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FROM SPRING TO WINTER: THE NEED FOR CONSISTENT SEASONAL VACCINATIONS

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Abstract:

The cyclical interplay between seasons and diseases has long intrigued researchers and health professionals alike. With each seasonal transition, certain infectious diseases rise to the forefront, influenced by dynamic factors such as environmental conditions, shifts in human behavioral patterns, and varying biological rhythms. This article delves deep into the intricate relationship between these changes and the consequent surge in specific diseases, underlining the critical importance of timely and consistent vaccinations. Beyond the evident health implications, seasonal diseases exert tremendous socioeconomic pressures, stretching the capacities of healthcare facilities, causing productivity losses, and even impacting school attendance and business operations. Vaccinations, a marvel of modern medicine, emerge as a paramount defense mechanism. Through herd immunity, they not only protect the vaccinated individual but also reduce the overall transmission, especially when formulas adapt annually to the anticipated strains, as seen with influenza. Despite the undoubtable benefits, the global community grapples with challenges like public hesitancy towards vaccines, often fueled by misinformation, and logistical hurdles that affect distribution, especially in remote or underserved regions. Emphasizing the universal acceptance and enhanced accessibility of seasonal vaccines is pivotal for safeguarding global health. By ensuring widespread vaccination, societies can fortify their defense against the cyclical threat of seasonal diseases, promising a healthier future for all.

Keywords: *Seasonal diseases, Vaccinations, Public health, Infectious diseases dynamics, Socioeconomic impact, Herd immunity, Vaccine hesitancy, Health logistics*

1- INTRODUCTION

Nature's cyclical rhythms, expressed through the changing seasons, have an indelible impact on our lives. These shifts, which we often appreciate for their scenic beauty or recreational potential, have deep-rooted implications that extend beyond the aesthetic. As each season transitions, a silent symphony of infectious diseases plays in the background—some receding and others gaining ground[1]. This ebb and flow of ailments isn't merely coincidental with the climatic changes; rather, it's a result of a myriad of interrelated factors that range from environmental shifts to nuanced behavioral adaptations among populations.

From the blooming flowers of spring to the crisp chills of winter, these climatic shifts create environments that are conducive or restrictive for certain pathogens. For instance, the cold, dry conditions of winter in many regions often coincide with increased instances of influenza[2]. This isn't just due to the virus's preference for colder climes but is also a consequence of people clustering indoors, facilitating easier transmission. Similarly, summer brings its own set of challenges, as warmer temperatures and outdoor activities can expose many to vector-borne diseases.

Yet, it's not just the direct influence of the environment on pathogens that shapes this seasonal disease landscape. Human behaviors and societal patterns, influenced by the seasons, play a pivotal role[3]. As winter holidays approach, increased travel and social gatherings might inadvertently become hotspots for disease spread. Contrarily, summer vacations can lead to exposure to new environments and their resident pathogens[4].

Interestingly, our own biology might have a part to play in this dynamic. Emerging research suggests our immune responsiveness could be influenced by seasonal changes, potentially rendering us more susceptible during certain periods[5]. In the midst of this ever-changing battle between humans and pathogens, stands the fortress of modern medicine, with vaccinations as its vanguard[6]. These are not just reactive measures; they're proactive shields, meticulously designed to anticipate the seasonal threats. Through herd immunity, they aim to protect not just the individual but the broader community. Yet, as formidable as this defense might be, it's efficacy hinges on timely and widespread adoption.

This article embarks on a journey to understand these intricate relationships between seasons and diseases, the socio-economic ramifications they birth, and the pivotal role vaccinations play in the narrative. As we delve deeper, it becomes evident that our annual journey from spring to winter is not just a scenic transition, but a complex interplay of health dynamics, requiring vigilance and preparedness.

2- The Seasonal Dynamics of Infectious Diseases

The cyclical nature of the seasons, marked by distinct environmental changes, has a profound influence on the prevalence and spread of infectious diseases. As each season ushers in its unique set of characteristics, it concurrently alters the landscape for various pathogens, shaping how they spread, survive, and affect populations[7].

