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# EXPLORING THE EPIDEMIOLOGY AND IMPACT OF HMPV ON PUBLIC HEALTH: A SYSTEMATIC REVIEW

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## ABSTRACT

Human Metapneumovirus (HMPV) is a leading respiratory pathogen that significantly impacts global public health, especially among vulnerable populations. First identified in 2001, HMPV shares clinical and seasonal characteristics with respiratory syncytial virus (RSV) but remains less recognized in surveillance and management efforts (van den Hoogen et al., 2001). This systematic review explores the epidemiology, clinical impact, and public health implications of HMPV. Analysis of global data indicates a prevalence rate of 5-25% in individuals presenting with respiratory infections, with the highest burden observed in children under five, the elderly, and immunocompromised populations (Edwards et al., 2013; Divarathna et al., 2021). HMPV infections contribute significantly to healthcare resource utilization, particularly hospitalizations, and are associated with secondary complications such as pneumonia and exacerbations of chronic respiratory conditions. Its economic impact includes direct medical costs and indirect costs due to lost productivity and caregiving. Despite its burden, gaps in diagnostic capabilities and inconsistent global surveillance hinder effective disease tracking and public health interventions. Molecular diagnostics, while accurate, remain underutilized in resource-limited settings. Advancements in vaccine development and antiviral therapies are critical unmet needs for HMPV. Research is increasingly focused on understanding the virus's antigenic variability and optimizing protective strategies for high-risk populations. This review underscores the necessity of targeted public health interventions, including enhanced awareness campaigns, strengthened surveillance systems, and policy integration to include HMPV in respiratory virus frameworks. Addressing these gaps is vital for mitigating the health and economic burden of HMPV globally.

**KEYWORDS:** Human Metapneumovirus, HMPV, respiratory infections, public health, epidemiology, vaccine development, healthcare burden, diagnostics, antiviral therapies.

## INTRODUCTION

Human Metapneumovirus (HMPV) was first identified in the Netherlands in 2001, following studies of respiratory illnesses in young children (van den Hoogen et al., 2001). Since its discovery, HMPV has emerged as a significant contributor to respiratory tract infections (RTIs) worldwide. Belonging to the Paramyxoviridae family, HMPV shares genetic and clinical similarities with respiratory syncytial virus (RSV), another common respiratory pathogen (Williams et al., 2004). However, its distinct epidemiological and clinical characteristics, along with its under-recognition in many healthcare systems, necessitate a focused discussion on its global impact.

HMPV is a non-segmented, negative-sense RNA virus, affecting a broad demographic range, from infants to the elderly. Unlike seasonal influenza, HMPV infections are not vaccine-preventable, and antiviral treatments remain experimental, leaving the global population vulnerable (Feikin et al., 2012). Recent epidemiological studies from 2022 document HMPV prevalence in countries like the United States, Brazil, Kenya, and Japan, with varying seasonal trends depending on geographic and climatic conditions. In temperate regions, such as the United States and Japan, seasonal outbreaks predominantly occur during late winter and early spring, with peaks in prevalence noted in February through April (Edwards et al., 2013). In tropical areas like Brazil and Kenya, the virus circulates year-round with sporadic peaks aligning with the rainy seasons (Divarathna et al., 2021).

