Let’s Control Flu: a digital gamification tool to increase vaccination coverage rates

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Abstract

Background: Influenza is a seasonal threat with pandemic potential. Influenza infection is particularly dangerous for vulnerable individuals, such as children, older individuals, and those with multiple illnesses, especially those with lower socio-economic status. Hence, it is necessary to have appropriate tools to mitigate these risks. Gamification presents an opportunity with immense potential for risk communication and community engagement (RCCE) for influenza for health decision-makers and patient advocacy groups to help inform policy decisions and behaviours.

Objective: A digital and interactive tool was designed using gamification to inform and facilitate Public Health Policy (PHP) decision-making on influenza to increase vaccination coverage rates. Increased coverage rates could help the achievement of the World Health Organization’s (WHO) goal of having 75% of target populations vaccinated against the virus by 2030.

Methods: The tool, called “Let’s Control Flu” (LCF), utilises a quantitative approach developed by Kassianos et al, which uses 42 PHP. The LCF tool models the impact of 13 Public Health Policies (PHPs) in pre-determined four target populations and seven health-related outcomes.

Results: This gamified process helps flu vaccination-related stakeholders understand the impact of any set of PHPs included in the LCF tool in influenza epidemiology until 2031, in different vulnerable population groups for a given country. It was first applied to model the potential impact on the population of Sweden.

Conclusions: Gamification in the context of PHPs helps scientifically evidence-based decision-making concerning influenza vaccination coverage for health decision-makers, those interested in patient advocacy, and the societal impact of influenza in general, helping to motivate and clarify both stakeholders and the population as a whole, resulting in increased vaccination coverage for influenza.

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Keywords: Influenza; Gamification; Public Health Policies; Vaccination Coverage Rates

Introduction

Influenza is an infectious respiratory disease caused by an airborne virus. There are four identified types of influenza viruses, with types A and B being responsible for most of the seasonal influenza epidemics that occur annually[1,2]. The influenza virus can cause mild to severe disease, with risk groups (elderly people, pregnant women, young children, and individuals with chronic health conditions and autoimmune diseases) being more vulnerable to severe forms of the disease[1].

The World Health Organization (WHO) estimates that annual influenza epidemics result in approximately 1 billion infections, 3 to 5 million cases of severe illness, and between 290 and 650,000 deaths[3]. The severity of influenza depends on multiple factors, including the virulence of the virus strain and the level of pre-existing immunity in the population[1]. Influenza is also responsible for the worsening of previous health conditions in the individual and has consequences on different domains of individual health[4], such as cardiovascular[5], neurological, renal, respiratory, and diabetic complications.

However, despite the large number of respiratory infections worldwide, it is difficult to estimate the proportion of hospitalizations attributable to influenza across countries or over time[6]. During influenza outbreaks, health systems experience increased demand for services due to an influx of patients seeking medical care. This surge in patient demand can strain healthcare resources, including hospital beds, medical staff, and supplies[7]. As a result, the pressure on health systems during flu outbreaks has an impact on access to care for other patients who require medical attention for non-influenza-related conditions, especially those at risk for complications[8].

Another study, published in 2023, which carried out a meta-analysis to improve understanding of the estimates of hospitalizations associated with influenza, concluded that seasonal influenza epidemics result in 3.2 million hospitalizations per year globally[9]. A study that evaluated ten flu seasons (between 2008 and 2018) in Portugal to estimate the clinical and economic costs of the flu reported that, on average, hospitalizations due to the flu were 11.6 cases per 100,000 inhabitants[10].

Vaccination against influenza began in the early 1940s and became more widely used with trivalent vaccines[11]. These were later followed by the introduction of quadrivalent vaccines in 2012[11]. Currently, the WHO is discussing the return to trivalent vaccines[12], indicating a continuous evolution

and reassessment of influenza vaccination strategies over the years. The effectiveness of influenza vaccination is estimated to be between 40-60%[13] in the general population, with these values being influenced by patient characteristics (age, underlying health conditions, etc.), correspondence between circulating influenza viruses and the administered seasonal influenza vaccination, among others[13]. Older population groups are given priority for flu vaccination, as they have a higher risk of severe influenza disease. However, this group has reduced antibody responses to the flu vaccine due to immune senescence. Higher-dose influenza antigen vaccines that enhance the immune response are more effective in preventing influenza infections than standard-dose vaccines[14], help increase the level of protection, and are more effective in preventing hospitalizations, and reducing mortality caused by the influenza virus[15].

The WHO has defined influenza as one of the greatest public health challenges in the world[16]. It recommends annual flu vaccination as the most effective way to prevent flu, being especially important for people who are most at risk of serious complications and for healthcare workers (WHO). The WHO has developed the Global Influenza Strategy 2019–2030 (GIS)[16], which aims to improve preparedness and response to influenza outbreaks, improve the development of and access to influenza vaccines and antivirals, and increase the capacity of health systems to prevent, detect and respond to outbreaks of the virus. This program represents a commitment by the WHO and its partners to improve public health outcomes and reduce the burden of disease caused by influenza. For this, it is critical to improve Vaccination Coverage Rates (VCR) worldwide.

The WHO and the Council of Europe recommend a vaccination coverage rate (VCR of 75% for populations at risk of complications following influenza virus infection (population 65 years of age and older, anyone aged 6 months or older suffering from a chronic medical condition, and pregnant women) and those likely to transmit the virus professionally to these same populations (health professionals and social workers)[17,18].

Health management by health and governance authorities and by other health decision-makers is carried out through public health policies (PHPs), which can manage potential risks, namely by anticipating them and mitigating their impacts. PHPs linked to vaccination are a good example of this, where creating immunity against the infection helps reduce the risk of contracting the disease, and if this still occurs, the disease is likely to be less severe, reducing the need for hospitalization and risk of death.

