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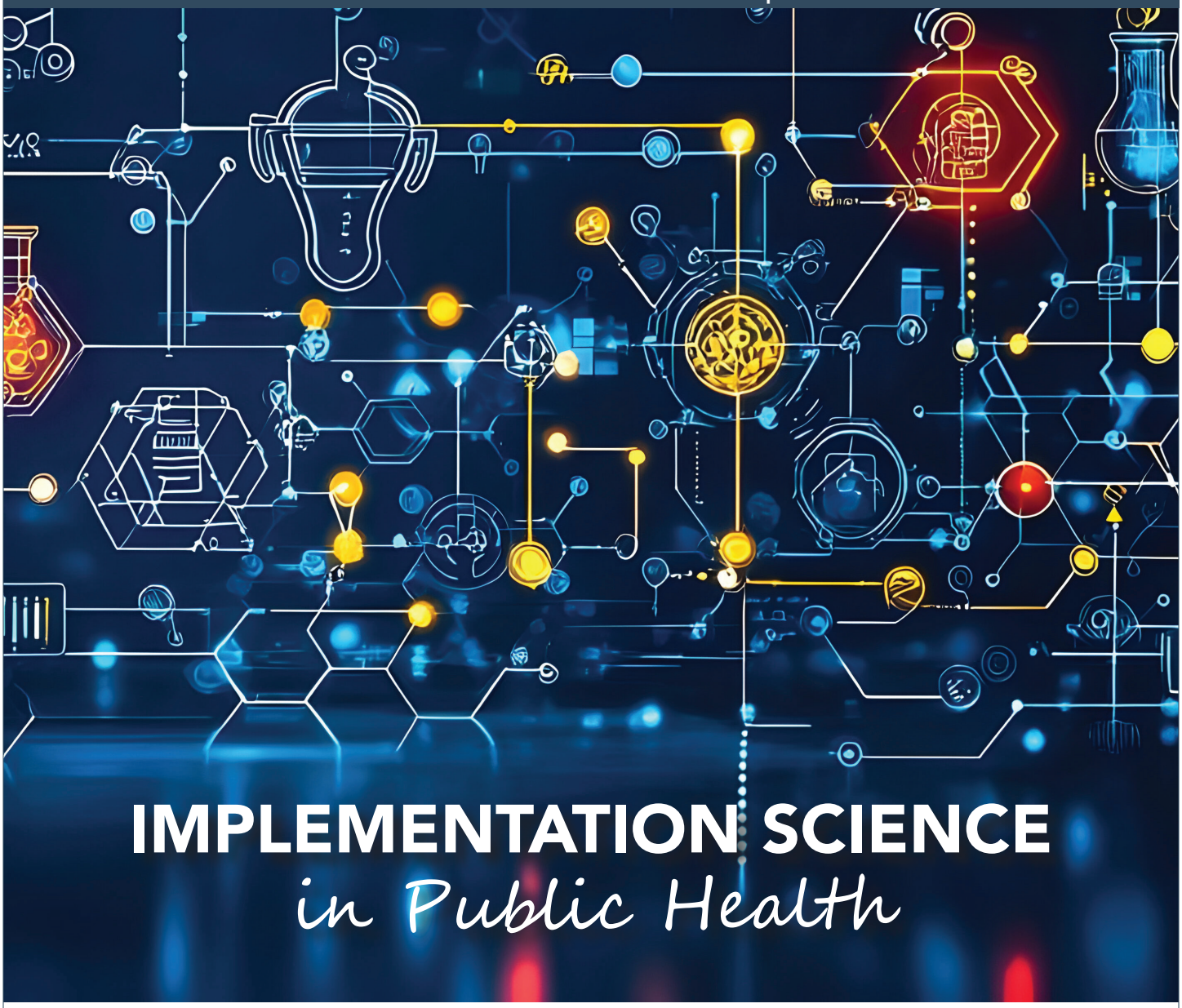

IMPLEMENTATION SCIENCE in Public Health

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CANADA COMMUNICABLE DISEASE REPORT

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IMPLEMENTATION SCIENCE IN PUBLIC HEALTH

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Summary of the National Advisory Committee on Immunization (NACI) Seasonal Influenza Vaccine Statement for 2025–2026

Katarina Gusic[1], Winnie Siu[1,2], Angela Sinilaite[1], Jesse Papenburg[3,4,5,6] on behalf of the National Advisory Committee on Immunization (NACI)*

Abstract

Background: The National Advisory Committee on Immunization (NACI) reviews the evolving evidence on influenza immunization and provides annual recommendations regarding the use of seasonal influenza vaccines. The NACI *Statement on seasonal influenza vaccines for 2025–2026* updates the NACI recommendations from the previous year.

Objective: To summarize the 2025–2026 NACI seasonal influenza vaccine recommendations and to highlight new and updated information.

Methods: For the development of the *Statement on seasonal influenza vaccines for 2025–2026*, the NACI Influenza Working Group applied the NACI evidence-based process to assess available evidence and formulate recommendations. These recommendations were evaluated and approved by NACI based on the available evidence.

Results: Key updates for the 2025–2026 influenza season include: 1) removal of the preferential recommendation for quadrivalent influenza vaccines in children; 2) reiteration of the safety of concurrent administration of seasonal influenza vaccines and other vaccines, including COVID-19, based on updated evidence; 3) new evidence on the protective effects of influenza vaccination on cardiovascular events; 4) updated language for Indigenous populations; and 5) addition of individuals at higher risk of avian influenza A(H5N1) exposure as a group for whom influenza vaccination is particularly important.

Conclusion: NACI recommends that seasonal influenza vaccine should be offered annually to anyone six months of age and older who does not have a contraindication to the vaccine. Influenza vaccination is particularly important for people at high risk of influenza-related complications or hospitalization, people capable of transmitting influenza to those at high risk, and others as outlined in the Statement.

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Introduction

Canada experiences annual seasonal influenza epidemics, primarily in the late fall and winter. The burden of influenza-associated illness and death varies each year due to factors such as circulating virus type and affected populations (1). Globally, approximately 3 to 5 million cases of severe influenza illness and 290,000 to 650,000 deaths from influenza occur annually (2). In Canada, prior to the COVID-19 pandemic (i.e., 2010–2011 to 2018–2019 influenza seasons), influenza caused approximately 15,000 hospitalizations annually, more than any other seasonal

respiratory virus (3). Vaccination remains the most effective form of protection against influenza and its complications.

The National Advisory Committee on Immunization (NACI) provides the Public Health Agency of Canada (PHAC) with annual recommendations on the use of authorized seasonal influenza vaccines, reflecting changes in epidemiology, immunization practices, and available products in Canada. The NACI Influenza Working Group (IWG) leads the annual update of the NACI statement on seasonal influenza vaccines, which involves a thorough review and evaluation of the literature, as well as discussion and debate at the scientific, clinical practice and population health levels. On April 30, 2025, PHAC released new guidance from NACI on the use of seasonal influenza vaccines for the 2025–2026 influenza season, based on current evidence and expert opinion. This article provides a concise summary of NACI's recommendations and supporting information for the 2025–2026 influenza season, with emphasis on new or updated information since the 2024–2025 statement on seasonal influenza vaccines. For detailed information, refer to NACI's *Statement on seasonal influenza vaccines for 2025–2026* (4).

Methods

In preparation for the *Statement on seasonal influenza vaccines for 2025–2026*, the NACI IWG identified the need for evidence reviews on new topics, analyzed available evidence, and developed updated recommendations using NACI's evidence-based process (5). Further details regarding the strength of NACI recommendations are available in **Table A1** in the **Appendix**. NACI's peer-reviewed framework and evidence-informed tools (including the Ethics Integrated Filters, Equity Matrix, Feasibility Matrix, and Acceptability Matrix) were applied to help ensure that issues related to ethics, equity, feasibility and acceptability were systematically assessed and integrated into NACI guidance (6).

Results

Transition from quadrivalent to trivalent influenza vaccines

Previously, NACI recommended quadrivalent vaccines for children due to the higher burden of influenza B disease in this population and the extra protection conferred by the presence of both B/Victoria and B/Yamagata lineages in quadrivalent vaccines. As noted in the *Statement on seasonal influenza vaccine for 2024–2025* and its addendum, confirmed B/Yamagata virus infections have not been detected globally since March 2020, leading to expert groups, including PHAC, endorsing the exclusion of the B/Yamagata component from influenza vaccine formulations. This aligns with the World Health Organization (WHO) guidance for the 2024–2025 Northern Hemisphere season (7–9). Due to this changing epidemiology, NACI now has no preference between quadrivalent and trivalent vaccines and considers both formulations to be clinically safe and effective.

Concurrent administration

NACI continues to recommend that all seasonal influenza vaccines (including live attenuated influenza vaccines [LAIV]) may be given at the same time as, or at any time before or after, administration of other vaccines (either live or non-live, including COVID-19 vaccines) for anyone six months of age and older. Evidence reviews on the concurrent administration of seasonal influenza vaccines (e.g., LAIV, inactivated influenza vaccines [IIV], recombinant influenza vaccines [RIV]) with other vaccines (e.g., COVID-19, respiratory syncytial virus, and pneumococcal) identified no safety, efficacy/effectiveness, or immunogenicity concerns. NACI will continue to monitor emerging evidence and update guidance as needed.

Protective effects of influenza vaccination on cardiovascular events

Influenza infection has been associated with increased risk of cardiovascular events, including myocardial infarction, heart failure, and stroke (10,11). Following a literature review of existing systematic reviews and meta-analyses, NACI found supporting evidence for a protective effect of influenza vaccination against cardiovascular events in high-risk populations, such as those with underlying cardiovascular disease (12).

Language pertaining to Indigenous peoples

In consultation with Indigenous immunization experts, NACI has updated its language on Indigenous peoples to specify "individuals in or from First Nations, Inuit, and Métis communities." In addition, the rationale for including these individuals under the list of "Groups for whom influenza vaccination is particularly important" has also been updated to emphasize that the increased risk of severe influenza outcomes experienced by this group is due to multiple intersecting determinants of health, including social, environmental, and economic factors, rooted in historic and ongoing colonization and systemic racism (i.e., structural inequity).

Guidance for people whose occupational or recreational activities increase their risk of exposure to avian influenza A(H5N1) viruses

Considering the ongoing outbreak of avian influenza A(H5N1) in humans and animals in countries such as the United States and Canada, NACI reiterates its recommendation that all individuals six months of age and older should receive a seasonal influenza vaccine. Although seasonal influenza vaccines do not protect against avian influenza infection, they may reduce the risk of seasonal and avian influenza A(H5N1) virus co-infection. Therefore, NACI has expanded its list of "Groups for whom

influenza vaccination is particularly important" to include "people whose occupational or recreational activities increase their risk of exposure to avian influenza A(H5N1) viruses." For preliminary guidance regarding the use of human vaccines against avian influenza, see the NACI rapid response on preliminary guidance on human vaccines against avian influenza as of December 2024 (13).

Summary of NACI recommendations for the use of influenza vaccines for the 2025–2026 influenza season

NACI recommends that any age-appropriate quadrivalent or trivalent influenza vaccine should be used for individuals six months of age and older who do not have contraindications or precautions. Vaccination should be offered as a priority to people at high risk of influenza-related complications or hospitalization, people capable of transmitting influenza to those at high risk of complications, and others as indicated in **List 1**. Refer to **Table 1** for the recommended influenza vaccine products and **Table 2** for the recommended dose and administration route for each age group.

List 1: Groups for whom influenza vaccination is particularly important

People at high risk of influenza-related complications or hospitalization:

- All children 6 to 59 months of age
- Adults and children with the following chronic health conditions[a]:
  - Cardiac or pulmonary disorders (including bronchopulmonary dysplasia, cystic fibrosis, and asthma)
  - Diabetes mellitus and other metabolic diseases
  - Cancer, immune compromising conditions (due to underlying disease, therapy, or both, such as solid organ transplant or hematopoietic stem cell transplant recipients)
  - Renal disease
  - Anemia or hemoglobinopathy
  - Neurologic or neurodevelopmental conditions (includes neuromuscular, neurovascular, neurodegenerative, neurodevelopmental conditions, and seizure disorders [and, for children, includes febrile seizures and isolated developmental delay], but excludes migraines and psychiatric conditions without neurological conditions)
  - Class 3 obesity (defined as body mass index of 40 kg/m² and over)

List 1: Groups for whom influenza vaccination is particularly important (*continued*)

  - Children 6 months to 18 years of age undergoing long-term treatment with acetylsalicylic acid, because of the potential increase of Reye's syndrome associated with influenza
- All pregnant women and pregnant individuals
- All individuals of any age who are residents of nursing homes and other chronic care facilities
- Adults 65 years of age and older
- Individuals in or from First Nations, Inuit, or Métis communities as a result of intersecting determinants of health rooted in historic and ongoing colonization and systemic racism

People capable of transmitting influenza to those at high risk:

- Healthcare and other care providers in facilities and community settings who, through their activities, are capable of transmitting influenza to those at high risk
- Household contacts, both adults and children, of individuals at high risk, whether or not the individual at high risk has been vaccinated:
  - Household contacts of individuals at high risk
  - Household contacts of infants less than 6 months of age, as these infants are at high risk but cannot receive influenza vaccine
  - Members of a household expecting a newborn during the influenza season
- Those providing regular childcare to children 0 to 59 months of age, whether in or out of the home
- Those who provide services within closed or relatively closed settings to people at high risk (e.g., crew on a cruise ship)

Others:

- People who provide essential community services
- People whose occupational or recreational activities increase their risk of exposure to avian influenza A(H5N1)

[a] Refer to immunization of persons with chronic diseases (14) and immunization of immunocompromised persons (15) in Part 3 of the *Canadian Immunization Guide* for additional information about vaccination of people with chronic diseases

Table 1: Recommendations on choice of influenza vaccine type for individual and public health program-level decision making by age group

Recipient by age group	Vaccine types authorized and available for use	Recommendations on choice of influenza vaccine
6–23 months	IIV-Adj IIV-SD IIV-cc	• Any age-appropriate quadrivalent or trivalent influenza vaccine should be used for infants and young children who do not have contraindications or precautions, noting the following considerations: ◦ Currently, there is insufficient evidence for recommending vaccination with Influvac® Tetra (IIV4-SD) in children younger than 3 years of age
2–17 years[a]	IIV-SD IIV-cc LAIV	• Any age-appropriate quadrivalent or trivalent influenza vaccine should be used for children and adolescents who do not have contraindications or precautions (see text below applicable to LAIV), including those with chronic health conditions, noting the following considerations and exceptions: ◦ Currently, there is insufficient evidence for recommending vaccination with Influvac® Tetra (IIV4-SD) in children younger than 3 years of age • LAIV may be given to children with: ◦ Stable, non-severe asthma ◦ Cystic fibrosis who are not being treated with immunosuppressive drugs (e.g., prolonged systemic corticosteroids) ◦ Stable HIV infection, i.e., if the child is currently being treated with ART for at least 4 months and has adequate immune function • LAIV should not be used in children or adolescents for whom it is contraindicated or for whom there are warnings and precautions, such as those with: ◦ Severe asthma (defined as currently on oral or high-dose inhaled glucocorticosteroids) or active wheezing ◦ Medically attended wheezing in the 7 days prior to vaccination ◦ Current receipt of long-term aspirin or aspirin-containing therapy ◦ Immune compromising conditions, with the exception of stable HIV infection, i.e., if the child is currently being treated with ART for at least 4 months and has adequate immune function ◦ Pregnancy: – In pregnancy, IIV-SD or IIV-cc should be used instead
18–59 years	IIV-SD IIV-cc RIV LAIV	• Any of the available influenza vaccines authorized for this age group should be used for adults 18 to 59 years of age without contraindications or precautions, noting the following considerations and exceptions: ◦ There is some evidence that IIV may provide better efficacy than LAIV in healthy adults • LAIV is not recommended for: ◦ Pregnant women and pregnant individuals – In pregnancy, IIV-SD, IIV-cc, or RIV should be used instead ◦ Adults with any of the chronic health conditions identified in List 1, including immune compromising conditions ◦ Healthcare workers (HCWs)
60–64 years	IIV-SD IIV-cc RIV	Any of the available influenza vaccines authorized for this age group should be used for adults 60 to 64 years of age without contraindications or precautions.
65 years and older[b]	IIV-Adj IIV-SD IIV-HD IIV-cc RIV	IIV-HD, IIV-Adj, or RIV should preferentially be offered, when available, over other influenza vaccines for adults 65 years of age and older. If a preferred product is not available, any of the available influenza vaccines authorized for this age group should be used.

