Developing and Evaluating Intelligent Health Systems

David Buckeridge, MD PhD FRCPC
Professor | McGill University
CIHR Chair | E-Health Interventions
Director | RI-MUHC Data Warehouse
Medical Consultant | INESSS
david.buckeridge@mcgill.ca

A Clinical System: Statistical Modeling for Prescribing Decision Support

A Population Health System: Knowledge Modeling for Public Health

Closing Thoughts

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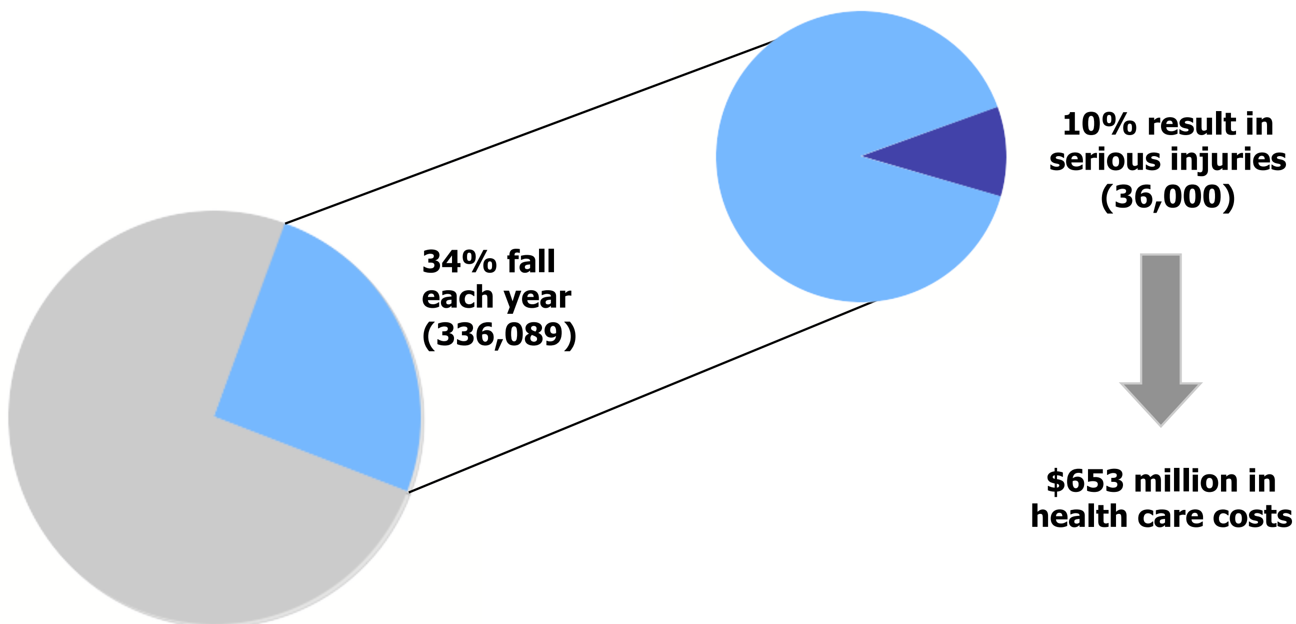
A Population Health System: Knowledge Modeling for Public Health

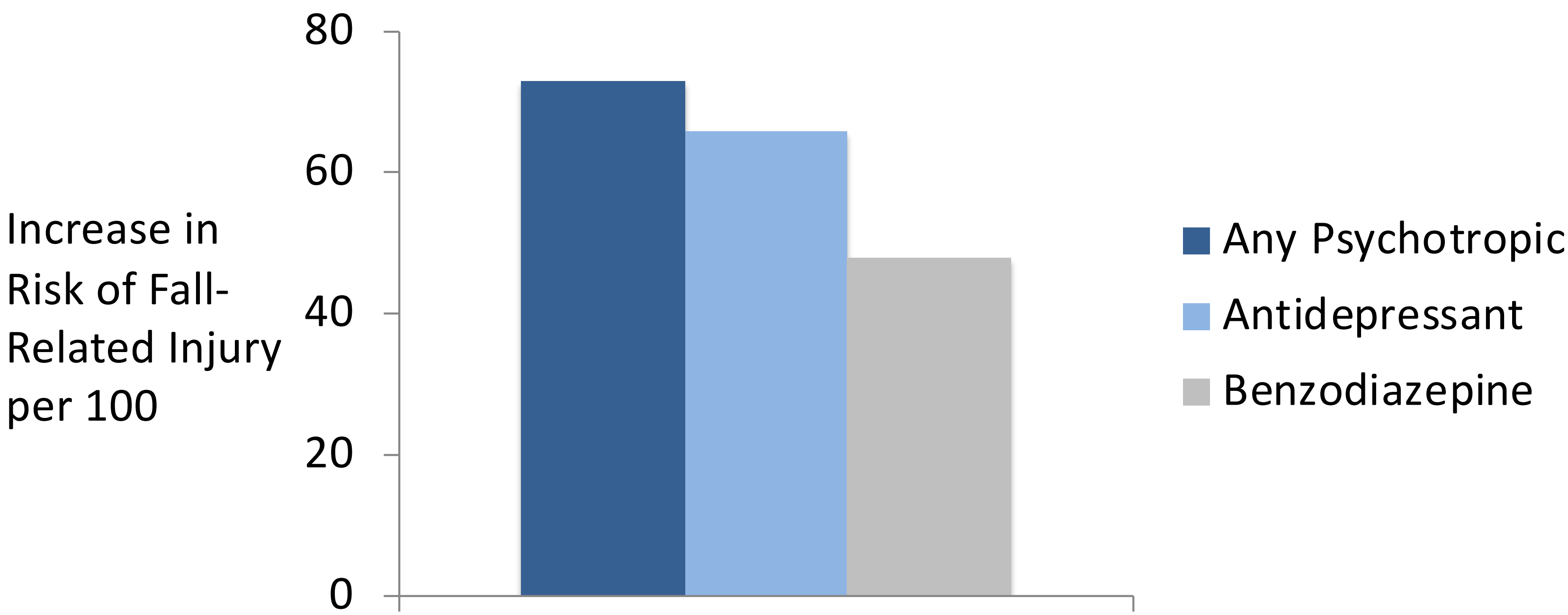
Closing Thoughts

Fall-Related Injuries in Older Adults are Common and Costly



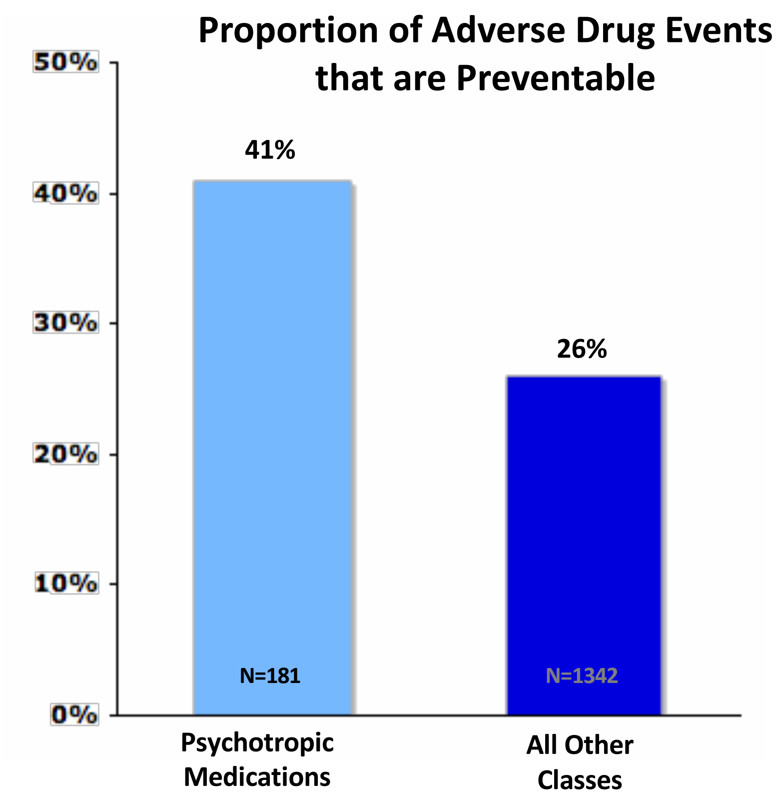
RAMQ insurance; Rubenstein & Josephson, 2002, Clinics in Geriatric Medicine; www.cdc.gov/npic/factsheets/fallcost.htm

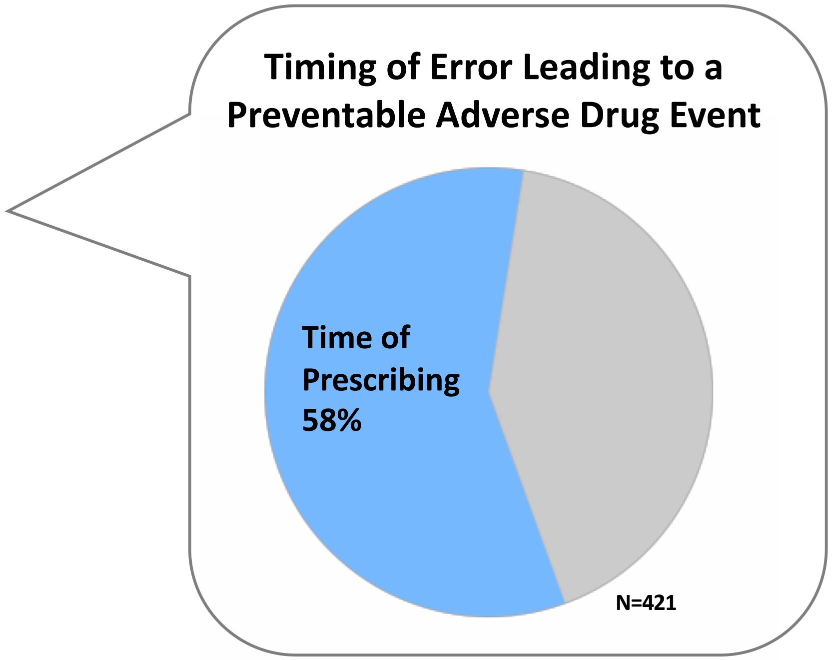
Psychotropic Medications Cause Fall-Related Injuries



Medication as a Risk Factor for Falls: Critical Systematic Review Sirpa Hartikainen, Eija Lönnroos, Kirsti Louhivuori. The Journals of Gerontology. Oct 2007. Vol. 62A, Iss. 10; p. 1172

Adverse Drug Events are Preventable at the Time of Prescribing





Gurwitz JH, Field TS, Harrold LR, Rothschild J, Debellis K, Seger AC, Cadoret C, Fish LS, Garber L, Kelleher M, Bates DW. Incidence and preventability of adverse drug events among older persons in the ambulatory setting. JAMA. 2003 Mar 5;289(9):1107-16.

Current Prescribing Decision Support

- "Top-down" knowledge engineering by expert opinion
  - Shared metabolic pathways
  - Potential (although vaguely defined) additive effects
- Encoded as large knowledge base (e.g., FDB, Vigilance)
- Many alerts (drug-drug, drug-disease, drug-age) can be generated for a single patient, graded by "importance"
- Implications of alerts for a given patient often unclear
- Clinicians ignore most (50%-90%) alerts

Statistical Guidance by Outcome

- Identify outcome(s) of clinical interest
- Develop a {statistical | ML} model to predict outcome
  - All known individual risk factors for outcome
  - Drugs associated with the outcome
- Use the model in clinical context
  - To estimate the (modifiable) drug risk for a patient
  - To predict the change in risk if medication(s) modified
  - (To prioritize changes based on likely risk reduction)

Prescribing Decision Support

- Traditional drug alerts
  - Generic
  - Clinical implications unclear
  - Ignored
- Probabilistic alerts can give clear, target message
  - Personalized alert
  - Linked to quantified risk of important outcome

Taylor & Tamblyn, 2005; Shah, et.al, 2006; Van der Sijs, et.al, 2006; Eslami,et.al, 2007

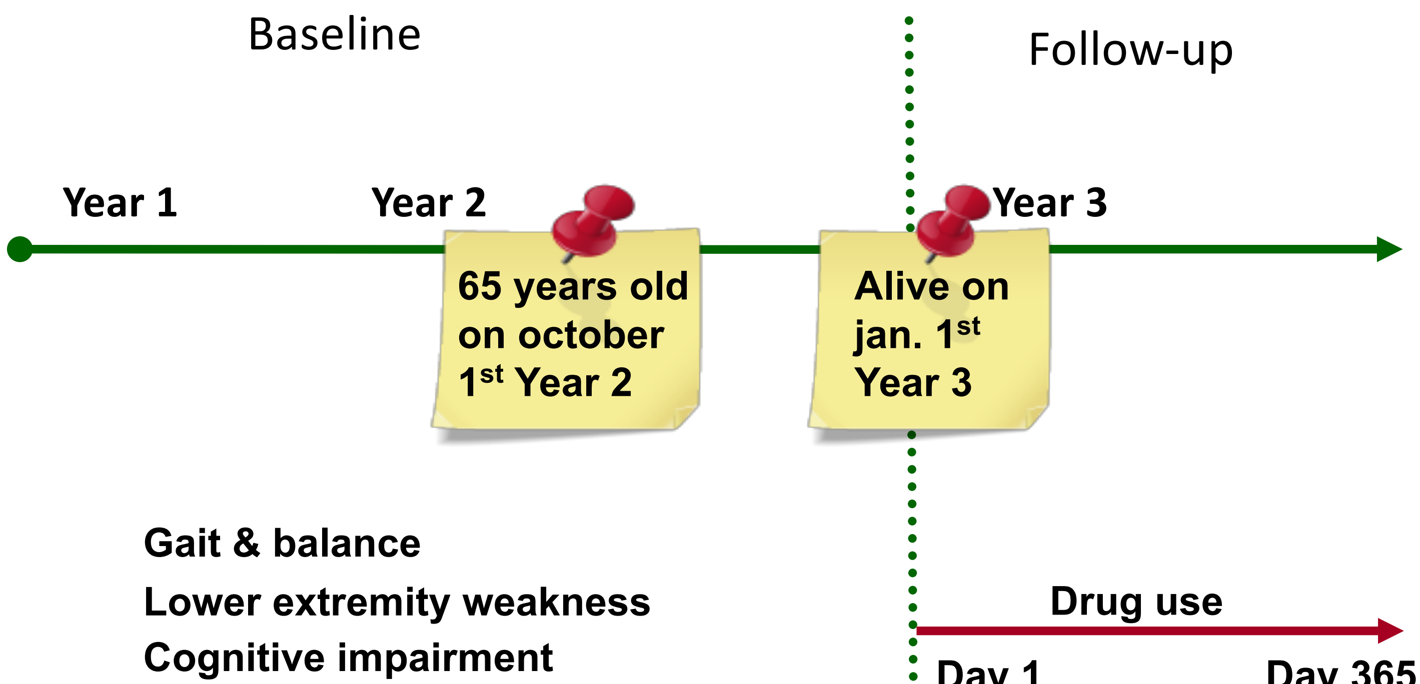
Traditional

"Level 2 Alert: Age-Drug Interaction with Opiates"