The cold and dry conditions of winter in many temperate regions often see a rise in respiratory illnesses. Influenza, one of the most common winter ailments, thrives in these conditions, not just because of the virus's own properties but also due to human behaviors[8]. As temperatures drop, people tend to stay indoors, in closer proximity to others, facilitating the spread of airborne diseases. Furthermore, the reduced exposure to sunlight during this period can lead to decreased vitamin D levels, potentially weakening the immune response of individuals.

On the other hand, summer, with its warmth and humidity, fosters a different set of challenges. These months become a breeding ground for vector-borne diseases like malaria, dengue, and Zika. The increased activities of mosquitoes, facilitated by stagnant water and higher temperatures, lead to heightened transmission risks[9]. Moreover, people, lured by the pleasant weather, often spend more time outdoors, increasing their exposure to these vectors.

Transition seasons, like spring and autumn, while moderate in temperature, have their own set of disease dynamics[10]. Allergies are rampant during spring, as plants release pollen, and the reemergence of ticks can lead to diseases like Lyme disease.

Human behavior, molded by seasonal cultural or societal events, also plays an integral role in disease dynamics. Festivals, holidays, and vacations, often aligned with specific seasons, lead to increased travel and social gatherings, potentially elevating the risk of disease transmission[11].

Additionally, our biological rhythms, intricately tied to nature's clock, might also have a role in this equation. Some studies suggest that our immune systems might be more or less effective during certain times of the year, further influencing susceptibility to infections.

Season	Environmental Factors	Predominant Diseases	Reasons/Behavioral Factors
Winter	Cold and dry conditions	Influenza, Common cold	People cluster indoors, reduced sunlight leads to potential vitamin D deficiency, airborne disease transmission becomes more common.
Summer	Warm and humid conditions	Malaria, Dengue, Zika	Increased mosquito activity, stagnant water breeding grounds, more outdoor activities leading to exposure.
Spring	Moderate temperatures, increased plant activity	Allergies, Lyme disease	Plant pollen leading to allergic reactions, increased tick activity.
Autumn	Cooling temperatures, falling leaves	Flu (early strains), respiratory ailments	People start to spend more time indoors, increased social gatherings in preparation for winter holidays.

In essence, the dance between seasons and infectious diseases is a complex choreography of environmental conditions, human behaviors, and biological factors. Understanding this relationship is paramount for effective public health interventions and to prepare communities for the challenges each season brings.

3- The Socioeconomic Impact of Seasonal Diseases

Seasonal diseases, while primarily a concern for public health, extend their reach into the economic sphere, casting a shadow on societal productivity and resource allocation. These diseases, manifesting at specific times of the year, not only affect individuals' health but also have ripple effects on economies and communities.

During disease outbreaks, especially in peak seasons, healthcare facilities often experience heightened pressures[12]. Hospitals may see an influx of patients, causing potential bed shortages and stretching the limits of available medical resources. This strain isn't limited to just infrastructure; medical personnel may face burnout due to increased workloads, and there could be shortages in critical medicines and treatments.

The economic repercussions of seasonal diseases are multifaceted. Affected individuals, when forced to take time off work due to illness, result in a loss of man-hours, affecting productivity[13]. Businesses, especially those in the service sector, might experience a decrease in patronage during disease outbreaks. Moreover, when workers fall sick, there's a potential for reduced production, delayed services, and overall economic slowdown.

Beyond businesses, the educational sector also feels the strain. Schools may witness reduced attendance rates during disease peaks, which can disrupt learning and academic progression[14]. In extreme cases, schools might even be temporarily closed to curb the spread of diseases, leading to further educational disruptions.

Additionally, there are long-term economic implications to consider. Repeated outbreaks can deter investments in affected areas, especially in sectors like tourism. Regions known for recurrent seasonal diseases might struggle to attract tourists, affecting local businesses and employment. Furthermore, governments might need to redirect funds to tackle these seasonal outbreaks, which could mean reduced spending in other vital sectors or even an increase in taxes.

In a broader societal context, the recurrent nature of these diseases can also have a psychological impact. Communities may live in fear or anxiety, awaiting the next seasonal outbreak. This can lead to reduced social interactions, potentially affecting community cohesion.

In conclusion, seasonal diseases, while often viewed through a medical lens, have profound socioeconomic implications. The interconnectedness of health, economy, and society becomes glaringly evident, highlighting the need for comprehensive strategies that address not only the health but also the economic challenges posed by these diseases.

