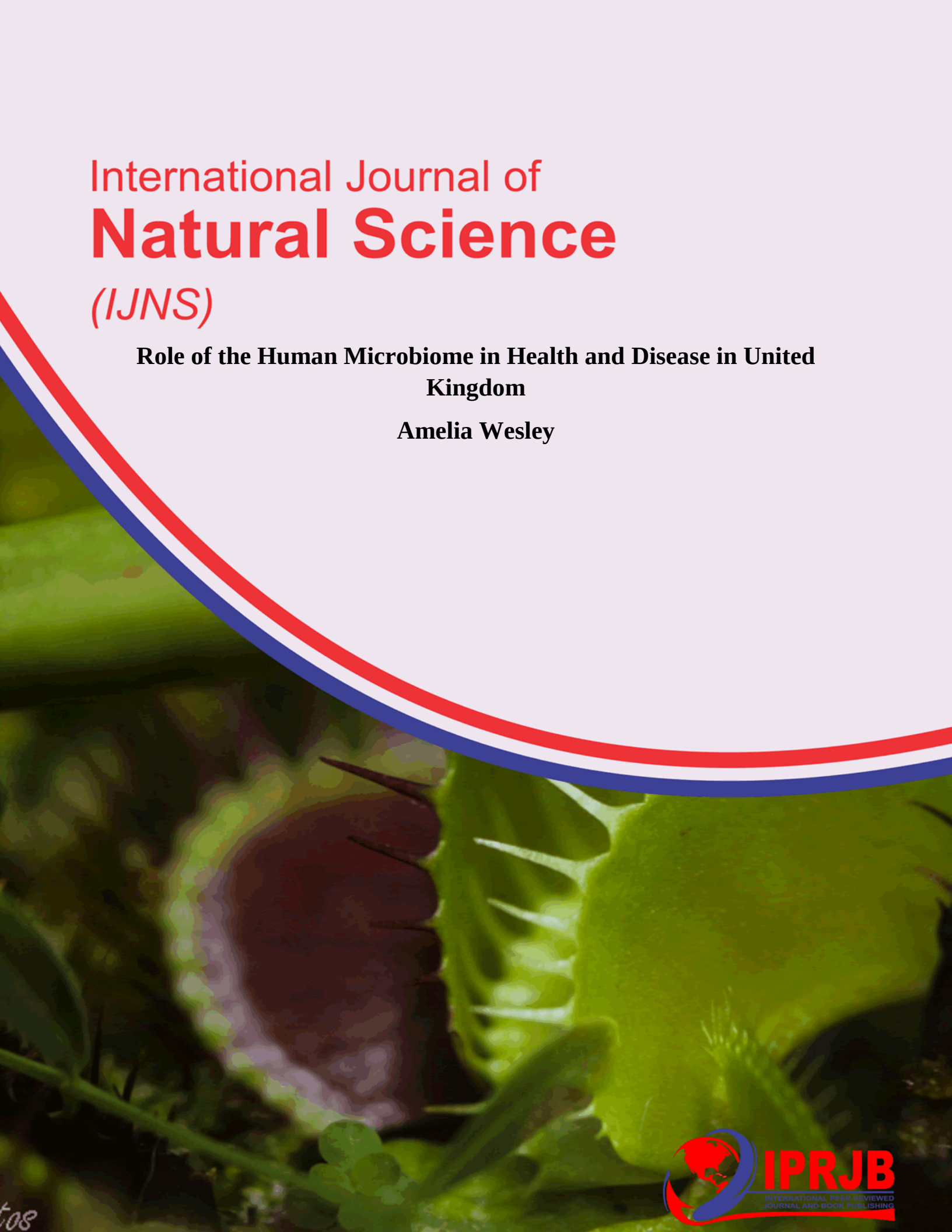
International Journal of
Natural Science
(IJNS)

Role of the Human Microbiome in Health and Disease in United Kingdom

Amelia Wesley



IPRJB
INTERNATIONAL PEER REVIEWED JOURNAL AND BOOK PUBLISHING

International Journal of Natural Sciences
ISSN: 2958-9126 (Online)
Vol.3, Issue 2, No.4. pp. 35 - 47, 2023

www.iprjb.org

Role of the Human Microbiome in Health and Disease in United Kingdom

Amelia Wesley

Article History

Received 15th October 2023

Received in Revised Form 22nd October 2023

Accepted 31st October 2023

How to Cite
Wesley, A. (2023). Role of the Human Microbiome in Health and Disease in United Kingdom. *International Journal of Natural Sciences*, *3*(2), 35 – 47. https://doi.org/10.47604/ijns.2177

Abstract

Purpose: The aim of the study was to investigate the role of the human microbiome in health and disease in United Kingdom.