The "Let's Control Flu" (LCF) tool is a digital, interactive tool designed to support PHP decision-making focused on influenza, help improve flu vaccination coverage rates, and, ultimately, help achieve the aims of the GIS. The project was developed based on the qualitative model proposed by Kassianos et al.[17] to achieve a VCR in line with the targets set by the WHO and the Council of Europe. The tool allows the creation of epidemiological scenarios without the user having to master epidemiological modeling techniques or having to look for and learn about complex data, such as statistical series.

The LCF tool uses gamification to help flu-related stakeholders better understand the effect of different PHPs, by allowing them to try out different policy scenarios in a simulated environment and verify the impact on vaccine coverage rates before practical application. It is thus possible to better understand the trade-offs and consequences of policy choices and make more informed decisions about PHPs to be chosen and applied. By presenting information in an interactive and appealing format, the tool makes it easier to understand the impact of different policies and make decisions based on insights driven by concrete data. In the Limitations section, the limitations inherent to the tool are presented. At the current phase of the research, the “Let’s Control Flu” tool has been successfully implemented in Sweden, serving as the initial pilot country for this project. Presently, the scope of the application is being expanded to include three additional European nations, aiming to enhance the robustness and geographical relevance of the findings.

Methods

The creation of the tool combined an epidemiological model of the flu burden of disease with the impact that the selected PHP will predictably have on the chosen population. In the first stage of the tool creation, the number of policies originally proposed by Kassianos et al. was reduced from 42 to 13, coming from each of the 5 proposed pillars of the Kassianos study, since it is not possible in this state of knowledge to create a model that isolates all the effects produced by all 42 PHPs. It was therefore decided to create bundles of strongly related PHPs in a search for orthogonality between them, keeping the grouping by the respective pillars unchanged (Annex 1).

To ensure the robustness and reliability of our model, a meticulous selection process was employed to identify the scientific works included in our analysis. The table presented below (Table 1) outlines the rigorous inclusion and exclusion criteria applied to each work, ensuring that only the most

relevant and high-quality studies were considered. To conduct a comprehensive and systematic literature review, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The PRISMA flowchart presented below illustrates the step-by-step process we employed to select the publications that informed the creation of our model. The PRISMA flowchart below (Figure 1) provides a visual representation of this systematic literature review process, highlighting the number of articles identified, screened, and included at each stage. By adhering to these rigorous methods, we aimed to generate a comprehensive and reliable model based on the most relevant and high-quality scientific literature available. It should be noted that during this process, deliberate avoidance of substantiation data from the years 2021/2022 was observed, given their atypical nature attributable to the COVID-19 pandemic that renders the available data intertwined with pandemic-related elements[19].

The interventions used in the studies were mapped to be as close as possible to the PHP categories identified by Kassianos et al. To monitor and validate the construction of the model, a National Advisory Board (NAB) was created, made up of four distinguished epidemiologists and public health specialists in Swedish health systems who could verify the values generated by the model and validate each of its results. The choice was made based on previous scientific articles published in journals with an impact factor (IF) and reports for health authorities in the previous 10 years. The NAB played a critical role in validating each proxy in situations where ecologically valid scientific literature was lacking to support the choice of relevant data for the development of the tool.

Table 1. Inclusion and exclusion criteria for scientific works included in the model.

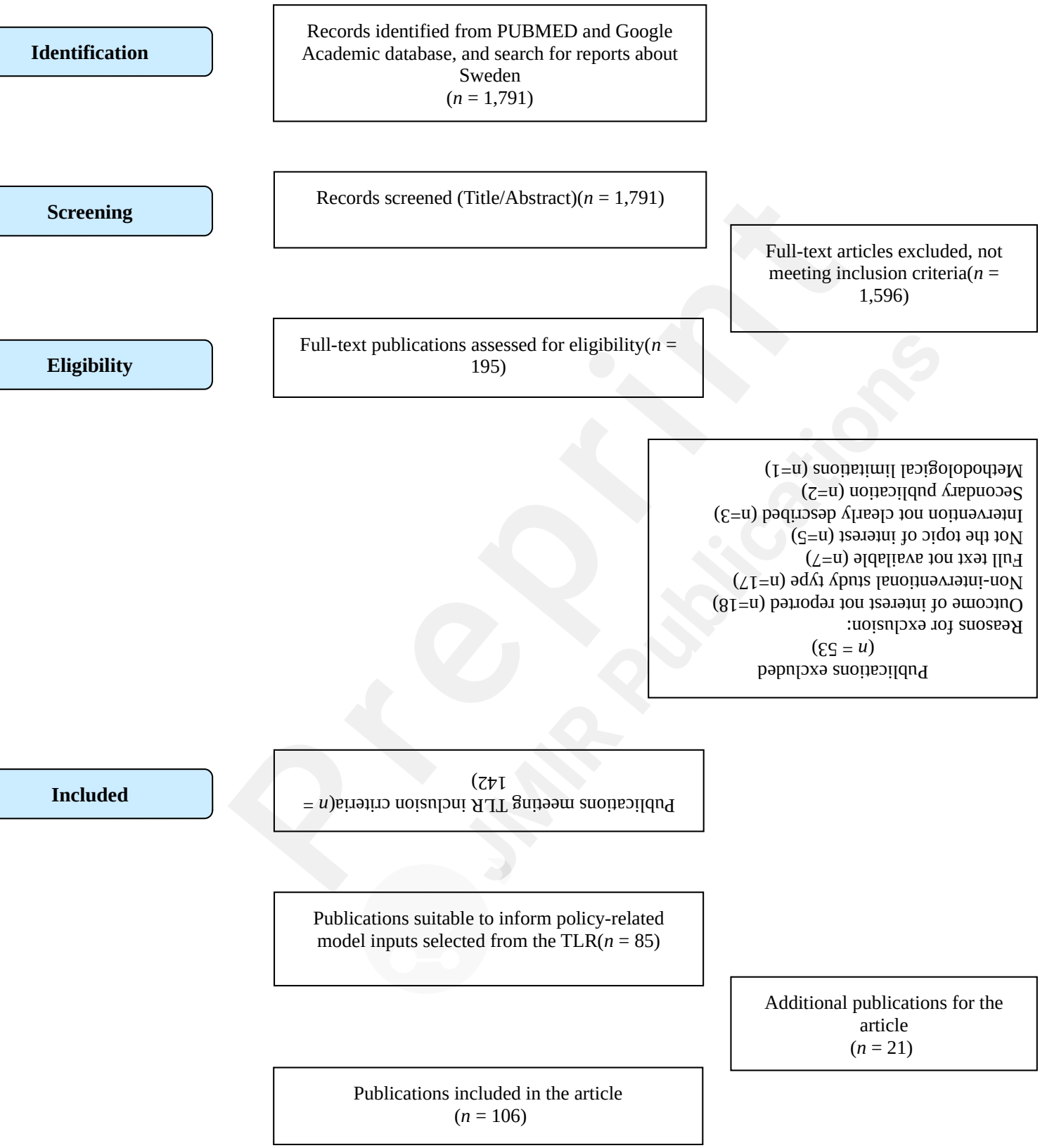
Inclusion criteria:

- Only pre-post intervention or controlled studies were included, enabling the effects of the policy to be effectively assessed independently of any background (and potentially not described) policies already in place.
- Studies were included whenever they contained data on one or more of the populations of interest for the model (children, health professionals, pregnant women, the elderly, including adults aged 65 years and over and adults between 50 and 64 years, and high-risk patients).
- Studies reporting seasonal vaccination uptake were included, as opposed to pandemic flu vaccination. This restriction was placed to ensure comparability of studies used to inform the model (i.e., avoid pooling data for seasonal and pandemic influenza, as the coverage may not be comparable).

Exclusion criteria:

- Reviews were not included.
- Articles in any other language than English.

Figure 1. Systematic literature review PRISMA flowchart.



Public Health Policies

Figure 2. The 13 PHPs chosen for the construction of the LCF model, categorized according to their respective pillars.

Pillar 1: Health authority accountability and strengths of the influenza program				
Vaccination Coverage Rates targets set at national and regional levels for recommended population	**Funding of flu vaccinations for all recommended groups**	**Nationwide regular monitoring of patient VCR at vaccination site/Healthcare Professional level by Health Authorities**	**HCP VCR as part of performance criteria in hospitals**	**Sustainable procurement system to ensure appropriate vaccine supply**
To boost influenza vaccination rates (20), policies set targets at national and regional levels for specific population groups (21). In Sweden, for example, this policy was implemented nationwide. Strategies programs (22-24) include educating individuals about vaccine benefits, improving vaccine accessibility, and offering incentives for vaccination, all aimed at increasing vaccine uptake.	To enhance influenza vaccine access, reduce the burden of disease, and prevent influenza-related deaths, immunization programs (25-29), intervention campaigns, and strategies (20, 30-38) can be created. Additionally, funds may be allocated to cover the cost of flu shots for vulnerable groups, such as the elderly, children, healthcare workers, and individuals with underlying health conditions. By doing so, public health officials improve vaccine accessibility and safeguard those with a higher risk of flu complications.	Regular tracking of vaccine uptake in designated health facilities like clinics, hospitals, and pharmacies (39, 40) allows for monitoring immunization program effectiveness and identifying areas of improvement. By monitoring immunization coverage rates, public health authorities can use data to enhance programs and achieve desired health outcomes for the population.	Boosting vaccine uptake among healthcare workers and minimizing disease transmission through vaccination. This policy mandates that health worker immunization coverage rates be used as a performance criterion in healthcare facilities, including hospitals and primary care settings (41). It encourages healthcare workers to get vaccinated, prioritizing their well-being and minimizing disease spread among patients, thereby fostering a safer and healthier environment for all.	Ensuring consistent and reliable availability of necessary vaccines for all individuals in need (42), irrespective of their location or financial circumstances. This policy aims to establish a procurement system that effectively manages vaccine acquisition, storage, and distribution to health units, considering cost, quality, and sustainability factors.

Pillar 2: Facilitated access to vaccination		
Access to multiple vaccination settings	**Call-to-action communications to target groups by multiple stakeholders**	**HCP pop-up notification/SMS to population to vaccinate eligible patients**
Enhancing vaccine access and reducing barriers to vaccination ensures that individuals can receive vaccines in various locations, including hospitals (37, 41, 43-45), clinics (24, 46), pharmacies (27, 47-50), schools (31, 40, 51-58), and other settings (34, 59). By doing this, public health authorities increase convenience and improve the chances of individuals getting vaccinated.	This policy targets flu-related stakeholders including public health agencies, health professionals, schools, and community organizations. Various methods like email (57, 58, 60-62), text messages (63-69), phone calls, health apps, and others (38, 70) are utilized to remind target groups about the importance of vaccination. The objective is to boost vaccine uptake by reminding individuals in target groups of vaccination's significance and encouraging them to get vaccinated (71-74).	Healthcare providers use pop-up notifications or text messages to remind eligible patients of the importance of vaccination and encourage them to get vaccinated (72, 73, 75-77), thus increasing vaccine uptake.

