Measuring Diarrhea: Quantifying Hawthorne Effects in Frequently-Collected Data

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Methodology Matters

How does the study design affect the data we are able to collect?
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...an RCT doesn’t guarantee unbiased causal estimates
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...an RCT doesn’t guarantee unbiased causal estimates

Is the data collection process actually changing the representativeness of the subject pool?
Health Impact Estimates of WASH Interventions and Policy

• Credible estimates of health impacts of alternative water, sanitation, and hygiene interventions are needed to allocate scarce resources

• WASH interventions affect diarrheal morbidity and mortality

• These health costs are challenging to quantify
  – mortality: rare event
  – morbidity: subjective or requires lab work (difficult in field conditions)
Measuring Diarrhea

• Common approach: self-reported
  – Subjective “three or more loose or watery stools”
  – (Bi)weekly visits for 20-30 weeks to monitor
    • Motivated in part by concern about recall bias
    • Also often intended to increase compliance with intervention for efficacy studies

• Potential biases in treatment effect estimates
  – Social desirability bias
  – Respondent fatigue
  – Hawthorne effect (behavior change as a result of survey participation)
Diarrhea Trends: Is this just seasonality?

Crump et al., 2005, Kenya

Luby et al., 2006, Pakistan

Figure 2 Longitudinal prevalence of diarrhoea by week and intervention group, Karachi 2003.
Our Research Contribution

• Think of data collection frequency as a “treatment” that can be randomized
  – Compare frequent and infrequent monitoring
    • Same approach as McCarney et al., 2007 BMC Med Research Methodology (Ginko biloba & dementia)

• Quantify the bias in measured diarrhea prevalence in biweekly self-reported data
  – Hawthorne effect is large
  – Changes conclusions about health effects of a water quality improvement project
Evolution of Our Research:

Estimate Health Effects of Spring Protection

First Approach (Economist-style)
- randomize 180 communities into phases of intervention
- random sample of 8 households in each community
- 4 survey visits (approximately 6-12 months)

Second Approach (Epidemiologist-style)
- randomize last phase of communities (n=76) into 2 final waves of intervention
- random sample of 2 households in each community drawn from existing sample
- 19 survey visits (every 2 weeks)
Data Collection Frequency: Another “Treatment”? 

• Randomly selected households for biweekly monitoring from among those who had already been surveyed 4 times (BWM households)

• Diarrhea rates started to fall drastically among this group compared to previous 6-12 month surveys

• Was this because of the surveying?

• Selected another random subset of original households for comparison (extension households); continued to survey them every 6 months
Outline for Remainder of Talk

• Study design and characteristics of sample
• Trends in diarrhea
• Changes in behavior associated with random assignment to high-frequency monitoring
• Consequences for inference: impacts of monitoring frequency on estimates of health effects of spring protection
• Implications for future research
Summary of “Treatments”

- Frequency of data collection
  (BWM versus extension)

Rural Water Project (RWP):
- Spring protection
- Distribution of dilute chlorine for point-of-use water treatment

cross-cut interventions
• Dilute chlorine is marketed in Kenya as *WaterGuard*
• A capful disinfects 20L of water, with residual protection against recontamination
• One 150 mL bottle lasts a typical household roughly one month
• Costs just US$0.29 in local shops (approximately one-quarter of the daily agricultural wage)
### Summary of RWP “Treatments”

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<table>
<thead>
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<tbody>
<tr>
<td>Spring Protection</td>
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<tr>
<td>Phase 1</td>
<td>(treatment)</td>
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<td></td>
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<td>Phase 2</td>
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## Summary of RWP “Treatments”

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<th>Chlorine Distribution</th>
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<td>(treatment: Households given a 6-month supply of chlorine and an improved water storage container)</td>
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**BWM, extension**
Context

• Demographics
  – Mothers have 6 years of education
  – 4 children under age 12; 1 or 2 children under age 3

• Water
  – < 20% of HH’s meet E.P.A. drinking water standard
  – < 30% boiled yesterday’s drinking water

• Hygiene & Sanitation
  – > 80% have a pit latrine, > 90% have a soap

• Knowledge
  – > 70% volunteer “dirty water as a cause of diarrhea
  – > 80% familiar with local brand of dilute chlorine
BWM & Extension: Samples and Timeline

- Both sub-samples *randomly chosen* from larger sample using same methodology
  - BWM n = 170, extension n = 160
- BWM surveys began in May 2007
  - Springs protected between rounds 5-8
- Extension households surveyed 3 times
- Interruptions
Outline for Remainder of Talk

• Study design and characteristics of sample

• **Trends in diarrhea**

• Changes in behavior associated with random assignment to high-frequency monitoring

• Consequences for inference: impacts of monitoring frequency on estimates of health effects of spring protection

• Implications for future research
Diarrhea Trends

Diarrhea Prevalence


RWP  BWM  Extension

Diarrhea Prevalence


RWP  BWM  Extension
A Potential Explanation: Recall Bias?

