

Mobile Health Technology in Health Applications

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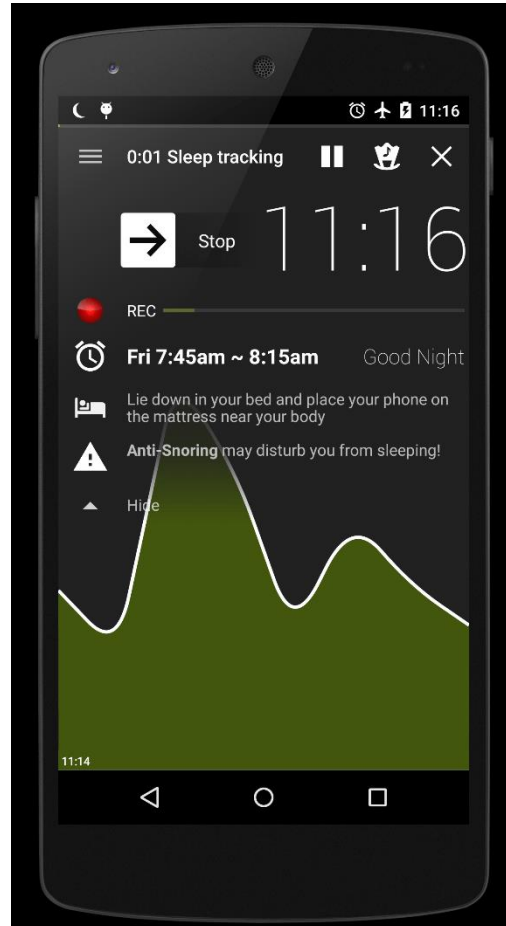
Mobile health

- Explosion of digital data
 - High performance computing
 - Data processing
 - Management of databases
 - Statistical modeling and analysis
 - Visualization

- Mobile health (mHealth) technology
 - Delivery of healthcare services
 - Improvement of health, mental and environmental wellness

Mobile health

➤ Mobile health (mHealth) technologies



Mobile health

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Mobile health

mHealth technologies:

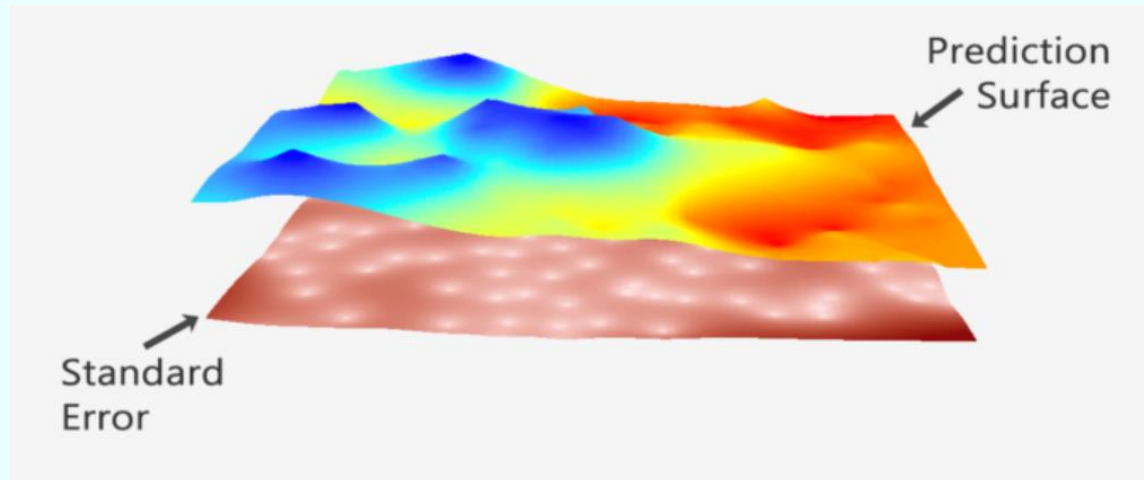
- Improvement of environmental wellness
 - Environmental health hazards that we may encounter unintentionally
 - Examples: toxic chemicals from chemical waste, arsenic in food, air pollution due to particle matters
- Improvement of mental wellness
 - Digital service that teaches people to cope with mental health conditions
 - Computerized Cognitive Behavior Therapy

Spatial analytics (I)

- Geographic information systems (GIS)
 - Geocode: finding latitudes and longitudes of the locations
 - Addresses are geocoded for mapping
 - Business or mobile phone apps
- Fit smooth surface of measurements of interest
- Calculate distances from residences and “target”
- Retrieve census tract and block data

Spatial analytics (II)

- Smooth surface of measurement of interest is fitted by *kriging*



- A prediction surface that models the overall trend
- Standard error is estimated
- Autocorrelations are quantified: closer neighbors are more related and have small “variance”