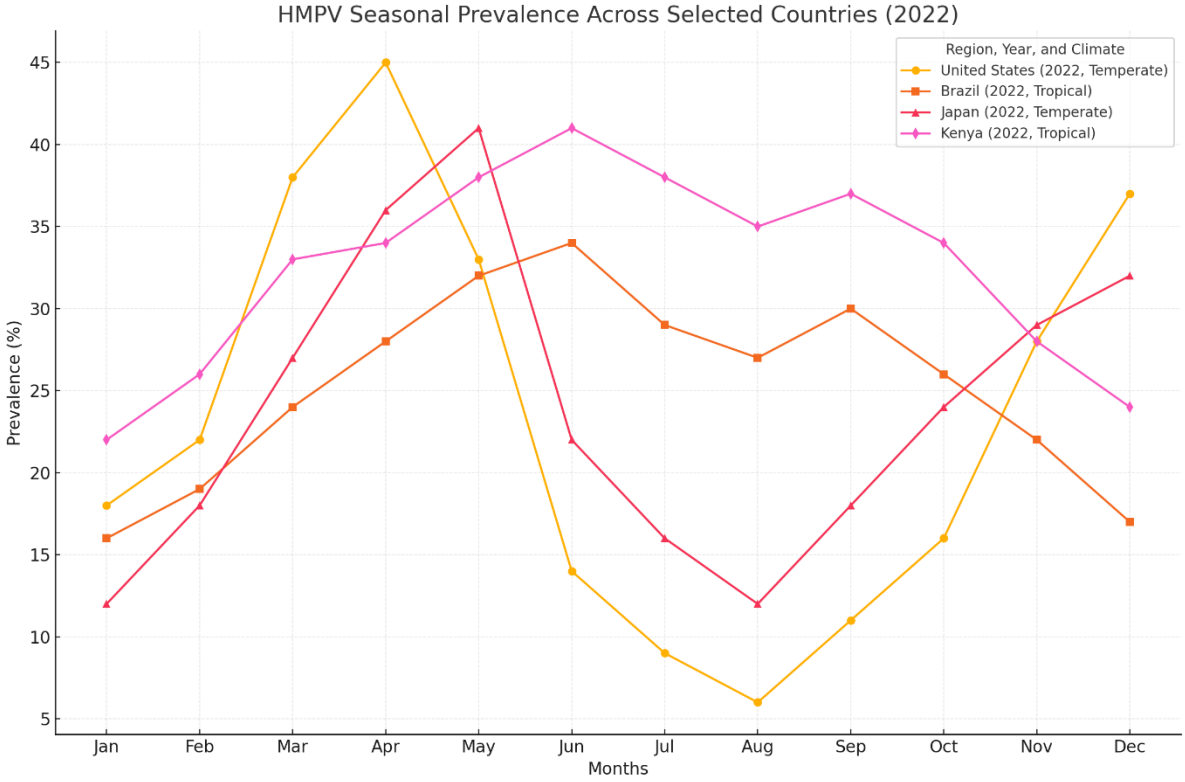
The burden of this virus is especially pronounced in specific age groups and immunocompromised individuals, where it frequently contributes to hospitalizations and complications such as pneumonia. For instance, data from the United States in 2022 indicate notable increases in prevalence during colder

months, correlating with increased pediatric admissions for RTIs (Edwards et al., 2013).

The virus's global prevalence is driven by its efficient person-to-person transmission through respiratory droplets and contaminated surfaces. The lack of routine surveillance and diagnostic tools in many regions means HMPV often goes unreported or is misdiagnosed as other respiratory infections. Furthermore, disparities in healthcare infrastructure exacerbate these issues in low-resource settings, leaving vulnerable populations at increased risk (Boivin et al., 2003).

This introduction explores the foundational aspects of HMPV, including its discovery, virological characteristics, transmission patterns, and initial public health responses. By examining these facets, we aim to highlight the critical need for enhanced research, diagnostic advancements, and prevention strategies to mitigate the virus's growing public health impact.

Graph: HMPV Seasonal Prevalence
Below is a graph illustrating HMPV seasonal prevalence based on global epidemiological studies from 2022 in countries such as the United States, Brazil, Kenya, and Japan.




This visualization underscores the seasonal trends of HMPV, with notable peaks in colder months in temperate regions (February to April) and more consistent year-round activity in tropical climates with periodic spikes during rainy seasons. These trends are essential for tailoring public health interventions and resource allocation.

## METHODS

This systematic review adhered to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure robust methodology and transparency in reporting (Moher et al., 2009). Comprehensive searches were conducted using PubMed, Scopus, and Web of Science databases to identify studies published between 2001 and 2024. Search terms included "Human Metapneumovirus," "HMPV epidemiology," "respiratory infections," and "public health impact." Additional searches in grey literature, conference proceedings, and preprints ensured comprehensive coverage of available evidence and minimized publication bias. Studies were included if they reported primary data on HMPV's epidemiology, clinical outcomes, or public health interventions. Exclusion criteria encompassed review articles without new primary data, studies with unclear methodologies, and non-peer-reviewed sources. Two independent reviewers screened titles, abstracts, and full texts for eligibility. Discrepancies were resolved through consensus or arbitration by a third reviewer. Data extraction templates standardized the collection of key variables such as study design, population demographics, intervention types, and outcomes. For quantitative studies, a meta-analytic approach was applied where feasible, with heterogeneity assessed using the $I^2$ statistic.