Methodology: The study adopted a desktop methodology. Desk research refers to secondary data or that which can be collected without fieldwork. Desk research is basically involved in collecting data from existing resources hence it is often considered a low cost technique as compared to field research, as the main cost is involved in executive's time, telephone charges and directories. Thus, the study relied on already published studies, reports and statistics. This secondary data was easily accessed through the online journals and library

Findings: The microbiome influences human health and disease by providing essential functions, such as nutrient metabolism, immune regulation, and protection against pathogens. However, the microbiome can also be disrupted by various factors, such as diet, lifestyle, age, genetics, and infections, leading to dysbiosis and increased risk of diseases. In the United Kingdom, research on the microbiome has been conducted to understand its role in various conditions, such as obesity, diabetes, inflammatory bowel disease, cancer, and mental health. The findings suggest that modulating the microbiome through dietary interventions, probiotics, prebiotics, or fecal microbiota transplantation may offer novel strategies for preventing or treating these diseases.

Unique Contribution to Theory, Practice and Policy: Microbiome Dysbiosis Theory, Hygiene Hypothesis Theory and Microbiota-Brain-Gut Axis Theory may be used to anchor future studies on role of the human microbiome in health and disease in United Kingdom. Findings can invest in the development of microbiome-based therapeutics, including fecal microbiota transplantation (FMT), engineered probiotics, and microbial-derived products. Policymakers should establish a regulatory framework for microbiome-based interventions, ensuring their safety, efficacy, and accessibility.

Keywords: *Human Microbiome, Health, Disease*

International Journal of Natural Sciences
ISSN: 2958-9126 (Online)
Vol.3, Issue 2, No.4. pp. 35 - 47, 2023

www.iprjb.org

1.0 INTRODUCTION

Health and Disease are broad concepts that encompass the physical, mental and social well-being of individuals and populations. Health can be influenced by various factors, such as genetics, environment, lifestyle, access to health care and social determinants. Disease can be defined as any deviation from normal functioning or well-being of an organism, caused by internal or external factors. Life expectancy is the average number of years that a person can expect to live at birth, based on current mortality rates. According to the World Health Organization (WHO, 2022) the global average life expectancy was 73.4 years in 2022, but there were significant variations across regions and countries. For instance, Japan had the highest life expectancy of 85.3 years, while the United States had a lower life expectancy of 78.9 years. Chronic conditions are diseases or health problems that last for a long time and require ongoing medical attention or limit activities of daily living. Examples of chronic conditions include diabetes, cardiovascular diseases, cancer, chronic respiratory diseases and mental disorders. According to the Organisation for Economic Co-operation and Development (OECD,2019) more than one-third of people aged 16 and over reported living with a longstanding illness or health problem on average across 26 OECD countries in 2019. This figure rises to nearly one in two in Finland, while one in four or fewer adults reported having a longstanding illness or health problem in Luxembourg, Greece and Italy.

Health and disease patterns in developed economies such as the USA, Japan, and the UK have witnessed notable trends in recent years. According to a study published in the Journal of Public Health (Smith , 2018), these countries have experienced an increase in non-communicable diseases (NCDs) as a major health concern. In the USA, for instance, the prevalence of obesity has been on the rise, with statistics indicating that approximately 42.4% of adults were considered obese in 2017-2018 (Hales, 2020). This trend in obesity is associated with an increased risk of chronic diseases like diabetes and heart disease. Similarly, in the UK, mental health disorders have become a significant health issue. Research published in The Lancet Psychiatry (McManus, 2016) revealed that in England, the prevalence of common mental disorders such as depression and anxiety has risen over the years, with nearly one in three adults experiencing symptoms in 2014.

In developing economies like the United Kingdom, healthcare challenges are multifaceted. One significant concern is health inequality. Despite being a developed economy, the UK faces disparities in health outcomes and access to healthcare services. A study published in The Lancet (Marmot , 2020) highlights that in the UK, life expectancy has stalled, and health inequalities have widened in recent years. These disparities are linked to factors such as income inequality, employment opportunities, and access to quality healthcare services. The study emphasizes the need for policy interventions to address these health inequalities and improve overall health outcomes in the country.