Spatial Analytics in Environmental wellness

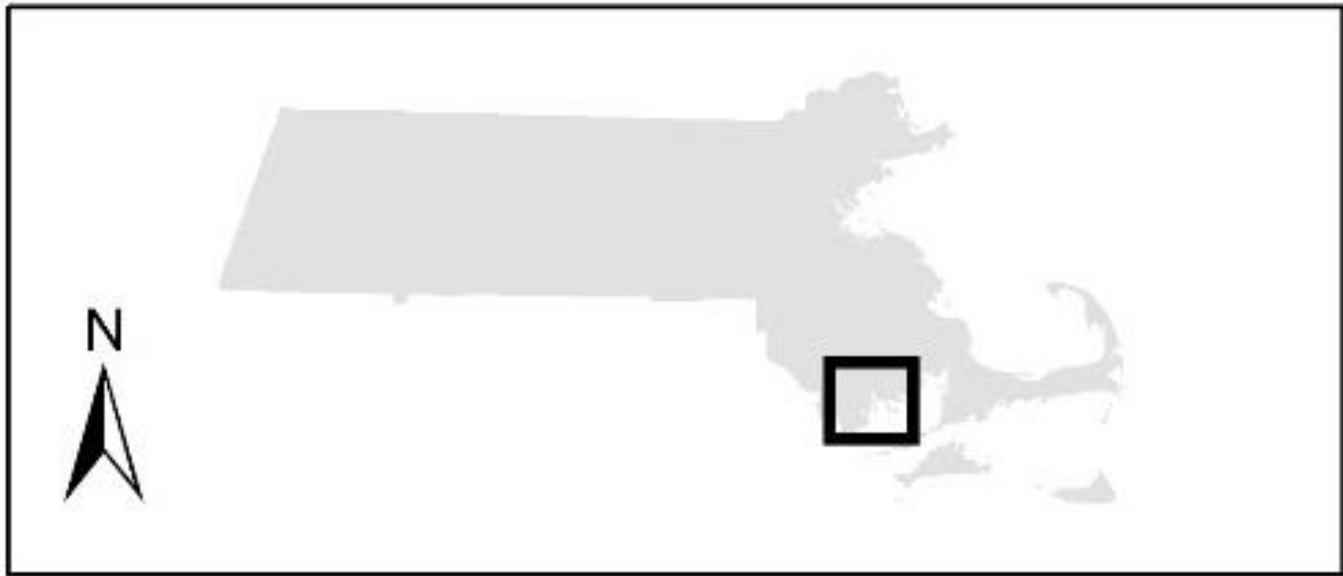
A study of environmental pollutant exposure
and health

Choi et al., EHP

New Bedford, MA

- In 1982, New Bedford was placed under the Superfund legislation for clean up
- Remediation plan - Dredging of sediments between April 1994 and September 1995

New Bedford, MA



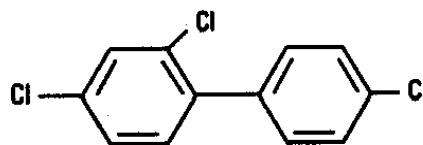
A New Bedford Harbor neighborhood

Korrick and Altshul. 1998

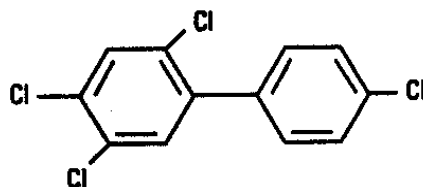


Polychlorinated Biphenyls (PCBs)

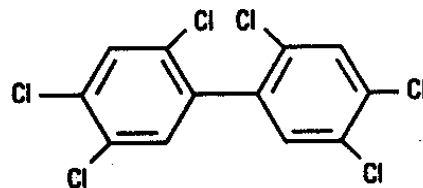
Structure of 3 PCB congeners measured at New Bedford
(Korrick and Altshul, 1998)



Congener 28: 2,4,4'-trichlorobiphenyl



Congener 74: 2,4,4',5-tetrachlorobiphenyl



Congener 153: 2,2',4,4',5,5'-hexachlorobiphenyl

Polychlorinated Biphenyls (PCBs)

➤ Chemistry

- Degree of chlorination
- Persistent, bioaccumulative, lipophilic

➤ Sources

- In transformers, sealants, paints

➤ Biomarkers

- Cord serum, maternal breast milk, maternal serum

Epidemiologic Evidence for Neurodevelopmental Effects of PCBs

- 2 mass PCB poisonings:
 - Japan in 1968 (Yusho)
 - Taiwan in 1979 (Yu-Cheng)
- Children exposed prenatally:
 - Intrauterine growth retardation
 - Hyperpigmentation, acne
 - ↓weight, height, IQ, behavioral disorders

Motivation

- Toxic effects of low-level PCBs have been controversial
- Concern of potential increased exposure risks in communities residing near a Superfund site
- Children, in particular, are vulnerable to these compounds
- A need for better understanding of PCB exposure and its effects in these communities