Abbreviations: ART, antiretroviral therapy; IIV, inactivated influenza vaccine; IIV-Adj, adjuvanted inactivated influenza vaccine; IIV-SD, standard-dose inactivated influenza vaccine; IIV-cc, mammalian cell–culture-based inactivated influenza vaccine; IIV-HD, high-dose inactivated influenza vaccine; IIV4-SD, standard-dose quadrivalent inactivated influenza vaccine; LAIV, live attenuated influenza vaccine; RIV, recombinant influenza vaccine

[a] Refer to Table 3 in the Statement on seasonal influenza vaccines for 2025–2026 for a summary of vaccine characteristics of LAIV compared with IIV in children 2 to 17 years of age

[b] Refer to the NACI supplemental statement on influenza vaccination in adults 65 years of age and older (16) for rationale, supporting evidence appraisal, and additional details on the evidence reviews that were conducted to support this recommendation

Conclusion

NACI continues to recommend annual influenza vaccination for all individuals aged six months and older, noting product-specific age indications and contraindications. Influenza vaccination is particularly important for people at high risk of influenza-related complications or hospitalization; people capable of transmitting influenza to those at high risk; people who provide essential community services; and people whose occupational or recreational activities increase their risk of exposure to avian influenza A viruses (e.g., H5N1). Regarding updates for the 2025–2026 influenza season, NACI: 1) recommends that any age-appropriate quadrivalent or trivalent influenza vaccine should be used for individuals aged six months and older without contraindications or precautions; 2) continues to recommend that influenza vaccines may be given on the same day or at any time before or after other vaccines, including COVID-19 vaccines; and 3) lists individuals whose occupational or recreational activities

Table 2: Recommended dose and route of administration, by age, for influenza vaccine types authorized for the 2025–2026 influenza season[a]

Age group	Influenza vaccine type (Route of administration)						Number of doses required
	IIV-SD[b] (IM)	IIV-cc[c] (IM)	IIV-Adj[d] (IM)	IIV-HD[e] (IM)	RIV[f] (IM)	LAIV[g] (Intranasal)	
6–23 months[h]	0.5 mL[i]	0.5 mL	0.25 mL	N/A	N/A	N/A	1 or 2[j]
2–8 years	0.5 mL	0.5 mL	N/A	N/A	N/A	0.2 mL (0.1 mL per nostril)	1 or 2[j]
9–17 years	0.5 mL	0.5 mL	N/A	N/A	N/A	0.2 mL (0.1 mL per nostril)	1
18–59 years	0.5 mL	0.5 mL	N/A	N/A	0.5 mL	0.2 mL (0.1 mL per nostril)	1
60–64 years	0.5 mL	0.5 mL	N/A	N/A	0.5 mL	N/A	1
65 years and older	0.5 mL	0.5 mL	0.5 mL	0.7 mL	0.5 mL	N/A	1

Abbreviations: IIV-Adj, adjuvanted inactivated influenza vaccine; IIV-cc, mammalian cell culture based inactivated influenza vaccine; IIV-HD, high-dose inactivated influenza vaccine; IIV-SD, standard-dose inactivated influenza vaccine; IM, intramuscular; LAIV, live attenuated influenza vaccine; N/A, not applicable; RIV, recombinant influenza vaccine

[a] Given the global transition to trivalent influenza vaccines, the availability of various influenza vaccine preparations in Canada is evolving. Should the availability of a specific vaccine change (i.e., be made available or unavailable) after the release of this statement and prior to the 2025–2026 influenza vaccine season, NACI will communicate relevant information regarding the new vaccine preparations, if required

[b] Afluria® Tetra (five years and older), Flulaval® Tetra (six months and older), Fluzone® Quadrivalent (six months and older), Influvac® Tetra (six months and older)

[c] Flucelvax® Quad (six months and older)

[d] Fluad Pediatric™ (6 to 23 months) or Fluad® (65 years and older)

[e] Fluzone® High-Dose Quadrivalent (65 years and older)

[f] Supemtek® (18 years and older)

[g] FluMist® Quadrivalent (2 to 59 years)

[h] There is insufficient evidence for recommending vaccination with Influvac® Tetra (IIV4-SD) in children younger than three years of age

[i] Evidence suggests moderate improvement in antibody response in infants, without an increase in reactogenicity, with the use of full vaccine doses (0.5 mL) for unadjuvanted inactivated influenza vaccines. This moderate improvement in antibody response without an increase in reactogenicity is the basis for the full dose recommendation for unadjuvanted inactivated vaccine for all ages. For more information, refer to the *Statement on Seasonal Influenza Vaccine for 2011–2012* (17)

[j] Children six months to less than nine years of age receiving seasonal influenza vaccine for the first time in their life should be given two doses of influenza vaccine, with a minimum interval of four weeks between doses. Children six months to less than nine years of age who have been vaccinated with one or more doses of seasonal influenza vaccine in the past should receive one dose of influenza vaccine per season thereafter

increase their risk of exposure to avian influenza A(H5N1) viruses as a group for whom influenza vaccination is particularly important.

Authors' statement

KG — Writing–original draft, writing–review & editing
WS — Writing–review & editing
AS — Writing–review & editing
JP — Writing–review & editing

The NACI *Statement on seasonal influenza vaccines for 2025–2026* was prepared by N Sicard, A Sinilaite, W Siu, P Doyon-Plourde and J Papenburg, on behalf of the NACI Influenza Working Group, and was approved by NACI.

Competing interests

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Appendix

Table A1: Strength of the National Advisory Committee on Immunization recommendations

Strength of NACI recommendations (based on factors not isolated to strength of evidence, e.g., public health need)	Strong	Discretionary
Wording	"should/should not be offered"	"may be considered"
Rationale	Known/anticipated advantages outweigh known/anticipated disadvantages ("should") OR known/anticipated disadvantages outweigh known/anticipated advantages ("should not")	Known/anticipated advantages closely balanced with known/anticipated disadvantages OR uncertainty in the evidence of advantages and disadvantages exists
Implication	A strong recommendation applies to most populations/individuals and should be followed unless a clear and compelling rationale for an alternative approach is present	A discretionary recommendation may be considered for some populations/individuals in some circumstances Alternative approaches may be reasonable

Abbreviation: NACI, National Advisory Committee on Immunization

RESEARCH

Does influenza vaccination contribute to the prevention of cardiovascular events? An umbrella review

Fazia Tadount[1,2]*, Nadine Sicard[1], Winnie Siu[1,3], Pamela Doyon-Plourde[1], Angela Sinilaité[1]

Abstract

Background: There is a growing body of evidence on the potential benefit of influenza vaccination against the occurrence of cardiovascular (CV) events.

Objective: This umbrella review of systematic reviews and meta-analyses (SRMAs) aims to summarize the available evidence on the risk of CV events in adults after receipt of influenza vaccine.

Methods: Four electronic databases were searched (CINAHL, PubMed, SYSVAC and Cochrane Library) for SRMAs published in English or French, between January 1, 2000, and January 14, 2025. Eligible SRMAs included those with a quantitative synthesis of data examining the association between influenza vaccination and the risk of CV events in adults. Data from the included SRMAs were extracted using predefined variables. The quality of each SRMA was assessed by two independent reviewers using the AMSTAR 2 tool.

Results: The review included 25 SRMAs published between 2012 and 2024. Overall, 15 SRMAs were deemed to be of moderate or high quality and were further considered in the evidence synthesis. The most frequently evaluated clinical outcomes were myocardial infarction (MI), all-cause and CV mortality, and major adverse cardiovascular events (MACE). In vaccinated individuals at high-risk for CV events, the risk of CV death was significantly reduced by 23% to 47%, MACE by 26% to 37%, MI by 29% to 34%, and stroke by 13% to 19% compared to unvaccinated individuals.

Conclusion: High-quality evidence from the existing literature supports influenza vaccination as an effective preventive measure for reducing CV disease burden. Highlighting this benefit to patients could increase vaccine uptake and improve both influenza and CV outcomes, especially where coverage remains suboptimal.

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Keywords: influenza vaccine, cardiovascular events, vaccine effectiveness, myocardial infraction, stroke

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Introduction

Cardiovascular disease (CVD) is the leading cause of mortality worldwide (1). In 2021, deaths attributable to ischemic heart disease (IHD) and stroke accounted for 23% (~16 million) of deaths globally (1). Excess mortality from CVD during influenza epidemics was first recognized early in the 20th century (2). Studies have since shown clinically significant association between respiratory infections, especially influenza and CVD (3–8). The risk of cardiovascular (CV) events, such as heart failure (HF), myocardial infraction (MI) and stroke, is several times higher after the onset of respiratory infection than in the absence of infection and increases in proportion to the severity of infection (2–6).

Despite vaccine availability, seasonal influenza causes significant morbidity and mortality (9). Part of its morbidity burden is for CV events, including MI, HF, and stroke, especially among individuals with pre-existing cardiac disorders, such as chronic HF or cardiomyopathy (10). Globally, it is estimated that 3%–5% of IHD deaths can be attributed to influenza, corresponding to 200,000–400,000 IHD deaths, annually (11). Studies have found that influenza infection can cause direct cardiac changes, and the hosts' response to influenza virus infection can increase circulation of inflammatory mediators and activate immune cells that can induce damage in the cardiovascular system (8).

Seasonal influenza vaccination is an effective means to protect against severe influenza disease and its complications (12). Furthermore, evidence on the cardioprotective effects of influenza vaccines is mounting (8,13). In the last decade, many randomized controlled trials (RCTs) and observational studies were conducted to explore this potential association. In Canada, the National Advisory Committee on Immunization (NACI) identifies individuals at high-risk of influenza-related complications or hospitalizations, including those with chronic health conditions, such as cardiac or pulmonary disorders, as a population for whom annual seasonal influenza vaccination is particularly important (14). However, seasonal influenza vaccine coverage is suboptimal, including in high-risk populations (15). Similar recommendations were made in other countries, such as the United Kingdom, the United States, and Australia (16–18).

Several systematic reviews and meta-analyses (SRMAs) assessing the secondary protection of influenza vaccines against CV events have been published (13). Therefore, the objective was to conduct an evidence review to provide a comprehensive summary of published SRMAs that assessed the effect of seasonal influenza vaccination on CV events.

Methods

This review was conducted according to a pre-established protocol and following guidance from the Systematic Reviews on Vaccines (SYSVAC) expert panel on the use of existing systematic reviews to develop evidence-based vaccination recommendations (19).

Search strategy and study identification

An *"a priori"* search strategy was developed to identify relevant studies on PubMed, CINAHL, Cochrane Library and the SYSVAC registry. The detailed search strategy can be found in **Appendix**, **Supplemental A**. Initially, we searched for studies published between January 1, 2000, and March 27, 2024, in English or French languages. The search was updated on January 14, 2025, to incorporate the latest available evidence. Following the electronic database searches, identified records were uploaded into the DistillerSR platform for the screening process. One reviewer conducted the title and abstract screening, then the full-text screening to assess studies eligibility. To be included in the review, each study had to be an SRMA; systematic reviews with only a narrative summary and no meta-analysis were excluded. Furthermore, the Population, Intervention, Comparison, and Outcome(s) (PICO) component of each SRMA, and relevance of the research question(s) were assessed. Relevant SRMAs were eligible if each of the following PICO definitions was met, as defined in each SRMA:

- Population (P): Adults, with or without CVD
- Intervention (I): Seasonal influenza vaccine (any formulation, dose or type)
- Comparison (C): No seasonal influenza vaccine or placebo
- Outcomes (O): Incidence or occurrence of CV events

Data extraction

An electronic data extraction form was developed for this review. The data extraction was first conducted by one reviewer and further validated and/or corrected by a second reviewer. Overall, abstracted data were general review characteristics (author, date of publication, search dates, objective and PICO elements), and a summary of main findings (i.e., participant characteristics, effect measures with a 95% confidence interval (CI), and the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) for the overall quality of evidence), if available (20).

Methodological assessment

The quality of each SRMA was assessed using A MeaSurement Tool to Assess Systematic Reviews (AMSTAR 2), a tool specifically designed to appraise systematic reviews and meta-analyses of randomized and non-randomized studies of healthcare interventions (21). In line with recommendations, the critical domains for the AMSTAR 2 tool were classified as items 2, 4, 7, 9, 11, 13 and 15 (**Table S1**) (21). For the present review, the AMSTAR 2 tool was further adapted so that any item with a "no" response was considered to be critical flaw, while items with a "partial yes" response were not considered critical flaws. The overall score derived using the AMSTAR 2 tool was used to rate the quality of each included SRMA as high (no critical flaws), moderate (one critical flaw), low (two to three critical flaws) or critically low (over three critical flaws) (21). This assessment was conducted by two independent reviewers, and conflicts were resolved through discussion and consensus.

Data synthesis

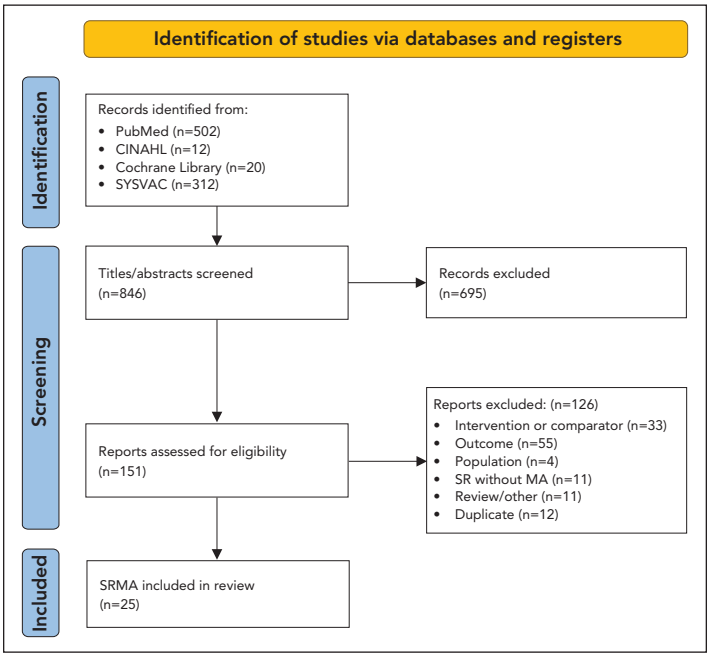
The characteristics and main findings of eligible SRMAs were narratively summarized. Following SYSVAC guidelines for developing recommendations based on existing systematic reviews, only SRMAs of moderate or high quality were included in the detailed summary of findings (19). The PICO items for each SRMA were compared to appraise the heterogeneity between selected SRMAs. A matrix was created to present overlapping studies across the SRMAs. Findings for four main CV events were synthesized: CV mortality, major adverse CV events (MACE),

MI and stroke. Effect measures and 95% CIs for these outcomes were presented in a forest plot, to provide a visual overview of the evidence. To account for potential heterogeneity due to the design of primary studies (i.e., RCT, or observational studies, or both), stratified results were presented by study design, when possible. Finally, results were reported separately for populations with and without underlying CVD to better appraise the effect of influenza vaccination in high-risk populations.

Results

Overall, 846 citations were identified and screened at the title and abstract level. A total of 151 studies were assessed for eligibility and screened at full-text level, and 25 SRMAs were finally included in the umbrella review (**Figure 1**) (22–46).

Figure 1: PRISMA diagram for study selection

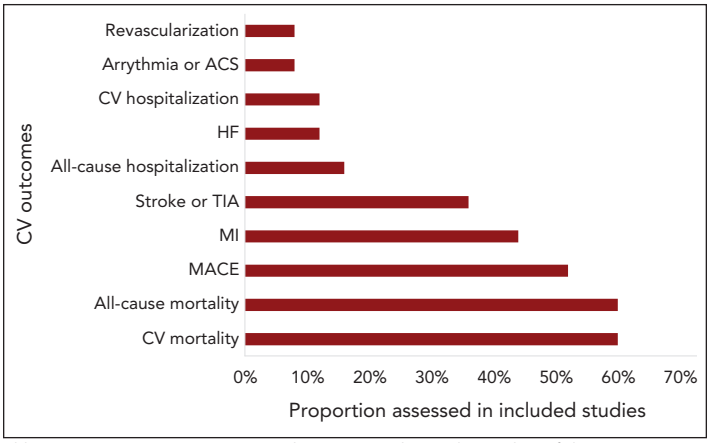


Abbreviations: MA, meta-analyse; PRISMA, Preferred Reporting Items for Systematic reviews and Meta-Analyses; SR, systematic review; SRMA, systematic review and meta-analyse; SYSVAC, Systematic Reviews on Vaccines

Studies description

Included SRMAs were published between 2012 and 2024 and included 5 to 22 individual studies in the quantitative synthesis (**Table 1**). Overall, nine (36%) of the studies were SRMAs of RCT (22,24,27,28,35,37–39,43), 10 (40%) were SRMAs of both RCT and observational studies (26,29,31,33,34,36,42,44–46), and six (24%) included only observational studies (23,25,30,32,40,41). The populations of interest in all SRMAs were adults aged 18 years and older, although most SRMAs (72%) focused on participants with diagnosed CVD or those at higher risk of CV events, as defined in each SRMA (Table 1) (22–25,28,29,31,32,34–40,42–44). In contrast, 28% of the SRMAs included a broader population definition, encompassing adults with or without CVD, and older adults (26,27,30,33,41,45,46). Furthermore, the eligible SRMAs assessed several CV outcomes, with MI, all-cause and/or CV mortality, and MACE being the most frequently evaluated outcomes (**Figure 2**).

Figure 2: Proportion of assessed cardiovascular outcomes in identified systematic reviews and meta-analyses



Abbreviations: ACS, acute coronary syndrome; CV, cardiovascular; HF, heart failure; MACE, major adverse cardiac events; MI, myocardial infarction; TIA, transient ischemic attack

Table 1: Characteristics of included systematic reviews and meta-analyses

Author, Year	Study design	PICO	Participant characteristics	Detailed outcome(s) definition	AMSTAR 2[a]
SRMA of RCT					
Liu *et al.* 2024	N=5 (RCT) Time covered: Until September 2024	P: Adult patients with IHD I: Influenza vaccinated people C: Unvaccinated people O: MACE or other clinical events	5,659 patients with IHD (2,838 vaccinated, 2,821 controls) Median age: 57–66 years 67.8% males Median follow-up: 12 months	MACE or other clinical events (including cardiovascular death, all-cause mortality, MI, hospitalization for HF, and re-vascularization)	High
Omidi *et al.* 2023	N=5 (RCT) Time covered: Until August 1, 2023	P: Patients with a diagnosis of CVD I: Influenza vaccine C: Placebo O: CV events	9,059 patients (4,529 vaccinated, 4,530 controls) Mean age: 61.3 years Mean follow-up: 9 months	MACE Included the following: MI, stroke, and/or CV death	Low

Table 1: Characteristics of included systematic reviews and meta-analyses (*continued*)

Author, Year	Study design	PICO	Participant characteristics	Detailed outcome(s) definition	AMSTAR 2[a]
SRMA of RCT (*continued*)					
Barbetta *et al.* 2023	N=5 (RCT) Time covered: Until September 2021	P: Patients with coronary artery disease I: Influenza vaccine C: Placebo or no vaccine O: Reported at least one of the specified CV outcomes	4,187 patients (2,098 vaccinated, 2,089 controls) Intervention group: Mean age: 54.9–65 years 61%–81.4% males Control group: Mean age of 54.5–67 years 52%–82.1% males	Primary outcomes: MACE: CV death, non-fatal MI, non-fatal stroke All cause mortality CV mortality Secondary outcomes: Hospitalization for HF, stroke or TIA, revascularization, ACS	Moderate
Modin *et al.* 2023	N=6 (RCT) Time covered: Until December 2022	P: Patients with high CV risk (ischaemic heart disease and/or HF) I: Influenza vaccine C: Placebo O: Incidence of CV outcomes assessed as efficacy outcomes	9,340 patients (4,670 vaccinated, 4,670 controls) Mean age: 54.5–67 years Follow-up: 9.8–36 months	Primary endpoints: Composite of CV death, acute coronary syndrome, stent thrombosis or coronary revascularization, stroke or HF hospitalization Secondary endpoints: CV death, all-cause death	Moderate
Behrouzi *et al.* 2022	N=6 (RCT) Time covered: 2000–2021	P: Patients with cardiac history I: Influenza vaccine C: Placebo and no treatment O: Major adverse CV events	9,001 patients (4,510 vaccinated, 4,491 controls) 42.5% females Mean age: 65.5 years Cardiac history: 52.3% Mean follow-up: 9 months	Primary outcomes: Composite of MACE (CV death or hospitalization for MI, unstable angina, stroke, heart failure, or urgent coronary revascularization) within 12 months of follow-up Secondary outcome: CV mortality within 12 months of follow-up	Critically low
Diaz-Arocutipa *et al.* 2022	N=5 (RCT) Time covered: Until September 2021	P: Patients with coronary artery disease I: Influenza vaccine C: Placebo or standard care O: MACE, all-cause mortality, CV mortality, and MI	4,175 patients (2,110 vaccinated, 2,065 controls) 75% males Mean age: 54.5–67 years Follow-up: 6–12 months Comorbidities: hypertension (55%), previous MI (23%), and diabetes (22%)	Primary outcomes: MACE Secondary outcomes: All-cause mortality, CV mortality, MI	Moderate
Maniar *et al.* 2022	N=8 (RCT) Time covered: Until May 2022	P: Patients hospitalized for acute MI or HF I: Influenza vaccination within a specified timeframe after hospitalization for MI or HF C: No influenza vaccination, placebo, or delayed vaccination O: Reduction in MACE and CV mortality	14,420 patients Follow-up: 6–36 months	MACE, CV mortality, all-cause mortality, MI	Critically low
Clar *et al.* 2015	N=8 (RCT) Time covered: Until February 2015	P: Patients 18 years and older who may or may not have had a history of CVD I: Influenza vaccination C: Control treatment O: CV death or non-fatal CV events	12,029 patients (1,682 with known CVD and 10,347 from general population or elderly people) Follow-up: 42 days–1 year	Primary outcomes: Patients without previous CVD: first-time MI, first-time unstable angina, death from CV causes Patients with previous CVD: MI, Unstable angina, death from CV causes Secondary outcomes: Composite clinical outcomes	Moderate