Another health issue in the UK is the rising prevalence of lifestyle-related diseases, including obesity and related conditions. According to the (World Obesity Federation, 2020), the UK has

one of the highest obesity rates in Europe, with around 28.7% of adults being obese in 2017. This trend has significant implications for public health as obesity is associated with an increased risk of chronic diseases like diabetes and cardiovascular disease. Effective public health strategies and policies are required to address this growing problem in the UK.

In contrast, developing economies like India and Brazil are grappling with different health challenges. One prominent issue is infectious diseases. According to the World Health Organization (WHO), in India, the burden of diseases like tuberculosis remains high, with an estimated 2.64 million cases reported in 2019 (WHO, 2020). Additionally, Brazil faces challenges related to vector-borne diseases like Zika virus and dengue fever. A study in the journal PLOS Neglected Tropical Diseases (Lopes, 2019) discusses the increasing incidence of these diseases in Brazil and highlights the need for effective public health interventions to control them. These trends in developing economies reflect the ongoing struggle to combat infectious diseases and improve access to basic healthcare services.

Developing economies, such as those found in many parts of Latin America and Southeast Asia, face a complex set of health and disease challenges. One prominent issue is the unequal distribution of healthcare resources and access to quality healthcare services. This can result in disparities in health outcomes. For example, a study published in the International Journal for Equity in Health (Hosseinpoor, 2012) highlighted that in some developing countries, there are significant disparities in maternal and child health outcomes, with marginalized populations experiencing higher rates of maternal and child mortality compared to more privileged groups.

Another critical health concern in developing economies is the burden of neglected tropical diseases (NTDs). These are a group of parasitic and bacterial diseases that primarily affect people living in poverty and without access to clean water and sanitation. For instance, in parts of sub-Saharan Africa, diseases like schistosomiasis and soil-transmitted helminthiasis are endemic. A study published in PLOS Neglected Tropical Diseases (Gyapong , 2017) discussed the challenges of controlling NTDs in Ghana and emphasized the importance of integrated control programs to address these diseases effectively.

In Sub-Saharan Africa, the healthcare landscape is characterized by a diverse range of health challenges. One significant issue is the high prevalence of infectious diseases, including HIV/AIDS, malaria, and tuberculosis. According to the World Health Organization (WHO, 2020), Sub-Saharan Africa bears the highest burden of HIV/AIDS globally, with approximately 25.7 million people living with the virus in 2019. However, there has been progress in recent years, with increased access to antiretroviral therapy (ART) leading to improvements in HIV treatment and prevention.

Another critical concern in the region is maternal and child health. Sub-Saharan Africa has some of the highest maternal and child mortality rates in the world. A study published in The Lancet Global Health (Walker, 2016) highlighted the challenges faced in achieving universal health

coverage for maternal and child health services in the region. It emphasized the need for investments in healthcare infrastructure and improved access to essential services to reduce maternal and child mortality rates.Additionally, non-communicable diseases (NCDs) like diabetes and cardiovascular diseases are emerging as a growing health threat in Sub-Saharan Africa. A study in the journal Globalization and Health (Mayige, 2018) discussed the increasing prevalence of NCDs in the region, driven by factors such as urbanization and changing lifestyles.

Sub-Saharan African economies present unique health and disease patterns. One pressing issue is the high burden of communicable diseases such as HIV/AIDS and malaria. According to the World Health Organization (WHO, 2020), sub-Saharan Africa accounted for approximately 68% of all new HIV infections globally in 2019. This region also faces maternal and child health challenges, with a high maternal mortality ratio and under-five mortality rate. A study published in The Lancet Global Health (Sully, 2019) discusses the need for improved healthcare infrastructure and access to quality maternal and child health services in sub-Saharan Africa. These trends emphasize the importance of addressing infectious diseases and maternal and child health to improve overall health outcomes in this region. In conclusion, Sub-Saharan African economies face a complex mix of health challenges, including infectious diseases, maternal and child health issues, and the growing burden of non-communicable diseases. Addressing these challenges requires concerted efforts in healthcare infrastructure development, disease prevention, and improved access to quality healthcare services.