Methods

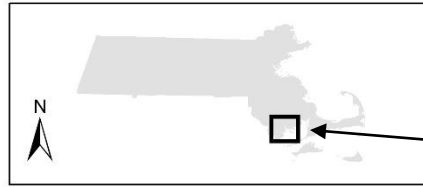
Design

- An ongoing prospective cohort study

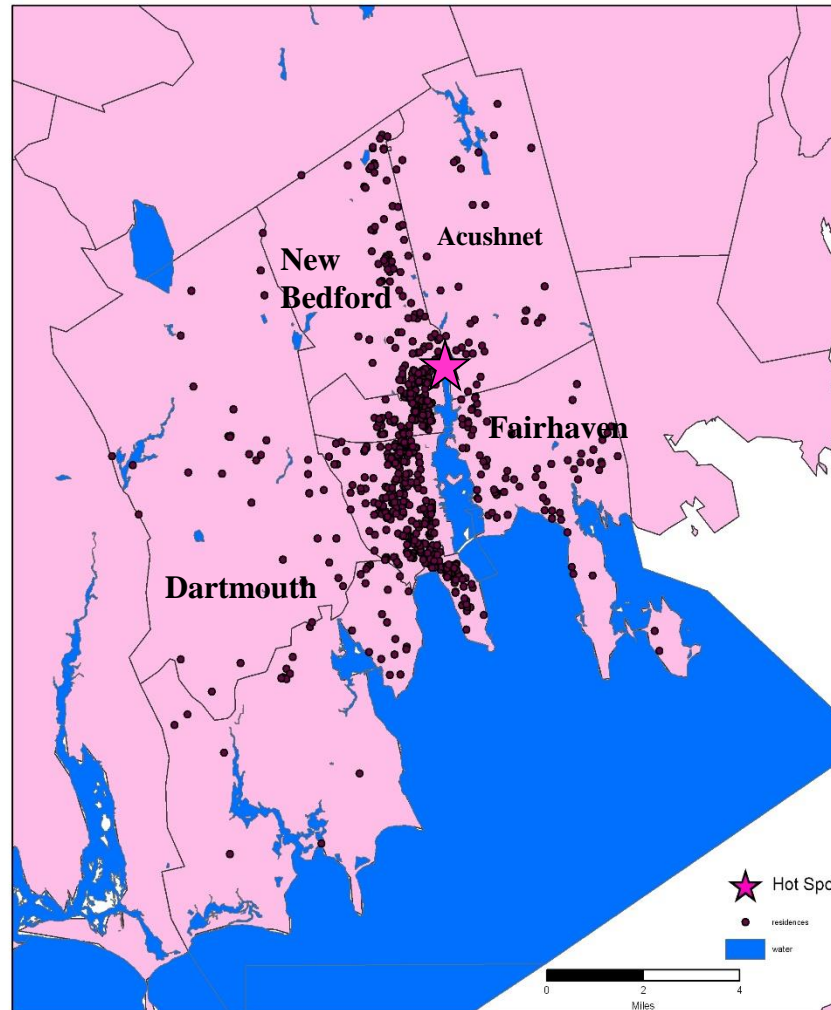
Study Population

- Mother-infant pairs with infants born between March 1993 and December 1998
- Recruited at birth at St. Luke's Hospital
- Mothers resided in the 4 towns (Acushnet, Dartmouth, Fairhaven, New Bedford) for the duration of their pregnancy