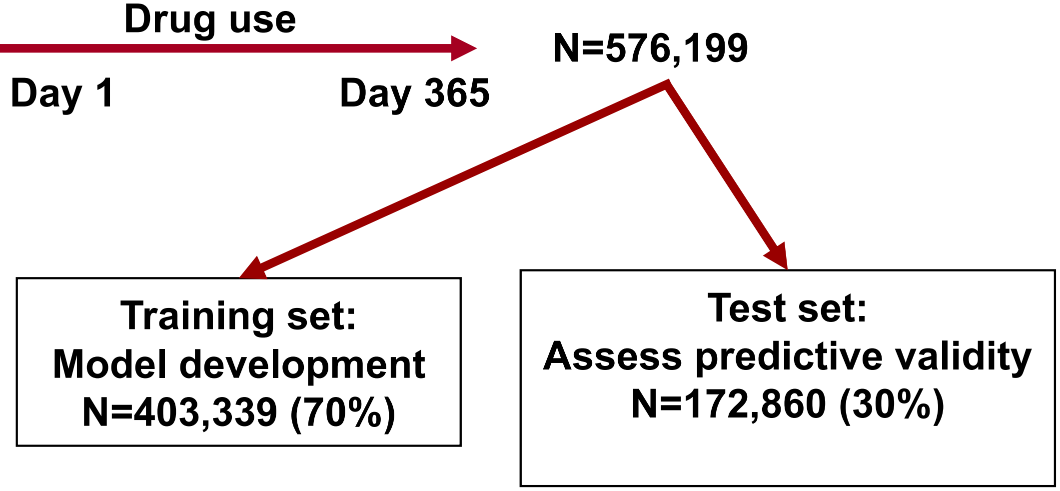
Probabilistic

"15% chance this patient will fall on current dose of codeine"

Model Building

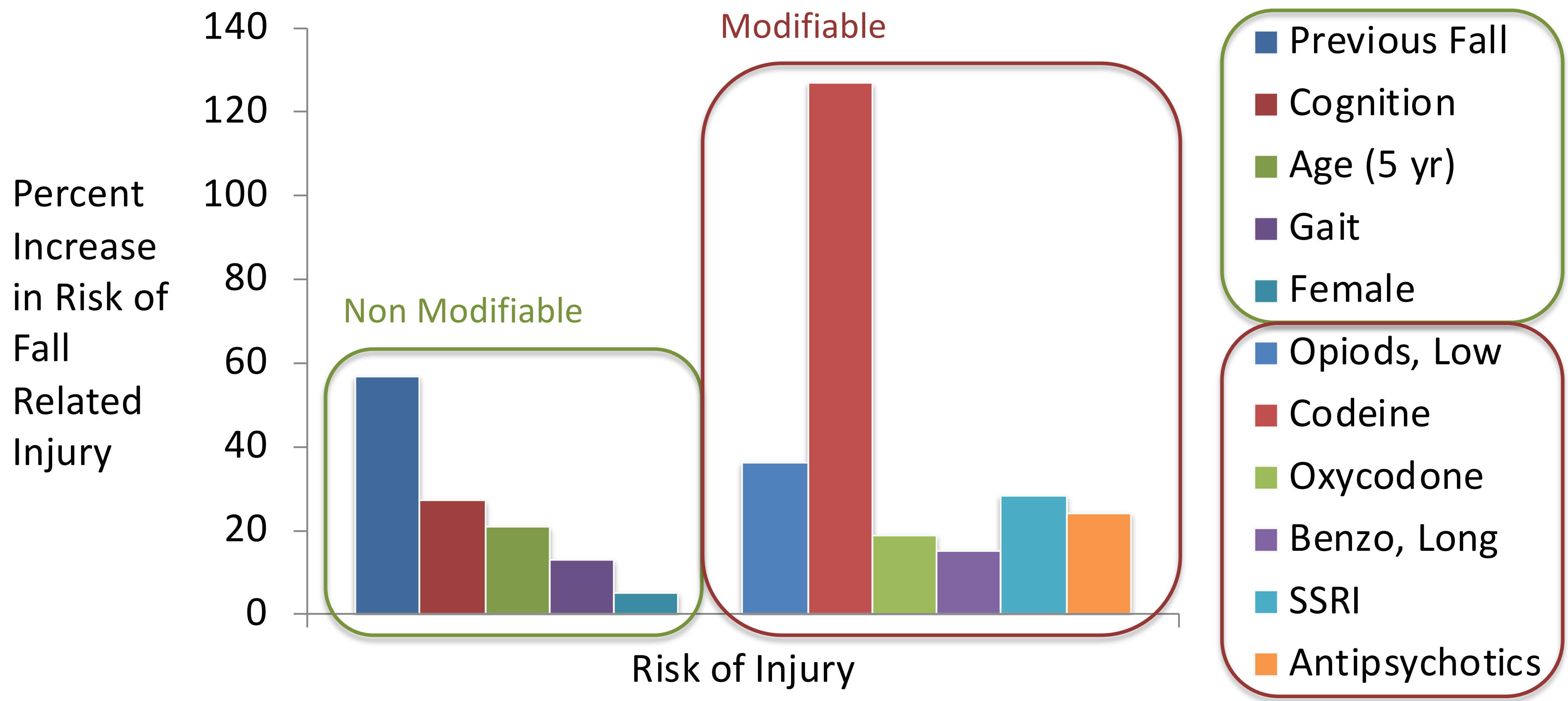


Gait & balance
Lower extremity weakness
Cognitive impairment
Number of falls related injuries
Age, gender



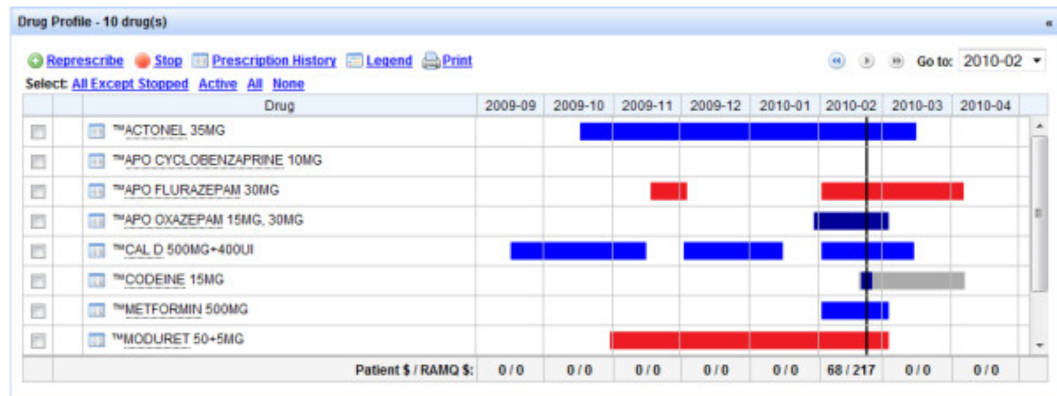
Buckeridge D, Huang A, Hanley J, Kelome A, Reidel K, Verma A, Winslade N, Tamblyn R. Risk of injury associated with opioid use in older adults. J Am Geriatr Soc. 2010 Sep;58(9):1664-70.

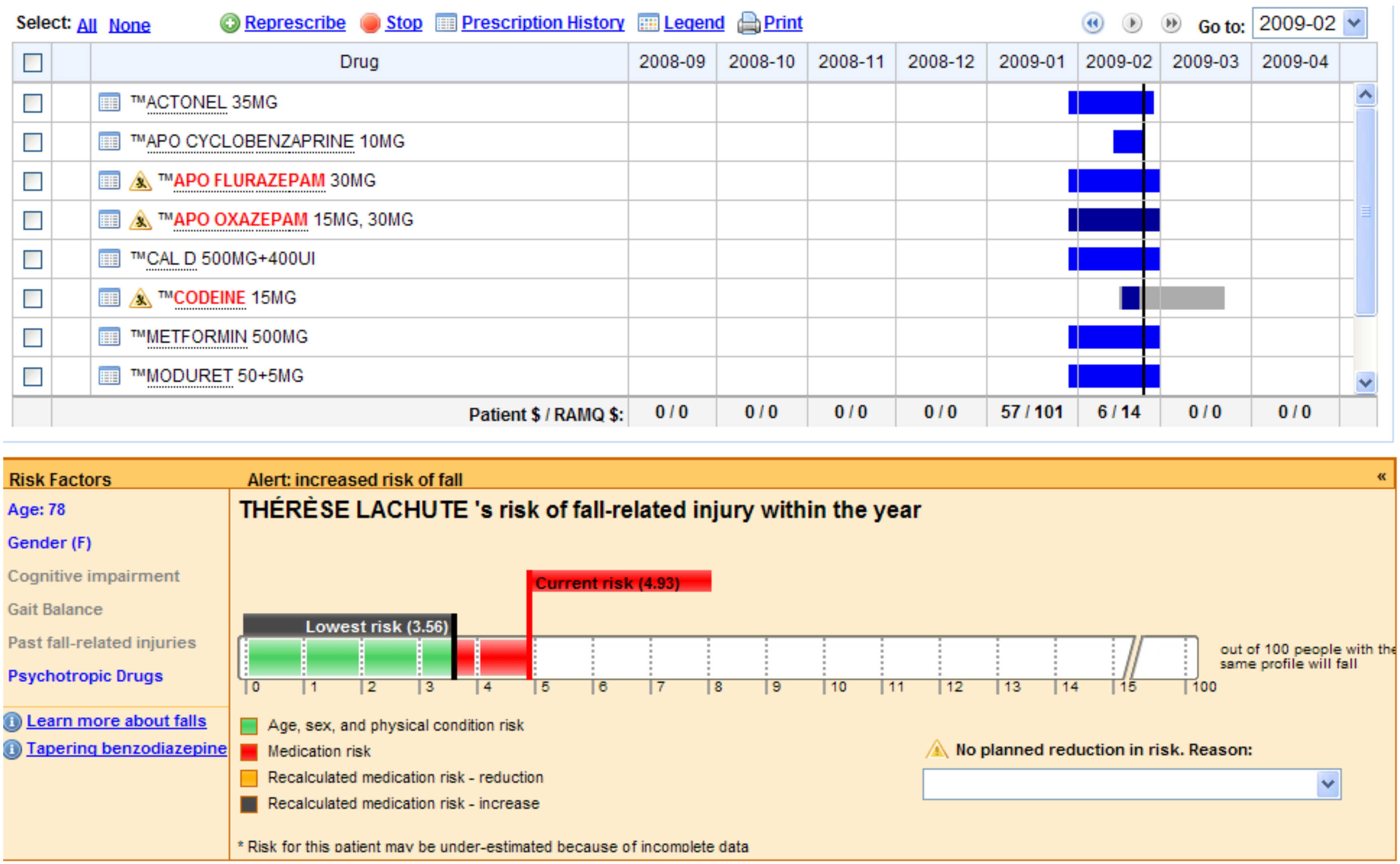
Adjusted Risk Factors for Fall Related Injury



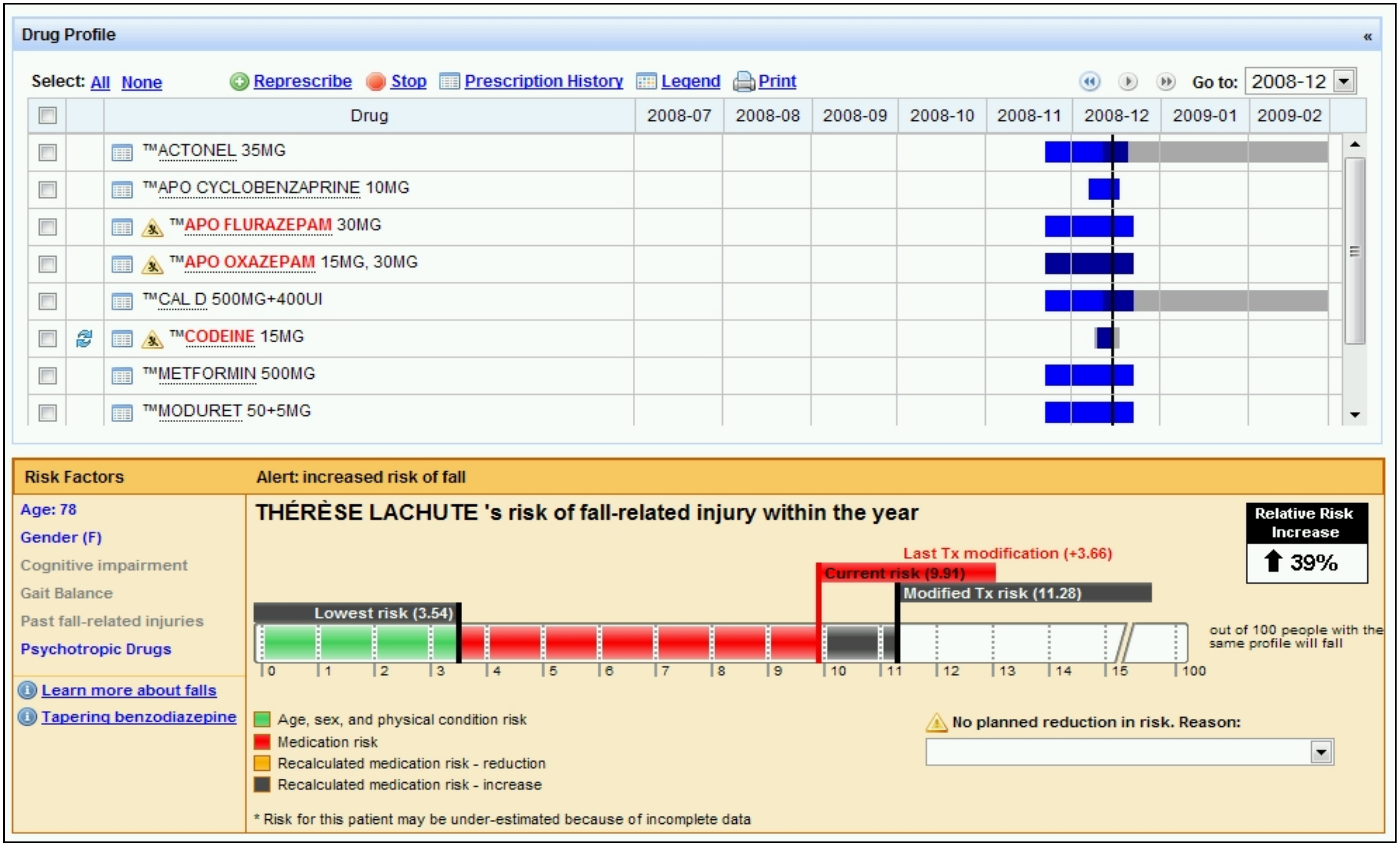
Embedding Model in EMR

- The MOXXI EMR
- User-centered design of risk communication
  - Focus groups with MD
  - Key concepts: absolute vs relative risk, modifiable risk