• What time frame are respondents really thinking of?

• If bi-weekly visits bracket recall intervals, survey frequency might affect recall bias
  – Maybe we should have visited extension households twice for each extension “round”

• Possible, but we have more compelling evidence of a Hawthorne effect than just the differences in diarrhea prevalence...
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Explaining Falling Diarrhea Prevalence

- Changes in reporting
  - Courtesy bias
    - Subjects aware that NGO that conducted BWM surveys also implemented water quality improvement interventions
  - Survey fatigue
    - Basic survey lasted around 20 minutes; reporting diarrhea symptoms triggered additional survey questions (up to 5 minutes per child) and in some cases a mini-exam (an additional 5 minutes)

- Changes in behavior
  - Prevention (water treatment)
  - Treatment (oral rehydration therapy)
  - Others?
Chlorination Trends

Fraction of HH w/ Positive Chlorine Test

- Chlorine Promotion
  - RWP
  - BWM
  - Extension

- No Chlorine Promotion
  - RWP
  - BWM
  - Extension
How Much of the Fall in Diarrhea Can Increased Chlorination Explain?

Diarrhea Prevalence, Positive Chlorine Test

BWM Survey Round

Diarrhea: Chlorine Use:
- BWM
- Extension
How Much of the Fall in Diarrhea Can Increased Chlorination Explain?

![Graph showing the relationship between BWM Survey Round, Diarrhea Prevalence, and Positive Chlorine Test. The graph includes data points for different rounds with corresponding diarrhea prevalence and positive chlorine test results.]

- **Diarrhea Prevalence:**
  - BWM: 5/2007
  - BWM: 16/2008
  - Extension: 18/2008
  - BWM: 19/2008

- **Chlorine Use:**

- **BWM Survey Round:**
  - 5/2007
  - 9/2007
  - 16/2008
  - 19/2008

The graph shows a decrease in diarrhea prevalence with increased chlorine use, indicating that increased chlorination can explain a portion of the fall in diarrhea.
How Much of the Fall in Diarrhea Can Increased Chlorination Explain?

• If effect of chlorination on diarrhea is the same in this sample as in RWP, accounting for different usage rates, then difference in chlorination between BWM and extension households in round 9 would lead to 12% lower diarrhea among BWM relative to extension.

• Since BWM had 50% less diarrhea than extension in round 9, chlorination alone could explain roughly a quarter of the difference.
Oral Rehydration Therapy

• IRB approval called for describing and distributing oral rehydration salts at each survey visit (one packet per child)

• In round 9, BWM households more than twice as likely to use ORS as extension households

• In round 16 (after interruption of survey activities), no difference in use
Other Illness: Cough

Diarrhea Prevalence

RWP Round 1 (2004)
RWP Round 2 (2005)
RWP Round 3 (2006)
RWP Round 4 (2007)
BWM Round 1 (5/2007)
BWM Round 9 (9/2007)
BWM Round 16 (4/2008)
BWM Round 18 (5/2008)
BWM Round 19 (12/2008)

Cough Prevalence

1 (5/2007)
9 (9/2007)
16 (4/2008)
18 (5/2008)
19 (12/2008)

BWM Survey Round

BWM
Extension
Other Illness: Vomiting

Diarrhea Prevalence

RWP Round 1 (2004)
RWP Round 2 (2005)
RWP Round 3 (2006)
RWP Round 4 (2007)
BWM Round 1 (5/2007)
BWM Round 9 (9/2007)
BWM Round 16 (4/2008)
BWM Round 18 (5/2008)
BWM Round 19 (12/2008)

Vomiting Prevalence

BWM Survey Round

BWM Extension
An Alternative Measure of Diarrhea

“Which type of stool did your child’s last bowel movement best resemble?”