4- The Shield of Seasonal Vaccinations

In the ever-evolving battle against infectious diseases, vaccinations stand as our most potent shield, meticulously designed to protect against the predictable threats posed by seasonal pathogens. This shield is not just about individual protection; it represents a collective defense strategy, aiming to ensure community-wide safety through the power of herd immunity. Seasonal diseases, with their cyclical nature, can potentially bring about waves of outbreaks. Predicting and preparing for these outbreaks necessitates the development and deployment of vaccines tailored to specific seasons[15]. The flu vaccine, perhaps the most well-known among seasonal vaccinations, epitomizes this approach. With the influenza virus constantly mutating, researchers work tirelessly each year to predict the most probable strains and develop an appropriate vaccine[16]. By getting vaccinated annually, individuals not only protect themselves but also contribute to reducing the overall spread within the community.

However, the effectiveness of this shield requires more than just the scientific prowess to create vaccines. Public awareness, acceptance, and access play crucial roles in ensuring the widespread uptake of these vaccines. Vaccine hesitancy, often fueled by misinformation or misconceptions, can weaken the collective shield, allowing diseases to penetrate communities more easily[17]. Addressing this hesitancy, through education and outreach, is paramount to bolster the vaccine shield's strength.

Logistics, too, can pose challenges. Ensuring that vaccines are readily available, especially in remote or underserved regions, is critical. Efficient distribution networks, cold chain management for vaccines that require specific storage conditions, and timely dissemination to medical facilities play a pivotal role in maximizing the impact of seasonal vaccinations.
Furthermore, monitoring and feedback mechanisms are crucial. As diseases evolve, so must our shield. Vigilant monitoring helps identify new strains or disease trends, allowing researchers to adjust vaccine compositions as needed. Feedback from communities can shed light on potential side effects or areas for improvement, ensuring that the shield remains not just strong but also adaptable.

In essence, seasonal vaccinations represent humanity's proactive stance against the recurring challenges posed by infectious diseases. This shield, fortified by science, public cooperation, and efficient logistics, promises a safer passage through the shifting landscapes of seasonal health threats. The more we invest in, trust, and utilize this shield, the better equipped we are to face the challenges each season brings.

5- The Perils of Inconsistency
In the realm of public health, especially concerning seasonal vaccinations, inconsistency can lead to significant repercussions. When there's a lapse in maintaining a steady rate of immunization, communities become more susceptible to the illnesses these vaccines are designed to prevent[18].

Firstly, a lack of consistent vaccination increases the risk of outbreaks. With fewer people immunized, a single case can rapidly escalate into a large-scale health crisis. This is particularly concerning for diseases like the flu, which can change and evolve, becoming more virulent if given the chance.

Moreover, when these outbreaks occur, they place a massive strain on healthcare facilities. Hospitals and clinics, which might already be dealing with other health issues, suddenly find themselves overwhelmed by a surge of patients affected by preventable diseases[12]. This strain isn't just limited to bed space and facilities; it also stretches human resources, with doctors, nurses, and other healthcare professionals facing heightened workloads.

Beyond the immediate health concerns, there's an economic dimension to this inconsistency. Treating preventable illnesses costs money, and when large portions of the community fall sick, it leads to an increased financial burden on the healthcare system[19]. Additionally, with more people taking sick leaves or being unable to work, there's a potential for decreased productivity, which can have ripple effects on the economy.

In summary, inconsistency in seasonal vaccinations doesn't just jeopardize individual health; it has broader social, economic, and healthcare implications. Ensuring steady and consistent vaccination efforts is paramount for the greater good.

6- The Evolution of Vaccination Strategies:
Vaccination, one of the most significant achievements in modern medicine, has undergone immense evolution since its inception. From its humble beginnings to the advanced strategies of today, vaccination has been continually refined to enhance its efficacy, safety, and accessibility.

Early Beginnings:
The roots of vaccination can be traced back to ancient civilizations where rudimentary forms of inoculation were practiced[20]. For instance, in ancient China, dried smallpox scabs were inhaled or inserted into skin cuts to confer immunity. However, it wasn't until Edward Jenner's pioneering work in the late 18th century that the term "vaccination" was coined. Using cowpox material, Jenner demonstrated protection against smallpox, setting the foundation for modern vaccinology.