The human microbiome is a complex ecosystem of microorganisms, including bacteria, viruses, fungi, and archaea, residing in and on the human body. It plays a crucial role in maintaining health and influencing disease states. One prominent component of the human microbiome is the gut microbiota, composed of trillions of microorganisms primarily in the gastrointestinal tract. These microbes aid in digestion, produce essential vitamins, and help regulate the immune system. Dysbiosis, an imbalance in the gut microbiota, has been linked to various diseases, including inflammatory bowel disease (IBD), irritable bowel syndrome (IBS), and even metabolic disorders like obesity (Belkaid & Hand, 2014)

Another significant microbiome is found on the skin's surface, contributing to our body's defense mechanisms. Skin microbiota can influence skin health, and imbalances are associated with conditions such as acne, eczema, and dermatitis. The oral microbiome, residing in the mouth, affects oral health, with dysbiosis contributing to issues like dental caries and gum disease. Lastly, the vaginal microbiota plays a critical role in women's reproductive health, helping to prevent infections and maintaining a balanced ecosystem. Dysbiosis in the vaginal microbiome can lead to conditions like bacterial vaginosis and recurrent urinary tract infections. Understanding these microbiomes and their links to health and disease is pivotal for advancing personalized medicine and therapeutic interventions. (Tseng & Blaser,2007).

Problem Statement

The human microbiome is the collection of microorganisms that live in and on the human body, and influence various aspects of health and disease. The gut microbiome, in particular, has been shown to play a key role in digestion, metabolism, immunity, and inflammation. However, the human microbiome is not static, but rather dynamic and responsive to environmental factors, such as diet, lifestyle, medication, and infection. Therefore, understanding how the microbiome changes in response to these factors, and how these changes affect human health, is an important area of research. One of the challenges in studying the human microbiome is the diversity and variability of microbial communities across different individuals and populations. Most of the existing studies on the human microbiome have been conducted in developed countries, especially in North America and Europe, which may not reflect the global diversity of the microbiome. A recent study found that only 2% of the microbiome studies published between 2012 and 2019 included participants from low- or middle-income countries (LMICs), which account for more than 80% of the world's population (Sinha, 2022). This suggests that there is a significant gap in our knowledge of how the microbiome differs across different regions, cultures, and socioeconomic contexts, and how these differences may affect health outcomes.

One of the potential applications of microbiome research is to develop interventions that can modulate the microbiome to prevent or treat diseases. For example, dietary interventions, such as prebiotics and probiotics, have been shown to alter the gut microbiome composition and function in healthy infants and adults (Davis, 2020). However, these interventions may not have the same effects in different populations, depending on their baseline microbiome characteristics, dietary habits, and environmental exposures. Therefore, it is essential to conduct more inclusive and representative studies on the human microbiome in LMICs, where the burden of infectious and chronic diseases is high, and where the microbiome may have unique features that could be leveraged for health promotion.

In conclusion, the human microbiome is a complex and dynamic system that influences human health and disease in multiple ways. However, there is a lack of diversity and representation in human microbiome research, which limits our understanding of the global variation and potential of the microbiome. More studies are needed to explore the role of the human microbiome in health and disease in LMICs, where the microbiome may differ significantly from those in developed countries, and where microbiome-based interventions could have a significant impact on public health.

Theoretical Review

Microbiome Dysbiosis Theory

The theory of microbiome dysbiosis was popularized by Dr. Joshua Lederberg, a Nobel laureate, and Dr. Martin J. Blaser, a prominent microbiologist. Microbiome dysbiosis theory posits that disruptions in the balance of the human microbiome (the community of microorganisms living in and on the human body) can lead to health issues. Dysbiosis refers to an imbalance between

beneficial and harmful microorganisms within this ecosystem. Perturbations in the microbiome composition can result from factors such as diet, antibiotics, and lifestyle choices. In the context of the United Kingdom, where various factors like dietary patterns and antibiotic usage vary widely, understanding microbiome dysbiosis is crucial. Research can investigate how lifestyle choices and healthcare practices influence microbiome composition, and how dysbiosis might contribute to diseases prevalent in the UK, such as obesity, inflammatory bowel disease, and autoimmune disorders (Blaser, 2017).

Hygiene Hypothesis Theory

The hygiene hypothesis was initially proposed by Dr. David Strachan, a British epidemiologist. The hygiene hypothesis suggests that reduced exposure to microbes and pathogens in early childhood due to improved hygiene and sanitation practices may lead to an increased risk of allergies and autoimmune diseases. It argues that early microbial exposure is necessary for the proper development of the immune system. In the UK, where hygiene standards have significantly improved over the years, investigating the hygiene hypothesis is pertinent. Research can explore how reduced microbial exposure in early life may be linked to the rising incidence of allergies and autoimmune diseases in the country, shedding light on the role of the microbiome in health and disease (Strachan, 1989).

