Living Human Geography for Public Health

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Living?

Exploring public health needs for a living approach to human geography
This Talk

• General problem:
  *Health knowledge: patchy; hard to contextualise*

• Examples:
  – *Obesity*
  – *Health inequalities*
  – *Allergies and asthma*

• Solution:
  *Collective sense-making ↔ living knowledge with useful complexity*
3 Big Gaps in Health Knowledge

1. Prevention

2. Clinical trials → real-world outcomes

3. Dynamics of health (care) systems
Prevention

• Healthcare affordability depends on it

• Little evidence of what works
  – Personalisation
  – Frequent reinforcement
  – Autonomy

• Most risks are interwoven: most research is not
Do we choose health?
Can we choose health?

Millions of years of evolution:
Spend energy to eat
Store at times of plenty

Recently:
\[ \text{energy-density of food} \uparrow \]
\[ \text{energy required to get food} \downarrow \]
\[ = \text{the obesogenic environment} \]
Child obesity: Today’s average child?

- BMI = Weight (kg) / Height (m²)

- A noisy measure

- A complex, changing, ubiquitous, easily-misinterpreted, yet important measure of body composition across populations.

Benn Index (β ≈ 2)
Regress: \( \ln(\text{wt}) = \beta \ln(\text{ht}) + c \)

Quetelet, 1796-1874
Intelligence from routinely-collected but *not* routinely analysed data:

Obesity in Wirral 3-yr-olds, 88 to 03...
Early Data, Late Actions

Body Mass Index (BMI) trend in Wirral 3y-olds from 1988 to 2003

Three-monthly rolling average BMI SDS

SDS = standard deviation score from 1990 British Growth Reference charts – adjusts for age and sex of the child
Wirral (0.3M), UK

BMI of 3 yr olds
1988 - 1989

Fifths of BMI
SDS BMI fifth
Red (light) = fattest
Red (dark)
Purple
Blue (dark)
Blue (light) = thinnest
BMI of 3 yr olds
1992 - 1993

Fifths of BMI
SDS BMI fifth
Red (light) = fattest
Red (dark)
Purple
Blue (dark)
Blue (light) = thinnest
BMI of 3 yr olds
1994 - 1995

Fifths of BMI
SDS BMI fifth
Red (light) = fattest
Red (dark)
Purple
Blue (dark)
Blue (light) = thinnest
BMI of 3 yr olds
1996 - 1997

Fifths of BMI
SDS BMI fifth

Red (light) = fattest
Red (dark)
Purple
Blue (dark)
Blue (light) = thinnest
BMI of 3 yr olds
1998 - 1999

Fifths of BMI
SDS BMI fifth
Red (light) = fattest
Red (dark)
Purple
Blue (dark)
Blue (light) = thinnest
BMI of 3 yr olds
2000 – 2001

Fifths of BMI
SDS BMI fifth
Red (light) = fattest
Red (dark)
Purple
Blue (dark)
Blue (light) = thinnest
Has the obesity ‘epidemic’ affected all age groups?
Behind the question

• Young children have less choice than older children over the factors that determine energy balance

• Children were developing as the obesity ‘recent-epidemic’ developed: the herd might adapt or differentiate
Signals: Rise in BMI at 2 & 3 years and infant length for children born on Wirral between 1990 and 2000
Secular trend to increasing BMI is much greater in taller children

Liverpool 10-yr-olds: BMI characteristics changing

Ln(weight) = Benn * Ln(height) + β₂ * age + β₃ * sex + c
Higher BMI with taller children persists after adjusting for grip strength

\[
\text{Ln(weight)} = \text{Benn} \times \text{Ln(height)} + \beta_2 \times \text{age} + \beta_3 \times \text{sex} + \beta_4 \times \text{grip strength} + c
\]
Higher BMI with taller children vanishes after adjusting for skin folds’ thicknesses.

\[ \ln(\text{weight}) = \text{Benn} \times \ln(\text{height}) + \beta_2 \times \text{age} + \beta_3 \times \text{sex} + \beta_4 \times \text{triceps} + \beta_5 \times \text{sub-scapular} + c \]
Rise in BMI and fall in cardio-respiratory endurance of Liverpool 10 year olds from 1998 to 2004

Data from G Stratton, Liverpool Sportlinx
Cardio-respiratory endurance levels of Liverpool 10-yr-olds fell in all BMI groups

Data from G Stratton, Liverpool Sportslinx
13-yr-olds’ Body Image vs. BMI

Data from S Gowers, Liverpool
Women and not men from low-income households are fatter in England.

Data from Health Survey for England
Women from low-income households and men from high-income households are fatter in Greater Manchester.