Select: All None
Represcribe
Stop
Prescription History
Legend
Print
Go to: 2009-02
Drug
2008-09
2008-10
2008-11
2008-12
2009-01
2009-02
2009-03
2009-04
™ACTONEL 35MG
™APO CYCLOBENZAPRINE 10MG
™APO FLURAZEPAM 30MG
™APO OXAZEPAM 15MG, 30MG
™CAL D 500MG+400UI
™CODEINE 15MG
™METFORMIN 500MG
™MODURET 50+5MG
Patient $ / RAMQ $:
0 / 0
0 / 0
0 / 0
0 / 0
57 / 101
6 / 14
0 / 0
0 / 0
Risk Factors
Alert: increased risk of fall
Age: 78
Gender (F)
Cognitive impairment
Gait Balance
Past fall-related injuries
Psychotropic Drugs
Learn more about falls
Tapering benzodiazepine
THÉRÈSE LACHUTE 's risk of fall-related injury within the year
Current risk (4.93)
Lowest risk (3.56)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
100
out of 100 people with the same profile will fall
Age, sex, and physical condition risk
Medication risk
Recalculated medication risk - reduction
Recalculated medication risk - increase
No planned reduction in risk. Reason:
* Risk for this patient may be under-estimated because of incomplete data


Drug Profile
Select: All None
Represcribe
Stop
Prescription History
Legend
Print
Go to: 2008-12
Drug
2008-07
2008-08
2008-09
2008-10
2008-11
2008-12
2009-01
2009-02
™ACTONEL 35MG
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Past fall-related injuries
Psychotropic Drugs
Learn more about falls
Tapering benzodiazepine
THÉRÈSE LACHUTE 's risk of fall-related injury within the year
Relative Risk Increase
39%
Last Tx modification (+3.66)
Current risk (9.91)
Modified Tx risk (11.28)
Lowest risk (3.54)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
100
out of 100 people with the same profile will fall
Age, sex, and physical condition risk
Medication risk
Recalculated medication risk - reduction
Recalculated medication risk - increase
No planned reduction in risk. Reason:
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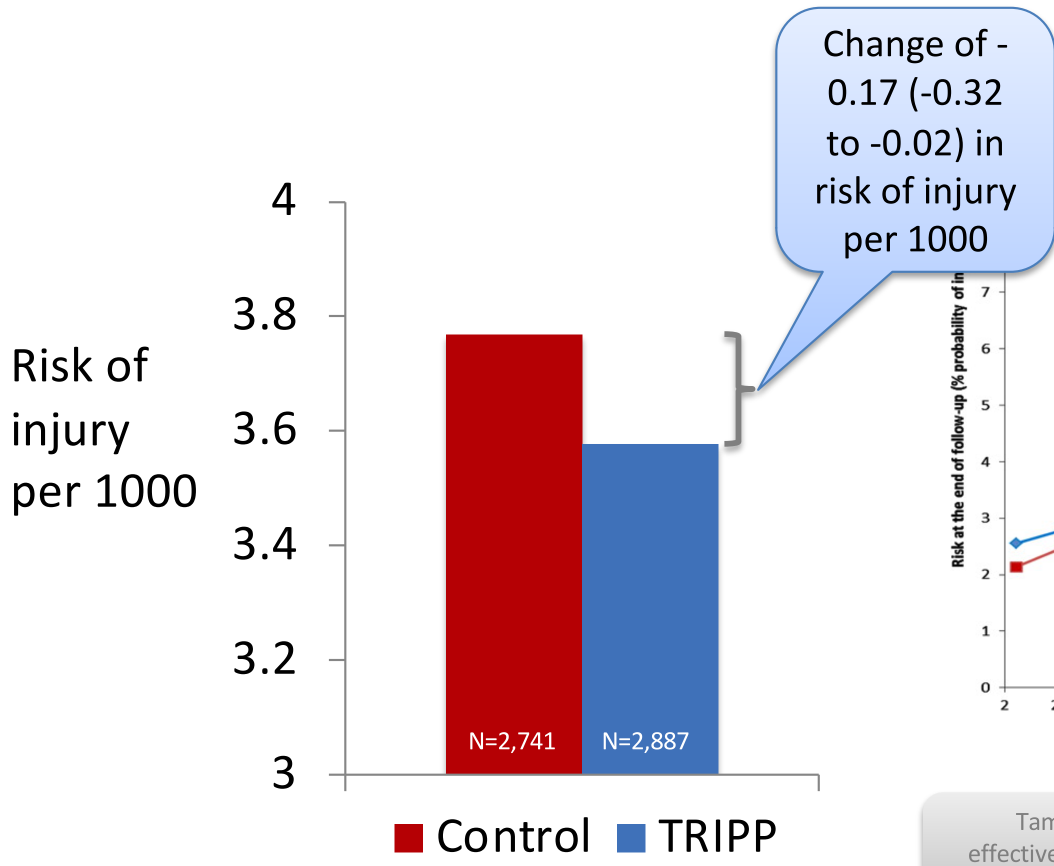
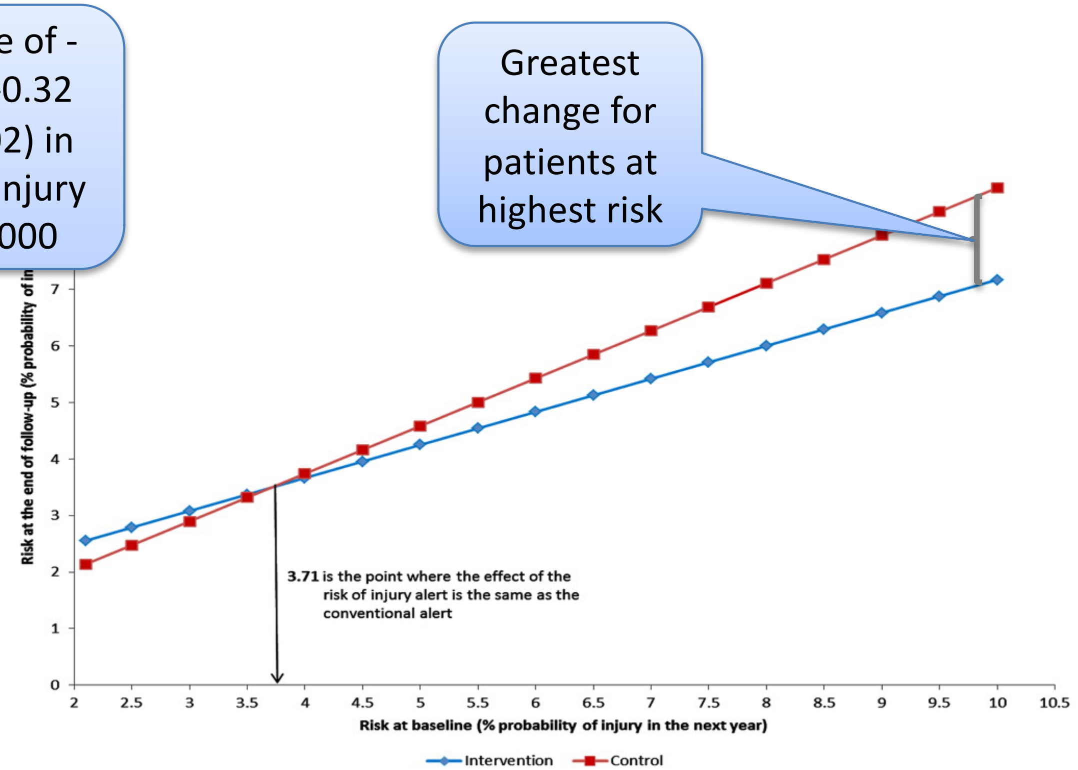
Randomized Controlled Trial





Tamblyn R, Eguale T, Buckeridge DL, Huang A, Hanley J, Reidel K, Shi S, Winslade N. The effectiveness of a new generation of computerized drug alerts in reducing the risk of injury from drug side effects: a cluster randomized trial. J Am Med Inform Assoc. 2012 Jul-Aug;19(4):635-43.

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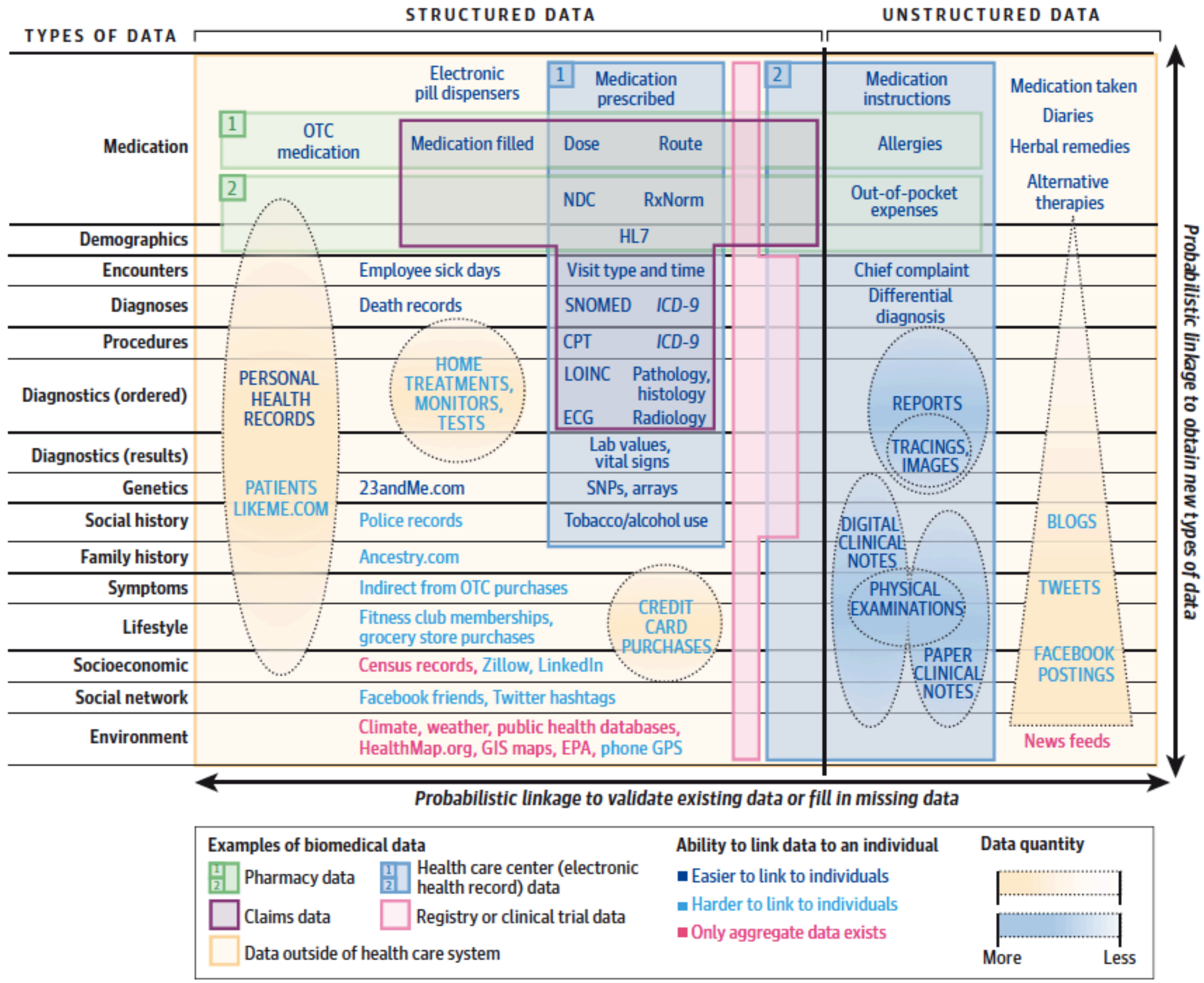
A Population Health System: Knowledge Modeling for Public Health

Closing Thoughts

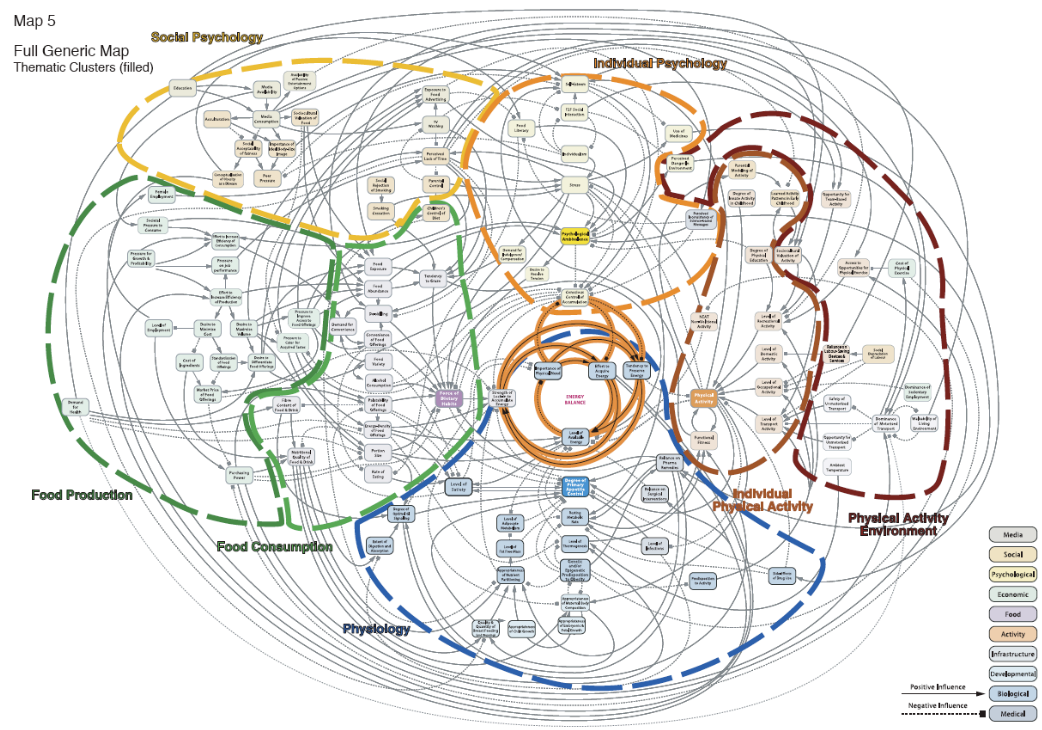
Lots of Relevant Data

Weber GM, Mandl KD, Kohane IS. Finding the Missing Link for Big Biomedical Data. JAMA. 2014;311(24):2479-2480.