Table 1: Characteristics of included systematic reviews and meta-analyses (*continued*)

Author, Year	Study design	PICO	Participant characteristics	Detailed outcome(s) definition	AMSTAR 2[a]
SRMA of RCT (*continued*)					
Udell *et al.* 2013	N=6 (RCT) Time covered: Until August 2013	P: Patients with high CV risk I: Influenza vaccination C: Placebo or standard of care O: CV events (efficacy or safety events)	6,735 patients 51.3% females Mean age: 67 years Cardiac history: 36.2% Mean follow-up time: 7.9 months	MACE, CV mortality, all-cause mortality, individual nonfatal CV events (MI, stroke, HF, hospitalization for unstable angina or cardiac ischemia, and urgent coronary revascularization)	Moderate
SRMA of RCT and observational studies					
Liu *et al.* 2024	N=6 (RCT) N=37 (Obs.) Time covered: Until September 2023	P: Adults (18+ years) from the general population or with established CVD I: Influenza vaccine C: Placebo or no vaccine O: All-cause or CV mortality, all-cause or CVD hospitalization	RCT: 12,662 participants Mean age, 62 years; 45% women; 8,797 (69%) with preexisting CVD Follow-up: 6–12 months Observational: 6,311,703 participants Mean age, 49 years; 50% women; 1,189,955 (19%) with pre-existing CVD	All-cause or CV mortality, all-cause or CVD hospitalization and CVD was defined as including any diagnoses relating to MI, HF, or stroke	High
Zahhar *et al.* 2024	Until December 2022 N=3 (RCT) N=23 (Obs.)	P: Patients >18 years I: Influenza vaccine C: No influenza vaccine O: Risk of stroke occurrence/ hospitalization	6,196,668 patients total 42% of studies included patients ≥65 years	Incidence/hospitalization due to stroke (any stroke, ischemic stroke, hemorrhagic stroke) and mortality	Moderate
Liu *et al.* 2022	N=1 (RCT) N=6 (Obs.) Time covered: Until October 2021	P: Adults (>18 years) I: Influenza vaccine C: No influenza vaccine or received vaccine beyond the period of efficacy O: Risk of arrhythmia	RCT: 2,532 patients Mean age: 59.85 years 80.51% males Mean/median follow-up: 1 year Observational: 3,167,445 patients Age range: 18–73.3 years 55.9%–85.29% males Mean/median follow-up: 9 months–3.7 years	Arrhythmia: including AF, atrial flutter, ventricular fibrillation, ventricular flutter, cardiac arrest	Moderate
Zangiabadian *et al.* 2020	N=6 (RCT) N=11 (Obs.) Time covered: January 2000–November 2019	P: Patients aged 18+ years I: Influenza vaccine C: No influenza vaccine O: CV events	Total: 180,043 cases and 276,898 control 47% of studies included patients ≥65 years RCT: 3,677 cases, 3,681 controls Age range: 18+ years Cohort: 78,522 cases, 127,833 controls Age range: 31+ years Case-control: 97,844 cases, 145,384 controls Age range: 40+ years	Occurrence of CV events (CV death, non-fatal MI, non-fatal stroke, hospitalization for HF, coronary ischemic events, HF, vascular death)	Low
Gupta *et al.* 2023	N=6 (RCT) N=9 (Obs.) Time covered: 2000–2021	P: Patients with and without CVD I: Influenza vaccination C: No influenza vaccination O: CV outcomes	745,001 patients Mean age: 70.11 (vaccinated) and 64.55 (unvaccinated) years Mean follow-up time: 6 months–2 years 50% females (vaccinated); 41% females (unvaccinated)	All-cause mortality, CV death, stroke, MI, hospitalization for HF	Critically low

Table 1: Characteristics of included systematic reviews and meta-analyses (*continued*)

Author, Year	Study design	PICO	Participant characteristics	Detailed outcome(s) definition	AMSTAR 2[a]
SRMA of RCT and observational studies (*continued*)					
Jaiswal *et al.* 2022	N=5 (RCT) N=13 (Obs.) Time covered: Until April 2022	P: Patients with established CVD or at high CV risk I: Influenza vaccine C: No influenza vaccine or placebo O: All-cause mortality, MACE, HF, MI, CV mortality, stroke	22,532,165 patients total 217,072 with high CV risk or established CVD (111,073 vaccinated, 105,999 unvaccinated) Mean age: 68 years Mean follow-up: 1.5 years	Primary outcomes: All-cause mortality, MACE Secondary outcomes: HF, MI, CV mortality, stroke	Low
Yedlapati *et al.* 2021	N=4 (RCT) N=12 (Obs.) Time covered: Until January 2020	P: Patients with CVD (atherosclerotic CVD or HF) I: Influenza vaccine C: Placebo O: Mortality and CV outcomes	237,058 patients total (RCT: 1,667 patients, observational: 235,391 patients) Mean age: 69.2 ± 7.01 years 36.6% females Median follow-up: 19.5 months	All-cause mortality, CV mortality, MACE, HF, MI	Low
Cheng *et al.* 2020	N=6 (RCT) N=69 (Obs.) Time covered: Until November 2018	P: Adults I: Influenza vaccine C: Placebo O: CV and respiratory disease outcomes and all-cause mortality	4,419,467 patients total Follow-up: 4 months–9 years	CVD (including stroke, MACE, MI, HF, ischemic heart disease, transient ischemic attack, acute coronary syndrome, cardiac arrest, CV mortality, atrial fibrillation) and all-cause mortality	Low
Tsivgoulis *et al.* 2018	N=5 (RCT-all included influenza) N=6 (Obs.) Time covered: Until March 2017	P: Adult patients at risk of cerebrovascular ischemia I: Influenza vaccination C: No influenza vaccination or different types of vaccination O: Ischemic stroke and other CV outcomes	431,937 patients total Mean age range: 59.9 + 10.3 years and older 19.9%–59.7% vaccinated 38.9%–72.5% males Follow-up time range: 6 months–2 years	Primary outcomes: Cerebrovascular ischemia, specifically acute ischemic stroke Secondary outcomes: Myocardial ischemic events, CV deaths	High
Loomba *et al.* 2012	N=3 (RCT) N=2 (Obs.) Time covered: 1998–2011	P: Patients with cardiovascular disease or at risk of CV events I: Influenza vaccine C: No influenza vaccine O: CV morbidity and mortality	292,383 patients total (169,203 vaccinated and 123,481 unvaccinated) Mean age: 58–77 years 42.6–73.9% males	MI, all-cause mortality, and MACE	Critically low
SRMA of observational studies					
Tavabe *et al.* 2023	N=14 (Obs.) Time covered: 1980–July 2021	P: Elderly I: Influenza vaccine C: No influenza vaccine O: Stroke and hospitalization occurrence	3,198,646 patients Mean follow-up: 30 months	Stroke occurrence or hospitalization due to stroke	Moderate
Gupta *et al.* 2022	N=7 (Obs.) Time covered: Until October 2021	P: Adult patients with heart failure I: Influenza vaccine C: No influenza vaccine O: All-cause mortality, CV-related mortality, all-cause hospitalization, CV-related hospitalization, non-fatal stroke, and non-fatal MI	247,842 patients Mean age: 68–77 years Male to female ratio close to 50% in most studies	All-cause mortality and hospitalization, CV mortality and hospitalization, non-fatal stroke, non-fatal MI within 12 months of receiving the influenza vaccine	Moderate

Table 1: Characteristics of included systematic reviews and meta-analyses (*continued*)

Author, Year	Study design	PICO	Participant characteristics	Detailed outcome(s) definition	AMSTAR 2[a]
SRMA of observational studies (*continued*)					
Rodrigues *et al.* 2020	N=6 (Obs.) Time covered: Until December 2018	P: Adult patients diagnosed with heart failure and/or if they had a reported abnormal/reduced ejection fraction (<50%) I: Influenza vaccination C: No influenza vaccination O: All-cause mortality, HF mortality, CV mortality, all-cause hospitalizations, CV hospitalization rates, HF-related hospitalization rates, hospitalization length and ventricular arrhythmias	179,158 patients Mean age: 62–75 years Follow-up: 3 months–8 years	Primary outcomes: All-cause mortality Secondary outcomes: HF mortality, CV mortality, all-cause hospitalizations, CV hospitalization rates, HF-related hospitalization rates, hospitalization length and ventricular arrhythmias	High
Caldeira *et al.* 2019	N=2 (SCCS) Time covered: Until September 2019	P: Adult (18+ years) patients with a first recorded AMI in the study period and recorded influenza vaccination I: Influenza vaccination C: No influenza vaccination O: incidence rate of AMI	32,676 patients Median age: 72.3–77 years	Incident rate ratio of MI within first month (1–28 days) of influenza vaccination	Low
Lee *et al.* 2017	N=11 (Obs.) Time covered: Until November 2016	P: Individuals (18+ years) at risk of stroke I: Influenza vaccine C: No influenza vaccine O: Risk of stroke (any, first, recurrent)	593,513 patients 45% of studies included participants ≥60 years	Risk of stroke (any, first, recurrent)	Moderate
Barnes *et al.* 2015	N=7 (case-control) Time covered: Until June 2014	P: Adult patients with AMI I: Influenza vaccine C: Patients without AMI, including those who did and did not receive the influenza vaccine O: Fatal or non-fatal AMI, including first or subsequent episode(s)	17,695 cases with AMI (9,428 vaccinated) and 65,343 controls without AMI (33,819 vaccinated) Mean age: ≥40 years	Risk of AMI (first, recurrent). AMI was defined as a constellation of clinical features, including ischemic symptoms, biochemical and/or electrical evidence of myocardial ischemia, evidence of critical artery stenosis on coronary angiography or autopsy evidence of MI	Moderate

Abbreviations: ACS, acute coronary syndrome; AF, atrial fibrillation; AMI, acute myocardial infarction; AMSTAR, A MeaSurement Tool to Assess Systematic Reviews; CV, cardiovascular; CVD, cardiovascular disease; HF, heart failure; IHD, ischemic heart disease; MACE, major adverse cardiovascular events; MI, myocardial infarction; Obs., observational; PICO, population, intervention, comparison, outcome(s); RCT, randomized controlled trials; SCCS, self-controlled case series; SRMA, systematic review and meta-analyses; TIA, transient ischemic attack

[a] The AMSTAR 2 tool was adapted for the present review, so that any item with a "no" response was classified as a critical flaw, while items with a "partial yes" response were not considered critical flaws

Quality assessment and primary studies overlap

The quality assessment of each SRMA was performed using AMSTAR 2. This tool was adapted so that any item with a "no" response was classified as a critical flaw, while items with a "partial yes" response were not considered critical flaws. Overall, four SRMAs were deemed of "critically low" quality, six were of "low" quality, and a total of 15 SRMAs (60%) were deemed to be of "moderate" or "high" quality. Consequently, only the 15 SRMAs of "moderate" or "high" quality were included in the detailed summary of findings synthesis (22,23,27–29,32–35,38,40–43,45). The main items in which most SRMAs scored poorly were: not including a full list of excluded studies (item 7); the absence of a satisfactory technique for assessing the risk of bias in included individual studies (item 9); the use of appropriate methods in meta-analyses for statistical combination of results (item 11); and not accounting for the risk of bias in primary studies when discussing/interpreting the results (item 13) (Table S1).

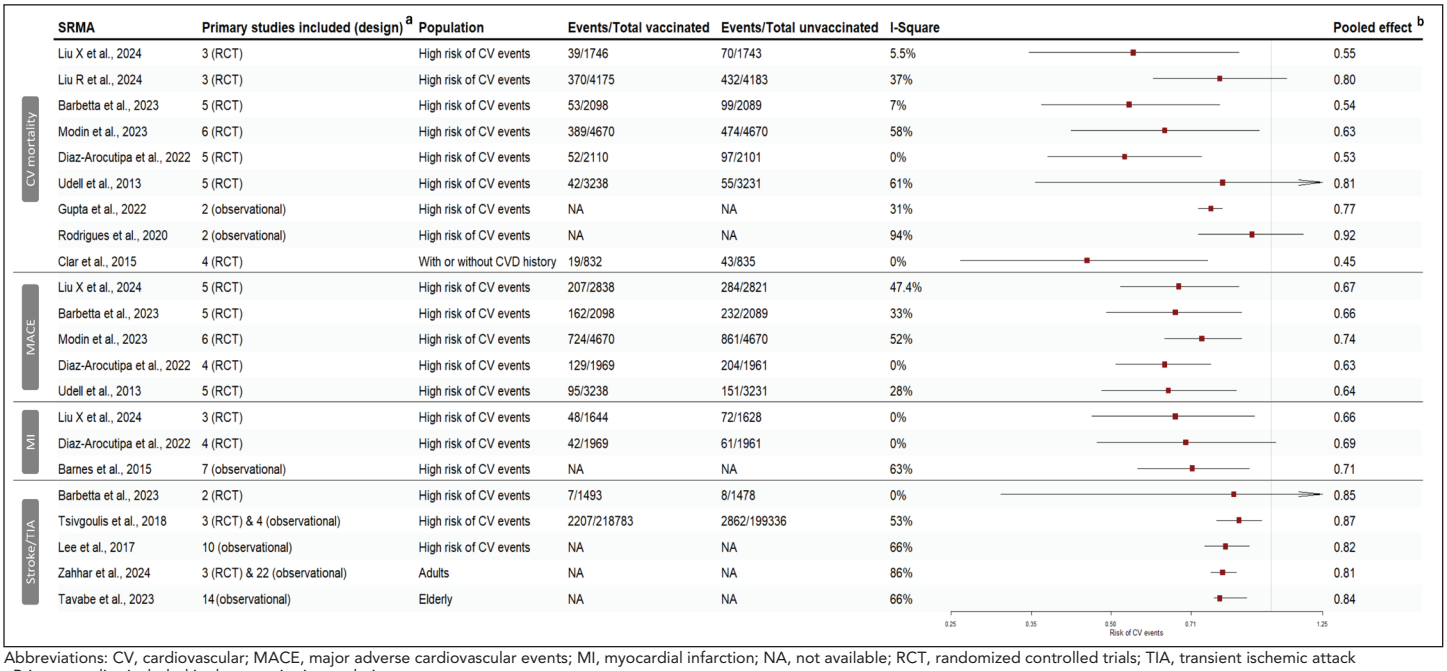
Finally, the overlap between primary studies included in each SRMA was assessed further, and only two SRMA presented a 100% overlap between their primary studies (**Table S2**).

Summary of findings

The umbrella review resulted in the following findings:

- **Cardiovascular mortality:** A total of nine out of 15 (67%) SRMAs assessed CV-related mortality, eight were in patients with underlying CVD or at higher risk of CV events, (22,28,29,34,35,38,40,43), while one consisted of adults with or without CVD history (28). Overall, six SRMAs (67%) showed a significant reduction in CV mortality following influenza vaccination (**Figure 3**) (22,27–29,35,38). In adults with a higher risk of CV events, the risk of death due to a CV event was reduced by 23% (95% CI: 19%–27%) to 47% (95% CI: 26%–62%) in vaccinated individuals compared to those who were not vaccinated. The heterogeneity of these findings was low to moderate, ranging between 0% and 58%. Similarly, pooled data from four RCTs that included adults with or without CVD history showed a 55% (95% CI: 24%–74%) risk reduction in CV mortality, with no heterogeneity (I^2: 0%). Conversely, results were not significant in three SRMAs, with moderate to critical heterogeneity (I^2: 37%–94%) (Figure 3) (34,40,43).
- **Major adverse cardiac events:** MACE is a composite outcome endpoint that generally included: CV death, all-cause mortality, acute coronary syndrome (ACS), MI, hospitalization for a CV event, revascularization, stroke, and HF. Overall, five (33%) SRMAs assessed the effect of influenza vaccination on MACE outcomes in participants with high-risk of CV events. All were SRMAs of RCT, and their overall findings were consistently showing a 26% (95% CI: 12%–51%) to 37% (95% CI: 23%–49%) significant reduction in the risk of MACE in vaccinated individuals. The heterogeneity of these results was low to moderate (I^2: 0%–47%) (Figure 3) (22,28,35,38,43).
- **Myocardial infarction:** The risk of MI following influenza vaccination was assessed in three (20%) SRMAs. Two were SRMAs of RCTs, whereas one included observational studies. Participants were at high-risk of CV events in all SRMAs. Findings showed a significant reduction in the risk of MI in vaccinated individuals, ranging between 29% (95% CI: 9%–44%) to 34% (95% CI: 7%–54%) with no heterogeneity (I^2: 0%) (24,36), whereas another SRMA reported a 31% reduction in MI, although it did not reach statistical significance and had substantial heterogeneity (I^2: 63%) (Figure 3) (28).
- **Stroke:** Stroke and transient ischemic heart attack (TIA) in influenza vaccinated individuals were evaluated in five (33%) SRMAs. Three of these SRMAs involved participants with high-risk for CV events (22,32,42), while two included adults and older adults (41,45). Other than one SRMA that was of RCTs only, the remaining SRMA included observational studies or both RCTs and observational studies. The overall risk reduction in stroke and TIA ranged between 13% (95% CI: 4%–21%) and 19% (95% CI: 14%–23%), and was statistically significant across four SRMAs, with substantial heterogeneity (I^2: 53%–86%) (Figure 3).