New Bedford, MA



Study Area

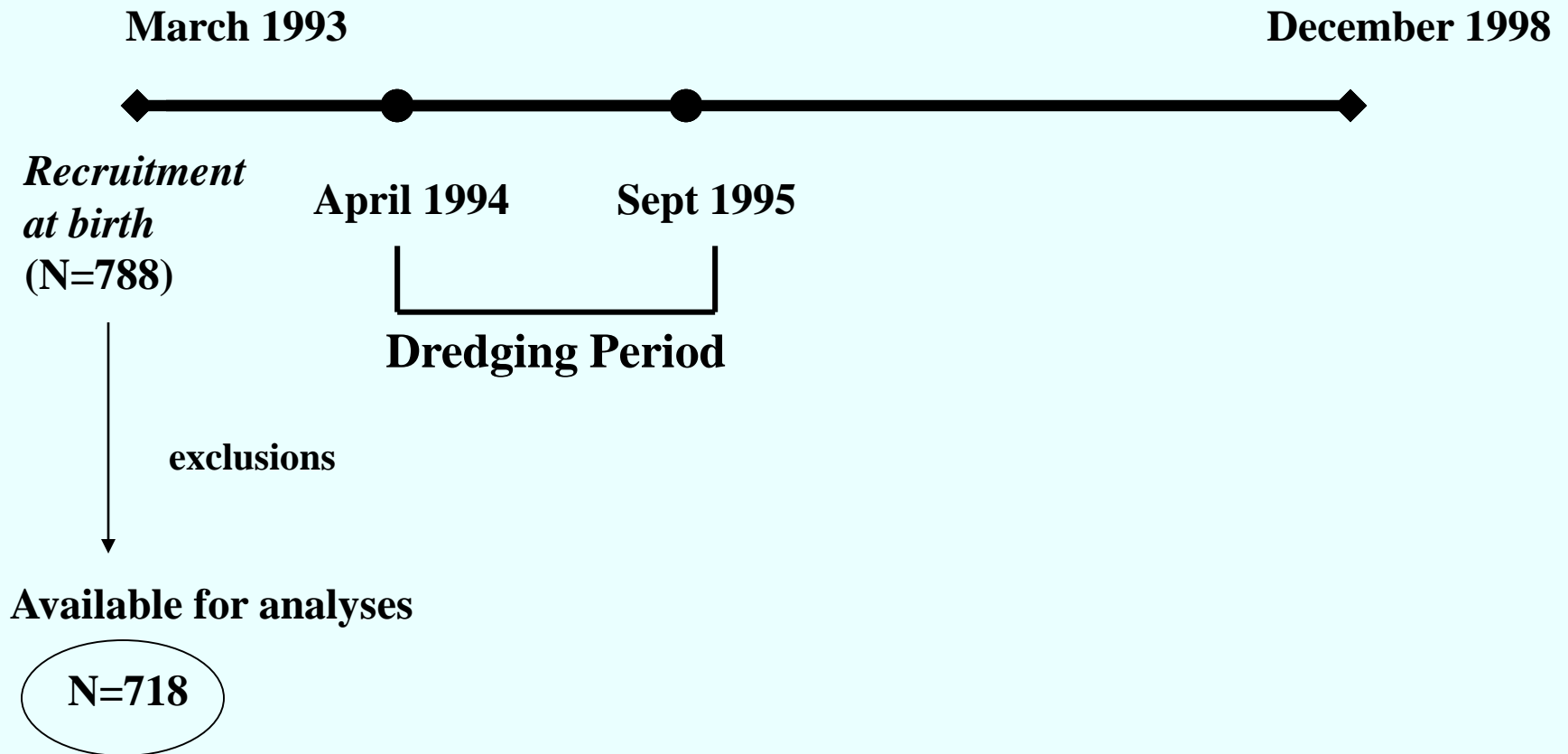


Research Questions

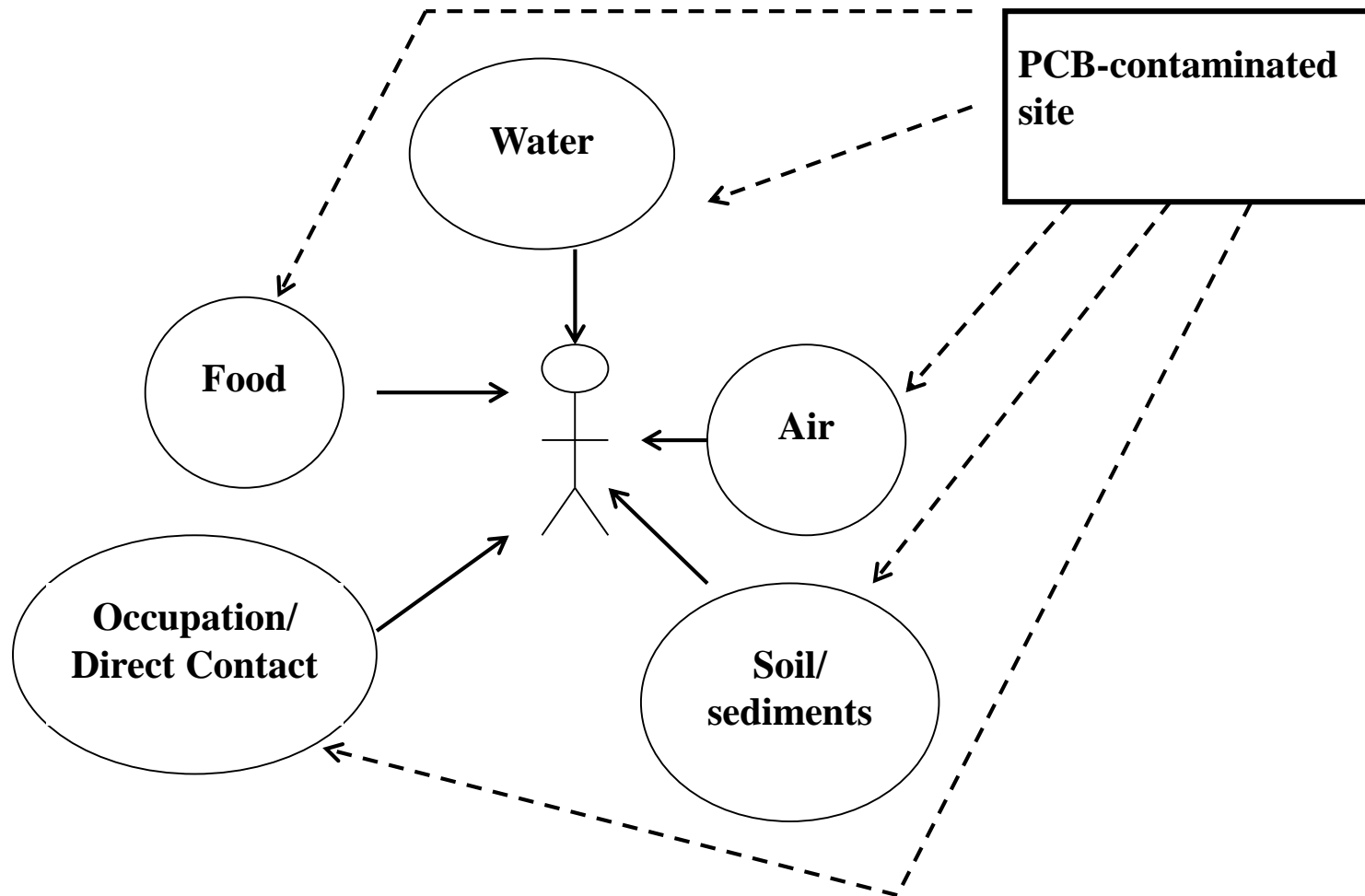
- Is residing closer to the Superfund site associated with increased cord serum PCB levels?
 - 718 infants with cord serum samples
 - $\Sigma\text{PCB} = 51$ PCB congeners

- What are the risk factors for PCB exposure among infants?