Complex Web of Knowledge

- Many diseases have complex causality
- Analysis requires longitudinal, linked data from multiple sectors
- Resulting indicators must be presented in interpretable manner



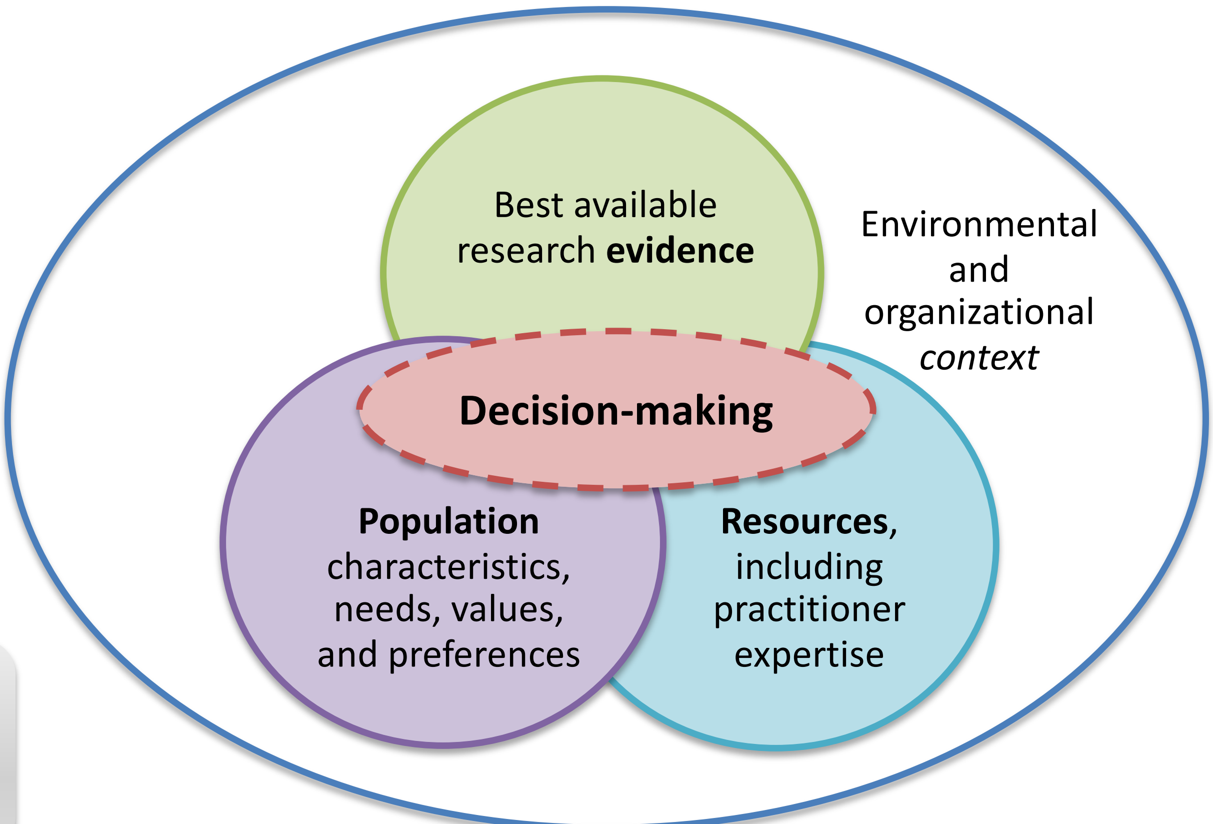
http://www.foresight.gov.uk/OurWork/ActiveProjects/Obesity/

Defining a Population Health Record

- Representative information for a defined population
- Evidence about population health and health systems
- Explicit population health framework used to organize information and evidence
- Facilitates population health decision making
  - Integrated data on determinants, outcomes, healthcare
  - Alignment of information and evidence regarding population health and health system interventions

Friedman DJ, Parrish RG. The population health record: concepts, definition, design, and implementation. JAMIA 2010;17:359-366.

Evidence-Based Public Health



Brownson, R. C., Fielding, J. E. & Maylahn, C. M. Evidence-based public health: a fundamental concept for public health practice. Annu Rev Public Health 30, 175–201 (2009).

Types of Scientific Evidence

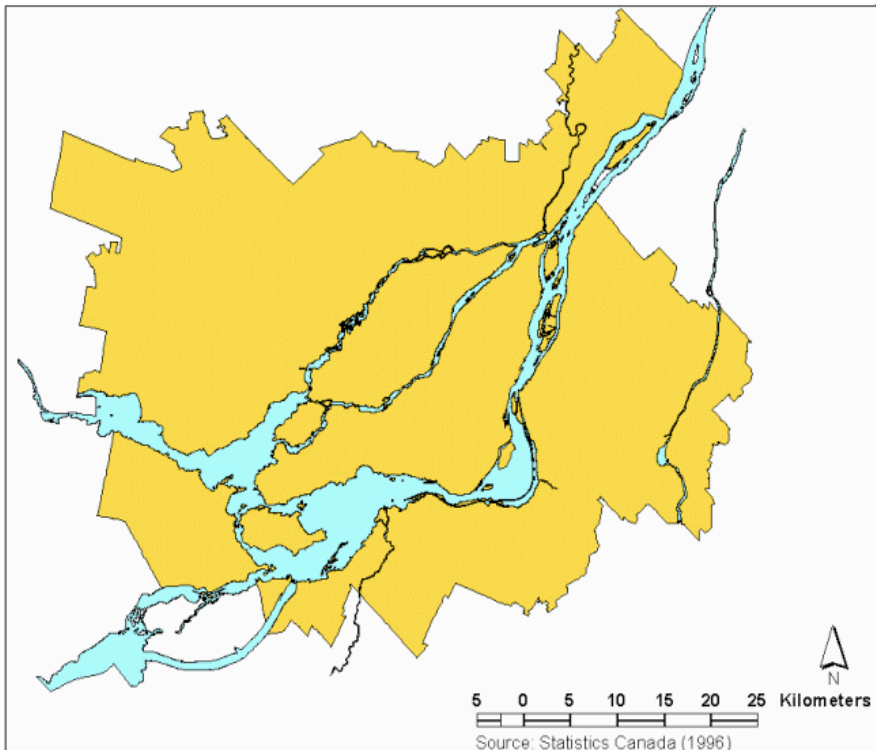
Characteristic	Type One	Type Two	Type Three
Typical data/ relationship	Size and strength of preventable risk—disease relationship (measures of burden, etiologic research)	Relative effectiveness of public health intervention	Information on the adaptation and translation of an effective intervention
Common setting	Clinic or controlled community setting	Socially intact groups or community wide	Socially intact groups or community wide
Example	Smoking causes lung cancer	Price increases with a targeted media campaign reduce smoking rates	Understanding the political challenges of price increases or targeting media messages to particular audience segments
Quantity	More	Less	Less
Action	Something should be done	This particular intervention should be implemented	How an intervention should be implemented

Brownson, R. C., Fielding, J. E. & Maylahn, C. M. Evidence-based public health: a fundamental concept for public health practice. Annu Rev Public Health 30, 175–201 (2009).

PopHR Project Timeline

PopHR Development

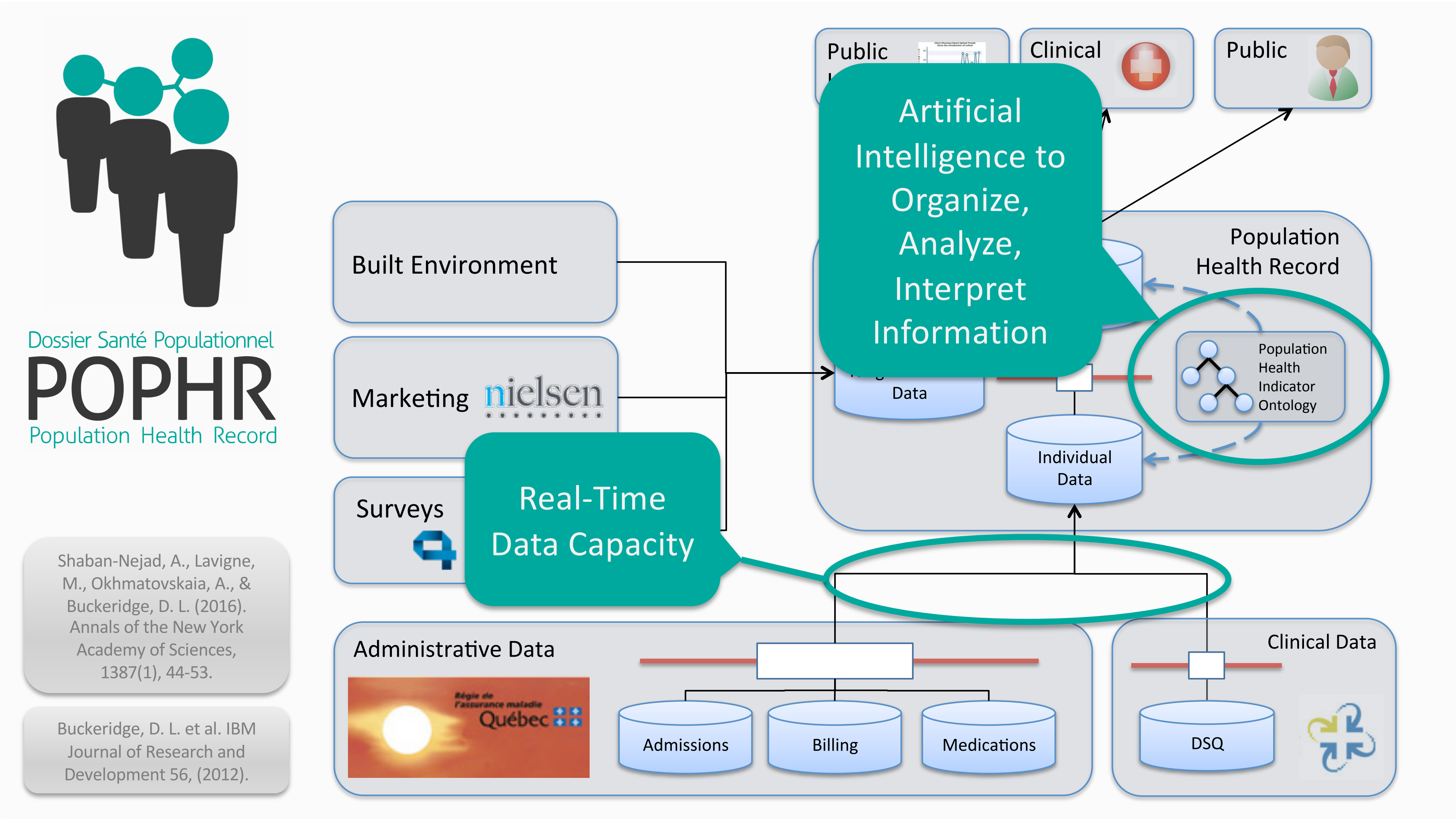
4.1 million people (2016)



Data from 1998 to present

25% random sample

~ 1 million people



Dossier Santé Populationnel
POPHR
Population Health Record
Shaban-Nejad, A., Lavigne, M., Okhmatovskaia, A., & Buckeridge, D. L. (2016). Annals of the New York Academy of Sciences, 1387(1), 44-53.
Buckeridge, D. L. et al. IBM Journal of Research and Development 56, (2012).
Built Environment
Marketing
nielsen
Surveys
Real-Time Data Capacity
Public
Clinical
Public
Artificial Intelligence to Organize, Analyze, Interpret Information
Population Health Record
Data
Population Health Indicator Ontology
Individual Data
Administrative Data
Régie de l'assurance maladie Québec
Admissions
Billing
Medications
Clinical Data
DSQ

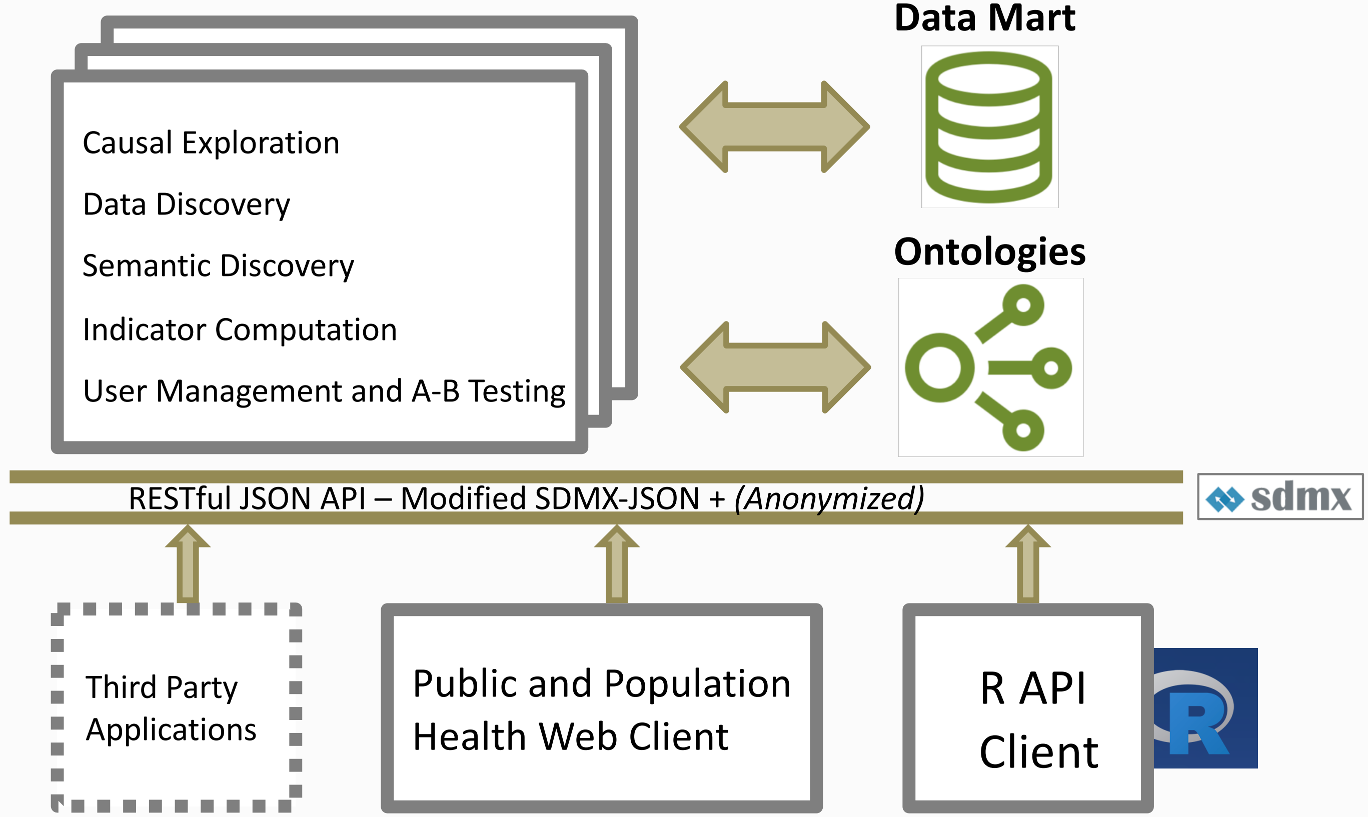
Dossier Santé Populationnel
POPHR
Population Health Record