Figure 3: Forest plot showing the pooled effect measures from systematic reviews and meta-analyses for the association between influenza vaccination and cardiovascular events[a,b]



Abbreviations: CV, cardiovascular; MACE, major adverse cardiovascular events; MI, myocardial infarction; NA, not available; RCT, randomized controlled trials; TIA, transient ischemic attack

[a] Primary studies included in the quantitative analysis

[b] Odds ratios (ORs), hazard ratios (HRs) and risk ratios (RRs) are plotted on the same graphic. Since cardiovascular events were rare (<10%), all measures tend to be equivalent. This graphic is solely a representation of the effects; no further analysis was conducted

Discussion

This review presents a comprehensive evidence synthesis from multiple published and robust SRMAs that assessed the association between influenza vaccination and CV events. Detailed pooled effect measures were reported for four main CV outcomes: CV mortality, MACE, MI and stroke/TIA. Most SRMAs reported a significant reduction in CV events following influenza vaccination, especially in individuals with underlying CVD, or at higher risk for CV events. Indeed, the risk for CV mortality was up to 47% lower in vaccinated individuals, whereas MACE was reduced by 37% and MI events by 34% compared to unvaccinated individuals. Finally, the risk of stroke/TIA was reduced by up to 19% in vaccinated individuals.

Interpretations

Influenza is well recognized as a trigger for CV outcomes, especially in the first two weeks following infection (8). The risk of CV exacerbation or complications following influenza infection is particularly high in individuals with pre-existing CVD (47). Thus, influenza vaccination stands out as a potentially effective intervention to reduce the burden of CV outcomes, especially among high-risk groups (8,13). Several mechanisms underlie the cardioprotective effects of influenza vaccination. While influenza triggers systemic inflammation, which can exacerbate atherosclerosis and CVD, the vaccine activates the immune system, enhancing overall immune health and preventing secondary infections that could worsen CV conditions. Additionally, it could help stabilize atherosclerotic plaques, thus reducing the risk of acute CV events, according to some earlier findings (39).

Altogether, the available evidence supports recommending annual influenza vaccination for high-risk individuals, particularly those with underlying CVD. This preventive measure can significantly reduce the risk of CV events and improve overall health outcomes in these populations.

However, despite the recommendations for individuals with chronic health conditions in Canada to be vaccinated (14), influenza vaccination coverage remains sub-optimal in these groups. During the 2023–2024 season, only 44.1% of adults aged 18–64 with chronic medical conditions were vaccinated against influenza, whereas the national goals for seasonal influenza in this population were to achieve 80% vaccination coverage (48).

Implications

An effective communication of influenza vaccine-associated benefits against specific outcomes could help foster vaccination (49). A large trial in Denmark titled Nationwide Utilization of Danish Government Electronic Letter System for Increasing Influenza Vaccine Uptake (NUDGE-FLU) investigated the effect of digital behavioural nudges on influenza vaccine uptake among individuals aged 65 years and older, with a focus on CVD status (50). Over 960,000 Danish citizens were randomized to usual care or one of nine electronically delivered letters, designed using behavioural concepts, prior to the 2022–2023 seasonal influenza vaccination period. One of these letters specifically emphasized the potential CV benefits of influenza vaccination. Interestingly, this CV-focused letter had the greatest effect on increasing vaccine uptake. The effect was consistent across individuals with and without CVD, as well as across CVD subgroups. This suggests that emphasizing CV benefits may be an effective strategy to boost vaccination rates, even among those without existing CVD (50).

Thus, clear communication about the potential CV benefits associated with influenza vaccination could help raise awareness and motivation to vaccinate among high-risk groups, who are already targeted for the annual vaccination campaign, about the usefulness of influenza vaccines. Nevertheless, since data on CV benefits are not usually included in studies analyzing the benefits of influenza vaccination and given the recent accumulation of studies on the subject, it would be interesting to consider this type of effect in future cost-effectiveness evaluations of influenza vaccines (13).

Limitations

Despite the strength of this evidence synthesis, this review possesses limitations inherent to included studies. First, the quality and heterogeneity of the included primary studies varied, which may influence the accuracy of pooled estimates. The observed heterogeneity could be attributable to differences in the study populations, CV outcomes definition, duration of follow-up and timing of vaccination. Secondly, many SRMAs included observational studies, which are prone to confounding bias. Finally, although associations were consistent, the causality of the effect cannot be ascertained, and large-scale RCTs are needed to further explore the cardioprotective effects of influenza vaccination.

Conclusion

In conclusion, this umbrella review provides a high-quality evidence synthesis supporting the CV benefits of influenza vaccination. The significant reductions in CV mortality, MACE, and stroke highlight the importance of promoting influenza vaccination, particularly among people with underlying chronic medical conditions, such as CVD. By integrating influenza vaccination into routine clinical practice and public health strategies, CV outcomes can be improved while reducing the burden of both CVD and influenza.

Authors' statement

FT — Conceptualization, data curation, visualization, formal analysis, writing–original draft
NS — Validation, writing–review & editing
WS — Validation, writing–review & editing
PDP — Conceptualization, validation, writing–review & editing
AS — Conceptualization, supervision, validation, writing–review & editing

Competing interests

None.

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Appendix

Supplemental material is available upon request to the author: naci-ccni@phac-aspc.gc.ca

Supplemental A: Search strategy
Table S1: AMSTAR 2 detailed assessment
Table S2: Overlap between primary studies matrix

Minimum data cleaning recommendations for infection prevention and control acute care surveillance reporting: A solution for "garbage in, garbage out"

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Abstract

Background: Outcome surveillance is an important component of infection prevention and control (IPAC) programs to guide healthcare decisions. It is crucial that the reported data are of the highest quality. Reviewing completeness, accuracy and timeliness of the data is important to reduce data inconsistencies. However, many IPAC staff do not have training in data cleaning or data quality activities.

Methods: Expert epidemiologists across Canada have created best practice guidance for data quality activities to provide sufficient detail to improve this important patient safety activity. Most of these activities are simple checks to review the accuracy of the data without requiring additional review of the patient record or linkage to other datasets.

Results: Based on consensus by surveillance experts across jurisdictions, comprehensive recommendations for data quality in IPAC surveillance programs were developed to improve completeness (22%), accuracy (68%), and timeliness (10%) of the data.

Conclusion: The data quality activities list may be used in Canadian IPAC surveillance activities to support or improve existing surveillance data quality activities for IPAC programs.

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Keywords: data quality, data cleaning, IPAC surveillance, completeness, accuracy, timeliness, recommendations

Introduction

Infection prevention and control (IPAC) surveillance programs guide important healthcare decisions, including resource allocation for IPAC programs and developing and evaluating IPAC measures. Surveillance data inform the evaluation of interventions, outbreak detection to prevent further transmission, monitoring of trends for preparedness for both seasonal and emerging infections, and resource allocation including staffing and cleaning protocols. Surveillance data also provides evidence to support guidelines and policies (1). It is crucial that the reported data are of the highest quality, and it is, therefore, important to determine which minimum elements of IPAC data should be reviewed and to identify data quality activities that are consistent across different datasets, institutions, and jurisdictions. Data quality encompasses different domains, but those of completeness, accuracy and timeliness are the most important considerations (2,3). Data are complete when all eligible patients are included as surveillance cases and all variables in the surveillance data entry form are reported. Data are accurate when cases reflect the protocol case definition and when data classification decisions are correct. Data are timely when they are available and disseminated when the results are required (2,3).

The Canadian Nosocomial Infection Surveillance Program (CNISP) is a collaboration between the Association of Medical Microbiology and Infectious Disease Canada (AMMI) and the Public Health Agency of Canada (PHAC) to conduct standardized surveillance of antimicrobial resistance and antimicrobial resistant organisms with Canadian sentinel acute care facilities (1). The CNISP data quality working group consists of Canadian surveillance experts who collectively have a background of infection prevention and control, surveillance, epidemiology and clinical expertise. They are CNISP staff or are representatives of the Canadian surveillance network sites. The group has conducted data quality activities to support CNISP surveillance since 2005.

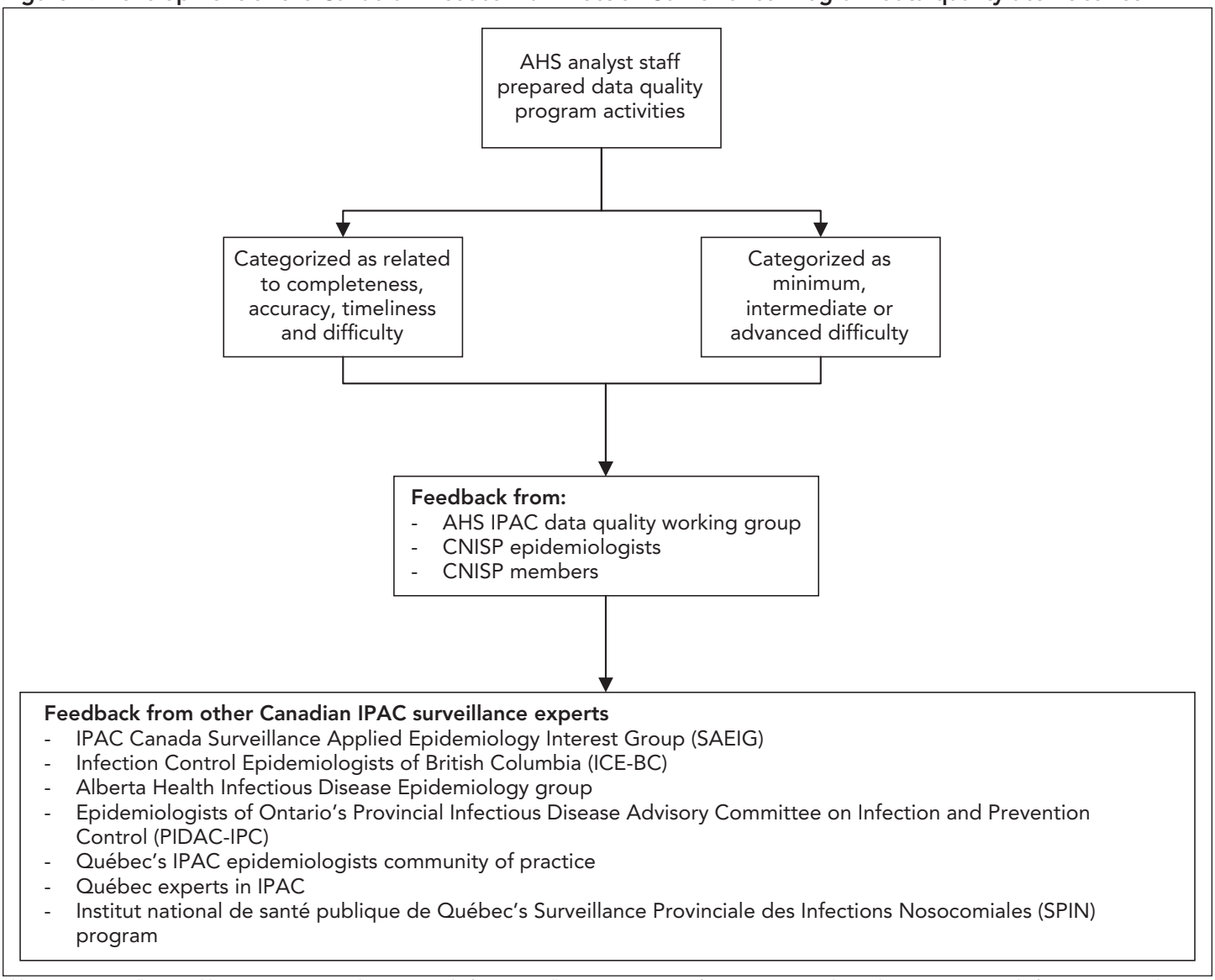
The purpose of this project was to provide data quality activities in sufficient detail to support existing IPAC surveillance data prior to analysis and reporting by Canadian IPAC staff.

Methods

This CNISP project built upon initial work by analysts in the Alberta Health Services (AHS) IPAC program. The list was initially compiled using the data quality activities that the AHS IPAC analysts undertook for data review and validation of each CNISP surveillance initiative, including antimicrobial resistant organisms, *Clostridiodes difficile* infection, and healthcare-acquired infections of surgical sites, bloodstream, and viral respiratory pathogens. The activities focused primarily on those data elements that require the data collector to interpret clinical events or those that are prone to data entry errors (e.g., date fields).

Following that initial development, the CNISP data quality working group refined the list and then sought feedback and endorsement from surveillance experts across Canada (**Figure 1**).

Figure 1: Development of the Canadian Nosocomial Infection Surveillance Program data quality activities list



Abbreviations: AHS, Alberta Health Services; CNISP, Canadian Nosocomial Infection Surveillance Program; IPAC, infection prevention and control; PIDAC-IPC, Provincial Infectious Diseases Advisory Committee on Infection Prevention and Control; SAEIG, Surveillance and Applied Epidemiology Interest Group; SPIN, Surveillance provinciale des infections nosocomiales

The activities were described for both data elements and data processes. A data element is the smallest unit of data, and it represents a case, event or individual (e.g., lab test result, sex at birth, age, etc). A data process refers to the steps involved in collecting, managing and analyzing the data elements, transforming raw data into meaningful information.

The specific data quality activities were categorized as completeness, accuracy, or timeliness, based on the definitions of those data quality domains (2,3). The difficulty level reflected the ability to review the data without additional data sources or without advanced data management skills. Minimum difficulty activities were those requiring data review only without reference to other data sources. Intermediate activities required review of both the data and the patient's record. Advanced difficulty activities required linkages with large administrative data sets (e.g., the Discharge Abstract Database) or those requiring expert physician review.

Results

Once validated, analysis showed the data quality activities were predominantly those involving data accuracy (68%), with fewer items for completeness (22%) and timeliness (10%). Most of the data quality activities were categorized as minimum activities (71%), with four intermediate (13%) and five advanced (16%) activities (**Table 1**).

Table 1: Data quality domains by level of difficulty for the listed data quality activities

Data quality domain	Level of difficulty			
	Minimum[a]	Intermediate[b]	Advanced[c]	Total
Completeness	3	2	2	7 (2%)
Accuracy	17	2	2	21 (68%)
Timeliness	2	0	1	3 (10%)
Total	22 (71%)	4 (13%)	5 (16%)	31

[a] Minimum difficulty activities: those requiring data review only without reference to other data source
[b] Intermediate activities: requiring review of both the data and the patient's record
[c] Advanced difficulty activities: requiring linkages with large administrative data sets (e.g., the Discharge Abstract Database) or those requiring expert physician review

The feedback from the different Canadian epidemiology experts was given in an interview format and changes were updated. Reviewer feedback was positive, with consensus on the proposed list of data quality activities (**Table 2**). For example, one expert noted that they included these activities in their practice but appreciated suggestions for other activities they had not considered. The activities list was then approved by all the groups that were contacted. Other actions resulted from the discussion with the IPAC Canada Surveillance and Applied Epidemiology Interest Group, including their discussions with the IPAC Canada executive, resulting in endorsement from the IPAC Canada board.

Table 2: Canadian Nosocomial Infection Surveillance Program data quality activities list

Data quality domain	Data element, data process	Level of difficulty	Process	Additional information/ activity/action
Completeness – all eligible cases are included; all data variables are reported.	Patient name, gender, healthcare identification number(s)	Minimum	Verify data entry correctness against the source of truth (clinical record).	Have options built in for linking to additional names for same person.
	Missing data in variables	Minimum	Review clinical system for data entry completeness.	Consider data validation rules within the surveillance system for mandatory data entry elements. Periodic review of missing data elements to consider whether data should continue to be collected (e.g., risk factors for carbapenemase-producing organisms (CPO) or viral respiratory infection (VRI) acquisition). Provide a report to surveillance leaders on low response data variables.
	Missing cases	Advanced	Confirm all positive, eligible specimens are considered for surveillance.	Confirm that all blood cultures taken in pre-admission (including emergency) where patients are direct transfer to inpatient care, are included since blood cultures may not be collected again during the inpatient's admission. Consider review of laboratory data to confirm all surveillance cases were captured. Consider review of surgical procedure denominator data to confirm all included patients meet surveillance eligibility.

Table 2: Canadian Nosocomial Infection Surveillance Program data quality activities list (*continued*)

Data quality domain	Data element, data process	Level of difficulty	Process	Additional information/ activity/action
Completeness – all eligible cases are included; all data variables are reported. (*continued*)	Entry of outcome variables (e.g., attributable death, attributable ICU admission, attributable colectomy, other attributable adverse events)	Advanced	These adverse events are followed for 30 days after surveillance event. To ensure complete case capture, data linkages can be performed with administrative discharge data to confirm that all patients with an eligible adverse event were captured.	Discharge abstract data (DAD) contain information on discharge reason, diagnosis and unit (ICU) admission. Admission, discharge, transfer (ADT) data contain information on all patient movements during an admission.
	Denominator and numerator linkages	Intermediate	Case included which is not present in denominator.	Analyst review, then record deletion.
	"Complete" records	Minimum	After data quality checks are completed, note that the record is finalized and allow no further edits unless documented.	"Completed" records can be removed from routine data extracts for cleaning/review purposes.
Accuracy – case meets the surveillance definition; classification decisions are correct.	Duplicates	Minimum	Check for duplicate patient names and records.	Delete duplicates, allow one surveillance case per protocol period.
	Surveillance cases meet protocol case definitions and eligibility criteria (synonyms: incident case, first infection case, surveillance case)	Minimum	Check for admission to acute care site at time of detection.	Create protocol interpretation decisions for emergency inpatients, pre-admission assessments, urgent care with direct transfer to acute care.
	Case classification decision	Minimum	Check the time from admission to culture date.	Calculate "time between" to confirm classification decision with protocol (e.g., community- vs. healthcare-acquired) or case eligibility.
	Infection onset	Minimum	Check that the infection onset date meets surveillance case definition.	Use gold standard infection definitions for comparability to other surveillance systems (e.g., CNISP, National Healthcare Surveillance Network [NHSN]) for infection decisions and bloodstream and surgical site infections surveillance. Review clinical record for agreement with infection control professional (ICP) decision.
	Time from admission to culture date	Minimum	For central-line associated bloodstream infection (CLABSI) surveillance, was the central line in place for minimum time before culture positive?	Calculate "time between" for insertion date to culture date and for date of admission to ICU to culture date to determine if case meets protocol definitions.
	Valid surveillance case for multiple data entries	Minimum	Check the time between surveillance cases for healthcare-acquired infections (4).	Confirm the new case with protocol definitions (4).
	Date of birth matches date of hospital admission	Minimum	Indicates data entry error for adults.	Edit record to correct errors. Note: may be correct for newborns.
	Date of birth matches lab collection date	Minimum	Indicates data entry error.	Note: may be correct for newborns.
	Date of birth matches date of infection onset	Minimum	Indicates data entry error.	Note: may be correct for newborns.
	Date of hospital admission matches date of lab collection	Minimum	Confirm if hospital-acquired infection.	Confirm timeframe of case classification definition.
	Date of infection matches date of procedure	Minimum	For surgical site infection surveillance.	An SSI case cannot occur on the same day as the first surgical procedure.
	Formatting errors in date fields	Minimum	Data entry error, e.g., month/year.	Use yyyy/mmm/dd date format.