Data from Health Survey for England.
Puddles of research around the organising principle ... but policies need the big picture
English Mortality

A Tale of Northern Excess
North South Health Divide 1965-2008

• Study:  
  *Trend over time in all-cause mortality between north and south England from 1965 to 2008*

• Finding:  
  *Substantial and persistent inequality*

• Main issue:  
  *Who owns the problem?*
A thousand years of English health & politics

Boundaries of Government Office Regions in Northern and Southern England showing Female Life Expectancy at birth 2006-2008

Contains Ordnance Survey data © Crown copyright and database right 2010
Numbers of People Affected

“38,000 people a year die sooner in North England than they would if they had life chances equivalent to those in the South”
Northern Excess Mortality Across Age Bands, 1965 to 2008
Premature Mortality
Northern Excess 1965 to 2008
Is a paper enough to inform action?

Trends in mortality from 1965 to 2008 across the English north-south divide: comparative observational study

John M Hacking, senior research officer; Sara Muller, statistician; Iain E Buchan, professor of public health informatics

<table>
<thead>
<tr>
<th>Year</th>
<th>North</th>
<th>South</th>
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<tbody>
<tr>
<td>1965</td>
<td>1000</td>
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<td>1980</td>
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<td>1985</td>
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<td>1200</td>
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<tr>
<td>1990</td>
<td>750</td>
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<td>1995</td>
<td>700</td>
<td>1300</td>
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<tr>
<td>2000</td>
<td>650</td>
<td>1350</td>
</tr>
<tr>
<td>2005</td>
<td>600</td>
<td>1400</td>
</tr>
<tr>
<td>2010</td>
<td>550</td>
<td>1450</td>
</tr>
</tbody>
</table>

Percentage excess deaths in North vs South England - all ages

From the mid-1970s the Northern-excess mortality became greater in men than women, whereas in the late 1960s it had been higher in women. From 1975 to 2008 the male Northern-excess mortality has been 15.0% (14.8% to 15.1%), whereas this gap was 12.5% (12.4% to 12.7%) in women.

On-line, reusable work:
Update
Learn
Expand
Combine
Translate
Own
Geography of phone calls in Great Britain

Source: MIT
England’s N:S Health Divide: Conclusion

• 20% premature mortality in north v. south England at a forty year high

• Publicly available data + simple analysis

• Publish & forget → live, public intelligence?
The need for realistic complexity in studying healthcare and environment

THE ALLERGIC CHILD?
Asthma is heritable:
But inconsistent genetic findings

★ Linkage in 1 study
★ Linkage replicated in >1 study
‘Asthmagenic Environment’
Allergy ‘epidemic’ is environmental:
But inconsistent environmental findings

- **Breast Feeding**
  - Protects (Kull et al, JACI 2005;116:657-61)
  - Increases the risk (Sears et al, Lancet 2002;360:901-7)
  - Does not matter (Burgess et al, Pediatrics 2006;117:e787-92)

- **Cat ownership**
  - Good (Hesselmar et al, CEA 1999;29:611-7)
  - Bad (Noertjojo et al, JACI 1999;103:60-65)
  - Does not matter (Rhodes et al, JACI 2001;108:720-5)
CD14

- Pattern recognition receptor-part of receptor complex for endotoxin

- Soluble or membrane bound CD14

- Activation of pathway → IL12 → ↓ allergy

- Maps to 5q32 - region of linkage to asthma
Asthma vs. CD14/-159 genotype

- C allele associated
- T allele associated
- No association
Endotoxin & CD14 inconsistent

- **Endotoxin**: protective in some populations but not others

- **CD14 polymorphisms**: associated with allergic sensitisation in some populations but not others
  - Risk allele different in different populations

Sengler et al Clin Exp Allergy 2003 33 166 -169
Goa et al : Clin Genetic 1999 56 (2) 164-5
• Population-based birth cohort
• Subjects recruited *in utero*
  – parents skin tested + questionnaire
• 1085 children born into the study
• Reviews at age 1, 3, 5 and 8 years
  – 980 children reviewed at age 8 years
    • 90.3% follow-up rate
• 11 year follow up to be completed in 2009
Outcomes

• Subjective outcomes, age 1, 3, 5 and 8
  – Validated questionnaires,
    • symptoms of asthma, eczema and rhinitis
    • medication use

• Atopic status, age 1, 3, 5 and 8
  – Skin tests to inhalant and food allergens
  – Total and specific IgE

• Lung function
  – Specific airways resistance (sRaw), Spirometry
  – Airway responsiveness
  – Exhaled Nitric Oxide (eNO), age 8
Lung Function in Pre-School Children

Mask with integrated mouthpiece

Lowe at al, Lancet 2002; 359: 1904-8
Environmental Exposures

- Allergen levels (mite, cat and dog)
- Endotoxin
- Pet ownership and contact
- Sibship
- Tobacco smoke exposure
- Childcare arrangements
- Vaccination uptake
- Duration of breastfeeding
- Dietary intake (Diet-Q), age 5 and 8
- Antibiotic and other medication usage (from GP records)
MAAS: No association between allergic sensitisation and CD14 Genotype

Simpson et al, AJRCCM 2006;174:386-92
MAAS: Endotoxin exposure decreases the risk of IgE-mediated sensitisation

Simpson et al, AJRCCM 2006;174:386-92
CD 14 promoter polymorphism, endotoxin exposure and sensitization

Simpson et al, AJRCCM 2006;174:386-92
At high endotoxin exposure:
T is the risk allele for sensitisation

Simpson et al, AJRCCM 2006;174:386-92
At low endotoxin exposure:
C is the risk allele for sensitisation

Simpson et al, AJRCCM 2006;174:386-92
At moderate endotoxin exposure:
No CD14 genotype vs. sensitisation

Simpson et al, AJRCCM 2006;174:386-92
Pool the data and mine it?