Pillar 3: Healthcare professional accountability and engagement		
Regular HCP education and training	**Fair and specific HCP compensation per vaccination**	**Mandatory HCP vaccination**
This policy ensures healthcare professionals, including doctors, nurses, and other professionals, receive ongoing education and updates on new technologies, medical advancements, and changes in vaccination practices (21, 22, 37, 53, 65, 75-82). Its objective is to equip healthcare professionals with the necessary knowledge and skills to deliver safe, effective, and high-quality care to patients.	Establishing a system where health professionals receive fair compensation for administering vaccines (83). This aims to incentivize healthcare professionals to administer vaccines and ensure they are adequately rewarded for their time and efforts. Fair compensation not only supports healthcare professionals but also encourages their dedication to protecting public health.	Mandating or strongly recommending that healthcare workers receive specific vaccines as part of their job (23, 24, 41, 84-94). This policy aims to safeguard public health by minimizing the transmission of communicable diseases in healthcare settings like clinics or hospitals, particularly to patients with weakened immune systems. By requiring or strongly recommending vaccination for healthcare professionals, the policy aims to prevent them from being carriers of diseases that could be transmitted to their patients.

Pilar 4: Awareness of the burden and severity of the
Coordinated multi-stakeholder awareness/communication ca
This policy promotes immunization through collaboration and coordination among various stakeholders, includ organizations (21, 22, 34, 36, 40, 45, 56-59, 65, 71, 74-77, 79, 85, 93, 99-102), health professionals (20, 29, 30, 46, universities (31, 103), as well as the media (93, 104). Its goal is to deliver a cohesive message about the import information on the benefits of immunization and how to access it. By addressing concerns, dispelling misinformati policy aims to enhance vaccine uptake.

Pilar 5: Belief in influenza vaccination benefit
Positive media coverage of vaccines
The policy promotes a positive approach to vaccine promotion, highlighting the benefits of vaccination and counteri a vaccine-friendly environment by showcasing the safety, efficacy, and importance of vaccines through various announcements, and other media content (29). The policy's purpose is to boost vaccine uptake by offering accurate inf to make informed decisions about vaccination.

Model design

The model was developed as a way of assessing the impact of PHPs that impact the VCR over a 10-year time horizon, in annual cycles. The chosen target groups cover age groups and flu risk groups in the country's population. In the development of the model, six age groups were considered: 12-14 years old; 15-34 years old; 35-49 years old; 50-64 years old; and 65+ years old. This encompassed five target groups: children (from 0 to 14 years old), elderly people (adults over 65 years old), health professionals, pregnant women, and high-risk patients (individuals aged <65 years old with at least a chronic condition). Seven predetermined health outcomes were modelled (flu infections averted, hospitalizations averted, flu-related doctor visits averted, workdays averted/loss of productivity, flu-related deaths averted, hospitalizations averted due to cardiovascular disease, and averted deaths due to cardiovascular disease). The LCF tool allows an assessment of outcomes over a period of 10 years, from 2022 to 2031, both in the total population of the country and in each of the target population segments of the study.

The weights given to each policy, in each target group and in a determined timeframe, come from one of five possible sources: 1. Policy effects based on literature (weighted averages per policy and target group); 2. Since the intervention in the study[42] refers to a

"failed procurement system" and reports a negative effect on VCR, it is assumed that a sustainable procurement system would result in positive effects of the same scale; 3. Imputed from the relative effect of other (most similar) policies on the target group or from the effect on other target groups; 4. In case of missing data on policy effects after year 1, an increase of 10% in year 2 and 20% in year 3+ (based on the effect in year 1) is assumed; and 5. Expert opinions and inputs.

The values and weights assigned to the selected policies are derived from a literature search. It should be noted that some of the identified literature is qualitative in nature and cannot be directly applied. In cases where qualitative information was unavailable from articles or the NAB's experience, temporary proxies were created to feed the model. The construction of these proxies involved discussion among the project's scientific coordination, followed by deliberation and validation with the NAB, and ultimately subjected to validation by the project's external scientific advisor.

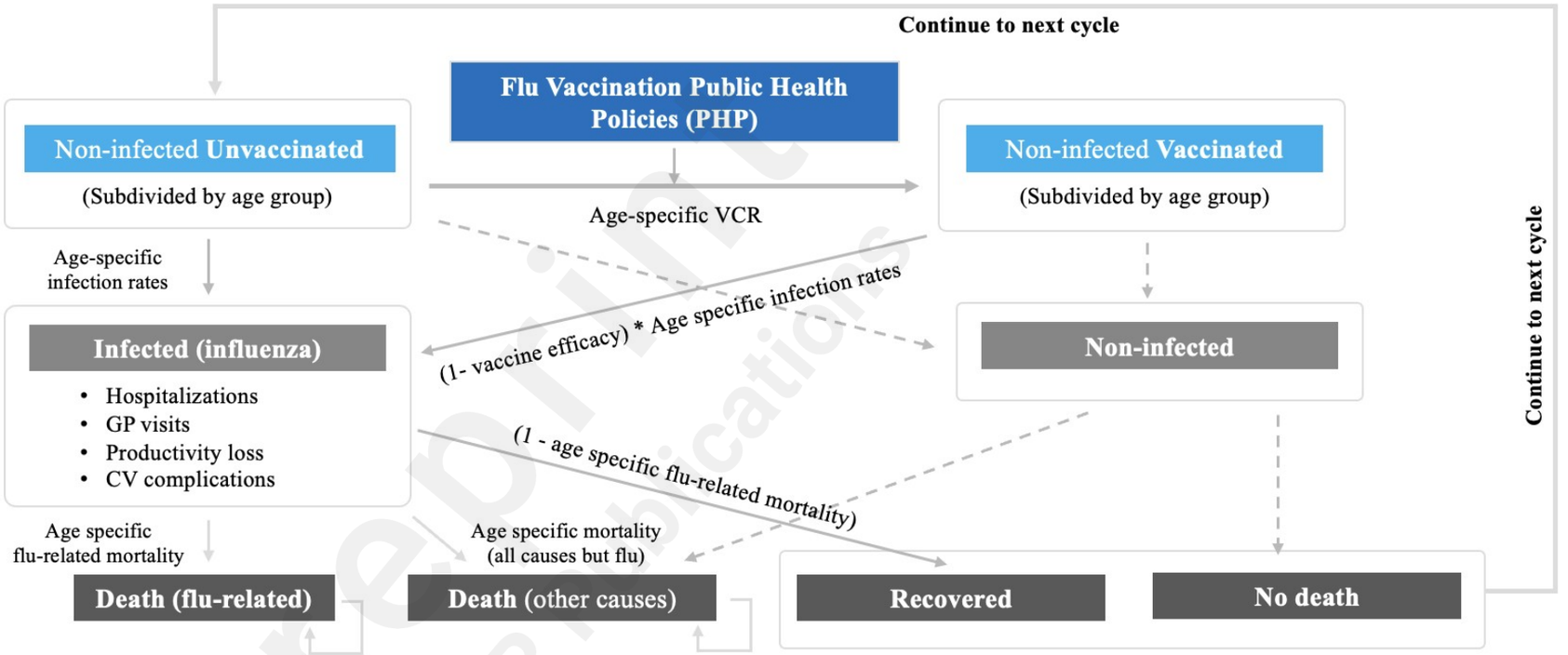
The proxy construction process followed the following model:

1. When the bibliography presented divergent values for weights, ratios, or other factors, the average of the identified values was used.
2. In the absence of quantitative bibliography, values were constructed in alignment with the qualitative literature. These values were discussed between the model-building team and the programming company, and agreement was reached. Individual written inquiries were then submitted to each NAB member, followed by a meeting with the scientific coordination for further discussion. A joint meeting involving the scientific coordination, modeling teams, and NAB members was held to finalize and validate the proxy list.
3. Proxies used in the model were subject to rules agreed upon. With each new model version, the scientific literature published during that time would be revisited. Ideally, weights, ratios, and other elements relying on proxies would be replaced with appropriate bibliography or research findings in the field.
4. The LCF Project aims to utilize epidemiological studies, proxies, and bibliography specific to each country or region when applying the model to new

locations. These decisions would be made on a case-by-case basis in consultation with the respective NAB. Additionally, whenever possible, more recent and region-specific statistical series would be considered. The construction of each proxy would be reconsidered based on local legislation, cultural practices, medical tradition, and other factors critical to the accurate application of the LCF model, as identified by the NAB.

Figure 2 provides a graphic representation of the model adopted in this study to estimate the effect of the 13 selected Public Health Policies on influenza prevention. The figure illustrates a compartmental-style model that captures the dynamic interplay between vaccination policies, influenza infection, and various health outcomes. Within a population, there is a group of non-infected individuals (divided by age group) who are initially unvaccinated against the flu virus. As the vaccination policies are implemented, these individuals are expected to be vaccinated. If they remain non-infected, there are no health issues or flu-related deaths, and the cycle repeats annually. However, if they become infected, the model considers consequences such as hospitalizations, GP visits, work productivity loss, and cardiovascular complications. These outcomes are calculated using a formula that incorporates vaccine efficacy and age-specific infection rates. The same dynamics apply to unvaccinated individuals who contract the virus. Those who experience complications from the infection can follow one of three scenarios: flu-related death, death from other causes, or recovery. The recovery rate is calculated using a formula that accounts for influenza-related mortality by age group. This comprehensive model, represented in Figure 2, enables a deeper understanding of the impact of vaccination policies and the potential health outcomes associated with influenza infection.

Figure 3. Graphic representation of the model adopted to estimate the effect of the 13 chosen Public Health Policies.



The operational functionality of the tool

The tool has been designed to be accessible to a broad user base, promoting inclusivity and ease of use. Its interactive nature ensures that individuals from various backgrounds, including healthcare professionals, the general public, and those involved in patient advocacy, can utilize it effectively. The choice of one or more of the 13 PHPs automatically generates an epidemiological scenario that shows the consequences of political decision-making through health output indicators in the desired target group(s) in a given year between 2022 and 2031.

Upon selection, the policies undergo a process of prioritization based on individual preferences, leading to the assignment of corresponding weights. The first policy chosen carries its full weight, while the second policy holds half of the weight, the third policy one-third of the weight, and so forth. This approach is adopted due to the unique impact that each policy, such as PHP x or PHP y, has on the overall outcome. However, when PHP x and PHP y are combined, their effects become cumulative. This serves to highlight the presence of individuals resistant to change despite efforts made. Consequently, to account for this resistance, the sum of PHP weights is reduced as a means of calculation.

The model uses as a baseline the PHPs that are already being applied in the country, which means that there have already been efforts, eventually even quite meritorious and possibly across all PHP, even if more so in some than in others. The results presented in the LCF tool correspond to what would be the full implementation of each PHP, that is, if applied in its entirety and with great efficiency. The concept of full implementation does not mean that 100% of the population can be persuaded, something that has never been possible to do, except by legal mandate, and, even then, sometimes resistance is encountered. There is, therefore, room for growth in all PHPs, as even in those that may be simpler to implement, there are efficiency losses throughout the implementation process. In other cases, when it depends directly on the choices of the population or the individual decision of the health professional, the inertia of change is even greater, and, therefore, this corresponds to a potential for implementation that is also greater.

In the future, we may even admit that there is a country or region where all PHPs are perfectly implemented. Even in this situation, there will be room for potential improvement as countries may come to develop tools for communication and education of populations with new technologies, new channels, changes in context, etc., which may improve (or worsen) the results of the PHPs.

Results

The creation of different epidemiological scenarios without the prior need for technical knowledge in terms of PHPs and modeling of the potential health impact of different scenarios allows not only the facilitation of political decision-making on health policies, but also the guarantee of the principle of technological opacity.