Knowledge-Based Architecture

Requests made to server via RESTful JSON API

Data packages returned in modified sdmx datacube format

R package pophr allows requests within R session



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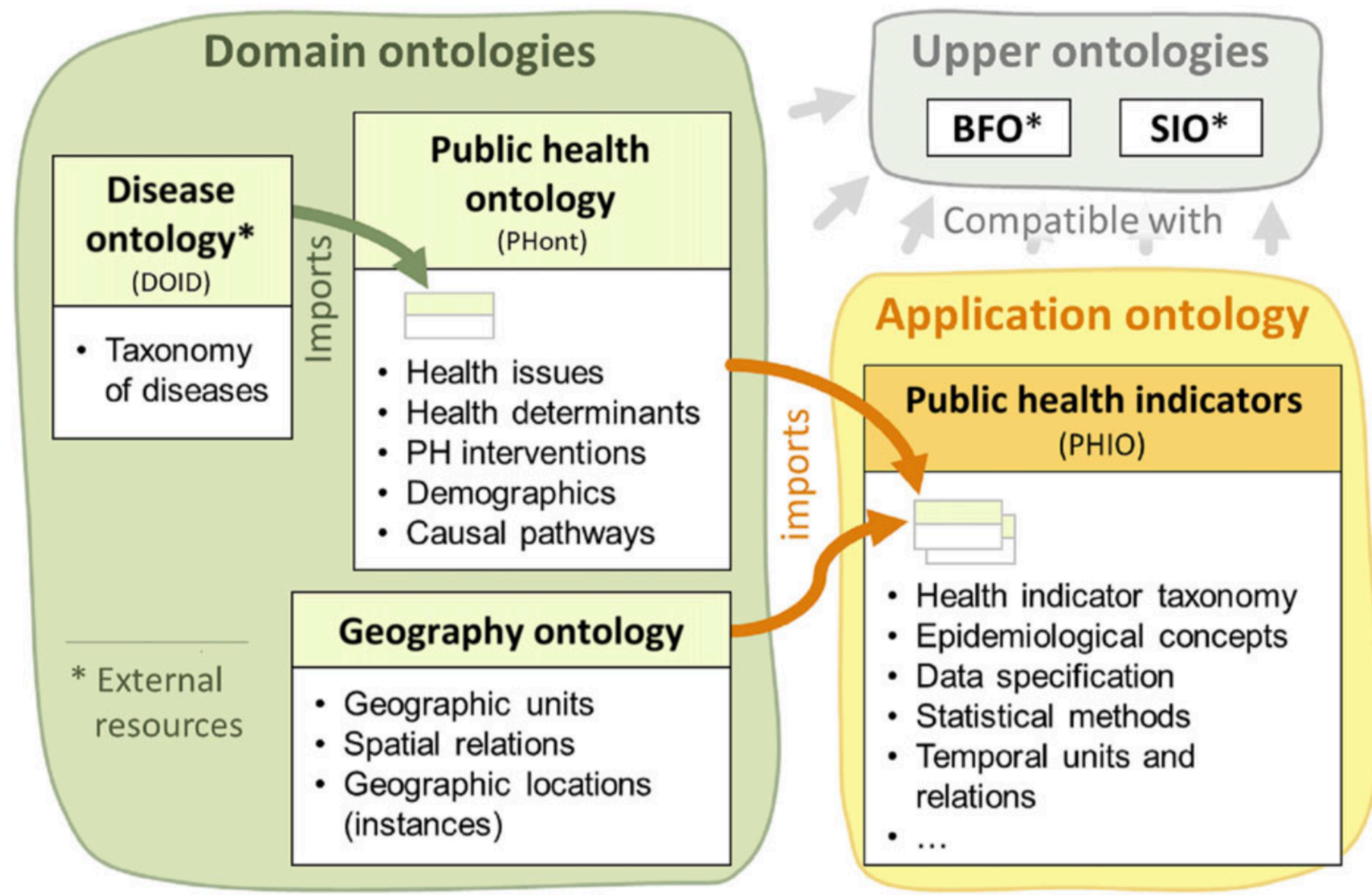
POPHR
Population Health Record

Ontologies



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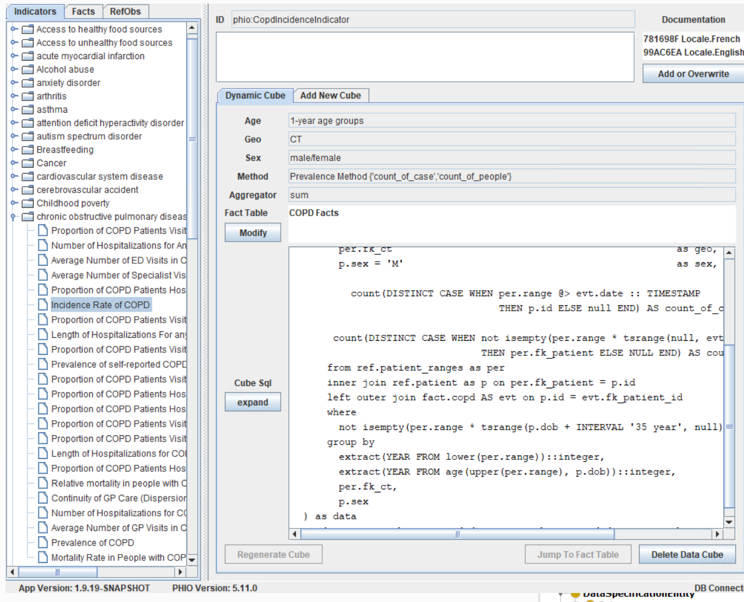
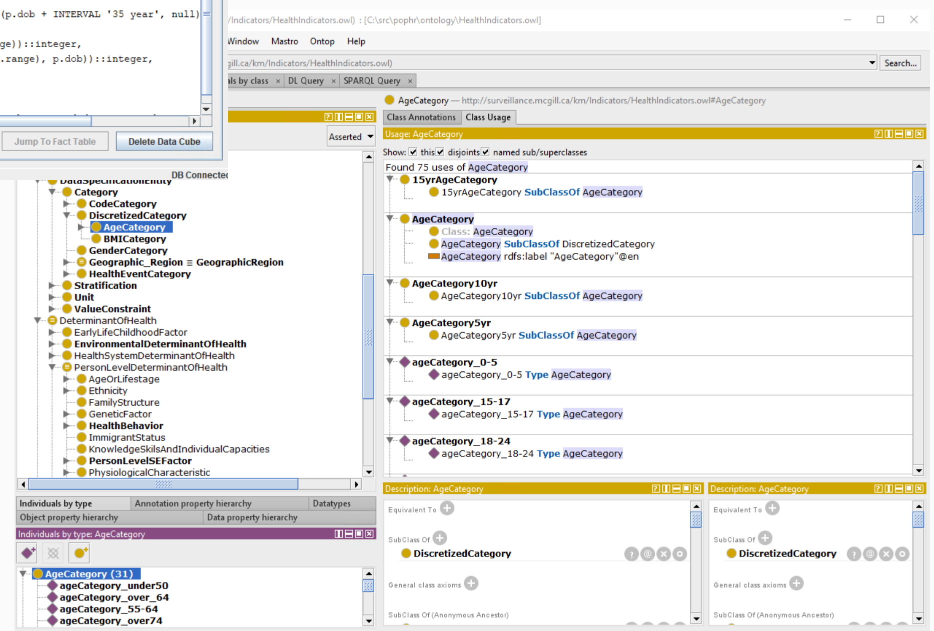
POPHR
Population Health Record

Loading and Annotating Data

Payload Specialist (PH Indicator & Case Loader)





protégé

Dossier Santé Populationnel
POPHR
Population Health Record

Downloaded Dataset

Query Parameters

Stratification Dimensions
Filtering Dimensions
Standardization Dimensions
Missing Data Strategy
Indicator and Concept

Indicator Details

Associated PH Concept
Units (as stored) and (for visualization)
Provenance (work in progress)

Data Cube

-> Cube Specification
-> Column 1 | Dimension | Ref | Number | Codelist
-> Column 2 | Measure | Ref | Number
-> ...

-> Data
-> Row 1 | Array of values
-> Row 2 | Array of values
-> ...

Dossier Santé Populationnel
POPHR
Population Health Record

Metadata in Ontology

Indicators

Type:

- several classification frameworks {CIHI, PHAC, ICD chapters}
- statistical {count, rate, etc.}

Properties:

- indicator of {disease, RF, etc.}
- burn-in period
- excluded age groups
- default age standardization groups
- unit, internal
- unit displayed
- highest geo resolution
- defined by {organization}
- data source {admin., survey, etc.}

Health issues & determinants

Type:

- established classifications of diseases, functioning issues, determinants of health, etc.
- property of individual, population, or environment (region)

Properties:

- has positive/negative effect on {health issue or determinant}

Unit

…

…

…

Organization

…

…

…

Uses of Metadata

Current (mainly internal)

- To inform data visualization
- To guide users in navigating with data
- To guide analysts in creating and maintaining public health indicators and case definitions
- To enable intelligent filtering and aggregation of dimension categories

Future (interoperability, transparency)

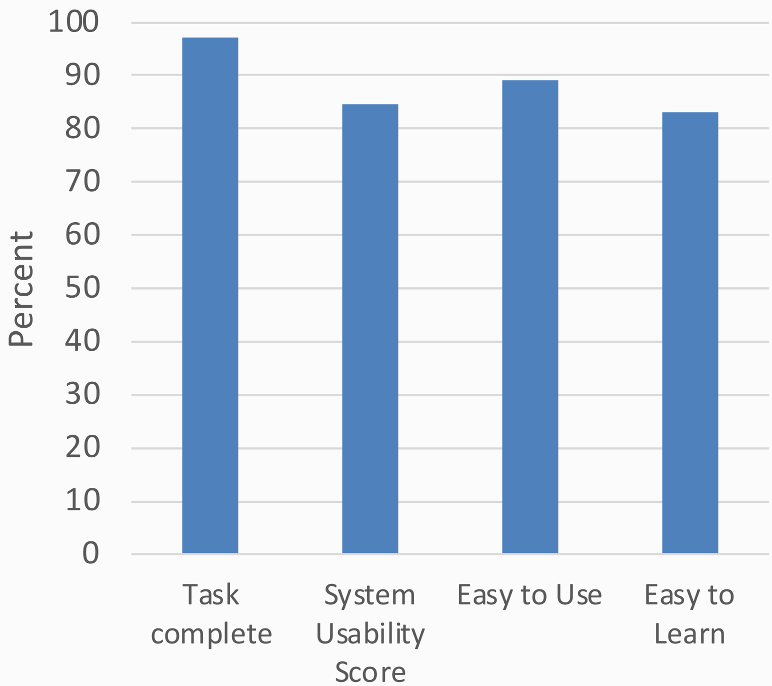
- Generation of methodology documents
- Shared annotation / aligned PH algorithms
- Extending causal annotations
- Adding supporting evidence
- References to know interventions
- Annotation of natural experiments