Study Timeline



Potential sources of human exposure to PCBs



Pathways

PCB Exposure Pathways

Variable Definition

- Diet fish, vegetables, dairy products and processed foods, meat and organs (amount consumed; local and general)
- Inhalation - outdoor distance of residence to Superfund site (miles)
- Inhalation - indoor age of home
- Dermal contact gardening; other PCB-related activities
- Occupation PCB-related work history

Risk Factors

PCB Exposure risk factors

Variable Definition

- Individual
Maternal age and birthplace, reproduction history (previous lactation), smoking during pregnancy, maternal education, household income, infant's gender and birth date
 - Neighborhood
Education, income level, poverty level, crowding (block group level)
- Unmeasured spatial correlates

Geographic Information Systems (GIS)

Uses of GIS:

- Map residential location
 - proximity to the contaminated site
- Acquire contextual variables associated with each residence
- Assess geographic variability in PCBs, independent of individual and contextual determinants of exposure
- Capture unmeasured determinants of PCB exposure

Methods

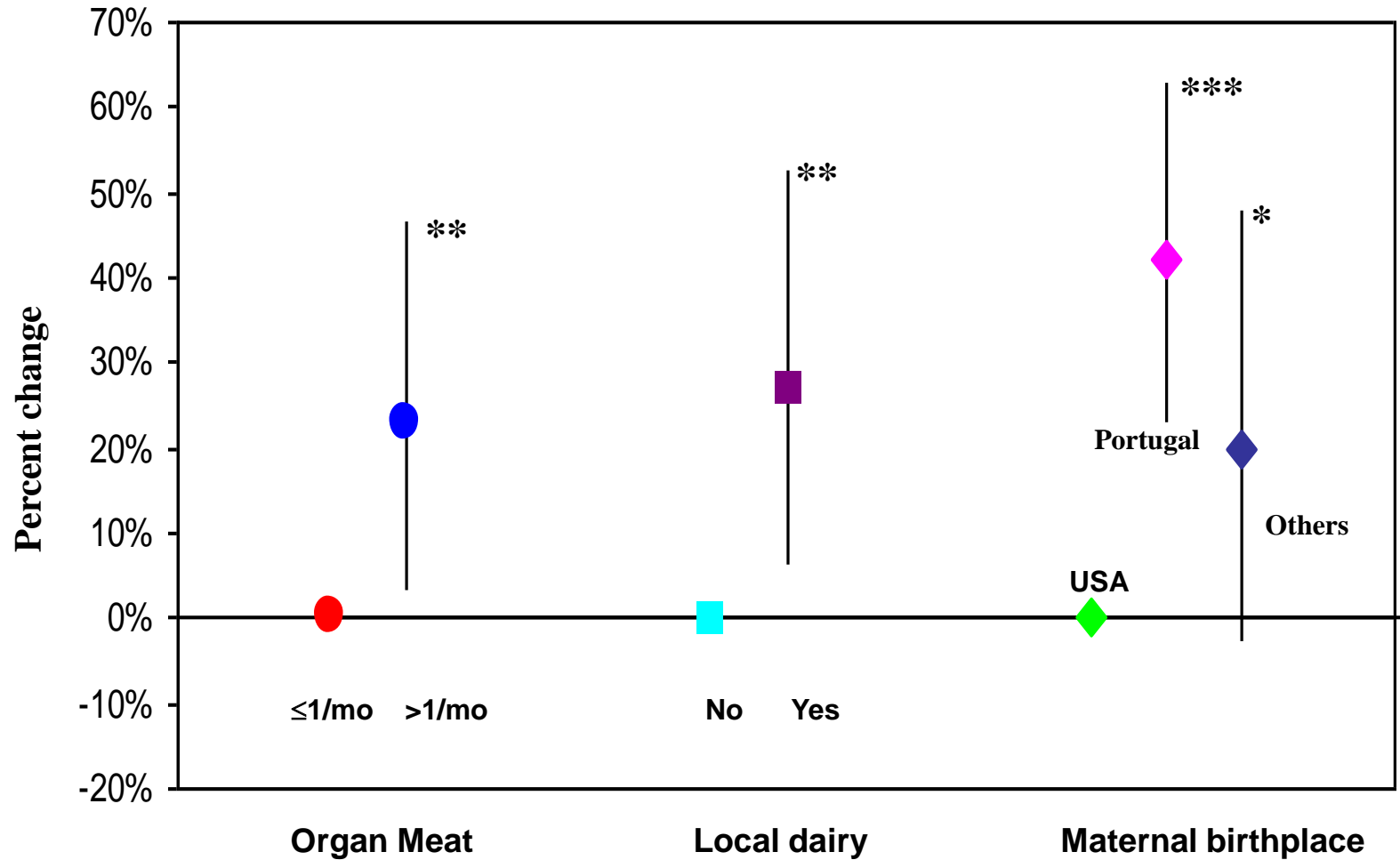
➤ Pathway models:

$$\ln(\text{PCB}) = \beta_0 + f(\text{pathway})^\Delta + g(\textit{core} \text{ individual risk factors})^\# + \varepsilon$$

Δ diet, outdoor inhalation, indoor inhalation, dermal contact, occupation, neighborhood

$\#$ maternal age, maternal birthplace, smoking during pregnancy, previous lactation, household income, child's date of birth and gender, dredging period