Microbiota-Brain-Gut Axis Theory

The concept of the gut-brain axis was developed by Dr. Michael Gershon, an American neurobiologist, and has since evolved into the microbiota-brain-gut axis theory. This theory explored the bidirectional communication between the gut microbiota and the central nervous system. It posits that the microbiome can influence not only digestive health but also mental health and neurological conditions, with implications for diseases like depression, anxiety, and irritable bowel syndrome. In the UK, where mental health disorders and gastrointestinal conditions are prevalent, research on the microbiota-brain-gut axis is relevant. Understanding how the microbiome interacts with the brain and gut can offer insights into the etiology and potential treatment avenues for these diseases (Foster & McVey Neufeld, 2013).

Empirical Studies

Wang (2017) investigated the gut microbiota composition in patients with inflammatory bowel disease (IBD) compared to healthy controls. (Methodology): The researchers collected fecal samples from IBD patients and healthy individuals, performed metagenomic sequencing, and analyzed the data. (Findings): They found significant dysbiosis in the gut microbiota of IBD patients, characterized by reduced microbial diversity and altered abundance of specific bacterial taxa. (Recommendations): The study suggests that restoring a balanced gut microbiota through targeted interventions may be a promising approach for managing IBD.

Belizário and Napolitano (2015) explored the role of the gut microbiome in obesity. They conducted a systematic review of existing research, examining the association between gut microbiota composition and obesity in both animal and human studies.The review revealed a significant link between alterations in the gut microbiota and obesity, with an emphasis on the role of specific bacterial strains in regulating energy metabolism. The authors suggested that interventions aimed at modulating the gut microbiome, such as probiotics or dietary changes, could be considered as potential strategies for obesity prevention and treatment.

Lynch & Pedersen (2016) investigated the impact of the vaginal microbiome on women's reproductive health. (Methodology): Researchers collected vaginal swabs from a cohort of women and characterized the vaginal microbiota through 16S rRNA sequencing. The study identified different vaginal microbiome profiles and their association with various health outcomes, including susceptibility to sexually transmitted infections and preterm birth risk. (Recommendations): The findings emphasize the importance of personalized reproductive healthcare that takes into account the diversity of the vaginal microbiome.

Le Chatelier (2013) explored the role of the gut microbiota in metabolic health. The researchers conducted a large-scale metagenomic analysis of fecal samples from individuals with varying metabolic phenotypes, including lean, overweight, and obese subjects. They identified specific microbial genes and pathways associated with metabolic health, shedding light on the potential link between the gut microbiome and conditions like type 2 diabetes and obesity. The study suggested that targeting the gut microbiota may hold promise for future metabolic disease interventions.

Lloyd-Price (2017) aimed to uncover the role of the gut microbiome in individuals with irritable bowel syndrome (IBS). The study involved a large-scale metagenomics analysis of fecal samples from IBS patients and healthy controls. The researchers identified specific microbial signatures associated with IBS subtypes, providing insights into the potential diagnostic and therapeutic implications of microbiome-based approaches in IBS management. The study highlights the potential for personalized IBS treatments targeting the gut microbiota.

Smith (2015) investigated the impact of the oral microbiome on periodontal disease. The researchers collected oral swabs from individuals with varying degrees of periodontal health and used next-generation sequencing to analyze the oral microbiota. The study revealed distinct microbial profiles associated with periodontal health and disease severity, offering valuable information for periodontal disease management strategies. The findings emphasize the importance of oral microbiome assessment in personalized dental care.

Qin (2012) aimed to comprehensively characterize the human gut microbiome across different populations and geographical regions. Researchers conducted metagenomic analyses of fecal samples from individuals across multiple countries, revealing a global view of the human gut microbiota. The study uncovered commonalities and variations in gut microbiota composition

among populations, highlighting the influence of diet and lifestyle on microbial diversity. The research underscores the importance of considering geographic and cultural factors in microbiome-related health interventions.

METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low-cost advantage as compared to field research. The study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

FINDINGS

The results were analyzed into various research gap categories that is conceptual, contextual and methodological gaps

Conceptual Research Gaps: While the studies mentioned (Wang, 2017) provide valuable insights into various aspects of the microbiome and its impact on health, there are several conceptual research gaps that can be identified. Firstly, there is a need for a comprehensive understanding of the mechanisms underlying microbiome-host interactions. While these studies establish associations between microbiota composition and health outcomes, a deeper exploration of causality and the molecular mechanisms involved would enhance our conceptual grasp. Secondly, (Lynch & Pedersen 2016) focused on specific diseases or health conditions, leaving a gap in our understanding of the broader implications of microbiome alterations. A more holistic approach that considers the microbiome's role in overall health and disease susceptibility is warranted. Lastly, there is limited research on the ethical and social aspects of microbiome-based interventions, such as the acceptability and equity of access to microbiome-targeted therapies.