Table 2: Canadian Nosocomial Infection Surveillance Program data quality activities list (*continued*)

Data quality domain	Data element, data process	Level of difficulty	Process	Additional information/ activity/action
Accuracy – case meets the surveillance definition; classification decisions are correct. (*continued*)	Organism name (CPO, BSI, CLABSI, SSI, VRI)	Minimum	Confirm and correct pathogen names and distinguish between different strains of the same pathogen, determine case eligibility for common commensals and handle data related to multiple pathogens within a single case.	Compare data to clinical health record and lab data source. Use NHSN "common commensal" table as gold standard.
	Culture site for ARO surveillance	Minimum	Confirm if clinical specimen site is entered.	If surveillance definition requires an infection to be present, antimicrobial resistant organism screening sites (e.g., nasal screening specimens) are not allowed for surveillance cases.
	"other" responses	Minimum	Confirm that "other" is not selected if the valid response is included in a checklist/pull-down menu.	Review all free text entries to minimize use.
	Formatting errors in text data variables	Minimum	Examples: hyphens included/not included in accession numbers, variability in site or unit name (acronym, spelling errors).	Review data quality to system standard. Consider drop-down fields in data entry system for consistency.
	Valid date of death	Minimum	Do not include deaths beyond protocol timeframe.	Most protocols ask for outcome at 30 days after surveillance record date. Do not include deaths or other outcomes greater than 30 days.
	Lab data: multiple specimens collected	Intermediate	Review lab and/or surveillance records compared to the clinical record: if multiple specimens were collected from different locations, inpatient positive specimens are selected as described by the patient population of each protocol.	Create additional data entry guidance for users to allow future lab data linkages for case-finding purposes for example, if the specimens have similar levels of clinical relevance (e.g., urine and wound), the specimen collected first is selected. If there are multiple accession numbers for the same microbe from multiple specimen sites, the more clinically relevant specimen is selected. If there are multiple specimens collected at the same time, the specimen reported first is selected.
	Encounter information: facility, unit, service, bed	Intermediate	Surveillance case is entered for where case is attributed rather than where case is detected.	Review clinical record, consider standard process for entering cases where patients have had multiple transfers (i.e., last unit patient was on vs. unit where patient was on at time of lab collection).
	Infection/colonization decision	Intermediate	Send back cases to the data collectors for re-review, to confirm the NHSN infection decision.	Periodic data quality activity: especially for cases with sputum, wound and urine specimens, which have higher likelihood of organism colonization.
	Symptom fields for VRI surveillance	Intermediate	Review virus name and associated symptoms to determine surveillance case eligibility.	Pathogen can determine which symptoms are considered as surveillance case.
	Vaccination status	Advanced	Cannot indicate COVID-19 or other vaccinations prior to vaccine availability.	Need to track different vaccine availability dates and indication in each province.
Timely – surveillance data are provided at the time the data are needed.	Time from lab to data entry	Minimum	Consider data entry timeline expectations to provide timely data, e.g., data entered within 5 days of positive culture date.	Time between data entry date and culture date – provide feedback to ICPs and leaders, work to create efficiencies to allow prompt surveillance data entry.
	Time for review	Minimum	Determine data quality activity frequencies.	Review each type of data quality check with reporting timelines to determine the frequency or schedule of required data cleaning (daily, weekly, monthly).
	Time to reporting	Minimum	Determine frequency of reporting (daily, weekly, monthly, quarterly, annually).	Create data quality activities and timelines to accommodate data reporting frequency, including time for review with ICPs.

Table 2: Canadian Nosocomial Infection Surveillance Program data quality activities list (*continued*)

Data quality domain	Data element, data process	Level of difficulty	Process	Additional information/ activity/action
Timely – surveillance data are provided at the time the data are needed. (*continued*)	Denominators for reporting	Advanced	Determine frequency of preliminary and final rate reporting.	Consider denominator data source and ability for timely case finding process to match stakeholder needs and data availability. Includes: patient-days, admissions, line-days, surgical procedures.

Abbreviations: ADT, admission, discharge, transfer; ARO, antibiotic-resistant organism; BSI, bloodstream infection; CLABSI, central-line associated bloodstream infection; CNISP, Canadian Nosocomial Infection Surveillance Program; CPO, carbapenemase-producing organisms; DAD, discharge abstract data; ICP, infection control professional; ICU, intensive care unit; NHSN, National Healthcare Surveillance Network; SSI, surgical site infection; VRI, viral respiratory infection

Discussion

The purpose of this project was to provide data quality activities in sufficient detail to support existing IPAC surveillance data prior to analysis and reporting by Canadian IPAC staff. As far as we are aware, this is the first detailed list of data quality activities for staff reporting IPAC surveillance results in Canada. The collaboration between Canadian IPAC surveillance experts has been important in validating these data quality activities and sharing them with IPAC programs across the country. Other programs have recommended data quality activities, including the Centers for Disease Control National Healthcare Surveillance Safety Network (NHSN), the Canadian Institute for Health Information (CIHI), and the Australian Commission on Safety and Quality in Health Care (ACSQHC) (3,5–7). These experts recommend creating an overall surveillance plan to understand data sources, data validation (including administrative and laboratory data linkages to validate case-finding), and other system-level checks, but with the exception of the Australian resource, do not offer specifics.

Performing IPAC outcome surveillance is a primary accountability of any IPAC program that considers due diligence in creating complete, accurate and timely data to be an important requirement prior to reporting results. A recent publication estimated that 45% of an infection control professional's time is directed towards surveillance activities and that manual systems may have an accuracy of only 62.5% (range: 16%–87%) (8). Based on this sub-optimal reported data accuracy, we aimed to develop a list to help improve the data quality of IPAC surveillance data. Although the CNISP data quality activities list is designed for CNISP surveillance, its value is that any IPAC staff member who is collecting and reporting surveillance data can use the suggested activities to improve their program's surveillance data quality.

Although this list offers data checks for completeness, fields that are difficult to collect and are often not reported should be routinely reviewed to determine their usefulness in surveillance reporting. Identifying required data elements and reviewing incomplete data submissions can often guide data entry towards the essential data required for reporting. A minimum basic data entry set is typically created from expert consensus for the required data items that are essential for reporting, to reduce the burden of data collection and improve the quality of the data submissions (9). Advanced quality activities involve using other sources of data to confirm that case finding is equivalent across the surveillance system and that all potential cases are reviewed, even if missed by the original data collector.

Accurate data begins with education and supports to the data collectors regarding the protocol's case definitions and inclusion/exclusion criteria. To evaluate the application of CNISP protocol definitions among hospitals reporting data for CNISP surveillance, the data quality working group has conducted several studies. These results show a correct response rate of 88% for bloodstream infection surveillance (10), 79% for COVID-19 surveillance (11), and 78% for *Clostridiodes difficile* infection surveillance (unpublished). Anecdotal reports have indicated that sites continue to use the survey questions when providing orientation for new staff to have discussions on correct CNISP protocol interpretation.

In the timeliness domain, there is a need for each reviewer to create a surveillance reporting schedule, so that expectations for data quality frequency checks and data entry timeliness can be set. Additional audits can be scheduled to spot-check the data quality by another reviewer as a quality control step.

The CIHI provides two additional data quality domains: relevance (the data meets the users' current and potential needs) and accessibility (the surveillance results are easily accessed and clearly presented in a way that is understood) (5). These are also important domains that allow for clinical partners to understand and use the data. Discussions with clinical partners can confirm that both the infections under surveillance and the data presented are actionable, as well as endorse the surveillance definitions to capture clinically relevant cases.

For generalizability, the CNISP data quality activities list is designed for different levels of checks. Minimum checks, which any IPAC staff member can perform, include 71% (22/31) of the total activities, of which 77% (17/22) are accuracy checks. This provides flexibility in performing data quality checks to accommodate surveillance systems that are not resourced to perform intermediate or advanced level checks. One reviewer comment recognized the usefulness of IPAC surveillance

analysts to support the epidemiologist in performing data quality activities, and these best practice activities can provide a business case rationale for analyst positions.

Limitations

Any metrics of local data improvement with the use of these data quality activities relies on the state of the original reported data. Some sites may have other interventions in place—such as ongoing education initiatives to help the data collectors with more accurate protocol interpretation—which would affect that site's overall data improvement. However, the fundamental "garbage in, garbage out" rule of data integrity applies to all data. The IPAC surveillance data have the advantage of being generated by the infection control professionals as primary data collectors, and therefore have the advantage over administrative data in the ability to improve the overall quality of the data and in avoiding the issues with administrative data, such as misleading conclusions because of the overall data inaccuracy (12).

Future plans for this work include dissemination of the data quality activities list and implementation of training in the CNISP network and for IPAC Canada surveillance data collectors. An evaluation of the usefulness, relevance, completeness and effectiveness of the list will follow once it has been in use for a few years, with a future version to include any suggestions for improvement.

Conclusion

The outlined data quality activities provide a list that establishes a standard set of data quality activities to ensure complete, accurate and timely reporting of IPAC surveillance data. The activities have been reviewed by IPAC surveillance experts across Canada and validated by the AHS IPAC program, and may be used to support or improve existing surveillance data quality activities in IPAC departments. Routine application of the CNISP data quality activities list may be used to support or improve existing surveillance data quality activities in IPAC departments and increase the confidence of the users of the surveillance results.

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The innovative and purpose-built veterinary antimicrobials sales reporting system

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Abstract

Background: Antimicrobial resistance (AMR) is one of the major public health threats of our time. Human activities across the One Health spectrum, such as the misuse and overuse of antimicrobials, can accelerate the resistance threat. A variety of antimicrobials used in veterinary medicine are also important in human medicine. As part of Canada's commitment to address AMR and antimicrobial use (AMU), and to align with international best practices aimed to minimize the impacts of AMR and preserve the effectiveness of existing antimicrobials, regulatory controls and enhanced surveillance initiatives have been implemented in veterinary medicine and animal health to improve intelligence on the quantities of antimicrobials available for use in animals. These efforts include the implementation of the national Veterinary Antimicrobial Sales Reporting (VASR) system in Canada, in 2018. The focus of this article is to describe the VASR data collection system and platform.

Methods: A custom-built data collection and analytical system was developed to enhance understanding of the volume of antimicrobials available for use in animals and contribute to the broader surveillance of trends in AMU and AMR in an effort to support stewardship. Partners from Health Canada's Veterinary Drugs Directorate, the Public Health Agency of Canada's Centre for Food-borne, Environmental and Zoonotic Infectious Diseases, and the Canadian Network for Public Health Intelligence worked together to envision, develop, and implement the national-scale, purpose-built technological intervention, the VASR system.

Results: The VASR surveillance system provides a robust data collection and analytical informatics platform to improve intelligence on antimicrobial sales available for veterinary use in Canada.

Conclusion: An innovative, purpose-built national antimicrobial sales reporting system was developed. This web-based platform is effective for data submission by the participants and facilitates analysis to provide a comprehensive picture of medically important antimicrobials available for use in animals in Canada, thereby supporting AMR and AMU surveillance and stewardship.

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Introduction

The World Health Organization (WHO) continues to stress the need for action, characterizing antimicrobial resistance (AMR) as one of the most pressing public health and development threats of our time (1). Antimicrobials include antibiotics, antibacterials, antivirals, and antifungals used to treat infectious diseases in humans, animals and plants/crops. Antimicrobial resistance occurs naturally over time as microbes adapt and become resistant to antimicrobials to which they were exposed. While AMR makes diseases more difficult to treat, it can also increase the risks of disease transmission and severe outcomes (2). Anytime antimicrobials are used, resistance can develop and spread, and the overuse and misuse of antimicrobials is a key driver of this process (3).

To address the complex challenge posed by AMR, the WHO has advocated since 2005 that actions are required within the areas of human health, food production, animal and environmental health, and that such efforts need to be coordinated both within national action plans as well as internationally, through a global One Health strategy (3). In 2014, various countries, including Canada, endorsed a World Health Assembly resolution committing to the development of national action plans and international coordination of efforts to counter the risks posed by AMR (4). In 2015, the World Organisation for Animal Health (WOAH)—formerly the Office International des Epizooties (OIE)—began collecting data on antimicrobials intended for use in animals, as part of the global response to AMR. In 2023, the Pan-Canadian Action Plan on AMR established a five-year (2023–2027) blueprint to coordinate and accelerate the national response to address AMR and antimicrobial use (AMU) (5).

In the spring of 2015, the Office of the Auditor General of Canada published a report on AMR, which identified that more work was needed to advance the national strategy and improve surveillance (6). This included the need for further actions in support of the prudent use of antimicrobials. Regulatory gaps were identified with respect to the oversight of veterinary drugs, including antimicrobial drugs of importance in human medicine (6). In response, Health Canada implemented a number of regulatory and policy changes in 2017 and 2018, and addressed a number of regulatory gaps to improve oversight and strengthen the responsible use of antimicrobials in animals. These regulatory changes included new rules for importation and quality of active pharmaceutical ingredients for veterinary use, restrictions on personal importation of drugs for food–producing animals, and the introduction of a new pathway for veterinary health products. The changes to the Food and Drug Regulations also established the mandatory requirement for antimicrobial sales reporting (7). Any antimicrobial drugs included in Health Canada's List A (certain antimicrobial active pharmaceutical ingredients that are important in human medicine) (8), intended for use in animals, are subject to annual sales reporting. These regulations also require data providers to estimate their sales of medically important antimicrobials by different animal species groups.

The focus of this paper is to recount the collaborative work leading to the creation of the innovative Veterinary Antimicrobial Sales Reporting (VASR) system, an adaptable data collection and analytical informatics solution designed and purpose-built by the Canadian Network for Public Health Intelligence (CNPHI) team at the Public Health Agency of Canada (PHAC), in collaboration with program experts.

Methods

Development of the Veterinary Antimicrobial Sales Reporting platform

Between 2005 and 2018, the Canadian Animal Health Institute (CAHI), a trade organization representing the animal health market in Canada (9), voluntarily provided data on the quantities of antimicrobials distributed for sale in animals from their members to PHAC's Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) (10). Each year, CAHI members covered 90%–95% of the animal health market, with the data stratified by province/territory and animal type (i.e., either production or companion animals). With the regulations coming into effect in November 2017, a commitment was set to establish 2018 as the first year for mandatory reporting of medically important veterinary antimicrobial sales from those who manufacture, import or compound, with the deliverable to be accomplished and data reports submitted by March 31, 2019.

Building on the voluntary data and data structure provided by CAHI, CIPARS worked with counterparts in the European Union (European Medicines Agency) (11) and the United States (Food and Drug Administration) (12) to review their data collection and management tools (including lessons learned) for sales data. Informal consultations were also held with counterparts in Japan. CIPARS also gained experience from participating in the development of WOAH's global database on antimicrobial agents intended for use in animals (13), which later became the ANImal antiMicrobial USE (ANIMUSE) global database (14). However, no tools were developed to collect data across more than ten different animal species while incorporating regional stratification. Hence, the VASR system needed to provide a modified and novel approach.

The objective of the initiative was to conceptualize, design, develop, test and launch a robust data collection and analytical informatics solution to enable a national-scale surveillance capability, yielding improved intelligence on antimicrobial sales for veterinary use in Canada. Partners from Health Canada's Veterinary Drugs Directorate (VDD) and the Food-borne Disease and Antimicrobial Resistance Surveillance Division (FDASD) at PHAC met with CNPHI for the first time in December 2016. Numerous planning and design meetings followed throughout 2017 to focus on the functionality and effectiveness of a data collection and analysis system. In keeping with their philosophy of working closely with public health program partners to fully understand their needs and vision, CNPHI worked with program experts to conceptualize the interoperable components that would comprise the VASR system. This would require versatility to accommodate the nuances and detailed complexities of the data and the required preliminary analyses. As a result, the VASR system was purpose-built to consist of a suite of interoperable systems within a single platform to achieve the required outcomes. The VASR platform components include:

- **Participant management:** Functionality is required to securely manage the private access of numerous data providers and categorize their roles as manufacturers, importers or compounders, as well as their contact and notification details. Over time, this component is designed to enable participant-specific summary reports, fully characterizing the products and formulations of veterinary antimicrobial products sold.
- **A user reporting portal:** The reporting portal provides a secure and easy-to-use means for data providers to submit reports directly into the VASR system.
- **Code management:** This customized component is required for managing hierarchical classifications of veterinary medicines using the international Anatomical Therapeutic Chemical classification system for veterinary medicinal products (ATCvet) (5th level), which facilitates the exchange and comparison of data on veterinary drug use at international and national levels. The code management functionality offers adaptability to accommodate periodic changes in substance naming and coding standards (15).
- **Product management and unit management:** An agile functionality is designed for managing and categorizing products, capturing drug identification numbers (DINs), product names, active ingredients, drug class, categories based on importance in human medicine, and product use (e.g., preventive, therapeutic), and providing the capability to link products to the ATCvet coding system. Furthermore, the system is pre-populated with information on over 400 Health Canada authorized veterinary antimicrobial products (that have DINs), streamlining the ease of sales reporting by participants.

Product formulations can vary widely, impacting how participants report sales. For example, formulations may include powders, tablets or vials, and quantities may be expressed in varying units, such as the number of packages, bulk mass or volume. As a result, the system offers tools to convert results to be consistently presented in kilograms sold.

In addition, some products reported may be prodrugs. A prodrug acts as a precursor (parent compound), which in turn undergoes a metabolic transformation once administered into the body of the animal, resulting in the presence of the active ingredient (16). Participants report the quantity of prodrugs sold in terms of the quantity of parent compound, which requires the application of a prodrug conversion factor to accurately reflect the quantity of active ingredient reported (17).