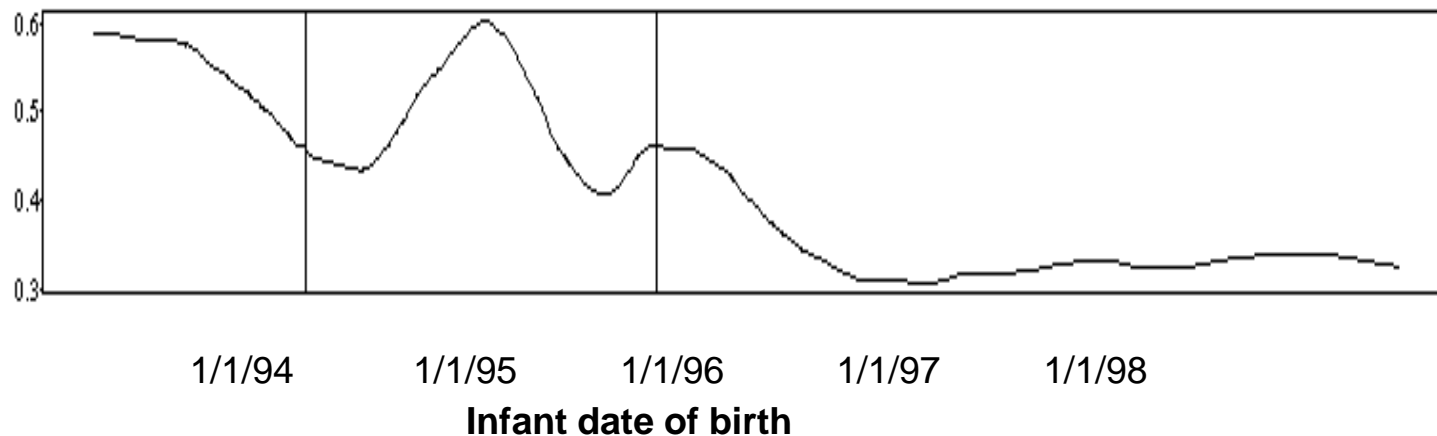
Percent change in cord serum PCB levels as a function of significant pathways and risk factors in multivariate models



*p<0.10 **p<0.05 ***p<0.01

Covariate-adjusted Cord serum PCB levels during study period

Predicted mean PCB levels

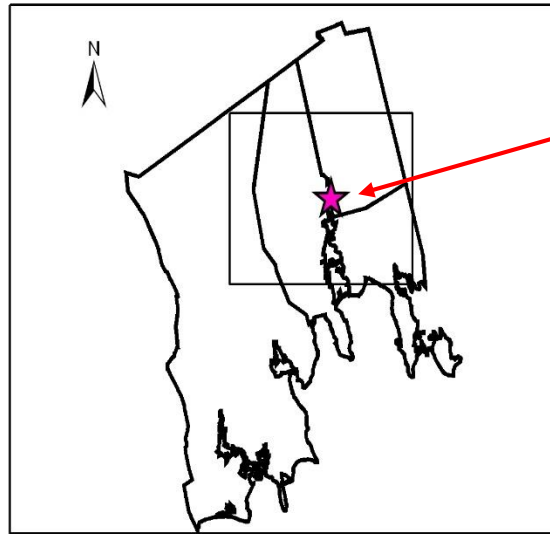


Prior

During

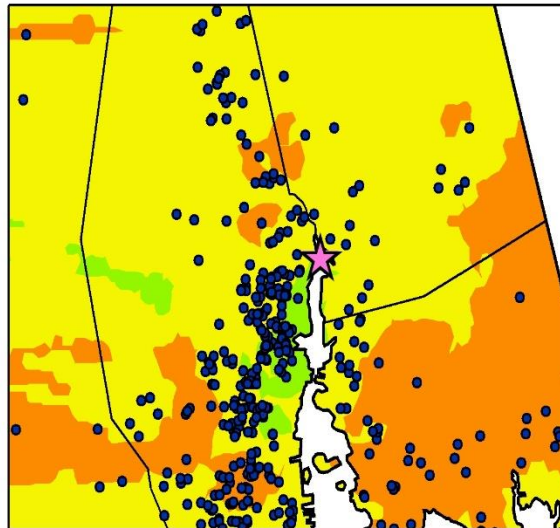
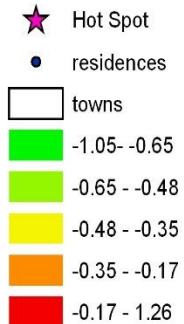
Post Dredging