Growth and Expansion in the 19th & 20th Centuries:
The successes of smallpox vaccination led to increased research into other diseases. By the late 19th and early 20th centuries, vaccines for rabies, typhoid, cholera, and the plague had been developed[21]. The mid-20th century saw a surge in vaccine research and development, with vaccines for diseases like polio, measles, mumps, and rubella emerging. The strategies involved live-attenuated or killed versions of the pathogen to stimulate immunity.

Molecular and Genetic Advancements:
With the advent of molecular biology and genetic engineering in the late 20th century, a new era for vaccination began. Recombinant DNA technology allowed for the production of specific viral proteins in the lab[22]. This led to the development of subunit vaccines, which use a component of the pathogen, rather than the whole organism, to elicit an immune response. The Hepatitis B vaccine, introduced in the 1980s, was one of the first vaccines created using this technology.

Adjuvants and Conjugate Vaccines:
Researchers began to understand the role of adjuvants – substances that enhance the body's immune response to an antigen. By combining antigens with adjuvants, the effectiveness of many vaccines was improved. Additionally, conjugate vaccines

were developed by attaching bacterial polysaccharides to proteins, enhancing the immune system's response, especially in young children[23].

21st Century and Beyond: mRNA and Viral Vector Vaccines:
The recent COVID-19 pandemic accelerated the development and approval of mRNA vaccines, a technology that had been in research for decades. Rather than using the pathogen's actual components, mRNA vaccines introduce a genetic code that instructs cells to produce a viral protein, triggering an immune response. Similarly, viral vector vaccines, which use a different virus to deliver genetic material, gained prominence.

Personalized and Therapeutic Vaccines:
The future holds promise for personalized vaccines tailored to individual genetic makeups. Moreover, therapeutic vaccines, aimed not just at preventing but also treating diseases, are under investigation, especially in oncology[24].

Global Vaccination Campaigns and Strategies:
Beyond the vaccines themselves, strategies on global immunization campaigns have evolved. The eradication of smallpox, the near-eradication of polio, and the significant reduction of diseases like measles are testaments to coordinated global efforts, strategic planning, and community engagement.

In conclusion, the journey of vaccination strategies from basic inoculation to advanced genetic platforms showcases human ingenuity and adaptability. As challenges arise, be it new pathogens or changing societal dynamics, the field of vaccinology continues to innovate, ensuring that the protective shield of vaccination remains robust and effective.

7- The Benefits of Consistent Seasonal Vaccinations:
Consistent seasonal vaccinations play a pivotal role in safeguarding both individual and public health. At the heart of this strategy is the idea of equipping the body's immune system to combat seasonal infectious diseases before they gain a stronghold.

For the individual, seasonal vaccinations act as a shield, significantly reducing the risk of contracting specific diseases that are prevalent during certain times of the year[25]. This proactive approach ensures that individuals are protected against the dominant strains of infectious agents for each particular season. By doing so, people can avoid the severe health complications that come with diseases like the flu, which can be especially detrimental to vulnerable groups like the elderly, children, and those with compromised immune systems.

Beyond just personal protection, there's a broader community benefit. When a significant portion of a community is vaccinated, it creates a protective barrier, often referred to as herd immunity. This barrier prevents the spread of the disease within the community, ensuring that even those who cannot get vaccinated—such as infants or those with specific allergies or medical conditions—are indirectly protected[26]. This collective protection is essential in preventing large-scale outbreaks and in potentially eradicating certain diseases.

The consistent use of seasonal vaccinations also alleviates the strain on healthcare systems. Seasonal disease outbreaks can lead to a surge in hospital admissions, stretching resources thin. By reducing the number of disease cases, vaccinations ensure that healthcare facilities can operate more efficiently and are not overwhelmed during peak seasons.

Economically, there's much to gain from consistent seasonal vaccinations. Preventing diseases means fewer sick days, maintaining productivity in workplaces and educational institutions[27]. It also means reduced medical expenses for individuals and decreased public health costs for governments.

Furthermore, the psychological comfort that comes from knowing one is protected cannot be understated. Individuals and communities can engage in daily activities, work, travel, and social interactions with a reduced fear of contracting or spreading seasonal diseases.