The practice of compounding also introduces complexities in data collection, reporting, and analysis. A compounded drug can be defined as an approved drug that has been manipulated to achieve a dosage, form or concentration other than that specified on the label; the combining of two or more drugs; a dilution of a drug other than that prescribed on the label; or the creation of a mixture to be administered by a different route. Compounding is an acceptable practice in veterinary medicine when no authorized product or formulation is available, typically carried out by a pharmacist or veterinarian (18) to fulfill an unmet need for a client. However, this practice bypasses federal pre–market authorization and safety reviews.

The main goal of the product management component is to consistently support surveillance of how much product is sold by product type, unit/size, DIN, formulation, an estimate of the product sales by animal/animal species group, distribution of package sales by province/territory, active ingredients, and total kilograms sold nationally and by province/territory. Animal species are specified to the categories of aquaculture, cattle (beef), cattle (dairy), cattle (veal), chickens, companion animals, horses, pigs, small ruminants, turkeys, and "others". While reporting of estimated antimicrobial sales by animal species is mandatory as per regulatory requirements, the information on provincial/territorial distribution is encouraged by the VASR administrator (i.e., VDD), in an effort to obtain relevant and robust information from the data providers. This includes:

- **Notification management and reporting compliance:** The secure notification management component facilitates the management of participant notifications and reporting reminders to assist the program in overseeing reporting compliance and validation.
- **Data collection:** To adequately support VASR's objectives, a custom-designed system for data flow is required. The data collection system enables the capture of details on each product sold, providing the capability to delineate sales by attributes of analytical and importance to human medicine. Data collection is initiated in conjunction with the notification system, whereby participants are made aware that reporting is due and are provided with a secure, dedicated link to access the online reporting. For ease of use, the system allows participants to save their data collection forms as drafts until finalized for submission. The flexibility and adaptability of the data collection system is key, as this allows participants to report sales according to their particular method of product packaging and labelling.
- **Review and validation of data submissions:** In the event that errors are detected during the program's review process, a resubmission capability is integrated within the process, leveraging the notification system to prompt participants to review and correct a submission, when required. For overdue reports, a built–in 'days overdue' indicator assists VDD program staff in identifying overdue reports and initiating reminders or communicating other required compliance actions to participants through the notification system. A customized aberration detection system is designed to flag potential anomalies in the data submitted for each product within a given submission, using historical data, supporting proactive validation and quality assurance.

- **Analytics:** Purpose-built analytical tools are designed to yield optimal intelligence from the collected data, providing readily available preliminary charts, trends and visualizations. From an interactive dashboard, the statuses of incoming reports are summarized to facilitate the ongoing tracking of submissions from participants, flagging reports as draft, submitted, accepted, and completed. It also flags reports containing potential errors and those noting no data to report. Reports are categorized according to their source, originating from manufacturers, importers and compounders, as well as the year the reports were submitted and their status.

As data on veterinary drug sales accumulates, the analytical features provide the capability to produce preliminary visual trends, insights and comparisons over time, including:

- Total drug sales reported, delineated by drug class, nationally or by province/territory, with estimates of percentages of totals by animal species/animal species groups
- Sales of antimicrobials delineated by their importance in human medicine, drug use purposes (e.g., treatment, prevention), antimicrobial classification, animal species and route of administration
- Visualization of annual percentage changes in the use of medically important drugs by antimicrobial classification
- Product summaries describing product names, company names, active ingredients, DINs and species
- Various unit conversion tools to support consistent surveillance results in kilograms sold from reported quantities of prodrugs and compounded drugs, as well as reports using varied product strengths or number of packages sold

The system also provides insights and resources to support the application of ATCvet groups and codes, and to fully describe products according to their related active ingredients, DINs, product name, category, company, and species.

Results

As the major outcome, the web-based VASR system was successfully developed and launched, with the first collection of veterinary antimicrobial sales data in the system for the year 2018. While voluntary reporting had been supported in previous years by CAHI, the newly established system provides innovations that resulted in various improvements in the sales reporting for this first year of mandatory collection (19). The VASR participants (i.e., data providers from manufacturers, importers and compounders) can enter and save the required product-by-product information in the system before submitting their final reports. For each participant, a sales summary report is generated, containing all required information, enabling the timely review of reported product information by VASR administrators to identify any missing or incorrect information. When issues are identified, participants are contacted to verify or correct submitted information. This timely review of submissions and communication between the VASR administrators and participants plays a key role in ensuring the data quality.

Since data reporting became mandatory, more data providers have participated in comparison to previous years of voluntary reporting by CAHI members, including sales data per animal species/groups and data from importers and compounders. New data were collected on sales in the territories, resulting in more nationally comprehensive data (20).

As the VASR system is a custom-built reporting interface through the CNPHI platform, updates can be made to the interactive forms based on user-experience and feedback to optimize data entry for providers and enhance reporting completeness and accuracy. Following each reporting year, the adaptability of the system allows for improvements that increase the ease of use for participants by supporting the ability to update and revise the previous year's submission, save draft reports in progress, and to submit a 'no sales to declare' response when applicable. Overall, the functionality of the system has improved over the last seven years, based on the experience from VASR participants and administrators.

As familiarity with the system has grown, voluntary reporting of sales by animal species at the provincial/territorial level has increased. Improvements in reporting of sales for minor species (e.g., small ruminants or "other species") have also been noted. Comparisons of reported sales for use in aquaculture with use data from aquaculture operations mandatorily reported to Fisheries and Oceans Canada (21) show very similar results between the two information sources, highlighting sales as a reliable indicator for use.

To date, annual sales reporting through the VASR system has been completed for six years (2018–2023), and reporting for the seventh year (2024) is currently underway. These data collection, analysis and reporting capabilities have achieved program objectives, resulting in the timely release of the data to the public via an interactive visualization (22).

Discussion

The VASR system provides an innovative, purpose-built platform with functional versatility. The system enables effective reporting of antimicrobials sales for veterinary use from the participants while also supporting the timely validation of submissions and data quality by VASR administrators, with the flexibility to modify components of the data capture system based on real-word experience and user feedback. Despite the complexity of the data, annual data collection, analysis and public reporting can be completed within months (22).

Overlapping reporting of antimicrobial sales in 2018 during the transition from data collection through CAHI and VASR provided an opportunity to compare the coverage between the two datasets. The quantity of sales (in kilograms) reported through VASR by manufacturers and importers in 2018 were 1.12 times higher than those reported through CAHI (by CAHI member manufacturers only) that same year. This reflects the importance of both the regulatory changes (mandatory data reporting) and the VASR system in achieving data capture beyond that achieved voluntarily through CAHI. To examine trends in antimicrobial sales over time for periods before 2018, the CAHI data were multiplied by 1.12 to adjust for the difference in coverage between the two sources of data, which enabled the historical comparison of decades-long veterinary antimicrobial sales data in Canada.

The creation of the VASR system not only allowed participants to fulfill the regulatory requirement of reporting sales information, it also helps governmental program staff to monitor the patterns of antimicrobials intended for use in animals in Canada. The latter are further analyzed by CIPARS in conjunction with the findings from ongoing active and passive surveillance of AMR and AMU in food animals and their derived food products (23). Together, these complementary aspects are essential for integrated surveillance under the One Health spectrum.

The system allows for, and encourages, the optional reporting of provincial/territorial sales distribution information. Given the importance of sales distribution across provinces and territories, the VASR administrators and participants have made efforts to work together to report provincial and territorial sales data as evident in recent sales reporting (22), which was largely attributed to the user-friendly functionality of the system and allowed for streamlined communications.

The easily produced and readily available extracts of VASR data in a csv format have facilitated deeper data validation processes and analytics using other software, activities that are beyond the scope of traditional database analytics and which require veterinary and epidemiological expertise. The resulting data have been presented in the annual CIPARS stakeholder meeting held every November during World Antimicrobial Resistance Awareness Week. The data are also summarized through VASR highlights reports. There are currently six published reports, and the data are available publicly via interactive data (22). Importantly, data from VASR have been provided annually as Canada's submission to the ANIMUSE database on antimicrobial agents intended for use in animals (14,17).

Limitations

There are limitations due to challenges with accurate provincial-level species reporting, as all data providers may not have these details available. This can lead to potential gaps and an incomplete picture of sales trends by species at the provincial level. These data are often requested by stakeholders. To ensure the data are as complete as possible, the VASR administrators regularly engage with the data providers to encourage the submission of this information as best estimates, in order to enhance data quality and species-level insights to inform targeted AMR and AMU stewardship and surveillance. While the completeness of the provincial-level species data may vary between species, in 2023, 92% of the total antimicrobial sales reported nationally at the species level were also reported provincially (an increase from 25% in 2018).

In addition, the VASR system relies on annual submissions from data providers across Canada. Despite the reporting requirement, compliance challenges remain in ensuring comprehensive awareness of the duty to report sales, especially among individuals and companies compounding the implicated products. To address this, concerted efforts are made via targeted emails, bulletins, and postings to inform all potential data providers and provincial authorities about VASR, its significance, and the annual reporting obligation, encouraging good compliance year to year.

Conclusion

The VASR system is an efficient, highly functional and sustainable system. Its design-for-purpose helps facilitate validation and deeper analysis of the data by Health Canada and PHAC analysts and veterinary epidemiologists. Experience gained from the last six years of annual reporting will help to further enhance the functionality of the system. The information generated from the system is indispensable in achieving an enhanced understanding of antimicrobial sales patterns and trends, and to support antimicrobial stewardship and further surveillance.

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RAPID COMMUNICATION

First reported Canadian case of *Trichophyton mentagrophytes* genotype VII infection among men who have sex with men (MSM)

Tatiana Lapa[1]*, Anna Banerji[2], Julianne Kus[3,4], Kendall Billick[1]

Abstract

Over the past 20 years, *Trichophyton mentagrophytes* (*T. mentagrophytes*) infections affecting the genital and pubic regions, with suspected sexual transmission, have been increasingly reported in South Asia and Europe. The first case in the United States was reported in 2024. We describe the first confirmed case of *T. mentagrophytes* genotype VII infection causing Majocchi granuloma in a Canadian male who had recently travelled to Mexico, with suspected sexual transmission. Raising awareness among healthcare professionals is critical for early diagnosis and preventing long-term sequelae. Tinea corporis presenting with deep lesions in the pubogenital region and not responding to topical medications should prompt consideration of sexually transmitted fungal infection and extended testing including molecular identification by DNA sequencing of fungal cultures.

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Keywords: *Trichophyton mentagrophytes* genotype VII, tinea genitalis, sexually transmitted infection

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Introduction

Trichophyton mentagrophytes is a zoophilic dermatophyte, a fungal organism that primarily infects animals but can occasionally infect humans, causing superficial fungal infections of the skin and its appendages. *Trichophyton mentagrophytes* genotype VII (TMVII) is a recently identified genotype, strongly associated with sexual transmission, particularly among men who have sex with men (MSM). Cases have been reported from Europe, South Asia, Australia, Africa and the United States (US) (1–14). Comparative analyses of cases from these regions (**Table 1**) suggest a predominance of pubogenital tinea presentations among MSM, often associated with international travel or sexual transmission. A related species called *T. indotineae* (formerly known as *T. mentagrophytes* type VIII) is known to be circulating in Canada (15,16), but this is the first report, of TMVII. Notably, fungal sexually transmitted infections (STIs), including TMVII, are not currently reportable to public health and are absent from the Public Health Agency of Canada's *Sexually transmitted blood-borne infections: Guides for health professionals* (17). This gap highlights the need for awareness and further research into their prevalence, transmission dynamics, and public health impact.

Current situation

A Canadian male in his 30s presented to the emergency room in May 2025 with a two-month history of a pruritic and progressive rash involving his arms and inguinal region (**Figure 1**). The rash began at the end of March, two weeks after returning from a two-week trip to an all-inclusive resort in Puerto Vallarta, Mexico. He was distressed because he had seen multiple doctors; his symptoms and rash persisted despite clotrimazole, betamethasone dipropionate as well as several topical and systemic antibacterials. Referrals to the departments of infectious diseases and dermatology were requested. Although he initially denied new sexual partners, he later reported sex with two other male partners while in Mexico. There was no significant environmental exposure or animal contact. The department of infectious diseases considered tinea, including tinea incognito due to prior topical steroids, secondary bacterial infection and psoriasis. Skin scraping revealed fungal elements but the culture was negative. The department of dermatology diagnosed Majocchi granuloma given numerous, coalescing, bright red, subcutaneous nodules and non-fluctuant papules in the inguinopubic region. Two biopsies were obtained: the one

Table 1: Global cases of dermatophytosis involving *Trichophyton mentagrophytes*, 2001–2024

Country/ region	Year of reports	Population affected	Place of possible infection	Mode of transmission	Clinical features	Reference
Spain	2001	Female commercial sex worker	Spain	Sexual transmission	Tinea cruris	Otero *et al.*
Nigeria	2002	Female sex worker	Nigeria	Sexual transmission	Tinea genitalis	Bakare *et al.*
Germany	2001	Female	Germany	Contact with infected ferret	Tinea corporis, Tinea genitalis	Beckheinrich *et al.*
Seoul, South Korea	2005	Female	South Korea	Contact with infected dog	Majocchi granuloma	Chang *et al.*
Denmark	2009	Heterosexual couple	Spain	Sexual transmission	Tinea gladiatorum, Tinea genitalis	Molenberg *et al.*
Switzerland, Zurich	2014	Heterosexual females (n=2) and males (n=5)	South-East Asia	Sexual transmission	Tinea genitalis	Luchsinger *et al.*
Bulgaria	2015	Female	Bulgaria	Unknown	Tinea genitalis, Majocchi granuloma	Bakardzhiev *et al.*
Germany	2016	Females (n=19) and males (n=11)	Austria, Germany, prior travelling to South Asia and Thailand	Close contacts with infected animals, sexual transmission	Tinea genitalis	Ginter-Hanselmayer *et al.*
Germany	2017	Heterosexual male	Thailand	Sexual transmission	Tinea barbae profunda	Wendrock-Shiga *et al.*
Australia	2017	Male	South-East Asia (Thailand)	Sexual transmission	Tinea genitalis, Majocchi granuloma	Gallo *et al.*
Germany	2017	Female	Egypt	Unknown	Tinea genitalis	Nenoff *et al.*
France, Paris	2021–2022	Male heterosexual and MSM (n=12)	Germany, France, Slovenia, Spain, India	Sexual transmission	Tinea barbae, Tinea genitalis, Majocchi granuloma	Jabet *et al.*
United States, NY	2024	MSM (n=4)	United States	Sexual transmission	Tinea faciei, Tinea genitalis, Tinea glutealis	Zucker *et al.*
Germany	2001	Female	Germany	Contact with infected ferret	Tinea corporis, Tinea genitalis	Beckheinrich *et al.*
Seoul, South Korea	2005	Female	South Korea	Contact with infected dog	Majocchi granuloma	Chang *et al.*
Nigeria	2002	Female sex worker	Nigeria	Sexual transmission	Tinea genitalis	Bakare *et al.*
United States, NY	2024	MSM (n=4)	United States	Sexual transmission	Tinea faciei, Tinea genitalis, Tinea glutealis	Zucker *et al.*
United States	2024	MSM (n=1)	Europe (Greece, England) and United States	Sexual transmission	Tinea corporis, Tinea cruris, Tinea genitalis	Caplan *et al.*

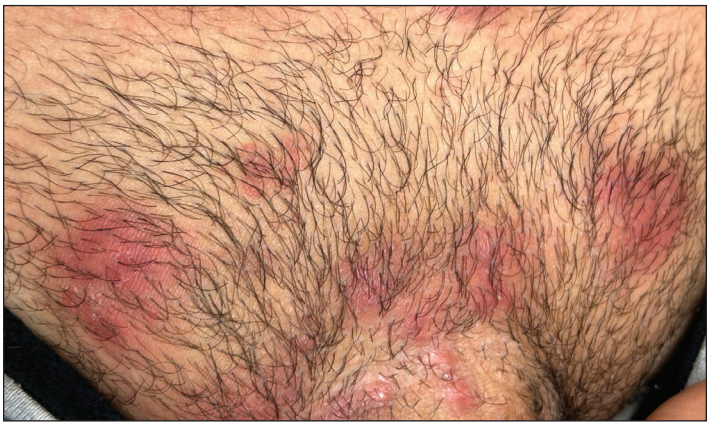
Abbreviations: MSM, men who have sex with men; NY, New York

for Hematoxylin and Eosin stain (H&E) revealed a superficial and deep dermal lymphoeosinophilic infiltrate with negative Periodic Acid-Schiff (PAS). The second was sent for mycology. The fungal stain was negative but the culture grew *Trichophyton* species.

This was later identified as TMVII through DNA sequence analysis of the internal transcribed spacer (ITS) region. Tests for immune compromise, including HIV infection, were negative.

The patient was treated with topical ciclopirox olamine and oral terbinafine until the lesions resolved; this required 10 weeks of therapy due to the involvement of hair follicles and deeper dermal layers, characteristic of Majocchi granuloma. The patient was advised not to shave the pubic region to prevent inoculating other parts of his body. In addition, he was advised to abstain from sexual relations until the lesions had fully resolved to avoid further transmission. Partner notification was suggested to raise

Figure 1: Multiple red papules, plaques, and subcutaneous nodules in the inguinopubic region of a male patient diagnosed with *Trichophyton mentagrophytes* genotype VII infection



awareness of potential exposure and to monitor for symptoms, such as pruritus or signs such as erythema or rash in the genital area. Our patient reported sex with two other partners with whom he maintained communication. Given that asymptomatic testing for fungal infections is not currently recommended and no chemoprophylaxis is available for sexually transmitted fungal infections, we advised that should these contacts develop symptoms or signs, they should abstain from further sexual relations and seek medical care.

Conclusion

Dermatophytes are the primary cause of superficial fungal infections in humans and animals. Among these, *T. mentagrophytes* is a zoophilic species that primarily infects rodents, cattle and domesticated animals but can also infect humans, often through direct or indirect contact with an infected host (4,18). While the infection typically manifests as superficial tinea, it can present as a deep infection, such as Majocchi granuloma, particularly in immunocompromised individuals.

Tinea genitalis, or pubogenital tinea, is a rare form of dermatophytosis that directly involves the genitals and pubic region, in contrast to tinea cruris, which primarily affects the inguinal folds, upper inner thighs and buttocks. This condition is often seen in warm, humid climates and is most commonly caused by *Trichophyton* species, including *T. rubrum*, *T. interdigitale* and *T. mentagrophytes*. The infection is usually transmitted through autoinoculation, though sexual transmission has also been reported.

Trichophyton mentagrophytes genotype VII is a recently identified variant that is strongly associated with sexual transmission. Most reported cases involve MSM, with a few cases among heterosexual partners (4). Sexually transmitted TMVII has been increasingly reported in MSM communities, particularly in South Asia and Europe (2).