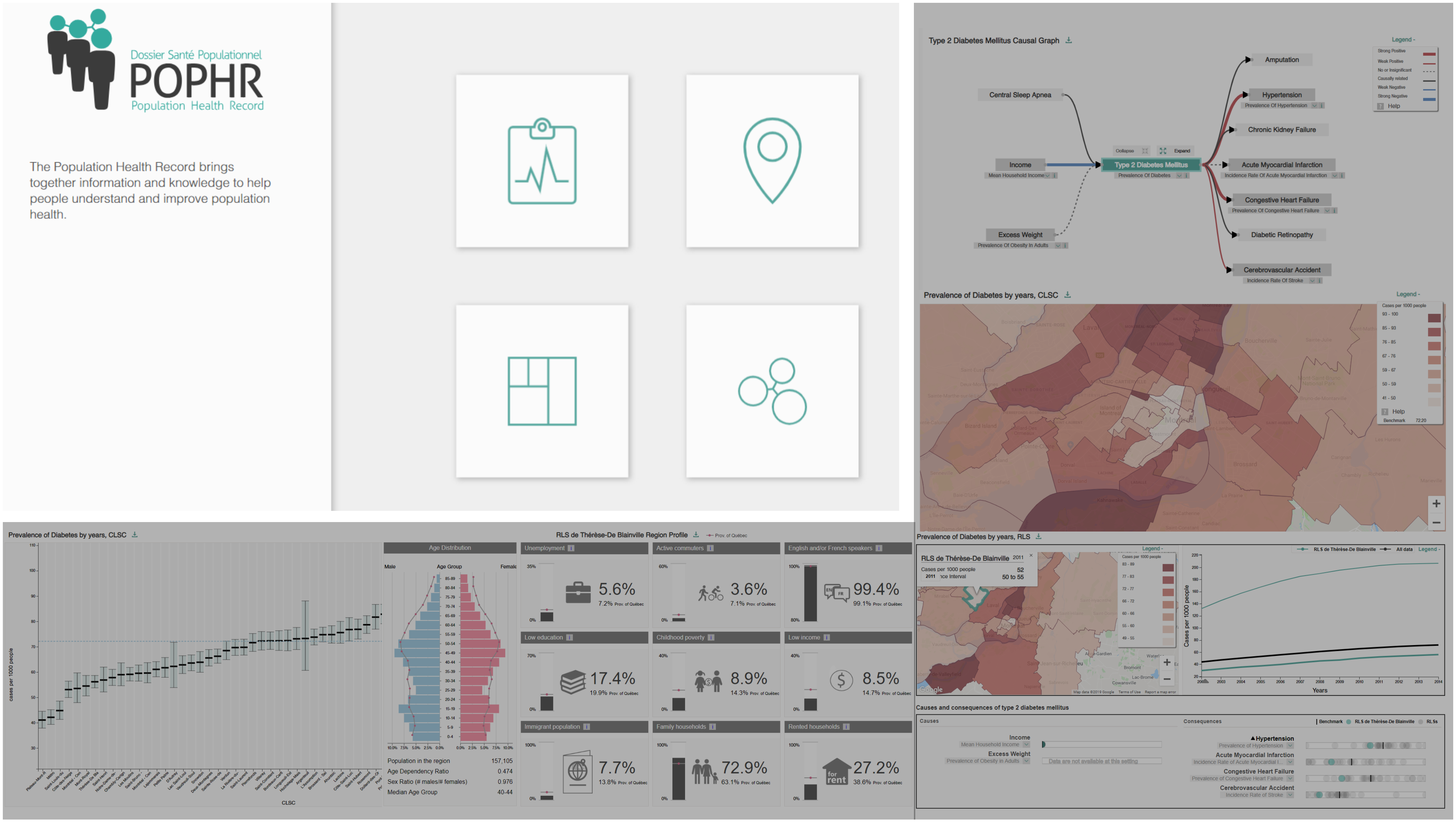
User Workshops

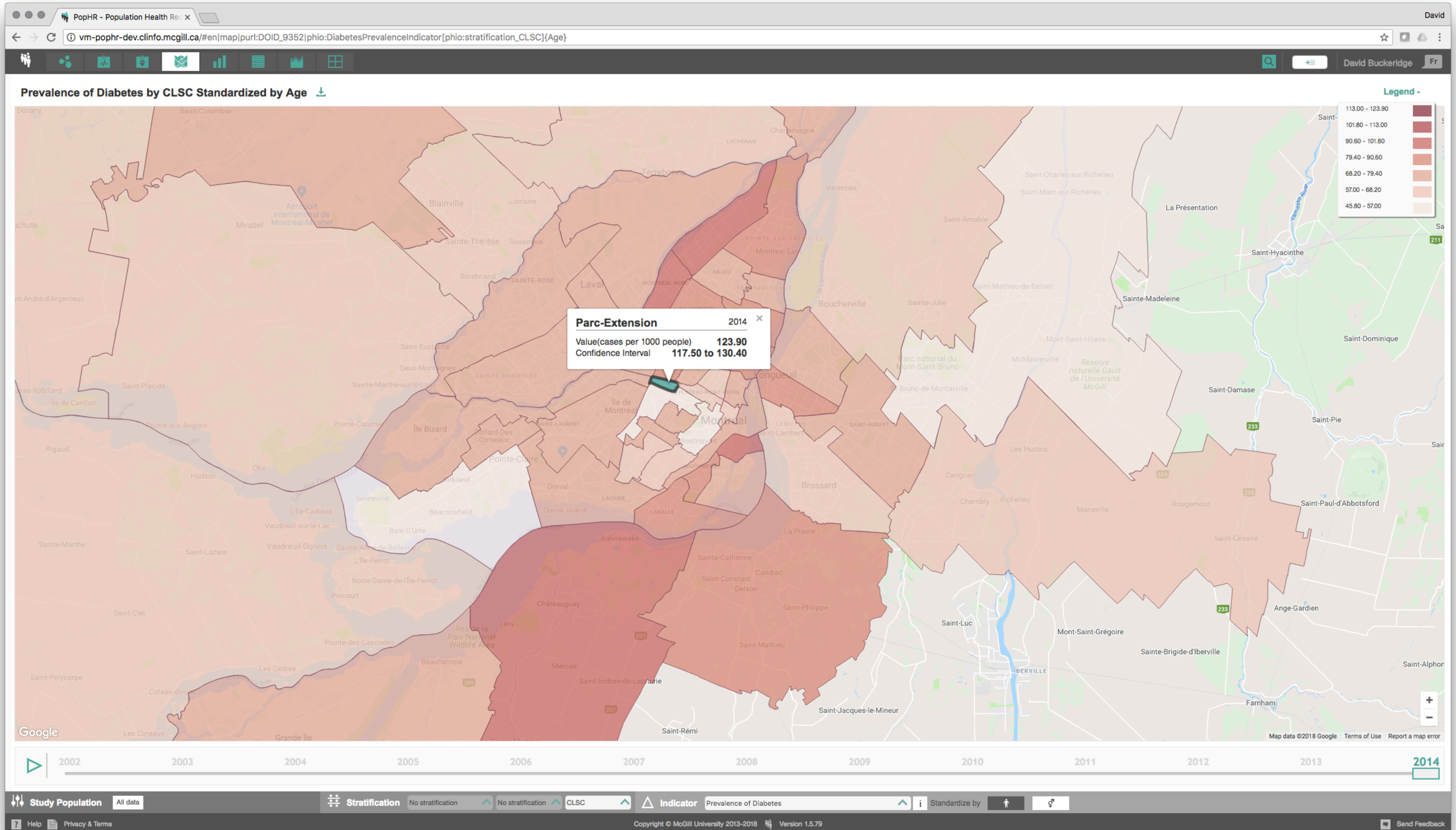
- Three interactive workshops using PopHR with 23 public health practitioners in Montreal and Quebec
- Obtained qualitative and quantitative feedback on application and suggestions for how to improve PopHR

"L'avantage c'est que c'est très visuel, en terme de la chronologie par exemple, pour stratifier par sexe, tout est là."

" C'est un avantage d'avoir les schémas qui présentent les facteurs de risqué, avec les indicateur et ses conséquences sur la santé, c'est une belle organisation. "




Dossier Santé Populationnel
POPHR
Population Health Record
The Population Health Record brings together information and knowledge to help people understand and improve population health.
Type 2 Diabetes Mellitus Causal Graph
Central Sleep Apnea
Income
Mean Household Income
Excess Weight
Prevalence Of Obesity In Adults
Type 2 Diabetes Mellitus
Prevalence Of Diabetes
Amputation
Hypertension
Prevalence Of Hypertension
Chronic Kidney Failure
Acute Myocardial Infarction
Incidence Rate Of Acute Myocardial Infarction
Congestive Heart Failure
Prevalence Of Congestive Heart Failure
Diabetic Retinopathy
Cerebrovascular Accident
Incidence Rate Of Stroke
Prevalence of Diabetes by years, CLSC
Prevalence of Diabetes by years, RLS
RLS de Thérèse-De Blainville Region Profile
Age Distribution
Unemployment 5.6%
Active commuters 3.6%
English and/or French speakers 99.4%
Low education 17.4%
Childhood poverty 8.9%
Low income 8.5%
Immigrant population 7.7%
Family households 72.9%
Rented households 27.2%
Population in the region 157,105
Age Dependency Ratio 0.474
Sex Ratio (# males/# females) 0.976
Median Age Group 40-44
Causes and consequences of type 2 diabetes mellitus


PopHR - Population Health Rec
vm-pophr-dev.clinfo.mcgill.ca/#en|map|purl:DOID_9352|phio:DiabetesPrevalenceIndicator[phio:stratification_CLSC]{Age}
David Buckeridge
Prevalence of Diabetes by CLSC Standardized by Age
Legend -
113.00 - 123.90
101.80 - 113.00
90.60 - 101.80
79.40 - 90.60
68.20 - 79.40
57.00 - 68.20
45.80 - 57.00
Parc-Extension
2014
Value(cases per 1000 people) 123.90
Confidence Interval 117.50 to 130.40
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Study Population
All data
Stratification
No stratification
No stratification
CLSC
Indicator
Prevalence of Diabetes
Standardize by
Help
Privacy & Terms
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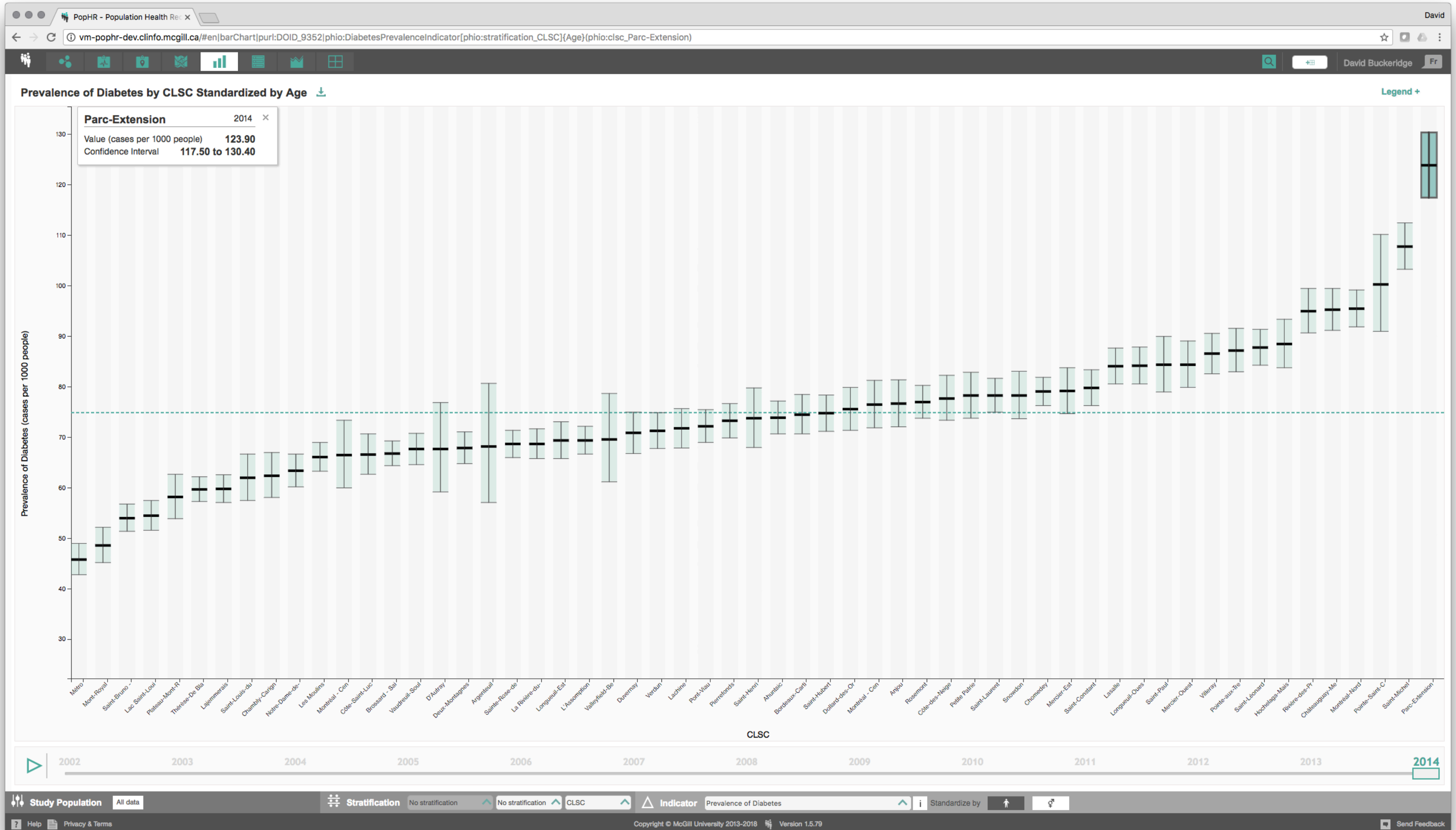
Version 1.5.79
Send Feedback


PopHR - Population Health Re
David
vm-pophr-dev.clinfo.mcgill.ca/#en|barChart|purl:DOID_9352|phio:DiabetesPrevalenceIndicator[phio:stratification_CLSC]{Age}(phio:clsc_Parc-Extension)
David Buckeridge
Fr
Prevalence of Diabetes by CLSC Standardized by Age
Legend +
Parc-Extension
2014
Value (cases per 1000 people) 123.90
Confidence Interval 117.50 to 130.40
Prevalence of Diabetes (cases per 1000 people)
130
120
110
100
90
80
70
60
50
40
30
Métro
Mont-Royal
Saint-Bruno -
Lac Saint-Loui
Plateau-Mont-R
Thérèse-De Bla
Lajemmerais
Saint-Louis-du
Chambly-Carign
Notre-Dame-de-
Les Moulins
Montréal - Cen
Côte-Saint-Luc
Brossard - Sai
Vaudreuil-Soul
D'Autray
Deux-Montagnes
Argenteuil
Sainte-Rose-de
La Rivière-du-
Longueuil-Est
L'Assomption
Valleyfield-Be
Duvernay
Verdun
Lachine
Pont-Viau
Pierrefonds
Saint-Henri
Ahuntsic
Bordeaux-Carti
Saint-Hubert
Dollard-des-Or
Montréal - Cen
Anjou
Rosemont
Côte-des-Neige
Petite Patrie
Saint-Laurent
Snowdon
Chomedey
Mercier-Est
Saint-Constant
Lasalle
Longueuil-Oues
Saint-Paul
Mercier-Ouest
Villeray
Pointe-aux-Tre
Saint-Léonard
Hochelaga-Mais
Rivière-des-Pr
Châteauguay-Me
Montréal-Nord
Pointe-Saint-C
Saint-Michel
Parc-Extension
CLSC
2002
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2011
2012
2013
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Study Population
All data
Stratification
No stratification
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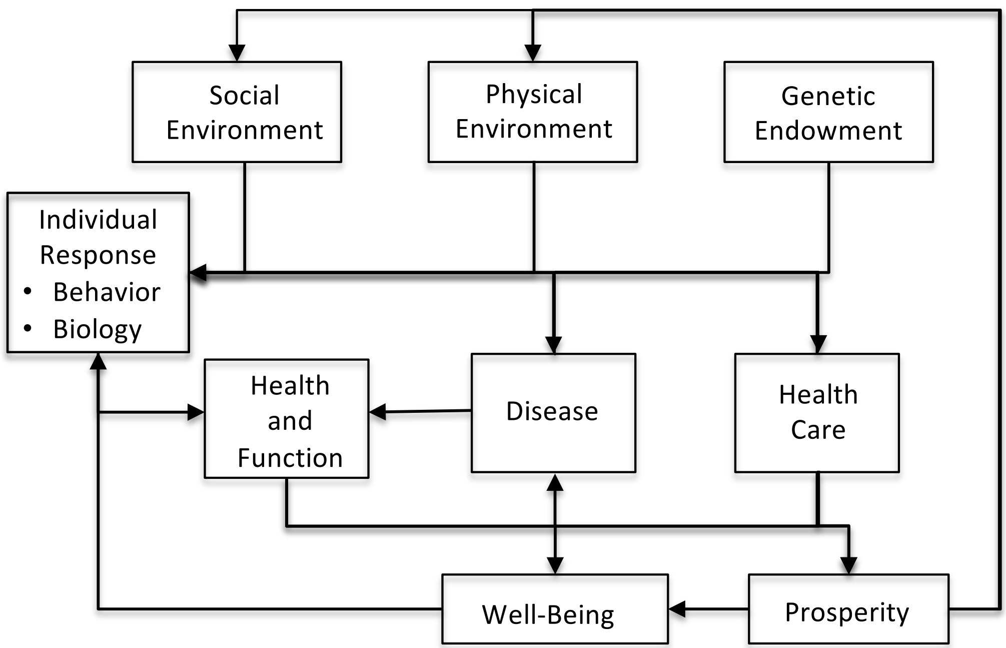
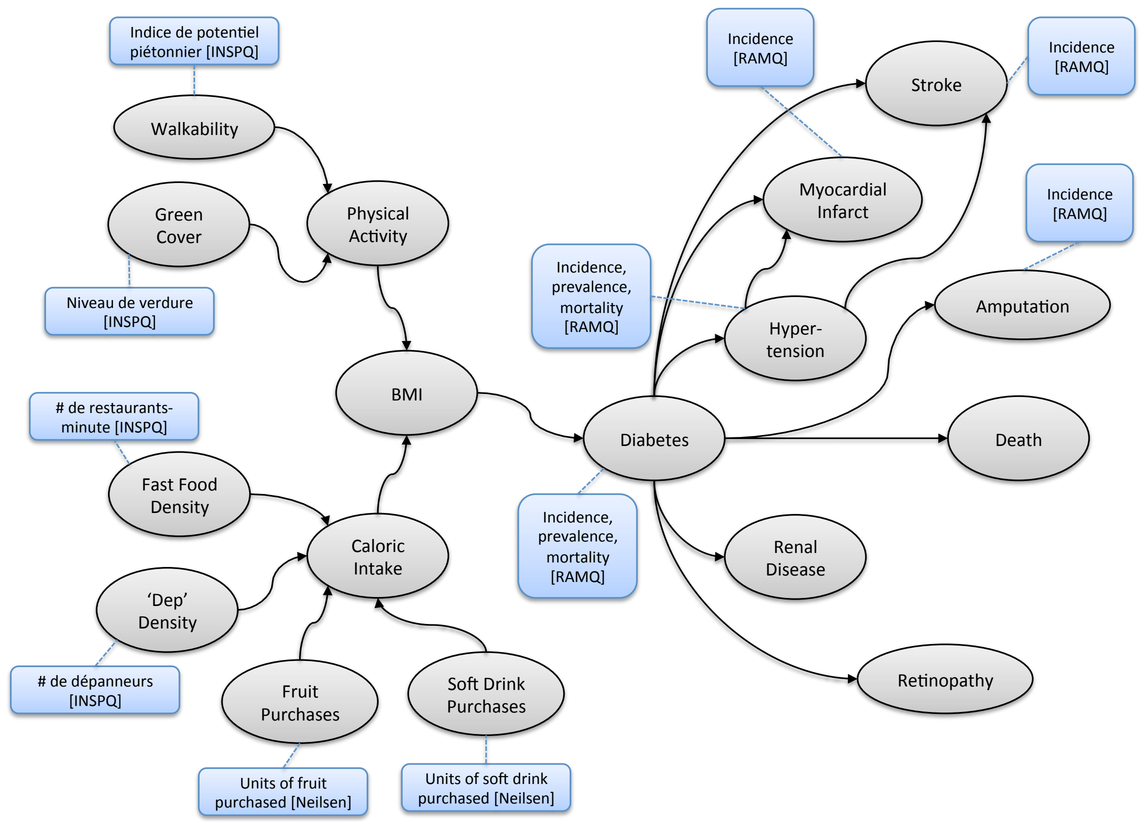
Send Feedback