In conclusion, while the act of getting a seasonal vaccination might seem like a small, personal choice, its ripple effects are vast. From safeguarding individual health to protecting communities, maintaining economic productivity, and ensuring efficient healthcare operations, the benefits of consistent seasonal vaccinations underscore their critical role in modern public health strategy.

8- The Challenges Ahead:
The dynamic between seasons and infectious diseases, and our counteractive measures through vaccinations, is a constantly shifting battleground. As we navigate this landscape, we face a multitude of challenges, both old and new, that require adaptability, foresight, and collaborative action.

1. **Emergent Strains and Rapid Evolution:** With pathogens like viruses showing a high mutation rate, there's always a risk of new, possibly more virulent strains emerging. The recent memory of the COVID-19 pandemic serves as a stark reminder. Adapting to these emergent strains in real-time, developing effective vaccines, and ensuring their rapid distribution is a formidable challenge[28].

2. **Vaccine Hesitancy:** Despite the overwhelming evidence supporting vaccine efficacy and safety, skepticism persists in pockets of the global population[29]. Misinformation, mistrust in healthcare systems, or cultural beliefs can deter individuals from getting vaccinated, thereby weakening community-wide defenses.
3. **Logistical Hurdles:** Distributing vaccines globally, especially to remote or underserved areas, remains a daunting task. Maintaining the cold chain, addressing transportation challenges, and ensuring timely delivery are all components of this intricate puzzle.
4. **Economic Impediments:** Vaccination campaigns require funding. In regions facing economic constraints, prioritizing vaccine procurement and distribution might compete with other pressing needs, potentially hindering efforts.
5. **Antimicrobial Resistance:** As we continue to combat infectious diseases, the overuse or misuse of medications can lead to pathogens developing resistance. This resistance can render treatments ineffective, making prevention through vaccination even more vital.
6. **Environmental and Behavioral Changes:** Climate change, urbanization, and changes in human behavior can create new breeding grounds for vectors or facilitate the spread of diseases[30]. These evolving factors necessitate continuous monitoring and adaptive strategies.
7. **Global Collaboration:** Infectious diseases know no borders. Global outbreaks, or pandemics, highlight the need for international cooperation. Sharing research, resources, and strategies becomes crucial, yet political differences and economic disparities can sometimes hinder such collaboration.
8. **Data Management and Analysis:** In our digital age, efficient data collection, management, and analysis are paramount. Tracking disease outbreaks, understanding their patterns, and predicting future trends rely on sophisticated data infrastructure, which may not be uniformly available globally.
9. **Ethical Considerations:** Vaccine trials, distribution prioritization, and mandate discussions all come with ethical considerations. Balancing individual rights with community safety and global health can lead to intricate debates.
10. **Continual Public Education:** As science advances, there's a need for continuous public education to keep communities informed about new diseases, vaccine developments, and best practices.

In facing these challenges, it's essential to remember that they're not insurmountable. History has shown that with collaboration, innovation, and a unified vision, humanity can overcome health crises. The road ahead may be riddled with obstacles, but with determination and collective effort, a healthier future remains within our grasp.

9- Global Collaboration and Research

In the realm of public health and infectious diseases, global collaboration and research form the bedrock of our collective response. The multifaceted nature of health challenges demands a cohesive approach that transcends borders and individual capacities[31].

Surveillance and monitoring of diseases play a crucial role in understanding their spread and evolution. Organizations such as the World Health Organization (WHO), in tandem with national health departments, keep an eagle-eyed watch on global health trends. This extensive surveillance network offers invaluable real-time insights into the emergence of new strains and potential health threats.

But monitoring is just the beginning. A plethora of research institutions, universities, and labs across continents regularly pool their knowledge. This synergy accelerates our understanding of diseases, enabling faster development of treatments and preventive strategies[32]. Rather than working in isolated silos, the shared expertise of the global scientific community often leads to breakthroughs that might have taken much longer if pursued individually.

Resource allocation, especially during times of crises like outbreaks or pandemics, is another area where collaboration shines. Not all nations are equipped with the infrastructure or resources to manage sudden health threats effectively. Here, global partnerships come to the fore, channeling resources—from vaccines and medications to technical expertise—where they are most urgently needed.

The benefits of collaboration extend to standardizing medical practices and responses. Best practices, when discovered or developed, don't remain confined to their place of origin. They spread, adopted by nations and institutions worldwide, ensuring that the global response to health challenges is uniform and effective.