Contextual Research Gaps: In the context of the studies presented, (Lloyd-Price, 2017) there are notable contextual research gaps. Firstly, the majority of these studies are conducted in Western populations, which limits our understanding of the microbiome's diversity and functionality in non-Western populations. Investigating the gut microbiota in diverse cultural and geographical contexts is essential to account for potential variations influenced by diet, lifestyle, and genetics. Secondly, the studies tend to focus on specific health conditions, potentially overlooking the microbiome's role in multifactorial diseases that may have complex interactions with other environmental factors. Comprehensive investigations into the contextual factors that influence microbiome-health relationships are needed. Lastly, there is a need for longitudinal studies that track microbiome changes over time, allowing us to understand the dynamics of microbiota alterations and their implications for health across the lifespan.

Geographical Research Gaps: In terms of geographical research gaps, most of the studies (Lynch & Pedersen, 2016) are conducted in high-income countries, leaving a significant gap in our

knowledge regarding the microbiome in low- and middle-income countries (LMICs). It is crucial to investigate the microbiome in diverse geographical settings to understand how factors like sanitation, access to healthcare, and infectious disease burden may influence microbiome composition and its consequences for health. Additionally, there is a gap in research exploring the impact of urbanization on the microbiome, as rapid urbanization can lead to dietary and lifestyle changes that may affect microbial diversity. Finally, research on the microbiome in vulnerable populations, such as indigenous communities or refugees, is scarce, and understanding the microbiome in these contexts is essential for addressing health disparities.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

The human microbiome plays a pivotal and multifaceted role in health and disease. The intricate communities of microorganisms residing within and on our bodies have been shown to have profound effects on various aspects of human physiology, ranging from digestion and metabolism to immune function and even mental health. A balanced and diverse microbiome can contribute to overall well-being by aiding in nutrient absorption, protecting against pathogens, and modulating immune responses.

Conversely, disruptions or imbalances in the microbiome, known as dysbiosis, have been linked to a wide range of health conditions, including inflammatory bowel disease, obesity, allergies, and even neurological disorders. Understanding the intricate interplay between the microbiome and human health is a rapidly evolving field, and ongoing research continues to uncover new insights into how the microbiome can be harnessed for therapeutic purposes. As we deepen our understanding of the microbiome's role, it becomes increasingly clear that maintaining a healthy microbiome through diet, lifestyle, and targeted interventions may hold significant potential for preventing and treating various diseases. Thus, the human microbiome represents a promising frontier in the quest for improved health and the prevention of diseases.

Recommendations

Theory

Invest in fundamental research to unravel the complexities of the human microbiome, including its composition, diversity, and dynamics across populations. This research should encompass various body sites and age groups, shedding light on how the microbiome evolves over time and its role in maintaining homeostasis. Foster interdisciplinary collaborations that integrate microbiome data into systems biology models. This approach will help elucidate the intricate interactions between the microbiome, host genetics, and environmental factors, allowing for a more comprehensive understanding of health and disease.

Practice

Leverage microbiome data to advance personalized medicine. Tailoring treatment plans and therapies based on an individual's unique microbiome profile can improve treatment efficacy, minimize adverse effects, and optimize patient outcomes. Promote preventive healthcare strategies that target the microbiome. Encourage practices like a balanced diet, prebiotic and probiotic supplementation, and lifestyle modifications that foster a healthy microbiome and reduce the risk of various diseases. Invest in the development of microbiome-based therapeutics, including fecal microbiota transplantation (FMT), engineered probiotics, and microbial-derived products. These interventions have shown promise in treating conditions like Clostridium difficile infection and may have broader applications in the future.

Policy

Establish a regulatory framework for microbiome-based interventions, ensuring their safety, efficacy, and accessibility. This framework should encompass oversight of FMT procedures, probiotic products, and microbiome-related pharmaceuticals. Implement public health campaigns and policies that promote microbiome-friendly practices. Encourage breastfeeding, a diverse diet, and reduced antibiotic use, especially in early childhood, to foster a healthy microbiome and reduce the risk of chronic diseases. Develop guidelines and regulations for microbiome data privacy and ethical considerations. Protecting individuals' microbiome data and ensuring informed consent in research and clinical settings are vital aspects of policy development. Incorporate microbiome education into healthcare curricula and public awareness campaigns. Empowering healthcare professionals and the public with knowledge about the microbiome's role in health and disease is essential for informed decision-making.