Template for Population Health

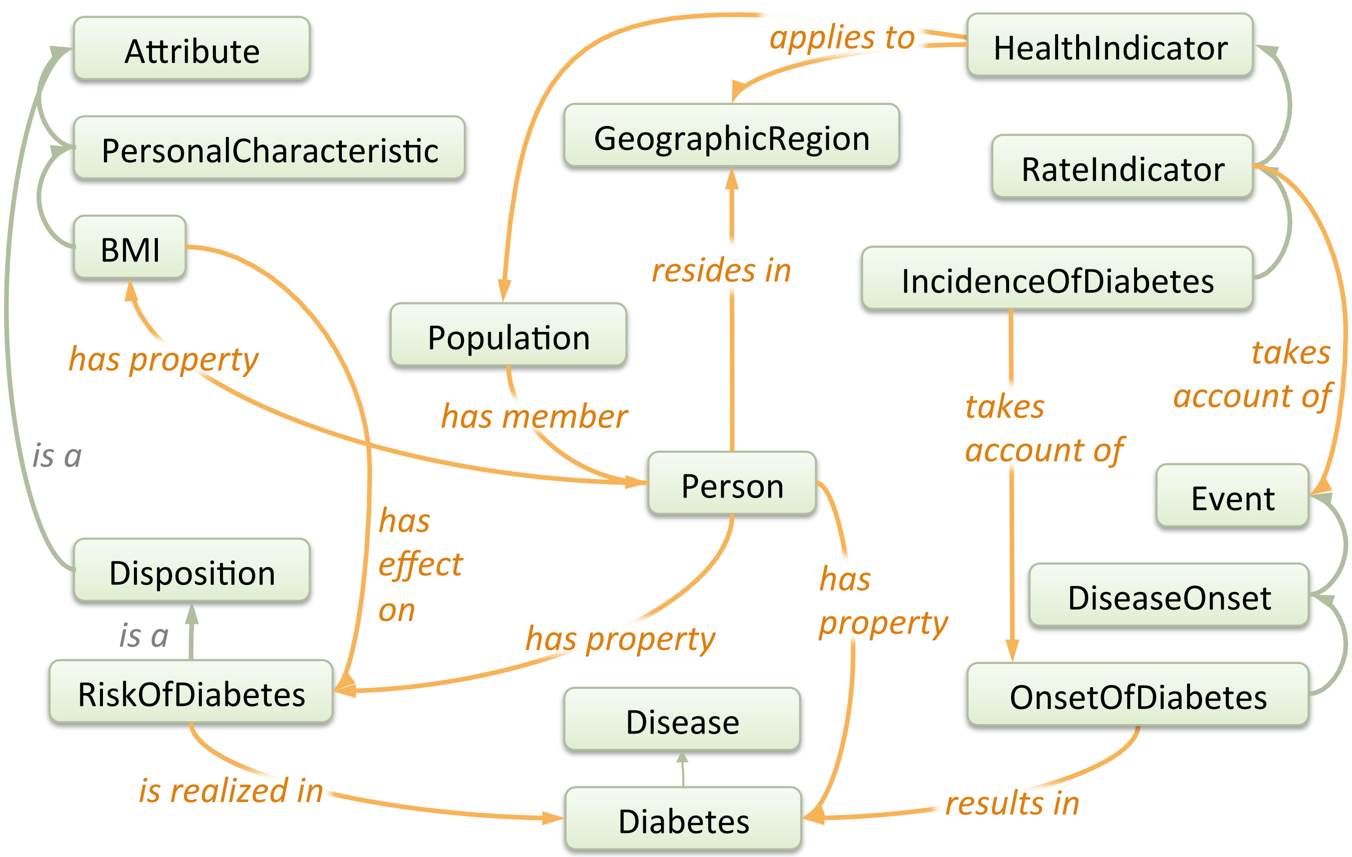


Evans R, Stoddart G. Producing Health, Consuming Health Care. Canadian Institutes for Advanced Research. Program in Population Health. Working Paper No. 6, p 51. Toronto, April 1990.

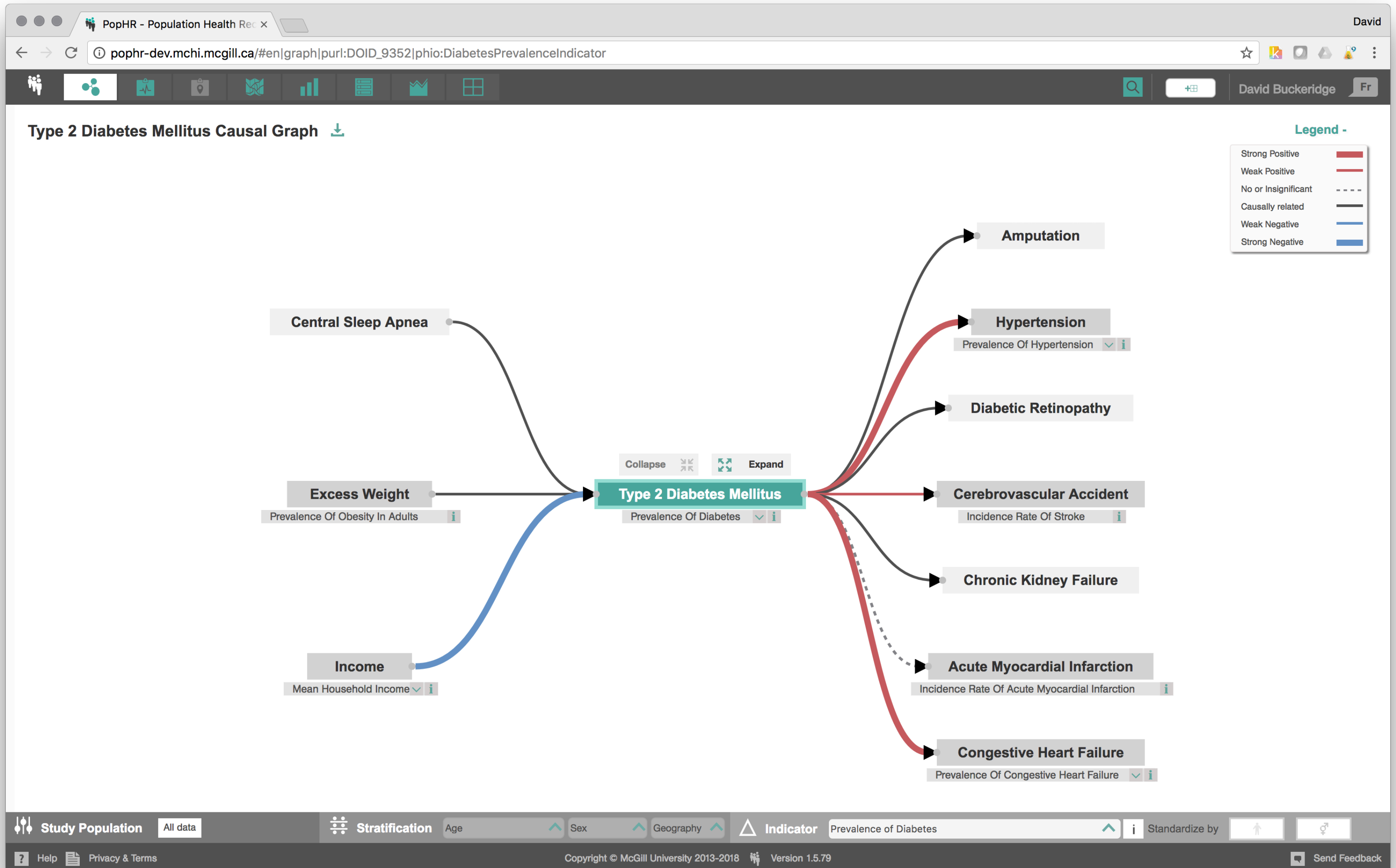
Informal Model



Formal Model



Shaban-Nejad, A. et al. PHIO: a knowledge base for interpretation and calculation of public health indicators. Stud Health Technol Inform 192, 1207 (2013).


PopHR - Population Health Rec
David
pophr-dev.mchi.mcgill.ca/#en|graph|purl:DOID_9352|phio:DiabetesPrevalenceIndicator
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Fr
Type 2 Diabetes Mellitus Causal Graph
Legend -
Strong Positive
Weak Positive
No or Insignificant
Causally related
Weak Negative
Strong Negative
Amputation
Central Sleep Apnea
Hypertension
Prevalence Of Hypertension
Diabetic Retinopathy
Collapse
Expand
Excess Weight
Prevalence Of Obesity In Adults
Type 2 Diabetes Mellitus
Prevalence Of Diabetes
Cerebrovascular Accident
Incidence Rate Of Stroke
Chronic Kidney Failure
Income
Mean Household Income
Acute Myocardial Infarction
Incidence Rate Of Acute Myocardial Infarction
Congestive Heart Failure
Prevalence Of Congestive Heart Failure
Study Population
All data
Stratification
Age
Sex
Geography
Indicator
Prevalence of Diabetes
Standardize by
Help
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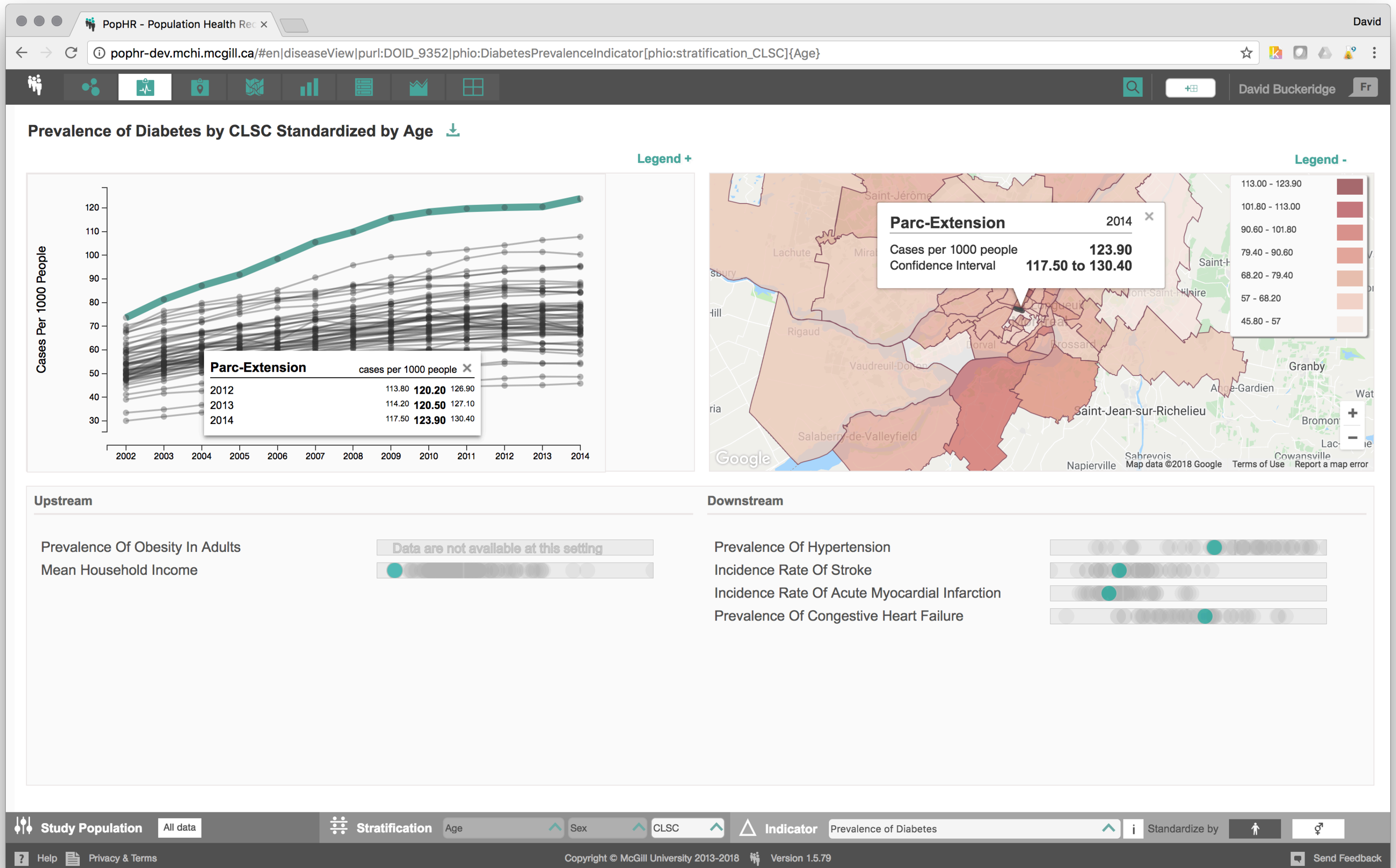