New Bedford, MA
5-mile neighborhood from Hot Spot

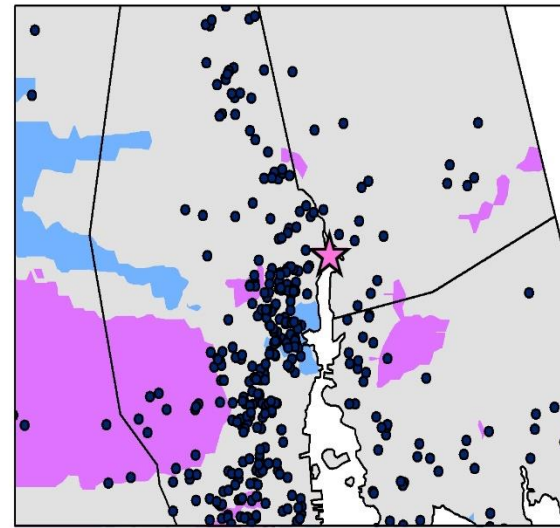


Hot spot

$\text{Log}_{10} \Sigma \text{PCB}$



ΣPCB residuals



Results and Conclusion

- No association between serum PCB levels and residential proximity to the site
- Important determinants of cord serum PCB levels include age, lactation, smoking and diet
- The efficacy of dredging in reducing PCB exposures
- mHealth technology - GIS is a useful tool in the improvement of environmental wellness

mHealth and Mental Wellness

Mental health

- One in four people in the world will be affected by mental or neurological disorders at some point in their lives (WHO, 2018)
- Around 450 million people currently suffer from such conditions, placing mental disorders among the leading causes of ill-health and disability worldwide
- Mental and behavioral disorders can be prevented, cured and treated.
- In the U.S., approximately 1 in 5 adults experiences mental illness in a given year (NAMI, 2018)

Depression: a worldwide illness

350 million:

Number of people worldwide who suffer from depression.



16 million:

Number of U.S. adults who had at least one major depressive episode in 2012.

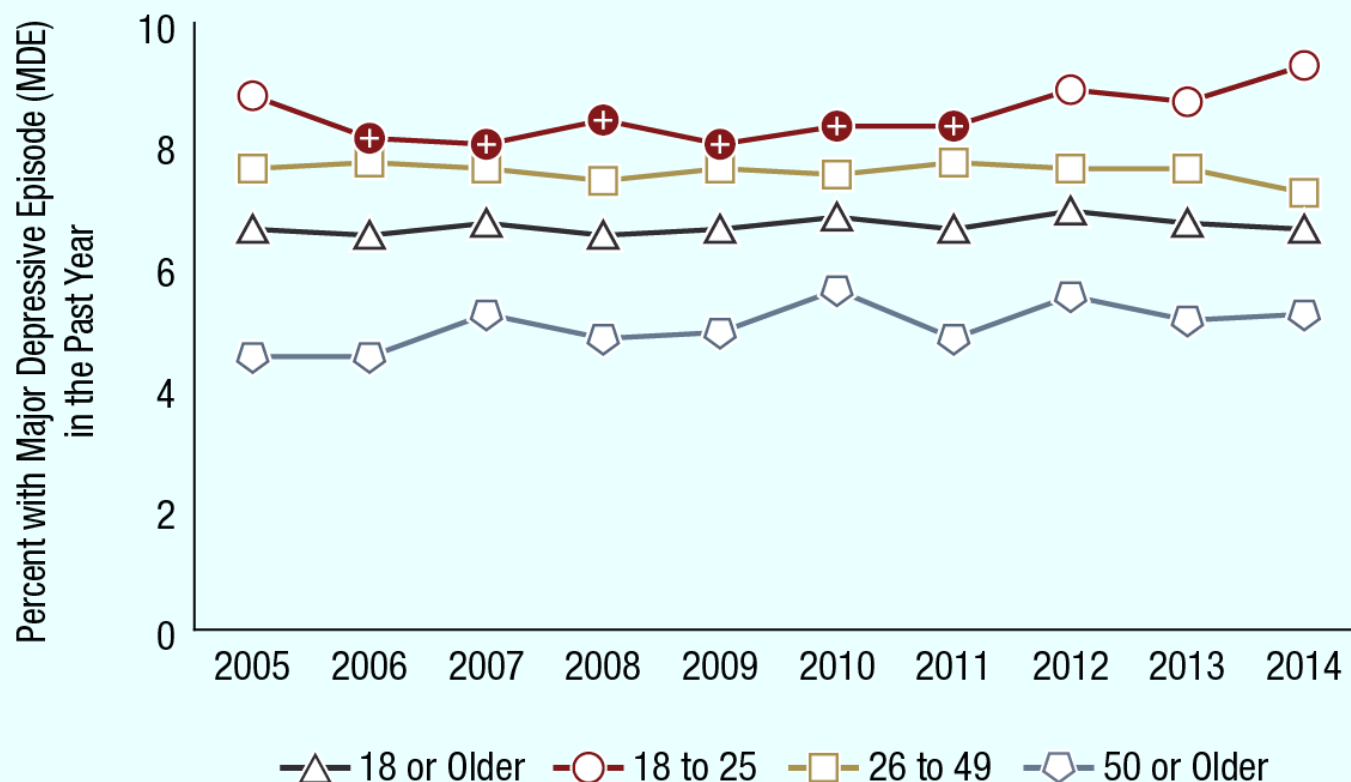
Women are more likely to be diagnosed with depression than men.