The website created to host the LCF tool (https://letscontrolflu.com) provides scientific information about the flu and flu vaccination in a language accessible to any individual, thus contributing to the fight against fake news and the attempt to decrease vaccine hesitancy, which remains a significant threat to global efforts to reduce the seasonal and pandemic influenza burden[105]. Thus, it also emerges as an empowering tool for education, literacy, and democracy in health.

The model was successfully applied to Sweden, where the LCF tool was used as a pilot country. In a practical example of using the tool, selecting all 13 policies and all target populations to observe the potential gains in terms of flu VCR in Sweden in the year 2025, the results obtained, which were validated by the NAB, show that the national vaccination rate would increase from 19.1% to 31.6%. Looking at the specific cases of the various target populations, it appears that the VCR would increase in all of them: 2.7% more in the case of children; 75.1% in the elderly; 27.1% in pregnant women; 75% in health workers; and also 75% in high-risk patients. In terms of gains in terms of health-related outcomes, the results show a total of 47,924 cases of flu infection avoided; 518 hospitalizations and 14,031 doctor visits avoided; 44,835 fewer workdays lost due to flu infection; minus 1,407 deaths; 151 fewer hospitalizations due to cardiovascular

complications and, finally, 586 fewer deaths due to cardiovascular complications.

Discussion

Gamification is an innovative approach that can play a significant role in improving public health policy decision-making. By using gaming mechanics and design, gamification can make complex information and issues more accessible and engaging, leading to a greater understanding of public health challenges, namely for health policymakers who come from outside the professional health sphere and need support tools for their decision-making that provide them with a decision that is best supported by science.

Gamification can also create opportunities for active participation and collaboration, allowing individuals to actively shape public health policies and decisions. Additionally, gamification can facilitate the collection of real-time data and feedback, providing valuable insights into the impact of public health policies and informing decision-making processes.

By combining play with the need for informed policy decisions, gamification has the potential to positively impact public health and help ensure that policies are both effective and evidence-based, and also helps to address social determinants of health by engaging disadvantaged communities and increasing their access to health information and resources. Through interactive experiences, gamification can help to break down barriers and increase health literacy, which can lead to better health outcomes.

Furthermore, gamification can foster a sense of community and collaboration among individuals, which can help to build a shared understanding of the importance of public health and create a culture of health.

The field of work on increasing VCR lends itself well to gamification because: general trust in vaccines has been deeply shaken by misinformation and fake news during the COVID-19 pandemic, and it is possible to demonstrate the immense advantages that good vaccine coverage provides; in particular, influenza is one of the diseases with the highest pandemic potential, and only through vaccination against the disease will it be possible to mitigate its potential effects; the entire community, from policymakers, often

disconnected from health issues, to the most vulnerable citizen, can understand how and where the benefits of influenza vaccination work. It is easy to demonstrate the need for the creation of multiple protective barriers (the PHP) contrary to the recent "One Best Solution" campaigns that emerged during COVID-19. It is possible to highlight the different outcomes for each target audience.

We highlight as main limitations: 1. Gamification poses ethical challenges, as the tools that use this approach cannot be seen as an exact prediction of the future, but rather should only be understood as a form of guidance, which offers a projection of the future based on what was the past, admitting a *Ceteris Paribus* condition; 2. The modeling is based on data analysis, which represents a challenge in terms of its availability, both in general and especially at a local level. Also, the qualification of sources that are often created for very different purposes and in ecosystems that are difficult to traverse, and this requires the production of proxies with all the risks that this entails, despite the production and validation of each one being a thorough and carefully done process; 3. Sudden contextual changes capable of altering the entire framework of healthcare management, which is contrary to the principles of modeling. For example, we can reflect on what happened with the COVID-19 pandemic, where populations previously in agreement with national vaccination plans began to show sudden resistance as a result of the large disinformation campaigns that have been witnessed in the last three years, which resulted, for example, in the decrease of VCR in many potentially vaccinal diseases[106]. A concrete example of this situation is the return of polio in London and New York, an unthinkable scenario 10 years ago. For this reason, the LCF project plans to revisit the bibliography and assumptions considered for each country every 6 months.

The greatest enemy of gamification in the field of vaccines is the terrible lack of empirical data that can be extrapolated. Most studies could not be integrated into the model construction because, although they are extremely interesting, they draw only qualitative conclusions or are valid in very restricted target populations, thereby losing ecological validity. We, therefore, appeal for the creation and availability of data that can more robustly feed the models, especially when considering that in the short to medium

term, gamification models will migrate to Artificial Intelligence, which requires an immense amount of quality data.

In summary, gamification is a valuable tool for improving public health policy decision-making by increasing engagement, providing data and insights, and fostering community and collaboration.

Author's contributions

Study concept and design: HL, RBL; Data acquisition: HL, Maple; Data analysis and study supervision: HL, Maple; Draft of the manuscript and administrative support: HL, CH; Critical review of the manuscript for important intellectual content: HL, RA, RBL.

All authors have approved the final version of the manuscript for publication.

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Disclaimer

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Conflicts of Interest

None to declare.

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Annex 1: Public health policies in the LCF model, organized by pillar, based on Kassianos et al.'s (2021) proposed model.