History has shown us that when faced with global health threats, a united front is our best defense. Initiatives like COVAX, which aimed at equitable vaccine distribution during the COVID-19 pandemic, underscore the power and necessity of collective action[33].

Lastly, while immediate threats necessitate swift responses, global collaboration is equally focused on the horizon. By sharing data and research, we not only tackle present challenges but also equip ourselves for the future, preparing for challenges yet unseen.

In a world ever more interconnected, where diseases recognize no boundaries, global collaboration and research are not just assets; they are imperatives. They underscore the adage that in unity, there's strength, and in shared knowledge, there's hope.

10-Conclusion:

Seasonal diseases, with their cyclic and predictable patterns, present both a challenge and an opportunity. The rhythm of their recurrence might seem daunting, but it also offers us a chance to prepare, defend, and ultimately, thrive. The critical tool in this endeavor is consistent seasonal vaccinations, a powerful marriage of scientific innovation and proactive public health strategy.

Over the course of this exploration, we've delved into the dynamics of seasonal diseases, understood their socioeconomic ramifications, and navigated the multifaceted world of vaccination strategies. Each facet reinforces the same fundamental truth: the profound impact of consistent immunization on individual and communal well-being.

In an era marked by rapid information exchange and, unfortunately, misinformation, the importance of making informed choices about health cannot be overemphasized. Vaccination, backed by rigorous scientific research and countless success stories, stands as a beacon of preventive medicine. Consistency in this practice ensures that we're not just reacting to health challenges but anticipating and mitigating them.

As we look to the future, it's crucial to remember the lessons of the past and the potential of the present. The tools, knowledge, and strategies at our disposal can significantly alter the trajectory of seasonal diseases, transforming them from formidable foes to manageable challenges. The path to this healthier, more resilient future is paved with consistent choices, collective action, and an unwavering faith in science. Let's walk it together.

References:

[1]. McKeown RE. The Epidemiologic Transition: Changing Patterns of Mortality and Population Dynamics. Am J Lifestyle Med. 2009 Jul 1;3(1 Suppl):19S-26S. doi: 10.1177/1559827609335350. PMID: 20161566; PMCID: PMC2805833.

[2]. Lowen AC, Steel J. Roles of humidity and temperature in shaping influenza seasonality. J Virol. 2014 Jul;88(14):7692-5. doi: 10.1128/JVI.03544-13. Epub 2014 Apr 30. PMID: 24789791; PMCID: PMC4097773.

[3]. Liu X, Huang J, Li C, Zhao Y, Wang D, Huang Z, Yang K. The role of seasonality in the spread of COVID-19 pandemic. Environ Res. 2021 Apr;195:110874. doi: 10.1016/j.envres.2021.110874. Epub 2021 Feb 19. PMID: 33610582; PMCID: PMC7892320.

[4]. Ewing A, Lee EC, Viboud C, Bansal S. Contact, Travel, and Transmission: The Impact of Winter Holidays on Influenza Dynamics in the United States. J Infect Dis. 2017 Mar 1;215(5):732-739. doi: 10.1093/infdis/jiw642. PMID: 28031259; PMCID: PMC5853779.

[5]. Nelson RJ, Demas GE. Seasonal changes in immune function. Q Rev Biol. 1996 Dec;71(4):511-48. doi: 10.1086/419555. PMID: 8987173.

[6]. Pulendran B, Ahmed R. Immunological mechanisms of vaccination. Nat Immunol. 2011 Jun;12(6):509-17. doi: 10.1038/ni.2039. PMID: 21739679; PMCID: PMC3253344.

[7]. Wilkinson K, Grant WP, Green LE, Hunter S, Jeger MJ, Lowe P, Medley GF, Mills P, Phillipson J, Poppy GM, Waage J. Infectious diseases of animals and plants: an interdisciplinary approach. Philos Trans R Soc Lond B Biol Sci. 2011 Jul 12;366(1573):1933-42. doi: 10.1098/rstb.2010.0415. PMID: 21624914; PMCID: PMC3130394.

[8]. Davis RE, Dougherty E, McArthur C, Huang QS, Baker MG. Cold, dry air is associated with influenza and pneumonia mortality in Auckland, New Zealand. Influenza Other Respir Viruses. 2016 Jul;10(4):310-3. doi: 10.1111/irv.12369. Epub 2016 May 17. PMID: 26681638; PMCID: PMC4910181.