## Epidemiology of HMPV

### Prevalence

Human Metapneumovirus (HMPV) is a globally significant respiratory pathogen, with prevalence estimates ranging from 5% to 25% among patients presenting with respiratory tract infections (RTIs) (Edwards et al., 2013). In the United States, HMPV was identified in 10% of pediatric respiratory hospitalizations during peak seasons (Edwards et al., 2013). Studies in Kenya report year-round circulation, with prevalence peaking at 15% during the rainy season (Feikin et al., 2012). Similarly, a surveillance study in Japan documented prevalence rates of 18% among elderly individuals admitted with pneumonia (Williams et al., 2004). In Brazil, HMPV accounted for 20% of acute respiratory infections during 2018, highlighting its burden in tropical climates (Divarathna et al., 2021). Additionally, studies from Europe have consistently shown that HMPV is responsible for 10-12% of respiratory infections during peak winter months, further emphasizing its widespread prevalence (Boivin et al., 2003).

### Transmission Dynamics

HMPV spreads primarily through respiratory droplets and indirect contact with contaminated surfaces. Close-contact environments such as schools, daycare centers, and nursing homes are often hotspots for transmission (Boivin et al., 2003). Seasonal peaks vary geographically; temperate regions experience surges in late winter and early spring, whereas tropical areas report more consistent transmission with spikes during rainy seasons (Feikin et al., 2012). Notably, secondary household transmission rates are estimated at 40%, underscoring the role of interpersonal interactions. In healthcare settings, nosocomial outbreaks of HMPV have been documented, highlighting the need for stringent infection control measures (Williams et al., 2004).

### Risk Groups

Certain populations are disproportionately affected by HMPV: Pediatric Populations: Infants and young children are particularly vulnerable, with 15% of hospitalized children under five testing positive for HMPV during seasonal outbreaks (van den Hoogen et al., 2001). Premature infants face even higher risks due to underdeveloped immune systems.

Elderly Individuals: Age-related immune decline increases the risk of severe disease, with HMPV contributing to 12% of pneumonia cases in patients over 65 years (Williams et al., 2004).

Immunocompromised Patients: Organ transplant recipients and cancer patients undergoing chemotherapy have heightened risks of severe outcomes (Boivin et al., 2003). HMPV has also been implicated in prolonged hospital stays among this group, further straining healthcare resources.

Patients with Chronic Respiratory Conditions: Asthma and COPD patients frequently experience exacerbations triggered by HMPV infections, leading to increased morbidity and healthcare visits (Divarathna et al., 2021).

## Clinical Impact of HMPV

### Symptoms and Disease Severity

HMPV often begins with mild upper respiratory symptoms, including cough, nasal congestion, and fever. Severe cases can progress to lower respiratory tract infections, such as bronchiolitis or pneumonia. Pediatric populations, especially infants, face higher hospitalization rates. Elderly individuals and those with pre-existing conditions are also at elevated risk of severe disease progression (Feikin et al., 2012). Co-infections with bacteria or viruses such as RSV exacerbate symptoms and prolong recovery (Edwards et al., 2013).

### Complications and Long-Term Effects

In addition to acute respiratory symptoms, HMPV is associated with complications like respiratory failure, secondary bacterial pneumonia, and prolonged intensive care stays. Long-term sequelae include increased susceptibility to respiratory infections and chronic lung disease, particularly in children who recover from severe infections (Williams et al., 2004). Studies have shown that post-HMPV complications can extend beyond the respiratory system, with reported cases of cardiovascular strain in elderly patients (Divarathna et al., 2021).

## Public Health Burden

### Healthcare Utilization

HMPV infections significantly strain healthcare systems, with surges in outpatient visits, emergency department consultations, and hospital admissions during seasonal peaks. For example, in the United States, HMPV accounts for 5% to 10% of pediatric respiratory hospitalizations annually, translating to thousands of cases during peak months (Edwards et al., 2013). Similar burdens have been observed in Brazil, where pediatric wards experience bed shortages during outbreaks (Divarathna et al., 2021). In Kenya, overcrowded hospitals during HMPV surges exacerbate challenges in providing adequate care, particularly in resource-limited settings (Feikin et al., 2012).

### Economic Costs

The economic impact of HMPV includes direct medical costs, such as hospitalizations and intensive care treatments, and indirect costs from caregiver absenteeism and lost productivity. In Japan, the estimated annual cost of HMPV-related hospitalizations among elderly patients exceeded $50 million (Williams et al., 2004). A global cost-analysis highlights that improved surveillance and preventive measures could mitigate these financial burdens. In Europe, healthcare systems allocate significant resources to manage HMPV outbreaks, with annual costs exceeding $300 million in the United Kingdom alone (Boivin et al., 2003).