Pillar 1: Health authority accountability and strengths of the influenza immunisation programme	Pillar 2: Facilitated access to vaccination	Pillar 3: HCP accountability and engagement	Pillar 4: Awareness of influenza burden and severity of disease	Pillar 5: Belief in influenza vaccination benefits
HA leaders willing to champion influenza vaccination	Access to multiple vaccination settings	Regular HCP education and training by multiple stakeholders	Structured and robust influenza surveillance network	Overall trust in influen vaccine safety a effectiveness
VCR targets set at national and regional levels for recommended populations	Multiple HCPs allowed to vaccinate target population	Fair and specific HCP compensation per vaccination	Reliable collection and dissemination of data on influenza burden	Trust in the influen vaccine as the mo effective prevention
Nationwide regular monitoring of patient VCR at vaccination site/ HCP level by HA	Convenient and seamless vaccination journey for all target populations	Attractive VCR-linked financial incentive for HCP	Proven evidence of the economic direct and indirect impacts of influenza	Public trust in HA and HC communication
Data collection and reporting on HCP vaccination status	No financial barriers to getting immunised (i.e. no out-of-pocket expenses or cash layout)	Individual vaccination status visibility across providers (e.g. GP, pharmacist)	Published data on influenza-related disruption of the healthcare system and company productivity	Positive media coverage vaccines
HCP VCR as part of performance criteria in hospitals and primary care	Awareness of vaccine recommendations by target populations	Competition through publication of VCR at vaccination area/HCP level	Coordinated multistakeholder communication campaigns	Effectively dealing wi active anti- vax groups
Multistakeholder coalition supporting influenza immunisation	Reminder call-to-action communications to target groups by multiple stakeholders	Mandatory/strongly recommended HCP vaccination	Patient associations actively support influenza vaccination	Monitoring a responsiveness vacci disinformation
Investment in pandemic preparedness	Vaccine dedicated refrigerators at vaccination setting (e.g. GP practice)	Simple influenza vaccine procurement process for GPs	Target populations motivated to get vaccinated	
Systematic assessment of cost-efficiency of VCR initiatives	HCP pop-up notification to vaccinate eligible individuals	HCP associations actively endorsing influenza vaccination		
Regional HAs willingness to develop new initiatives to drive VCR	Availability of influenza vaccines (including cold chain management) in close proximity to the patients	Clear guidance about vaccine-specific usage per target population		
Sustainable procurement system to ensure appropriate vaccine supply				
Funding of flu vaccinations for all recommended groups				

Supplementary Files

Figures

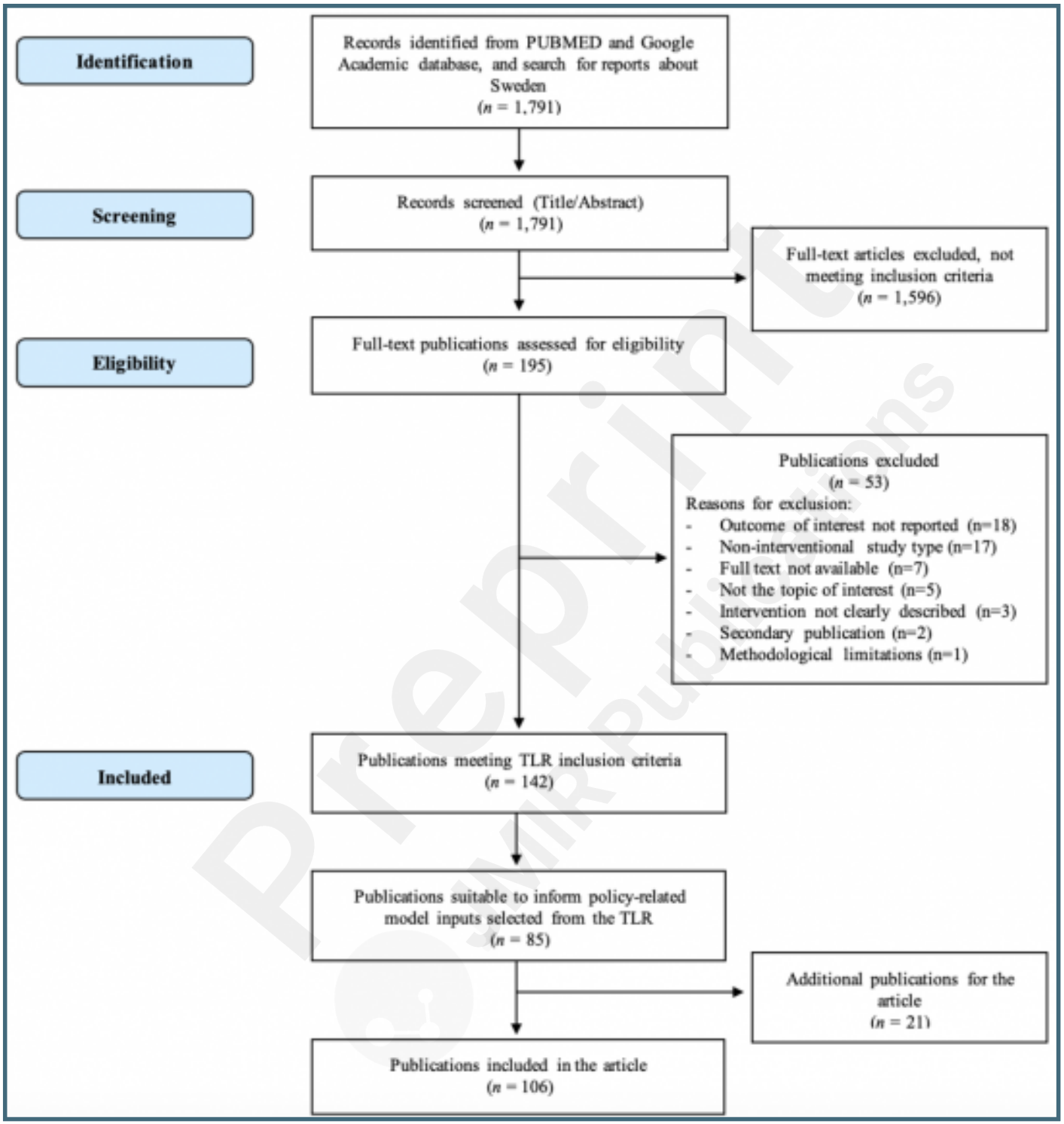
The 13 PHPs chosen for the construction of the LCF model, categorized according to their respective pillars.