The first documented cases of tinea genitalis occurred in 2001, involving female sex workers in Spain (5). Since then, cases have been reported across Europe, Asia and, more recently, in the US. In 2023, the first case of TMVII was identified in a young male in the US with tinea genitalis and glutealis, suspected to be sexually transmitted (1).

Our patient, who is the first documented case in Canada, presented with a similar infection but involved deeper hair follicles and dermis, which is called Majocchi granuloma. Although the patient is immunocompetent, microtrauma may have predisposed him to the infection. Both *T. mentagrophytes* and *T. interdigitale* have been increasingly reported, yet the accurate identification of *Trichophyton* to the species level can be challenging especially due to evolving taxonomic assignments based on new understanding of genomic relationships (18). The *T. mentagrophytes* complex is now differentiated into *T. mentagrophytes*, which is zoophilic and associated with more inflammatory dermatophytosis in humans, and *T. interdigitale*, which is anthropophilic and primarily causes non-inflammatory tinea unguium and tinea pedis. While there are no commercial PCR assays that can distinguish between *T. mentagrophytes* and *T. interdigitale,* molecular markers, specifically sequencing the ITS region of fungal DNA, are used for accurate strain identification (18,19).

According to the nomenclature proposed by Nenoff *et al.* (18), the ITS phylogenetic tree includes *T. mentagrophytes* and *T. interdigitale* genotypes III (strains from animal hosts), III* (strains from soil), IV, V, VII, VIII and IX. *Trichophyton mentagrophytes* genotype VIII has been reclassified as a new species, *T. indotineae*, which is an emerging pathogen. Molecular analysis reveals that while *T. mentagrophytes* and *T. interdigitale* are difficult to distinguish from each other, they are clearly different from *T. indotineae*, which is known for human-to-human transmission, severe infections and a propensity for antifungal resistance to both terbinafine and fluconazole (15,20).

Accurate identification of *Trichophyton* species is critical, especially given the emergence of TMVII and *T. indotineae*. Traditional methods such as fungal scraping, culture and phenotypic identification may not be sufficient to distinguish between all *Trichophyton* species. Molecular techniques, particularly sequencing of the fungal ITS region, are currently essential for accurate identification and may be warranted in some cases. It is important to note that DNA sequencing of dermatophytes is not routinely performed and may need to be specifically requested.

Reported cases highlight the need to consider fungal STIs in patients with atypical presentations, especially in the genital area. This case emphasizes the potential for global spread and the importance of considering travel history in patients with similar symptoms. It contributes to the growing evidence linking TMVII with STIs. The global spread of this genotype underscores the need for clinicians to be vigilant in identifying and managing such cases, particularly in patients with relevant travel histories and sexual activity within at-risk communities.

This is the first reported case of sexually transmitted TMVII infection in Canada. The case highlights the need for heightened awareness among healthcare providers regarding the potential for sexually transmitted fungal infections, especially in patients with atypical tinea presentations involving the pubogenital region. Accurate diagnosis through molecular identification is essential for effective management. This case also underscores the importance of considering longer treatment durations for deep-seated infections, such as Majocchi granuloma, which require systemic antifungal therapy. Partner notification remains

a critical component of care, raising awareness of potential exposure, encouraging medical evaluation if symptoms and signs develop, and especially abstinence until diagnosis and definitive therapy to prevent further spread. Sexually transmitted fungal skin infections are neither reportable to public health, nor covered in the Public Health Agency of Canada's *Sexually transmitted and blood-borne infections: Guides for health professionals* (17). This underscores the importance of enhanced surveillance and public health initiatives in raising awareness and educating clinicians about these rare but impactful conditions. Finally, collaboration between clinicians, laboratories, and public health authorities are vital to improve detection, management, and prevention of such infections.

Authors' statement

TL — Conceptualization, writing–original draft, writing–review & editing
AB — Conceptualization, writing–review & editing, picture credit
JK — Writing–review & editing
KB — Conceptualization, writing–review & editing

The content and view expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

Competing interests

None.

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Estimating the population size of people who inject drugs in Canada, 2021

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Abstract

Background: People who inject drugs are disproportionately affected by HIV and hepatitis C infections. Estimating the size and distribution of this population is essential in monitoring infectious diseases rates and progress towards elimination.

Objective: This study aims to estimate the population sizes of people in Canada who have ever injected drugs, stratified by sex (assigned at birth), province/region and steroid injection, and those who have recently injected drugs (past 12 months), stratified by sex and steroid injection. While a previous national study reported estimates of recent injection by province, this study provides the first estimates of people who have ever injected drugs at both the national and provincial/regional levels. It is also the first to incorporate stratification by sex and steroid injection, using the most currently available data.

Methods: Using combined cycles (2017–2021) of the Canadian Community Health Survey (CCHS), a nationally representative population-based survey, we applied the weighted prevalence of injection drug use to the 2021 Statistics Canada national population size estimate of individuals aged 15 years or more. To this, further adjustments were made using additional data to account for populations not sampled in the CCHS and under-reporting of injection drug use in surveys.

Results: In 2021, an estimated 388,400 (95% CI: 338,900–436,500) people in Canada had ever injected drugs, representing 1.22% of the Canadian population 15 years of age and older. Among these, 75% were male and 25% were female. These estimates varied across regions, ranging from 0.92% to 2.47%. The estimated number of people who have recently injected drugs was 100,300 (95% CI: 82,300–119,200) or 0.31% of the population, of which 74% were male and 26% were female.

Conclusion: Estimates of people who inject drugs at the national and provincial/regional levels can be used to track key epidemiological metrics that inform public health policy and programming.

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Keywords: people who inject drugs, injection drug use, HIV, hepatitis C, population size estimates

Introduction

In Canada, people who inject drugs face a disproportionate burden of sexually transmitted and blood-borne infections (STBBI), including HIV and hepatitis C, due to intersecting risk factors that increase their vulnerability to STBBI transmission (1). In 2022, 24.5% of the 1,848 estimated new HIV infections occurred among people who inject drugs, an increase from 22.2% of the 1,610 new infections in 2020 (2). Regarding hepatitis C, it was estimated that in 2021, 36.9% of people who had recently injected drugs (in the past 6–12 months) had chronic hepatitis C (3).

Accurate estimates of the population size of people who inject drugs are crucial for planning resource allocation and informing harm reduction policies and programs, since injection drug use (IDU), particularly through sharing of injection equipment, increases the risk of transmission of blood-borne infections (4). From an epidemiological perspective, population size estimates help quantify burden of disease, monitor trends and measure progress towards elimination targets (5,6). Various methods exist to produce population size estimates, each requiring unique data sources, impacting the feasibility and validity of the estimates (7).

In Canada, national estimates of people who inject drugs were published using indirect multiplier methods (8,9), while provincial and local estimates have used administrative health data linkage (10) and capture-recapture methods (11). The use of population-based surveys is a method previously employed for estimating the population size of people who inject drugs (12,13). This method uses the proportion of people who inject drugs (i.e., self-reported information) within a given population and multiplies it by the total population size of the respective jurisdiction (14). This approach is feasible nationally, as it utilizes existing and representative data sources; however, limitations exist when adjustments are not made to account for unsampled populations within surveys, and under-reporting of the behaviours of interest. This study aims to estimate the population size of both people who have ever injected drugs, and who have recently (in the past 12 months) injected drugs for 2021 by sex and province/region, by implementing an adjusted direct multiplier method using recent national survey data and additional data to account for unsampled populations.

Methods

A crude portion of the estimate was produced using data from Statistics Canada's Canadian Community Health Survey (CCHS), otherwise referred to as a CCHS-derived estimate. The CCHS is a nationally representative cross-sectional, population-based survey with ~97% coverage of the Canadian population, described elsewhere (15). Coverage of the CCHS excludes persons living in Indigenous communities, full-time members of the Canadian Forces, institutionalized populations, children aged 12–17 that are living in foster care, and persons living in the Québec health regions of Nunavik and Terres-Cries-de-la-Baie-James. For this analysis, CCHS 2017–2021 data were combined using the pooled approach to combining CCHS cycles, noting that data from each province and territory were not captured in every cycle (16). The CCHS asks participants about the use of various substances, routes of administration, and recency of use. For this analysis, weighted proportions of both people who have ever injected drugs and who have recently injected drugs were calculated to account for survey design. These weighted proportions were applied to Statistics Canada's 2021 population aged 15 years and older (17). Weighted estimation and bootstrap variance were used to calculate CCHS model inputs and 95% confidence intervals (CIs) using the PROC SURVEYFREQ procedure. Analyses were performed using SAS EG version 7.1 (18).

In addition to the CCHS-derived estimate, four additional estimates were computed for populations that were not captured in the CCHS sampling frame. First, an estimate of people who inject drugs among First Nations peoples living in First Nations communities was made by applying IDU data from a cross-sectional biobehavioural survey implemented by First Nations in Saskatchewan and Alberta (19) to corresponding population size estimates from Statistics Canada (17). Second, an estimate of people who inject drugs among people who are incarcerated was made by applying IDU data from Correctional Services Canada (20,21) to population size estimates from Statistics Canada (22). Only people incarcerated in federal prisons were included in this adjustment, as people serving provincial sentences of less than two years would have been eligible to be sampled by the CCHS. Third, the number of people who inject drugs among active military personnel was estimated, however, due to an absence of data on IDU in the military, the proportions of IDU were assumed to be the same as the CCHS. These proportions were then applied to population size estimates from the Canadian Armed Forces (23). Lastly, the number of people who inject drugs experiencing homelessness or unstable housing was estimated. Data from the Tracks survey of people who inject drugs were used and the proportion of people who inject drugs reporting homelessness and/or unstable housing within the past six months was applied to the CCHS-derived estimate of people who have recently injected drugs (1). This adjustment applied only to estimates of recent injection because only individuals who had injected drugs six months prior to recruitment are included in the Tracks survey, and individuals experiencing unstable housing beyond this timeframe would be eligible to be sampled by the CCHS. After each unsampled group was estimated, they were added to the estimates derived from the CCHS to form the main estimates of people who have ever injected drugs, and who have recently injected drugs. Since all data sources involved self-reported IDU behaviours, a final adjustment to the main estimates was made to account for underreporting.

For this adjustment, the weighted sensitivity of self-reported substance use of injectable substances compared to a gold standard laboratory detection test in hair samples, taken from a meta-analysis, was used (24). The weighted sensitivity was calculated by assigning each study a weight proportional to its sample size when combining results. This weighted sensitivity (52.35%) was applied to the main estimate to derive a final estimate of people who inject drugs. A diagram of the method is presented in the **Appendix**, Supplementary Figure S1.

A 95% CI was used to produce plausible ranges around each estimate and were obtained using original data sources, where available. The 95% CIs were not available for both people who have ever, and recently, injected drugs among people living in

First Nations communities, people who are incarcerated, and those experiencing unstable housing among people who inject drugs. In these situations, 95% CIs were constructed using parametric bootstraps with 1,000 simulations of N samples of n/N probability from the binomial distribution and subsequently removing the upper and lower 2.5 percentiles (25–27).

Estimates were stratified by sex (assigned at birth) for both people who have ever, and recently, injected drugs and by geographic region for people who have ever injected drugs. Due to insufficient observations in smaller provinces, estimates for each individual province could not be produced; therefore, some were grouped into larger geographic regions. Estimates over 1,000 were rounded to the nearest 100, and those under 1,000 to the nearest 10. These analyses were conducted in Microsoft Excel, with data inputs presented in Supplementary Tables S1–S6.

Sensitivity analysis: Effect of including people who inject steroids

A sensitivity analysis was conducted to assess the impact of excluding individuals who reported injecting only steroids on the CCHS. People who inject steroids represent a unique subset of people who inject drugs, and previous literature has suggested that these individuals should be distinguished from people who inject other substances, due to distinct differences in lifestyle and injecting practices (28,29). This adjustment was applied to the CCHS-derived estimate by removing individuals who exclusively injected steroids from the survey responses. Results are presented under both scenarios.

Results

In 2021, an estimated 388,400 (95% CI: 338,900–436,500) people in Canada had ever injected drugs, representing 1.22% of the population aged 15 and older (**Table 1**). Of these, approximately 75% were male (n=290,800) and 25% female (n=97,500). For those who have recently injected drugs, the estimated prevalence was 100,300 (95% CI: 82,300–119,200) people, or 0.31% of the population aged 15 and older. Similarly, 74% were male (n=74,600) and 26% were female (n=25,600). When excluding individuals who injected only steroids, the prevalence of people who have ever injected drugs decreased by 9.83% to 350,200 (95% CI: 317,200–381,800), and people who have recently injected drugs decreased by 0.60% to 99,700 (95% CI: 81,900–118,600). These reductions were observed only among males, as no female respondents reported injecting only steroids.

When stratified by region, some geographic variation across Canada was observed (**Figure 1**). The highest prevalence of people who have ever injected drugs was estimated in the territories at 2.47%, although this represents the smallest estimated number of people at 2,400 (95% CI: 1,400–3,400).

Table 1: National population size estimates of people who inject drugs by sex (assigned at birth), Canada, 2021

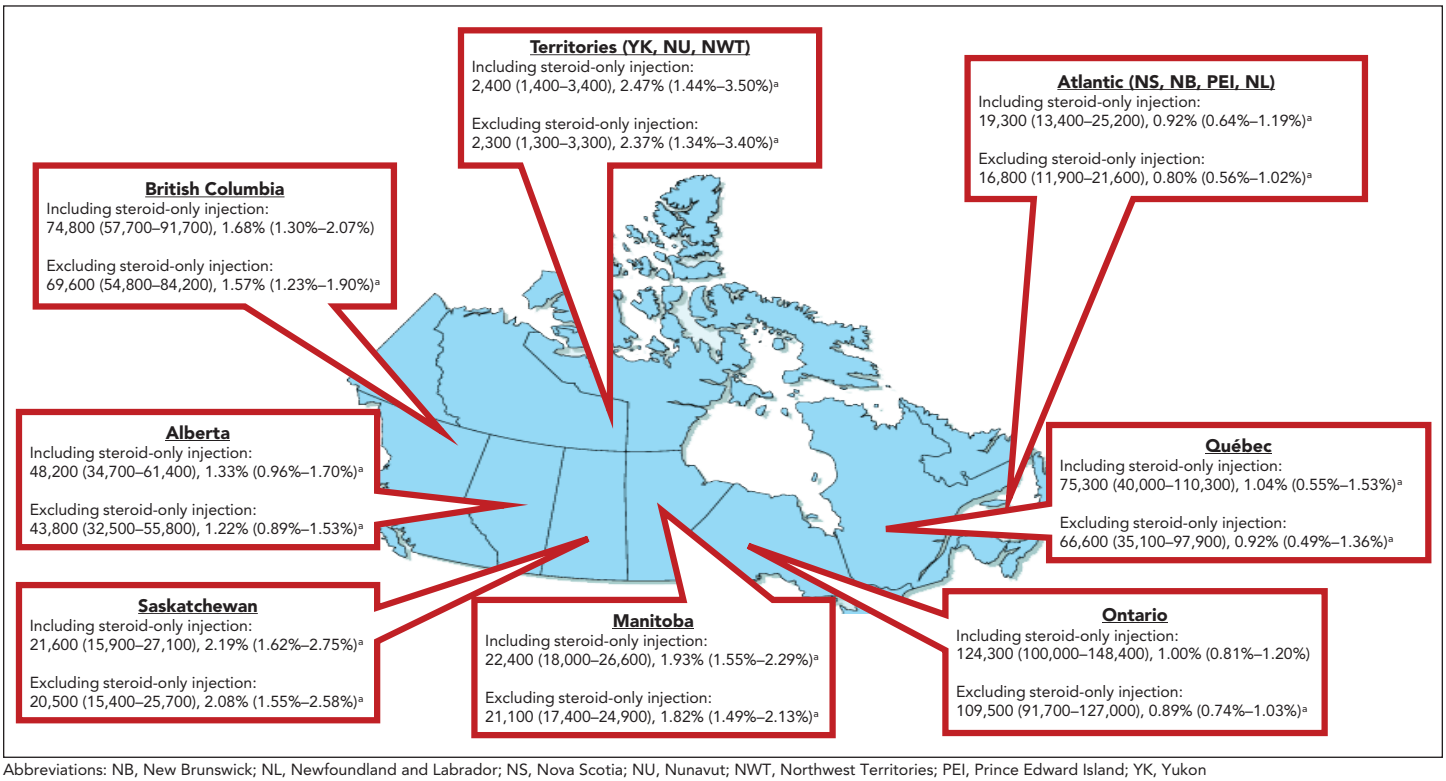
Estimate		Population sizes of people who inject drugs in Canada	
		% (Plausible range)	n (Plausible range)
Including steroid-only injection	People who have ever injected drugs	1.22 (1.06–1.37)	388,400 (338,900–436,500)
	Male	1.84 (1.62–2.05)	290,800 (256,500–323,700)
	Female	0.61 (0.51–0.70)	97,500 (82,300–112,700)
	People who have recently injected drugs (past 12 months)	0.31[a] (0.26–0.37)	100,300[a] (82,300–119,200)
	Male	0.47[a] (0.39–0.56)	74,600[a] (61,900–88,000)
	Female	0.16[a] (0.13–0.19)	25,600[a] (20,300–31,200)
Excluding steroid-only injection	People who have ever injected drugs	1.10[a] (0.99–1.20)	350,200[a] (317,200–381,800)
	Male	1.60[a] (1.48–1.71%)	252,600[a] (234,600–269,600)
	Female	0.61[a] (0.51–0.70)	97,600[a] (82,600–112,000)
	People who have recently injected drugs (past 12 months)	0.31[a] (0.26–0.37)	99,700[a] (81,900–118,600)
	Male	0.47[a] (0.39–0.55)	74,000[a] (61,400–87,300)
	Female	0.16[a] (0.13–0.19)	25,600[a] (20,300–31,200)

[a] Estimates have a high level of sampling variability (15.0< coefficient of variation <35.0). These data should be interpreted with caution

In comparison, the Atlantic region had the lowest estimated prevalence of 0.92%. The province with the highest estimated number of people who have ever injected drugs was Ontario with 124,300 (95% CI: 100,000–148,400), translating to 1.00% of the adult population. When broken down into groups not sampled in the CCHS (**Table 2**), the highest prevalence was observed among people who are incarcerated, with 21.75% reporting having ever injected drugs, and 10.80% reporting having recently injected drugs. The highest estimated number of people who have recently injected drugs was observed among people experiencing homelessness or unstable housing at 20,300, however, it was not possible to calculate a prevalence rate due to the lack of a denominator. In comparison, an estimated 16.7% of people living in First Nations communities

had ever injected drugs, with 8.1% reporting recent injection. Active military personnel were estimated to have the lowest prevalence, with an estimated 0.51% reporting having ever injected drugs, and 0.04% reporting having recently injected drugs. Estimates of model inputs are presented in the Appendix, Supplementary Tables S1–S6.