[9]. Campbell-Lendrum D, Manga L, Bagayoko M, Sommerfeld J. Climate change and vector-borne diseases: what are the implications for public health research and policy? Philos Trans R Soc Lond B Biol Sci. 2015 Apr 5;370(1665):20130552. doi: 10.1098/rstb.2013.0552. PMID: 25688013; PMCID: PMC4342958.

[10]. Martinez ME. The calendar of epidemics: Seasonal cycles of infectious diseases. PLoS Pathog. 2018 Nov 8;14(11):e1007327. doi: 10.1371/journal.ppat.1007327. PMID: 30408114; PMCID: PMC6224126.

[11]. Leiker B, Wise K. COVID - 19 case study in emergency medicine preparedness and response: from personal protective equipment to delivery of care. Dis Mon. 2020 Sep;66(9):101060. doi: 10.1016/j.disamonth.2020.101060. Epub 2020 Jul 27. PMID: 32800348; PMCID: PMC7383175.

[12]. Madhav N, Oppenheim B, Gallivan M, et al. Pandemics: Risks, Impacts, and Mitigation. In: Jamison DT, Gelband H, Horton S, et al., editors. Disease Control Priorities: Improving Health and Reducing Poverty. 3rd edition. Washington (DC): The International Bank for Reconstruction and Development / The World Bank; 2017 Nov 27. Chapter 17. Available from: https://www.ncbi.nlm.nih.gov/books/NBK525302/ doi: 10.1596/978-1-4648-0527-1_ch17

[13]. Lee DW, Lee J, Kim HR, Kang MY. Health-Related Productivity Loss According to Health Conditions among Workers in South Korea. Int J Environ Res Public Health. 2021 Jul 16;18(14):7589. doi: 10.3390/ijerph18147589. PMID: 34300042; PMCID: PMC8307799.

[14]. Barrot JS, Llenares II, Del Rosario LS. Students' online learning challenges during the pandemic and how they cope with them: The case of the Philippines. Educ Inf Technol (Dordr). 2021;26(6):7321-7338. doi: 10.1007/s10639-021-10589-x. Epub 2021 May 28. PMID: 34075300; PMCID: PMC8162157.

[15]. Grassly NC, Fraser C. Seasonal infectious disease epidemiology. Proc Biol Sci. 2006 Oct 7;273(1600):2541-50. doi: 10.1098/rspb.2006.3604. PMID: 16959647; PMCID: PMC1634916.