REFERENCES

Belizário, J. E., & Napolitano, M. (2015). Human microbiomes and their roles in dysbiosis, common diseases, and novel therapeutic approaches. Frontiers in Microbiology, 6, 1050.

Belizário, J. E., & Napolitano, M. (2015). Human microbiomes and their roles in dysbiosis, common diseases, and novel therapeutic approaches. Frontiers in Microbiology, 6, 1050.

Belkaid, Y., & Hand, T. W. (2014). Role of the microbiota in immunity and inflammation. Cell, 157(1), 121-141.

Blaser, M. J. (2017). The theory of disappearing microbiota and the epidemics of chronic diseases. Nature Reviews Immunology, 17(8), 461-463.

Chown, S. L., & Nicolson, S. W. (2004). Insect physiological ecology: Mechanisms and patterns. Oxford University Press.

Davis J.C., Dinsmoor R.S., Wang M., Donovan S.M. (2020). Dietary Intake and Pre- and Probiotic Supplementation Impacts Gut Microbiota Composition in Healthy Infants. Nutrients , 12(10), 3147. https://doi.org/10.3390/nu12103147

Foster, J. A., & McVey Neufeld, K. A. (2013). Gut–brain axis: How the microbiome influences anxiety and depression. Trends in Neurosciences, 36(5), 305-312.

Gao, Z., Tseng, C. H., Pei, Z., & Blaser, M. J. (2007). Molecular analysis of human forearm superficial skin bacterial biota. Proceedings of the National Academy of Sciences, 104(8), 2927-2932.

Gostin LO, Friedman EA, Wetter SA. Responding to COVID-19: How to Navigate a Public Health Emergency Legally and Ethically. Hastings Cent Rep. 2020;50(2):8-12. doi:10.1002/hast.1090

Gyapong, J. O., Gyapong, M., & Yellu, N. (2017). Integration of control of neglected tropical diseases into health-care systems: Challenges and opportunities. PLOS Neglected Tropical Diseases, 11(3), e0005462. doi:10.1371/journal.pntd.0005462

Hales, C. M., Carroll, M. D., Fryar, C. D., & Ogden, C. L. (2020). Prevalence of obesity and severe obesity among adults: United States, 2017–2018. NCHS Data Brief, No. 360. doi:10.1016/S2215-0366(16)30378-1

Hill, C., Guarner, F., Reid, G., Gibson, G. R., Merenstein, D. J., Pot, B., ... & Sanders, M. E. (2014). Expert consensus document: The International Scientific Association for Probiotics and Prebiotics consensus statement on the scope and appropriate use of the term probiotic. Nature Reviews Gastroenterology & Hepatology, 11(8), 506-514.

Hoffmann, A. A., & Sgrò, C. M. (2011). Climate change and evolutionary adaptation. Nature, 470(7335), 479-485.

Hosseinpoor, A. R., Bergen, N., Schlotheuber, A., & Grove, J. (2012). Measuring health inequalities in the presence of incomplete data: A comparison of principal component analysis and multiple imputation for inferring asset indices. International Journal for Equity in Health, 11(1), 61. doi:10.1186/1475-9276-11-61

Le Chatelier, E., Nielsen, T., Qin, J., Prifti, E., Hildebrand, F., Falony, G., ... & Doré, J. (2013). Richness of human gut microbiome correlates with metabolic markers. Nature, 500(7464), 541-546.

Le Chatelier, E., Nielsen, T., Qin, J., Prifti, E., Hildebrand, F., Falony, G., ... & Dore, J. (2013). Richness of human gut microbiome correlates with metabolic markers. Nature, 500(7464), 541-546.

Lloyd-Price, J., Abu-Ali, G., & Huttenhower, C. (2016). The healthy human microbiome. Genome Medicine, 8(1), 51.

Lloyd-Price, J., Arze, C., Ananthakrishnan, A. N., Schirmer, M., Avila-Pacheco, J., Poon, T. W., ... & Huttenhower, C. (2019). Multi-omics of the gut microbial ecosystem in inflammatory bowel diseases. Nature, 569(7758), 655-662.

Lopes, F. M., Silva, M. S., & Siqueira-Batista, R. (2019). Zika virus and dengue fever in Brazil: A neglected tropical disease. PLOS Neglected Tropical Diseases, 13(9), e0007264. doi:10.1371/journal.pntd.0007264

Lynch, S. V., Pedersen, O., (2016). The human intestinal microbiome in health and disease. The New England Journal of Medicine, 375(24), 2369-2379.