...like squinting at an image through a doyley and prism

Data & algorithms insufficient: need to harness prior knowledge carefully
Machine Learned Epidemiology

• Suspected myth: false division of children into allergic tendency (atopy) or not

• Life-course data: birth cohort of 1,000 children from Manchester with careful measurements

• Potential heresy: unsupervised search for patterns of sensitisation instead of hypothesis
Model: Unsupervised Clustering of Allergic Sensitisation Across Ages
### From 2 to 5 Useful Classes of Atopy

#### Asthma

<table>
<thead>
<tr>
<th>Ever Atopic</th>
<th>Atopic, age 8</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="#">Graph showing distributions</a></td>
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</tbody>
</table>

#### Asthma exacerbation after age 1

<table>
<thead>
<tr>
<th>Non-dust mite</th>
<th>Dust mite</th>
<th>Multiple late</th>
<th>Multiple early</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td><a href="#">Graph showing distributions</a></td>
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</table>

#### Persistent wheeze

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#### Current wheeze

<table>
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Better Prediction of Real-world Outcomes

Admitted at Any Age

First Admitted > 3 Years Old
(remove early virus wheeze)
Harnessing useful complexity from and for real-world healthcare

LIVING LABS
Real-world Healthcare Evidence

• Clinical trials usually exclude
  – Women of child bearing age
  – People with multiple conditions
  – People on other medications

• More than two thirds of what will happen to patients when treated is unpredictable with current evidence
**Missing:** Patient & Community

‘**Big-picture**’ Across Diseases/Services/Pathways

**Self Care**
- **Diabetology:** Glucose control
- **Ophthalmology:** Diabetic eye care
- **Nephrology:** Chronic kidney disease

**Clinical Care**

**Primary Care**

**Secondary Care**

**Specialist A**

**Specialist B**

**Future:** Realistically complex and dynamic models of individual or community care: i.e. Mr Smith’s care pathway, not diabetes + eye + kidney care pathways
Anaemia at lower levels of kidney impairment than commonly thought.

Clinical (audit) question leading to scientific finding: required local metadata (assay change) not in national datasets.
Data aggregation isn’t enough!

Methods/Models/Applications ↑

Experts ↔

Data ↑↑↑↑
Health Records & Knowledge Silos

Data-intensive Paradigm shift

Open Unifying Modelling: Across mechanisms and contexts

Health Avatars & Dynamic Models

🍂 models = Avatar

Electronic Health Records (eHR)

Unified Graphical Model

Expertise

Expertise

Expertise

Large scale inference

Model refinement

Multi-scale & Multi-system Health:
• Research
• Policy
• Care

e.g. Coronary heart disease

e.g. Lung cancer

e.g. Chronic obstructive pulmonary disease

Data

Data

Data
Digital Leap

• From
  – Silos of reward for knowing more about less
  – Silos of healthcare evidence & practice
  – Public health complexity hidden

• To
  – Reward for “big picture contribution”
  – Complex models linked to practical decision making
  – Palpable public health
What might the future of healthcare intelligence look like?

FROM MANAGING KNOWLEDGE TO INTELLIGENT HEALTHCARE SYSTEMS
NHS e-Lab
Turning “tombs” of data into useful intelligence

Usual suppliers

Local Community Integrated Health Record

Depersonalised records

Commissioning
Audit
Public Health
Research

“unified sense-making”

ONS vital statistics
Local authority socio-economic
Public health

Optometrist
Community nurse
Podiatrist

Biobanks
Local surveys
Individual research

NHS no.

Hosp.
Data queries: From this...
...to this
Prevalence of high HBA1C values for diabetics

Investigation into diabetes in Salford
HBA1C by ward

Mean HBA1C values by ward

Legend Title
- 6.63 - 6.81
- 6.81 - 6.97
- 6.97 - 7.09
- 7.09 - 7.12
- 7.12 - 7.40

Value
Mean: 7.106
Sample Size: 16

[Map Settings]
[Take Snapshot]
[Save Image to My Computer]
e-Lab

Research/Work Object

Research protocol
Data-sources
Data-preparation scripts
Working datasets
References

Statistical analysis scripts
Analysis-logs & notes
Figures/Graphics
Manuscripts
Slides

Find
Share
Reuse

Socially-stimulating science & service, in-silico
Exploit Heterogeneity

• Incorporating more information about differences between centres increases the estimated effects of interventions from meta-analysis of observational studies

• Federation of e-Labs could generate extremely useful healthcare intelligence at scale

Conclusion: Living Human Geography

- Public health needs usefully complex & timely health sciences & systems

- Open linked data is not enough

- Need **socially scalable** reasoning across disciplines