[16]. Agor JK, Özaltın OY. Models for predicting the evolution of influenza to inform vaccine strain selection. Hum Vaccin Immunother. 2018 Mar 4;14(3):678-683. doi: 10.1080/21645515.2017.1423152. Epub 2018 Feb 12. PMID: 29337643; PMCID: PMC5861780.
[17]. Kricorian K, Civen R, Equils O. COVID-19 vaccine hesitancy: misinformation and perceptions of vaccine safety. Hum Vaccin Immunother. 2022 Dec 31;18(1):1950504. doi: 10.1080/21645515.2021.1950504. Epub 2021 Jul 30. PMID: 34325612; PMCID: PMC8920251.
[18]. Anderson EL. Recommended solutions to the barriers to immunization in children and adults. Mo Med. 2014 Jul-Aug;111(4):344-8. PMID: 25211867; PMCID: PMC6179470.
[19]. Kruk ME, Gage AD, Arsenault C, Jordan K, Leslie HH, Roder-DeWan S, Adeyi O, Barker P, Daelmans B, Doubova SV, English M, García-Elorrio E, Guanais F, Gureje O, Hirschhorn LR, Jiang L, Kelley E, Lemango ET, Liljestrand J, Malata A, Marchant T, Matsoso MP, Meara JG, Mohanan M, Ndiaye Y, Norheim OF, Reddy KS, Rowe AK, Salomon JA, Thapa G, Twum-Danso NAY, Pate M. High-quality health systems in the Sustainable Development Goals era: time for a revolution. Lancet Glob Health. 2018 Nov;6(11):e1196-e1252. doi: 10.1016/S2214-109X(18)30386-3. Epub 2018 Sep 5. Erratum in: Lancet Glob Health. 2018 Sep 18;: Erratum in: Lancet Glob Health. 2018 Nov;6(11):e1162. Erratum in: Lancet Glob Health. 2021 Aug;9(8):e1067. PMID: 30196093; PMCID: PMC7734391.
[20]. Riedel S. Edward Jenner and the history of smallpox and vaccination. Proc (Bayl Univ Med Cent). 2005 Jan;18(1):21-5. doi: 10.1080/08998280.2005.11928028. PMID: 16200144; PMCID: PMC1200696.
[21]. National Immunization Program, CDC, Achievements in Public Health, 1900-1999 Impact of Vaccines Universally Recommended for Children -- United States, 1990-1998. April 02, 1999 / 48(12);243-248. https://www.cdc.gov/mmwr/preview/mmwrhtml/00056803.htm
[22]. Khan S, Ullah MW, Siddique R, Nabi G, Manan S, Yousaf M, Hou H. Role of Recombinant DNA Technology to Improve Life. Int J Genomics. 2016;2016:2405954. doi: 10.1155/2016/2405954. Epub 2016 Dec 8. PMID: 28053975; PMCID: PMC5178364.
[23]. Pichichero ME. Protein carriers of conjugate vaccines: characteristics, development, and clinical trials. Hum Vaccin Immunother. 2013 Dec;9(12):2505-23. doi: 10.4161/hv.26109. Epub 2013 Aug 16. PMID: 23955057; PMCID: PMC4162048.
[24]. Bilusic M, Madan RA. Therapeutic cancer vaccines: the latest advancement in targeted therapy. Am J Ther. 2012 Nov;19(6):e172-81. doi: 10.1097/MJT.0b013e3182068cdb. PMID: 21317622; PMCID: PMC3601372.
[25]. CDC, Seasonal Flu Vaccines. Centers for Disease Control and Prevention, National Center for Immunization and Respiratory Diseases (NCIRD), August 25, 2023. https://www.cdc.gov/flu/prevent/flushot.htm
[26]. APIC, Herd Immunity, June 2021. https://apic.org/monthly_alerts/herd-immunity/
[27]. Rodrigues CMC, Plotkin SA. Impact of Vaccines; Health, Economic and Social Perspectives. Front Microbiol. 2020 Jul 14;11:1526. doi: 10.3389/fmicb.2020.01526. PMID: 32760367; PMCID: PMC7371956.
[28]. Fang E, Liu X, Li M, Zhang Z, Song L, Zhu B, Wu X, Liu J, Zhao D, Li Y. Advances in COVID-19 mRNA vaccine development. Signal Transduct Target Ther. 2022 Mar 23;7(1):94. doi: 10.1038/s41392-022-00950-y. PMID: 35322018; PMCID: PMC8940982.
[29]. Lazarus, J.V., Wyka, K., White, T.M. et al. A survey of COVID-19 vaccine acceptance across 23 countries in 2022. Nat Med 29, 366–375 (2023). https://doi.org/10.1038/s41591-022-02185-4
[30]. Caminade C, McIntyre KM, Jones AE. Impact of recent and future climate change on vector-borne diseases. Ann N Y Acad Sci. 2019 Jan;1436(1):157-173. doi: 10.1111/nyas.13950. Epub 2018 Aug 18. PMID: 30120891; PMCID: PMC6378404.
[31]. Salm M, Ali M, Minihane M, Conrad P. Defining global health: findings from a systematic review and thematic analysis of the literature. BMJ Glob Health. 2021 Jun;6(6):e005292. doi: 10.1136/bmjgh-2021-005292. PMID: 34083243; PMCID: PMC8183196.
[32]. Commission on a Global Health Risk Framework for the Future; National Academy of Medicine, Secretariat. The Neglected Dimension of Global Security: A Framework to Counter Infectious Disease Crises. Washington (DC): National Academies Press (US); 2016 May 16. 5, Accelerating Research and Development to Counter the Threat of Infectious Diseases. Available from: https://www.ncbi.nlm.nih.gov/books/NBK368388/
[33]. Fajber K. Business as Usual? Centering Human Rights to Advance Global COVID-19 Vaccine Equity Through COVAX. Health Hum Rights. 2022 Dec;24(2):219-228. PMID: 36579321; PMCID: PMC9790946.