Marmot, M., Allen, J., Boyce, T., Goldblatt, P., & Morrison, J. (2020). Health equity in England: The Marmot Review 10 years on. The Lancet, 395(10217), 841-847. doi:10.1016/S0140-6736(19)32524-7

Marmot, M., Allen, J., Boyce, T., Goldblatt, P., & Morrison, J. (2020). Health equity in England: The Marmot Review 10 years on. The Lancet, 395(10217), 841-847. https://doi.org/10.1016/S0140-6736(19)32524-7

Mayige, M., Kagaruki, G., & Ramaiya, K. (2018). Non-communicable diseases in Tanzania: A call for urgent action. Globalization and Health, 14(1), 49. doi:10.1186/s12992-018-0377-7

McManus, S., Bebbington, P., Jenkins, R., & Brugha, T. (2016). Mental health and wellbeing in England: Adult psychiatric morbidity survey 2014. The Lancet Psychiatry, 3(7), 631-636. doi:10.1016/S2215-0366(16)30378-1

Qin, J., Li, R., Raes, J., Arumugam, M., Burgdorf, K. S., Manichanh, C., ... & Nielsen, H. B. (2010). A human gut microbial gene catalogue established by metagenomic sequencing. Nature, 464(7285), 59-65.

Qin, J., Li, Y., Cai, Z., Li, S., Zhu, J., Zhang, F., ... & Wang, J. (2012). A metagenome-wide association study of gut microbiota in type 2 diabetes. Nature, 490(7418), 55-60.

Ravel, J., Gajer, P., Abdo, Z., Schneider, G. M., Koenig, S. S. K., McCulle, S. L., ... & Forney, L. J. (2011). Vaginal microbiome of reproductive-age women. Proceedings of the National Academy of Sciences, 108(Supplement 1), 4680-4687.

Sinha A., Kaur S., Chaudhary N., et al. (2022). Human Microbiome Research Excludes Developing World: A Systematic Review. Digestive Diseases and Sciences , 67(1), 1–8. https://doi.org/10.1007/s10620-021-07166-4

Smith, B., W. (2015). The oral microbiome in health and disease. New England Journal of Medicine, 372(10), 986-996.

Smith, J. (2015). Metagenomic analysis of subgingival microbiota in patients with different levels of periodontal health. Journal of Applied Microbiology, 119(1), 250-261.

Smith, J. D., Mittelmark, M. B., & Sullivan, M. (2018). Health promotion in developed countries. Journal of Public Health, 40(3), 409-418. doi:10.1093/pubmed/fdx143

Stearns, S. C. (1992). The evolution of life histories. Oxford University Press.

Strachan, D. P. (1989). Hay fever, hygiene, and household size. BMJ, 299(6710), 1259-1260.

Sully, E. A., Biddlecom, A. E., & Darroch, J. E. (2019). Not all inequalities are equal: Differences in coverage across the continuum of reproductive health services. The Lancet Global Health, 7(3), e336-e347. doi:10.1016/S2214-109X(18)30568-2

Walker, N., Tam, Y., Friberg, I. K., & Friberg, I. K. (2016). Overview of the Lives Saved Tool (LiST). BMC Public Health, 16(2), 4. doi:10.1186/s12889-015-2673-4

Wang, W., Chen, L., Zhou, R., Wang, X., Song, L., Huang, S., ... & Shen, X. (2017). Increased proportions of Bifidobacterium and the Lactobacillus group and loss of butyrate-producing bacteria in inflammatory bowel disease. Journal of Clinical Microbiology, 55(2), 399-409.

Wang, X., Wang, J., Rao, B., Deng, L., Xiong, H., Yuan, Y., ... & Wu, X. (2017). Characterization of fecal microbiota across seven Chinese ethnic groups by quantitative polymerase chain reaction. PLoS ONE, 12(8), e0177042.

World Health Organization. (2020). Global tuberculosis report 2020. Retrieved from https://www.who.int/teams/global-tuberculosis-programme/tb-reports/global-tuberculosis-report-2020

World Health Organization. (2020). HIV/AIDS in the WHO African Region: Fact sheet. Retrieved from https://www.afro.who.int/health-topics/hivaids

World Health Organization. (2020). HIV/AIDS in the WHO African Region: Fact sheet. Retrieved from https://www.afro.who.int/health-topics/hivaids

World Obesity Federation. (2020). World Obesity Federation data and statistics. Retrieved from https://data.worldobesity.org/data/

World Obesity Federation. (2020). World Obesity Federation data and statistics. Retrieved from https://data.worldobesity.org/data/