PopHR - Population Health Rec
David
pophr-dev.mchi.mcgill.ca/#en|diseaseView|purl:DOID_9352|phio:DiabetesPrevalenceIndicator[phio:stratification_CLSC]{Age}
David Buckeridge
Fr
Prevalence of Diabetes by CLSC Standardized by Age
Legend +
Legend -
Cases Per 1000 People
120
110
100
90
80
70
60
50
40
30
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Parc-Extension
cases per 1000 people
2012 113.80 120.20 126.90
2013 114.20 120.50 127.10
2014 117.50 123.90 130.40
Parc-Extension
2014
Cases per 1000 people 123.90
Confidence Interval 117.50 to 130.40
113.00 - 123.90
101.80 - 113.00
90.60 - 101.80
79.40 - 90.60
68.20 - 79.40
57 - 68.20
45.80 - 57
Saint-Jérôme
Lachute
Rigaud
Granby
Saint-Jean-sur-Richelieu
Salaberry-de-Valleyfield
Napierville
Map data ©2018 Google
Terms of Use
Report a map error
Upstream
Prevalence Of Obesity In Adults
Data are not available at this setting
Mean Household Income
Downstream
Prevalence Of Hypertension
Incidence Rate Of Stroke
Incidence Rate Of Acute Myocardial Infarction
Prevalence Of Congestive Heart Failure
Study Population
All data
Stratification
Age
Sex
CLSC
Indicator
Prevalence of Diabetes
Standardize by
Help
Privacy & Terms
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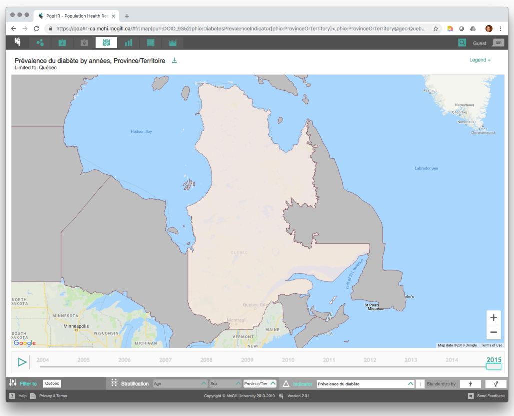
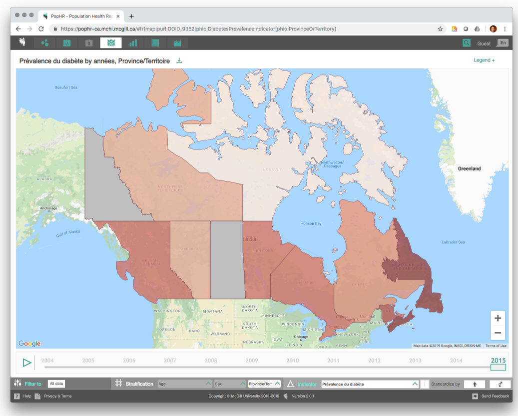
System Implementations

Quebec

- Outcomes computed from individual claims data
- High geographical resolution (Local health region)
- Adoption workshops in Fall 2019 in Montreal, Quebec with public health partners
- Roll-out to entire province in 2020





Institut national de santé publique Québec

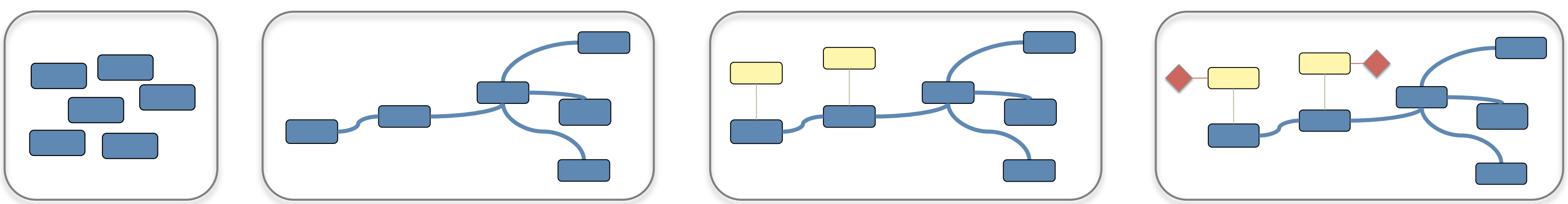
Public Health Agency of Canada
Agence de la santé publique du Canada

Canada

- All indicators pre-computed
- Low geographical resolution (Province, health area)
- Initial presentation to funding agency in Summer 2019
- Plans for extension to US indicators and interoperability project

Knoweldge in PopHR System

	Type I	Type 2	Type 3	
	Causal relationships between health indicators	Effectivenss of public health interventions	Adaptation and translation of effective interventions	**EBPH Types of Evidence**
	Interpret indicators using existing knowledge	**Identify interventions suited to a population**	**Document implemented interventions**	**PopHR Function**



Display

Precision Public Health

"Stratify populations to improve prioritization of health status and selection of interventions."


The NEW ENGLAND JOURNAL of MEDICINE

Perspective

"Precision" Public Health — Between Novelty and Hype

Merlin Chowkwanyun, M.P.H., Ph.D., Ronald Bayer, Ph.D., and Sandro Galea, M.D., Dr.P.H.

THE LANCET

COMMENT | VOLUME 392, ISSUE 10157, P1504, OCTOBER 27, 2018

Offline: In defence of precision public health

Richard Horton

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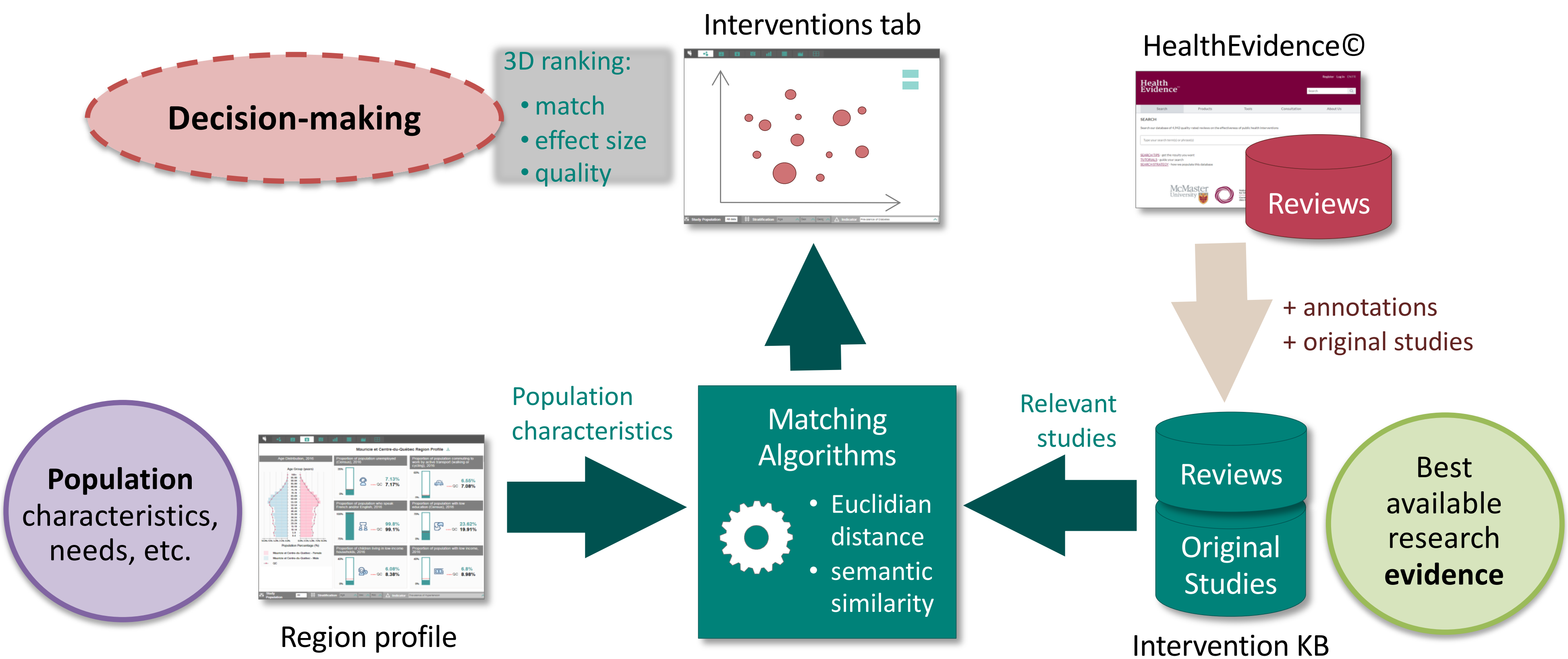
NATURE | COMMENT

Four steps to precision public health

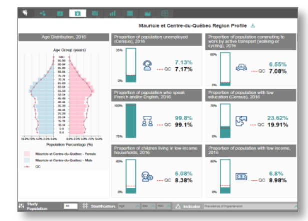
Scott F. Dowell, David Blazes & Susan Desmond-Hellmann

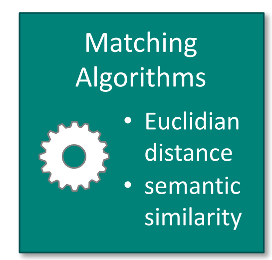
Precision Public Health: Using AI to Match Interventions to Populations



Inputs to Precision Public Health

- Information about defined population
  - Indicators often created from big (e.g., grocery retailing, remote sensing) or large (e.g., administrative claims) data
  - Many indicators may be needed to classify the population
- Evidence about possible interventions
  - Currently extracted mainly manually, but automation (i.e., NLP) necessary to scale efficiently
- Mechanism to determine ‘match’ or even estimate effect of intervention
  - Ontology defined criteria for classification
  - Matching can be semantic (logical similarity) or quantitative





A Clinical System: Statistical Modeling for Prescribing Decision Support

A Population Health System: Knowledge Modeling for Public Health

Closing Thoughts

Challenges, Opportunities for Intelligent Systems in Health

1. Management of ‘Knowledge’
   - Probabilistic approaches
     - model and parameters
     - (re) training, transferring, equity
   - Logical approaches
     - ontologies
     - scope, reuse, alignment, extension and maintenance

Challenges, Opportunities for Intelligent Systems in Health

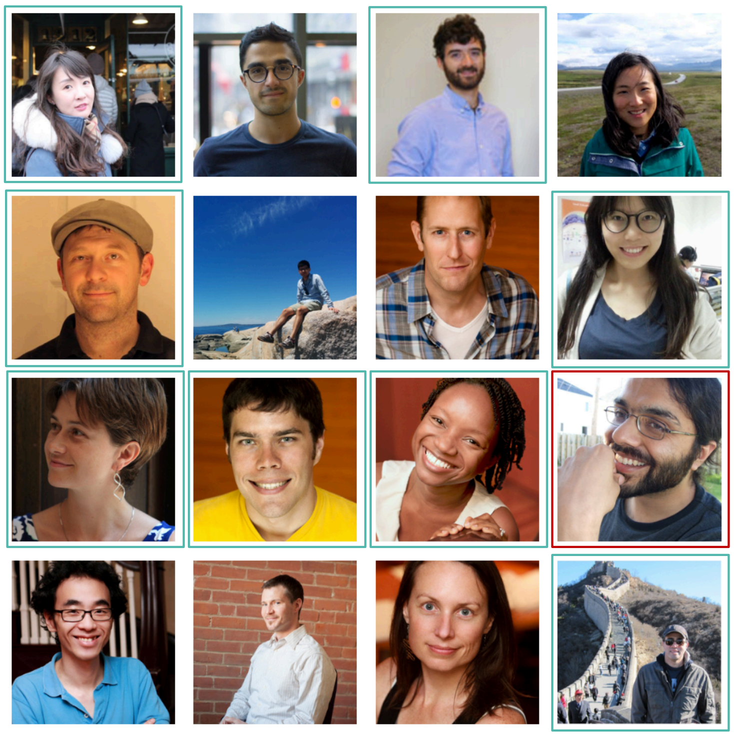
2. Mixing Probabilistic and Logical Approaches
   - Clinical setting
     - A logical framework to prioritize, integrate multiple alerts
     - Maintenance and provenance of predictive models
   - Population health setting
     - Causal knowledge as a prior for statistical learning
     - Prioritization, evaluation of ‘natural experiments’

Challenges, Opportunities for Intelligent Systems in Health

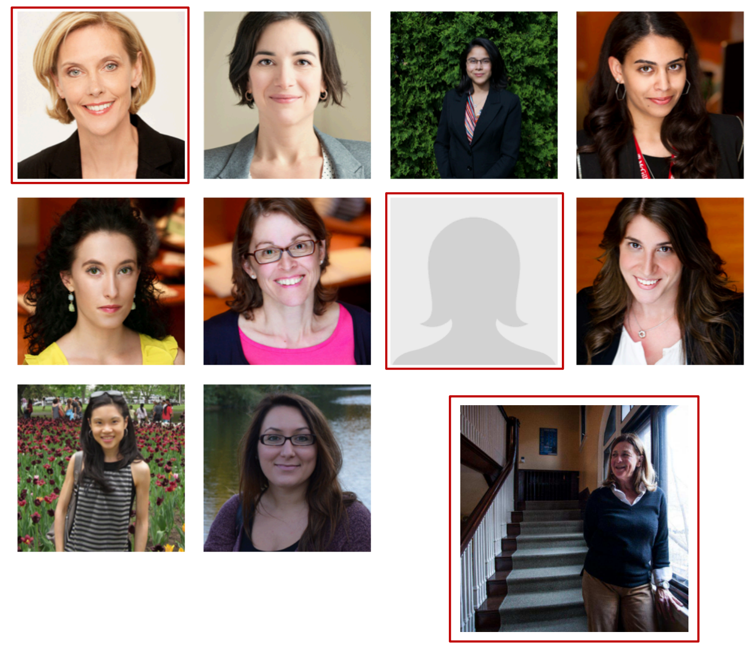
3. Evaluation in Real-world Settings
   - Clinical settings
     - Challenges: to insert into clinical workflow, to work with commercial software vendors
     - Opportunities: interest in ‘precision medicine’ has heightened awareness of potential, accuracy of predictions improving
   - Population health settings
     - Challenges: research with resource-constrained partners, limited foundational infrastructure
     - Opportunities: interest in ‘learning health systems’, growing desire for ‘open’ data at population level

McGill Clinical and Health Informatics

Surveillance Lab



Clinical Decision Support Lab



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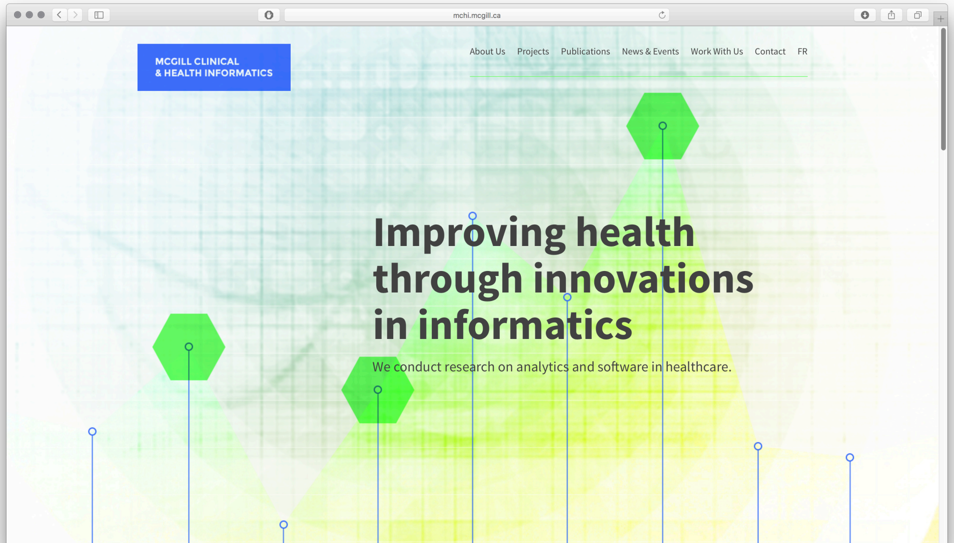
Research Partners

THE NATIONAL CENTER FOR BIOMEDICAL ONTOLOGY

National Collaborating Centre for Methods and Tools
Centre de collaboration nationale des méthodes et outils



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