<http://www.who.int/>

Depression

- Nearly one in 10 American adults ages 18+ has a mood disorder, including depression (www.nimh.nih.gov)
- Depression is the most common, affecting about one in 15 adults. Of these cases, about 30% are classified as severe
- The 2010 Singapore National Mental Health Survey reported that the lifetime prevalence of depression in Singapore adults was 6.3% (Subramaniam et al., 2012)
- According to the Health Promotion Board 2015 report, women have a relatively higher rate of occurrence of depression than men
- In a survey of 739 NUS incoming students (July 2016), 68.9% have none/minimal depression, 23.9% have mild depression, and 7.2% have moderate/severe depression; and women are more likely to be depressed

Major Depressive Episode (MDE)* in the Past Year among Adults Aged 18 or Older, by Age Group: Percentages from 2005-2014



* Adults were defined as having an MDE if they had a period of 2 weeks or longer in the last 12 months when they experienced a depressed mood or loss of interest or pleasure in daily activities including sleep, eating, energy, and concentration

+ Difference between this estimate and the 2014 estimate is statistically significant at the .05 level.

Causes of Depression

- Stressful life events
- Medical problems
- Changes in brain functions
- Family history: the role of genetics

Managing depression

- Of the various mental disorders, depression is one of the most treatable. The World Health Organization estimates that treatment is effective for 60-80% of those affected (www.who.int)
- Depression is highly treatable and is most effectively managed through early detection and treatment.
- Depression can be managed using a range of different strategies including medication, counselling or psychological intervention and lifestyle changes which include:
 - Exercise
 - Diet
 - Mindfulness meditation
 - Expressive writing

Psychotherapy

- Cognitive behavioral therapy (CBT)
 - Aims to recognize distorted, self-critical thoughts and asks the client to judge the truth of these assumptions
 - Helps the client to schedule enjoyable experiences, especially with other people who can reinforce the enjoyment
 - Treatment for mild to moderate depression

Digital therapy for mental health wellness

- Psychotherapy making effective and efficient use of ubiquitous smartphones, tablets, and laptop computers: individual treatment that uses online components to reduce (not eliminate) direct contact with psychotherapist
- Therapist Assisted Online (TAO) is a digital platform of tools and educational materials to help the clients understand and change their thought pattern (<http://www.taoconnect.org/>)
- Uses of TAO: (1) self-help (2) support and encouragement from a therapist (3) face-to-face therapy (4) provide continuity of care for people transitioning from hospitals to after-care and (5) homework for group therapy
- Multiple modalities and machine learning intelligence are used to effectively teach the clients to manage their depression and anxiety
- Tools are accessed through the mobile device to improve outcomes: (1) mind elevator to evaluate and improve one's thoughts (2) logs to help clients practice new skills and (3) messaging system with individual reminders, suggestions and encouragers focused on what works best based on research findings with other TAO users
- Recent study at an university counseling center shows that TAO clients had greater reduction in anxiety and improvement in mental health, life functioning and their sense of well-being than treatment-as-usual clients (*Benton et al., 2016*)

Therapist Assisted Online (TAO)

Map of TAO



- Enhances client engagement with online education, tools to practice new skills, and accountability
- Clients learn mindfulness meditation, relaxation strategies, how to challenge cognitive distortion, and positive psychology skills
- Multiple tools are accessed through the mobile device to improve outcomes

Digital therapy for mental health wellness (2)

- *A two-year computerized Cognitive Behavior Therapy (cCBT) trial* for patients with mild to moderate depression in Scotland
 - Clients receive treatment by working through an on-line package without the need of therapist input, though it can be combined
 - The treatment can be done from a range of locations and in parallel with existing services
 - cCBT can be suitable for clients who do not like the idea of talking therapies and would be more comfortable doing a computerized treatment



- The treatment provides anonymity for clients in small communities who are often put off by the potential embarrassment of being seen by someone they know in a talking therapies setting. cCBT can be done from home.

<http://sctt.org.uk/programmes/digital-services-and-apps/mental-health/ccbt/>

Digital therapy for mental health wellness (3)

- *Use of activity tracker apps and wearables to predict symptoms of common mental health disorders (Wright et al., 2018)*
 - Monitoring is integral to adequately recognize and track mental health indicators of symptoms and functioning
 - Early identification of warning signs from digital footprints could facilitate adaptive and dynamic just-in-time monitoring and care for individuals with common mental disorders
 - Daily activity duration was significantly greater from wearable devices when compared with smartphone apps
 - Subjects who used the activity tracker apps for longer than 45 days showed a correlation between increased anxiety and randomness of activity
 - Wearables resulted in more daily activity than activity tracker apps
 - While the study lacks the ability to show a causal relationship, it shows that smartphones and wearables can be used as a resource for mental health tracking

Conclusion

- With the explosion of digital data, mobile health technologies are ubiquitous in the delivery of healthcare services
- The mobile devices can be used to collect health data to improve wellness
- GIS and spatial modeling are tools to study and improve environmental wellness
- Digital therapy, fitness trackers and smartphones are emerging technologies for mental wellness research. More work is needed to assess their efficacy

Contextual Bandits in Mobile Health

Introduction

- Advances in mobile technology offer opportunities to deliver interventions that accommodate an individual's immediate needs (Tewari and Murphy, 2017)
- Just-in-time adaptive interventions (JITAIs) aim to provide support for health behavior change at times when users most need the support
- A key problem in designing JITAIs for mobile health is to learn decision rules from data that can map tailoring variables (e.g. user mood, time of day) to intervention options (e.g. should a message be send to the user's phone right now?)
- Contextual bandits provide a natural framework for sequential decision making in mobile health:
 - Attempts to construct decision rules with the goal of maximizing some numerical outcome following every decision point
 - For example: walked 1000 steps in an hour after sending an activity encouraging message