![Bristol Stool Chart](chart.png)
An Alternative Measure of Diarrhea

“Which type of stool did your child’s last bowel movement best resemble?”

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**Bristol Stool Chart**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Separate hard lumps, like nuts (hard to pass)</td>
</tr>
<tr>
<td>Type 2</td>
<td>Sausage-shaped but lumpy</td>
</tr>
<tr>
<td>Type 3</td>
<td>Like a sausage but with cracks on its surface</td>
</tr>
<tr>
<td>Type 4</td>
<td>Like a sausage or snake, smooth and soft</td>
</tr>
<tr>
<td>Type 5</td>
<td>Soft blobs with clear-cut edges (passed easily)</td>
</tr>
<tr>
<td>Type 6</td>
<td>Fluffy pieces with ragged edges, a mushy stool</td>
</tr>
<tr>
<td>Type 7</td>
<td>Watery, no solid pieces. Entirely Liquid</td>
</tr>
</tbody>
</table>

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Two Measures of Diarrhea

![Graph showing prevalence of diarrhea over different survey rounds.]

BWM Survey Round:
- 1 (5/2007)
- 9 (9/2007)
- 16 (4/2008)
- 18 (5/2008)
- 19 (12/2008)

Prevalence:
- BWM: Self Report Observed

BWM:
- Black line: Self Report
- Red line: Observed
Two Measures of Diarrhea

BWM Survey Round

Objective:
- BWM
- Extension
Self Reports vs. “Objective” Measure?

Caveat: “Objective” measure not validated by epidemiologists

• Was there a Hawthorne effect?
Self Reports vs. “Objective” Measure?

Caveat: “Objective” measure not validated by epidemiologists

• Was there a Hawthorne effect?  **YES**

• Hawthorne effect is about change in behavior, not just reporting bias – we saw real changes in behavior vis a vis chlorination

• But “objective” measure might draw into question whether or not chlorination was actually making kids healthier
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Summary of Results from RWP Low-frequency Data Collection

• Spring protection led to 66% less source contamination, moderate home water gains
  – Child diarrhea fell by 25%

• Free provision of dilute chlorine led to high usage rates (58% of households with detectable chlorine), big home water quality gains
  – Child diarrhea fell by 35%
Comparing Results: Health Effects of Spring Protection in RWP and BWM Samples

<table>
<thead>
<tr>
<th>Dependent Variable: Diarrhea in past week</th>
<th>RWP Panel (1)</th>
<th>RWP Panel (2)</th>
<th>BWM Panel (3)</th>
<th>BWM Panel (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (spring protection) indicator variable</td>
<td>-0.045***</td>
<td>-0.047**</td>
<td>-0.025**</td>
<td>0.010</td>
</tr>
<tr>
<td>Child and treatment wave fixed effects; controls for month of year, gender-age, and survey round</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>R²</td>
<td>0.00</td>
<td>0.53</td>
<td>0.00</td>
<td>0.18</td>
</tr>
<tr>
<td>Child-round observations</td>
<td>6750</td>
<td>6660</td>
<td>5298</td>
<td>5294</td>
</tr>
<tr>
<td>Mean (s.d.) of the dependent variable in non-protected spring group</td>
<td>0.19</td>
<td>0.19</td>
<td>0.091</td>
<td>0.091</td>
</tr>
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Different conclusions about reduction in diarrhea due to spring protection, depending on frequency of data collection
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Hawthorne Effects Change Unobservables

• We were able to document changes in chlorine use among households who were frequently surveyed
  – Chlorination is a substitute for spring protection, so there was less scope for spring protection to reduce diarrhea

• But what about all sorts of other behaviors that we didn’t / couldn’t objectively observe?

• Self-reported outcome variables are problematic, but objective outcomes won’t eliminate Hawthorne bias

• Blinding subjects and/or enumerators to the treatment also isn’t enough to avoid the problem
Conclusions

• High frequency data collection appears to have led to unreliable measures of child diarrhea prevalence

• We found objective evidence that at least one confounding behavior (chlorination) changed as a result of frequent data collection

• This in turn partially explains why estimates of the health effects of spring protection differ depending on data collection frequency
Recommendations

• Studies that use frequent data collection should report time trends in the outcomes of interest

• Future studies should randomly assign data collection frequencies so that it is possible to control for Hawthorne effects
  – Large infrequent samples may preferred to high frequency data collection
Thank You!