Diarrhea and Colds in Child Day Care Centers

Impact of Various Numerator and Denominator Definitions of Illness Episodes

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Background: Numerators and denominators used to estimate infections’ incidence rates (IRs), incidence rate ratios (IRRs), and differences (IRDs) vary. Our objective is to quantify the impact of various common definitions for illness episodes (numerators) and person-time at risk (denominators) in estimating these measures.

Methods: Data were from a cohort study in which daily occurrence of illness and children’s attendance in day care centers were recorded. We compared 4 IR estimates using various definitions of episode and at-risk time units.

Results: IRs for diarrhea and colds were highest using child-days, lowest for diarrhea using child-weeks, and lowest for colds using child-months. The 4 methods led to similar IRRs but considerably different IRDs.

Conclusion: Incidence rate differences and ratios for infectious diseases can vary by the definition of episode and person-time at risk. This limits the value of the evidence base on which public health recommendations are formulated. Development of a more standard approach to measurement and reporting of IRs is recommended.

Public health questions have been raised about the increased incidence rates (IRs) of diarrhea and respiratory infections in day care settings. 1–7 However, the numerators and denominators used in estimating IRs and incidence rate ratios (IRRs) or incidence rate differences (IRDs) vary considerably. Numerators (ie, numbers of new illness episodes) are defined in terms of symptoms, duration and a lag period between independent episodes. Lag periods are not standardized (Table 1). Denominators (ie, total person-time at risk), vary by both the unit of time used and lag period.

Our objective is to quantify the impact of commonly used definitions for numerators and denominators in estimating the incidence rates of diarrhea and colds in children attending day care centers and to evaluate the impact of these definitions on IRRs and IRDs.

METHODS

Data
We used data from a randomized trial of a hygiene program aimed at reducing the incidence of diarrhea and colds in 47 day care centers in Québec, Canada in 1996–1997. 8 Data had been collected between the fall of 1996 (preintervention period) and the fall of 1997 (postintervention period). Only children who attended the day care center for more than 5 days during each period were included. Day care educators used study-provided calendars to indicate the daily occurrence of illness, the days each child was expected to attend day care center, and absences with their causes. 9 Standard definitions for colds and diarrhea were used.

The day care center was the unit of randomization. Employees and educators of intervention day care centers were given a 1-day hygiene training session and educational materials. Control day care centers continued to follow their usual hygiene policies and practices. Both intervention and control day care centers were monitored (ie, required to record and report illness episodes). 10

Lag-Time and Population-Time Definitions
A comprehensive literature search identified the most frequently used numerators and denominators to estimate IRs of diarrhea and colds in day care center-based studies (eTable 1, http://links.lww.com/EDE/A341). Additional variation was observed in the numerator definition for respiratory infections, with varying duration of symptoms. 3,8,11–29 From these commonly used methods, we chose 4 for comparison (Table 1; eFigure, http://links.lww.com/EDE/A341). Methods 1, 3, and 4 all use the same numerator definition (ie, 1 day of symptoms for colds and diarrhea) with a lag period of 7 days; Method 2 uses a lag of the previous calendar week. The denominators are defined differently for each method. The numerator and denominator definitions for each
method are interrelated reflecting the lag period and unit of observation used.

**Statistical Analysis**

All analyses were carried out separately for colds and diarrhea, even though they might have co-occurred.

Monitoring was assessed by IRRs which compared the control group’s adjusted IR in the fall of 1996 to the control group’s adjusted IR in the fall of 1997. The effectiveness of the intervention was the additional reduction in the adjusted IR in 1997 compared with 1996 in the intervention group. The “measure of impact” of the intervention and the monitoring was estimated using IRDs adjusted for clustering and age.  

More details on the statistical analyses are provided in the eAppendix (http://links.lww.com/EDE/A341).

**RESULTS**

Data included 709 children in the fall of 1996 and 873 children in the fall of 1997, with 284 children followed in both periods.