Pillar 2: Facilitated access to vaccination		
Access to multiple vaccination settings	**Call-to-action communications to target groups by multiple stakeholders**	**HCP pop-up notification/SMS to population to vaccinate eligible patients**
Enhancing vaccine access and reducing barriers to vaccination ensures that individuals can receive vaccines in various locations, including hospitals (37, 41, 43-45), clinics (24, 46), pharmacies (27, 47-50), schools (31, 40, 51-58), and other settings (34, 59). By doing this, public health authorities increase convenience and improve the chances of individuals getting vaccinated.	This policy targets flu-related stakeholders including public health agencies, health professionals, schools, and community organizations. Various methods like email (57, 58, 60-62), text messages (63-69), phone calls, health apps, and others (38, 70) are utilized to remind target groups about the importance of vaccination. The objective is to boost vaccine uptake by reminding individuals in target groups of vaccination's significance and encouraging them to get vaccinated (71-74).	Healthcare providers use pop-up notifications or text messages to remind eligible patients of the importance of vaccination and encourage them to get vaccinated (72, 73, 75-77), thus increasing vaccine uptake.
Pillar 3: Healthcare professional accountability and engagement		
Regular HCP education and training	**Fair and specific HCP compensation per vaccination**	**Mandatory HCP vaccination**
This policy ensures healthcare professionals, including doctors, nurses, and other professionals, receive ongoing education and updates on new technologies, medical advancements, and changes in vaccination practices (21, 22, 37, 53, 65, 75-82). Its objective is to equip healthcare professionals with the necessary knowledge and skills to deliver safe, effective, and high-quality care to patients.	Establishing a system where health professionals receive fair compensation for administering vaccines (83). This aims to incentivize healthcare professionals to administer vaccines and ensure they are adequately rewarded for their time and efforts. Fair compensation not only supports healthcare professionals but also encourages their dedication to protecting public health.	Mandating or strongly recommending that healthcare workers receive specific vaccines as part of their job (23, 24, 41, 84-94). This policy aims to safeguard public health by minimizing the transmission of communicable diseases in healthcare settings like clinics or hospitals, particularly to patients with weakened immune systems. By requiring or strongly recommending vaccination for healthcare professionals, the policy aims to prevent them from being carriers of diseases that could be transmitted to their patients.

The 13 PHPs chosen for the construction of the LCF model, categorized according to their respective pillars.

Pilar 4: Awareness of the burden and severity of the disease
Coordinated multi-stakeholder awareness/communication campaigns
This policy promotes immunization through collaboration and coordination among various stakeholders, including government agencies, hospitals and other health organizations (21, 22, 34, 36, 40, 45, 56-59, 65, 71, 74-77, 79, 85, 93, 99-102), health professionals (20, 29, 30, 46, 53, 60, 95, 96), community organizations, schools and universities (31, 103), as well as the media (93, 104). Its goal is to deliver a cohesive message about the importance of immunization, reaching a wide audience with information on the benefits of immunization and how to access it. By addressing concerns, dispelling misinformation, and creating a supportive environment (97, 98), the policy aims to enhance vaccine uptake.
Pilar 5: Belief in influenza vaccination benefits
Positive media coverage of vaccines
The policy promotes a positive approach to vaccine promotion, highlighting the benefits of vaccination and countering negative or misleading information. It aims to foster a vaccine-friendly environment by showcasing the safety, efficacy, and importance of vaccines through various media channels such as news articles, public service announcements, and other media content (29). The policy's purpose is to boost vaccine uptake by offering accurate information, debunking myths, and empowering the public to make informed decisions about vaccination.

Systematic literature review PRISMA flowchart.



The 13 PHPs chosen for the construction of the LCF model, categorized according to their respective pillars.

Pillar 1: Health authority accountability and strengths of the influenza program				
Vaccination Coverage Rates targets set at national and regional levels for recommended population	**Funding of flu vaccinations for all recommended groups**	**Nationwide regular monitoring of patient VCR at vaccination site/Healthcare Professional level by Health Authorities**	**HCP VCR as part of performance criteria in hospitals**	**Sustainable procurement system to ensure appropriate vaccine supply**
To boost influenza vaccination rates (20), policies set targets at national and regional levels for specific population groups (21). In Sweden, for example, this policy was implemented nationwide. Strategies programs (22-24) include educating individuals about vaccine benefits, improving vaccine accessibility, and offering incentives for vaccination, all aimed at increasing vaccine uptake.	To enhance influenza vaccine access, reduce the burden of disease, and prevent influenza-related deaths, immunization programs (25-29), intervention campaigns, and strategies (20, 30-38) can be created. Additionally, funds may be allocated to cover the cost of flu shots for vulnerable groups, such as the elderly, children, healthcare workers, and individuals with underlying health conditions. By doing so, public health officials improve vaccine accessibility and safeguard those with a higher risk of flu complications.	Regular tracking of vaccine uptake in designated health facilities like clinics, hospitals, and pharmacies (39, 40) allows for monitoring immunization program effectiveness and identifying areas of improvement. By monitoring immunization coverage rates, public health authorities can use data to enhance programs and achieve desired health outcomes for the population.	Boosting vaccine uptake among healthcare workers and minimizing disease transmission through vaccination. This policy mandates that health worker immunization coverage rates be used as a performance criterion in healthcare facilities, including hospitals and primary care settings (41). It encourages healthcare workers to get vaccinated, prioritizing their well-being and minimizing disease spread among patients, thereby fostering a safer and healthier environment for all.	Ensuring consistent and reliable availability of necessary vaccines for all individuals in need (42), irrespective of their location or financial circumstances. This policy aims to establish a procurement system that effectively manages vaccine acquisition, storage, and distribution to health units, considering cost, quality, and sustainability factors.

Graphic representation of the model adopted to estimate the effect of the 13 chosen Public Health Policies.