Figure 1: Regional population size estimates of people who have ever injected drugs, Canada, 2021[a]



Abbreviations: NB, New Brunswick; NL, Newfoundland and Labrador; NS, Nova Scotia; NU, Nunavut; NWT, Northwest Territories; PEI, Prince Edward Island; YK, Yukon
[a] Estimates have a high level of sampling variability (15.0< coefficient of variation <35.0). These data should be interpreted with caution

Table 2: National population size estimates of people who inject drugs among additional populations with data sources (includes steroid-only injection), Canada, 2021

Population	Estimates of people who have ever injected drugs[a]		Estimates of people who have recently injected drugs[a]		References
	% (Plausible range)	n (Plausible range)	% (Plausible range)	n (Plausible range)	
CCHS-derived estimate (Canadian population aged 15+)	0.51 (0.44–0.58)	161,800 (140,300–183,300)	0.04[b] (0.02–0.05)	12,200[b] (7,500–16,800)	(15,17)
People living in First Nations communities[c]	16.7 (14.9–18.2)	38,000 (34,000–41,500)	8.1 (6.9–9.4)	18,500 (15,700–21,400)	(17,19)
People who are incarcerated	21.7 (20.0–23.2)	3,000 (2,800–3,300)	10.80 (6.64–14.96)	1,500 (930–1,940)	(20–22)
People experiencing homelessness or unstable housing[d]	N/A	N/A	N/A	20,300 (18,900–22,200)	(1)
Active members of the Canadian Armed Forces[e]	0.51 (0.44–0.58)	370 (320–410)	0.04 (0.02–0.05)	30 (20–40)	(23)

Abbreviations: CCHS, Canadian Community Health Survey; N/A, not applicable
[a] Results in this table are shown before the adjustment for false negative self-reporting of injection drug use (IDU), and include people who inject steroids only
[b] Estimates have a high level of sampling variability (15.0< coefficient of variation <35.0). These data should be interpreted with caution
[c] Census data were available from 2021, however, data collection issues led to a higher number of incompletely enumerated reserves and settlements and a lower estimated number of people living on reserve compared to the 2016 census (Statistics Canada, 2022)
[d] Data on IDU among people experiencing homelessness and/or unstable housing was not available. Instead, the proportion of people who inject drugs reporting unstable housing within the past six months was applied to the baseline estimate of people who inject drugs from the CCHS
[e] Due to an absence of data on IDU in the military, the prevalence of people who inject drugs was assumed to be the same as the general population

Discussion

This study used an adjusted direct multiplier method, combining data from national population-based surveys with additional data sources, to estimate the number of people who inject drugs in Canada in 2021. Potential response bias in survey data was also accounted for. As a result, it is estimated that there were 388,400 people who have ever injected drugs and 100,300 who have recently injected drugs. When interpreting these estimates, it is important to consider the broader social and historical contexts that affect people who inject drugs. Inequities in the social determinants of health, as well as factors such as intergenerational trauma, socioeconomic disparities, and the impacts of colonialism and institutional racism are deeply embedded within the experiences of people who inject drugs (30,31). These underlying factors are difficult to measure and incorporate into an estimation method such the one used in this study.

Previously published estimates in the United States, using comparable methodologies, provide similar estimates of recent IDU, with one study reporting 0.30% (95% CI: 0.19%–0.41%) (13) and another reporting a range of 0.24% to 0.59% (12). Previously published estimates in Canada vary due to differences in methodology. A study by Jacka *et al.* (2020) used provincial data on recipients of Opioid Agonist Therapy (OAT) and the proportion of people who inject drugs who received OAT to estimate the population size in 2011 and modelled annual increases up to 2016 using data from two provinces. For 2016, they obtained an estimate of 0.70% (range: 0.62%–0.78%) or 171,900 people aged 15 to 64 years who recently injected drugs (8). This estimate is higher than our most comparable estimate of recent IDU for the year 2021 at 0.31% (95% CI: 0.26%–0.37%). This difference might be explained by a sub-optimal sampling of the target population using our data sources and the use of modelling by Jacka *et al.* to project the population size using older data sources. However, we cannot exclude the impacts of the opioid and toxic drug supply crisis, which would not have been accounted for by Jacka *et al.* due to the reference period of their estimate. Janjua *et al.* (2018) estimated that 41,358 (95% CI: 40,944–41,771) people in British Columbia had recently (defined as in the past three years) injected drugs during the period 2013–2015, using an algorithm based on diagnostic codes and prescriptions records in healthcare administrative datasets. Due to major differences in reference periods, our provincial lifetime injection estimate should not be compared to this estimate.

When comparing to other estimates (8), the estimates in the current study suggest a potential decrease in the number of people who inject drugs in Canada, which may be attributed to differences in methodologies with previous estimates, but may also be reflective of broader trends related to IDU. Notably, the estimates in this study are the first to partly capture some of the impacts of the COVID-19 pandemic, within the context of the ongoing opioid crisis. The pandemic worsened substance-related harms due to reduced access to services, increased solitary drug use, lack of assisted injections, and sharing or reusing supplies (32). Between 2016 and 2023, there were 44,592 reported opioid toxicity deaths in Canada (33). Although not all opioid toxicity deaths are attributed to IDU, mortality among people who use drugs in the years following the last published Canadian estimate is likely an important factor in the observed reduction in the population size of people who inject drugs. Another potential contributing factor is recent data suggesting a shift away from injection as the primary mode of consumption in some provinces. In British Columbia, injection was the leading mode of consumption in drug toxicity deaths in 2016, but by 2021, smoking was reported in 56% of deaths compared to 20% for injection (34). Similar trends were observed in Ontario, where deaths with indication of injection alone dropped by 64.4%, from 29% in 2017 to 10.3% in 2021, while inhalation-related deaths rose from 22% to 43.5% (35). Although drug toxicity deaths are not a direct reflection of all drug use behaviours, these data may suggest a downward trend in injection in these large provinces.

A primary strength of the estimation method used for the current study is the use of the most currently available data sources, which cover the beginning of the COVID-19 pandemic and the ongoing opioid crisis. Another strength is the replicability of this estimation method, allowing the 2021 estimates to serve as an initial data point, which can be repeated as new data becomes available to observe trends in the population of people who inject drugs. While a previous study has reported estimates of people who have recently injected drugs by province, the current study is the first to provide national and provincial/regional estimates of people who have ever injected drugs and to incorporate stratification by sex and steroid-only injection. Another strength of this method is the attempt to account for response bias, for which survey data can be particularly vulnerable. Due to the nature of questions being asked, survey respondents may be hesitant to disclose substance use behaviours due to stigma and discrimination, as well as fear of legal repercussions, among other reasons (7,24,36). Failure to account for this bias would likely have led to an underestimation of people who inject drugs.

Limitations

There are several limitations to the methods used in this study, mainly related to the availability and generalizability of data sources. First, people who inject drugs may not be well represented in the sampling of government surveys such as the CCHS, since they may be hard to reach or reluctance to participate (11,37,38), leading to uncertainty in the final estimates. Second, there is a potential that people who are incarcerated in provincial prisons may be underrepresented in the CCHS sample, as the timing of their incarceration may limit the likelihood of their inclusion during the sampling period. Third, the survey used to estimate people who inject drugs

among those living in First Nations communities is limited to seven communities in Alberta and Saskatchewan and may not be representative of all First Nations communities in Canada, which affects external validity of this estimate. Fourth, CCHS data collection in the territories was limited in the observed cycles of the CCHS, which could potentially affect generalizability of the territorial estimate. However, a sensitivity analysis using territorial data from previous cycles of the CCHS yielded statistically similar results. Fifth, the survey used to estimate the number of people who inject drugs experiencing homelessness or unstable housing excluded Toronto and Vancouver; however, previous phases of the same survey that included these cities showed similar rates of unstable housing, suggesting a minimal impact. Sixth, when excluding people who inject steroids only, regional estimates from the CCHS were not reliable due to insufficient statistical power. Instead, national proportions were used, which has potential to mask regional differences. Seventh, data on IDU among members of the Canadian Armed Forces were not available, and our estimates assume that the level of IDU among military personnel is the same as in the CCHS. Lastly, although CCHS cycles spanning up to five years were used, data were pooled to reach sufficient sample size for reliable estimation. Furthermore, other data sources used were restricted to single-year estimates, precluding estimation at different timepoints. Further detail on limitations and their potential effects on the estimates are outlined in **Table A1**.

Conclusion

In Canada, people who inject drugs face a disproportionate burden of STBBIs, due to intersecting risk factors such as stigma, discrimination, increased levels of poverty and marginalization, unstable housing, and incarceration history (1). Estimating the population size of this group is essential for tracking key epidemiological metrics that inform public health policy and programming. The estimates from this study will serve as a benchmark, to be updated and refined as new data emerges.

While these estimates provide valuable insights, there is a need for further efforts to estimate the broader population of people who use drugs, not only those who inject. Expanding the scope of research to include qualitative data on broader social and historical contexts will provide a more comprehensive understanding of the community.

Authors' statement

AW — Designed the study methodology, analyzed the data, interpreted the results, drafted the manuscript
JS — Designed the study methodology, analyzed the data, interpreted the results, revised the manuscript
SP — Designed the study methodology, interpreted the results, revised the manuscript
QY — Designed the study methodology, reviewed the results and manuscript
JC — Designed the study methodology, reviewed the results and manuscript
MB — Consulted on study methodology, results and manuscript
AS — Consulted on study methodology, results and manuscript
NP — Designed the study methodology, interpreted the results, revised and approved the manuscript

All authors approved the final version of the manuscript.

Competing interests

JC has received research funds paid to his institution from the Canadian Institutes of Health Research (CIHR), ViiV Healthcare and Gilead. He has received honoraria as a speaker, paid by ViiV Healthcare and Gilead. He has also received the Canadian Association for HIV Research (CAHR) Health Care Professionals Travel Award to attend conferences.

MB has received consulting fees from the Public Health Agency of Canada (PHAC) for their participation in the submitted work. Outside of the submitted work, MB has received consulting fees and payment or honoraria from AbbVie and Gilead, as well as support for attending meetings and/or travel from CIHR.

AS has received consulting fees from PHAC for their participation in the submitted. Outside of the submitted work, AS has received grants or contracts from PHAC, Health Canada, and the Canadian Research Initiative in Substance Misuse (CRISM). AS has received consulting fees from the Dr. Peter Centre's Mentoring, Education, and Clinical Tools for Addiction: Partners in Health Integration (META:PHI), PHAC and Health Canada, as well as payments or honoraria from the Ontario Drug Policy Research Network (ODPRN), the Centre on Drug Policy Evaluation (CDPE), and Public Health Ontario. AS has received support for attending meetings and/or travel from the CDPE, the London InterCommunity Health Centre, and the Ministry of the Attorney General, ON. AS notes participation in advisory boards for the ODPRN, CDPE and META:PHI, and holds a leadership or fiduciary role in the Ontario Network of People Who Use Drugs (ONPUD).

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Appendix

Table A1: Key limitations in the data used to estimate the population size of people who inject drugs in Canada, 2021, and their potential effects

Limitations of data	Potential effect on estimates
Representation of people who inject drugs within CCHS may be low, given they may be hard to reach or reluctant to participate in a government survey.	Underestimation
The CCHS questions regarding injection drug use pertain exclusively to the injection of substances not prescribed by a doctor. Consequently, the data excludes individuals who inject prescription medications for reasons outside of the intended medical purpose. We assess this number of individuals to be small, resulting in minor impact on estimations.	Minimal
Individuals that reside in rural communities may be underrepresented in the Tracks survey among people who inject drugs, which was used to estimate the proportion of people who inject drugs experiencing unstable housing. Individuals residing in rural areas often face increased barriers to accessing services and may be therefore less likely to participate in a survey.	Underestimation
People incarcerated in provincial prisons may be underrepresented in the CCHS sample, as the timing of their incarceration may reduce the likelihood of inclusion within the sampling period.	Underestimation
In the absence of specific data on regular members of the Canadian Armed Forces, we assumed the proportions of IDU among active military personnel were the same as the CCHS sample. Survey data in the United States suggests that illicit drug use among active military members and military veterans differs from the civilian population (39).	Unknown
In the adjustment for underreporting of injection drug use behaviours, we assumed the same degree of underreporting across all surveys. Self-report bias is likely to vary depending on the context in which respondents are asked.	Unknown
The data used to estimate the population of people who inject drugs among First Nations Peoples living in First Nations communities was limited to communities in Alberta and Saskatchewan. These data may not be generalizable to all First Nations communities across Canada.	Unknown
Surveys used to estimate the population of people experiencing homelessness or unstable housing are venue-based (i.e., used non-probability-based sampling). As a result, the findings from these surveys may not be representative of all these groups at any given site or across Canada.	Unknown
Regional estimates of people who inject steroids from the CCHS were not reliable due to insufficient observations. Instead, the national proportions of steroid-only injection were used for each region.	Unknown
The biobehavioural survey used to estimate people who inject drugs experiencing homelessness or unstable housing excluded major Canadian cities of Toronto and Vancouver. Previous phases of this survey that did include these cities were also examined, and they reported similar rates of unstable housing.	Minimal

Abbreviations: CCHS, Canadian Community Health Survey; IDU, injection drug use

Supplemental material is available upon request to the author: stbbi.estimates.field.surv-itss.estimations.surv.terrain@phac-aspc.gc.ca

Figure S1: Data sources used to estimate the population size of people who inject drugs in Canada, 2021
Table S1: Data inputs for estimates of people who have ever injected drugs (excluding people who inject steroids only)
Table S2: Data inputs for estimates of people who have ever injected drugs (including people who inject steroids only)
Table S3: Data inputs for estimates of people who have recently injected drugs (excluding people who inject steroids only)
Table S4: Data inputs for estimates of people with a recent history of injection drug use (including people who inject steroids only)
Table S5: Unadjusted Canadian Community Health Survey (CCHS)-derived provincial/regional prevalence of people who have ever injected drugs (including people who inject steroids only)
Table S6: Unadjusted Canadian Community Health Survey (CCHS)-derived national-level prevalence of people who have ever injected drugs and people who have recently injected drugs, by sex (including people who inject steroids only)

Travel-related dengue, Zika and chikungunya in Canada, 2024

Update to results from a feasibility pilot study on laboratory-based surveillance

- **Dengue, Zika and chikungunya** are vector-borne diseases (VBD) spread by **mosquitoes** that people living in Canada may encounter during **travel abroad**[1]. These diseases are **not currently endemic in Canada** and are not reportable and/or nationally notifiable; yet **hundreds of travelers returning from endemic regions are diagnosed** in Canada each year[2,3].
- Laboratory-based surveillance uses routine laboratory requisition and testing data to identify and monitor disease activity. The **Retro 3 feasibility pilot**[4] applied this approach to retrospectively analyze travel-related dengue, Zika, and chikungunya in Canada from 2012 to 2023[3], now updated through 2024. **Results reflect testing conducted at the National Microbiology Laboratory (NML) only**, including confirmatory serology for all provinces and territories and molecular testing for all except British Columbia, Alberta, Ontario and Québec, and underestimate the total disease burden[5].

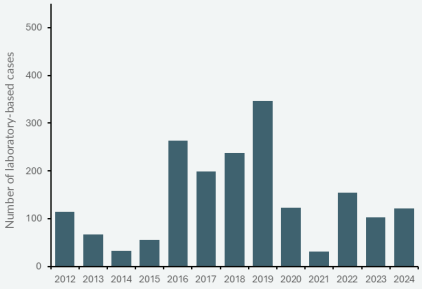
DENGUE

120 cases[6]

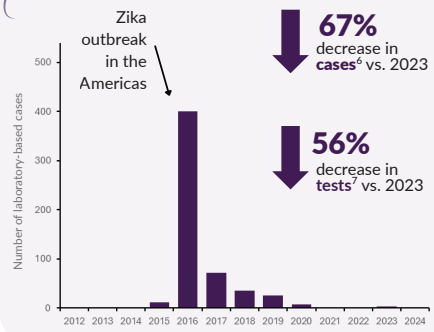
17% increase vs. 2023

47% women

43% 55+ years



ZIKA



67% decrease in **cases**[6] vs. 2023

56% decrease in **tests**[7] vs. 2023

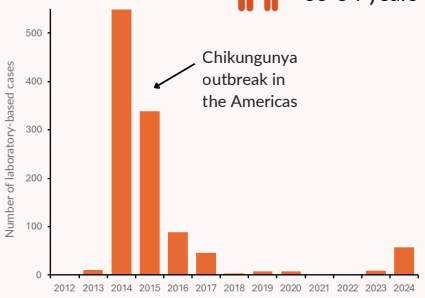
CHIKUNGUNYA

57 cases[6]

>500% increase vs. 2023

57% women

44% 35-54 years



In 2024, **6%** of tested individuals reported pregnancy, down from 20% in 2023 and 31% on average from 2019 to 2023[8]

The Latin America and Caribbean region[9] was the top travel destination linked with laboratory-based cases of dengue and chikungunya in 2024

- **A total of 120 dengue, 1 Zika and 57 chikungunya laboratory-based travel-related cases were identified among a total of 752 persons tested for these diseases at the NML in 2024**[10].
- Disease patterns closely reflected global trends and those observed in countries of travel destination.
- Dengue cases in 2024 had higher proportions aged 55+ (43% vs. 20% average in 2019–2023) and men (53% vs. 31%). Most chikungunya cases in 2024 were aged 35–54 (44%) and women (57%); prior years had few cases for comparison.
- No dengue or chikungunya laboratory-based cases among individuals with reported pregnancy in 2024, compared to 28% on average for dengue and only 1 case for chikungunya from 2019 to 2023[8].

In 2024, results from a pilot laboratory-based surveillance study revealed a marked increase in identified laboratory-based travel-related cases of dengue and chikungunya. Laboratory data can be leveraged for epidemiological analyses, offering timely insights to support surveillance of evolving trends and inform public health response.

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Public Health Agency of Canada, BCCDC Public Health Laboratory, Alberta Precision Laboratories, Public Health Ontario Laboratory. Travel-related dengue, Zika and chikungunya in Canada, 2024: Update to results from a feasibility pilot study on laboratory-based surveillance. Can Commun Dis Rep 2025;51(9):374.

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