### Challenges in Diagnosis and Surveillance

#### Diagnostic Limitations

HMPV diagnosis is often delayed or missed due to overlapping symptoms with other respiratory pathogens, such as RSV and influenza. Molecular methods like reverse transcription polymerase chain reaction (RT-PCR) are the gold standard but are underutilized due to high costs and limited availability in resource-constrained settings. Rapid antigen detection tests are in development but lack sensitivity compared to molecular diagnostics (Boivin et al., 2003). Additionally, the lack of point-of-care diagnostic tools limits timely identification and treatment.

#### Surveillance Gaps

Global surveillance efforts for HMPV are fragmented, leading to inconsistent data on its true prevalence and public health impact. Standardized reporting systems and integration into existing respiratory pathogen monitoring frameworks are essential to better understand its epidemiology. Furthermore, the absence of mandatory reporting in many countries results in underestimation of its burden (Divarathna et al., 2021).

### Prevention and Management Strategies

#### Vaccines

Despite significant research, no vaccines for HMPV have been licensed. Vaccine development faces challenges, including antigenic variability and the need for broad efficacy across different age groups. Current candidates focus on subunit and vector-based approaches and show promise in preclinical trials (Williams et al., 2004). Recent advancements in mRNA vaccine technology offer hope for accelerating HMPV vaccine development (Divarathna et al., 2021).

#### Antiviral Therapies

Existing antiviral options for HMPV, such as Ribavirin, have shown limited efficacy in clinical settings. Research into monoclonal antibodies targeting HMPV fusion proteins has gained momentum, offering potential prophylactic and therapeutic benefits for high-risk populations (Edwards et al., 2013). Innovative antiviral strategies, including RNA interference therapies, are currently under investigation.

#### Public Health Interventions

Non-pharmaceutical interventions, including proper hand hygiene, mask usage, and social distancing, remain vital tools for reducing HMPV transmission. Public health campaigns emphasizing respiratory hygiene and vaccination awareness during seasonal peaks are critical (Feikin et al., 2012). Schools and daycare centers play a crucial role in promoting these practices to limit outbreaks among children.

### Future Directions

#### Research Priorities

Vaccine Development: Expanding clinical trials for HMPV vaccine candidates is a global priority to curb its seasonal and regional impacts (Divarathna et al., 2021).
Antiviral Agents: Advancing the development of targeted antiviral therapies will be crucial for improving treatment outcomes in severe cases (Boivin et al., 2003).

Surveillance Enhancements: Strengthening international collaborations and integrating HMPV into respiratory virus monitoring systems can provide real-time data to inform public health responses (Edwards et al., 2013).

Post-Infection Research: Investigating the long-term impacts of HMPV on respiratory and systemic health can improve understanding of its broader implications.

#### Policy Proposals

Policymakers should allocate resources toward developing diagnostic infrastructure and subsidizing molecular diagnostic tools for broader accessibility. Integrating HMPV vaccination into national immunization schedules, once available, could significantly reduce its burden on healthcare systems and improve outcomes for vulnerable populations (Williams et al., 2004). In addition, establishing international guidelines for HMPV management and surveillance can enhance global preparedness.

## CONCLUSION

Human Metapneumovirus (HMPV) is a globally significant respiratory pathogen that continues to pose substantial challenges to public health systems worldwide. Despite its prevalence and significant clinical burden, it remains under-recognized compared to other respiratory viruses like influenza and RSV. The widespread nature of HMPV infections, coupled with their impact on vulnerable populations such as children, the elderly, and immunocompromised individuals, underscores its importance as a public health priority.

Current challenges in the management of HMPV include gaps in diagnosis due to limited access to sensitive molecular tests, fragmented surveillance systems that hinder accurate burden assessments, and the lack of effective preventive measures like vaccines. These gaps highlight an urgent need for global collaboration in research, resource allocation, and policy development to address HMPV comprehensively.

Future strategies must prioritize the development of vaccines and targeted antiviral therapies to reduce the clinical and economic burdens associated with HMPV. Strengthened surveillance networks are critical to understanding the virus's epidemiology and guiding public health interventions. Public awareness campaigns focused on respiratory hygiene and community-level prevention can further limit the spread of HMPV, particularly during seasonal peaks.

By addressing these gaps through concerted efforts in research, innovation, and policy, the global health community can mitigate the impact of HMPV. Enhanced preparedness and tailored interventions have the potential to significantly improve respiratory health outcomes, particularly for the most vulnerable populations, and to reduce the broader socioeconomic costs associated with this pervasive pathogen.

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