The number of diarrhea episodes using Method 2 was slightly higher (315 episodes) than that obtained from the other 3 methods (309 episodes) (Table 2). The 4 child-time denominators ranged from 180 child-years with Method 1 to 317 child-years with Method 2. Method 1 produced the largest IR for diarrhea—nearly twice that using Method 2. Methods 3 and 4 gave intermediate results. Similar results were obtained for IRs for colds. However, the total episodes of colds are much higher than for diarrhea, and the variations in calculated IRs are much greater. Again, the IR for colds calculated using Method 1 is nearly twice that obtained with Method 4, while Methods 2 and 3 gave intermediate results.

The point estimates and 95% Bayesian credible intervals of monitoring and intervention incidence rate ratios are very similar across the 4 methods for both diarrhea and colds (Table 3). The eFigure (http://links.lww.com/EDE/A341) shows incidence rate differences per 100 child-years for diarrhea and colds. Unlike the ratio measurements, the 4 point estimates of intervention IRDs are different for both diarrhea and colds. Method 1 gave the most precise estimates, and

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**TABLE 1. Population-Time Definitions and Lag Times Used to Calculate Incidence Rates of Diarrhea and Colds in Children Attending Day Care Centers**

<table>
<thead>
<tr>
<th>Method Number</th>
<th>Unit of IR</th>
<th>Measurement Unit of Episodes</th>
<th>Episode (Numerators)</th>
<th>Child-time at Risk (Denominators)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No. episodes/child-day at risk</td>
<td>Day of reported illness at the day care center</td>
<td>1 day of illness preceded by 7 days without symptoms</td>
<td>Number of children present at day care center without symptoms of illness in the past 7 days</td>
</tr>
<tr>
<td>2</td>
<td>No. episodes/child-week at risk</td>
<td>Week with a reported illness at the day care center</td>
<td>1 week of illness with the previous calendar week free of symptoms</td>
<td>Number of children present at day care center at least 1 day/week without symptoms of illness in the previous week and the present week</td>
</tr>
<tr>
<td>3</td>
<td>No. episodes/child-fortnight at risk</td>
<td>1 day of illness preceded by 7 days without symptoms</td>
<td>Number of children present at day care center at least 1 day/week without symptoms of illness in the previous week and the present week</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>No. episodes/child-month at risk</td>
<td>1 day of illness preceded by 7 days without symptoms</td>
<td>Average number of children present per month</td>
<td></td>
</tr>
</tbody>
</table>

aOne day with symptoms during that calendar week.
bAssuming child is free of symptoms during the weekend and on days of nonattendance.
cCalculated as number of days of presence at the DCC divided by number of days of follow-up during that month.

**TABLE 2. Number of Episodes, Child-Time at Risk, and Incidence Rates (95% Bayesian Credible Interval) of Diarrhea and Colds for the 4 Different Methods**

<table>
<thead>
<tr>
<th>Method Number</th>
<th>No. Episodes (Numerator)</th>
<th>No. Child-Years at Risk (Denominator)*</th>
<th>Incidence Rates (95% Credible Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. Cases</td>
<td>(T denominator)</td>
<td>No. Episodes/Child-Year at Risk</td>
</tr>
<tr>
<td>1</td>
<td>309</td>
<td>180 (365 child-days)</td>
<td>1.72 (1.53–1.92)</td>
</tr>
<tr>
<td>2</td>
<td>315</td>
<td>317 (52 child-weeks)</td>
<td>0.99 (0.89–1.11)</td>
</tr>
<tr>
<td>3</td>
<td>309</td>
<td>286 (26 child-fortnights)</td>
<td>1.08 (0.96–1.21)</td>
</tr>
<tr>
<td>4</td>
<td>309</td>
<td>295 (12 child-months)</td>
<td>1.05 (0.94–1.17)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method Number</th>
<th>No. Episodes (Numerator)</th>
<th>No. Child-Years at Risk (Denominator)*</th>
<th>Incidence Rates (95% Credible Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>149</td>
<td>365 child-days</td>
<td>11.73 (11.18–12.29)</td>
</tr>
<tr>
<td>2</td>
<td>247</td>
<td>52 child-weeks</td>
<td>8.35 (7.99–8.71)</td>
</tr>
<tr>
<td>3</td>
<td>223</td>
<td>26 child-fortnights</td>
<td>7.85 (7.49–8.23)</td>
</tr>
<tr>
<td>4</td>
<td>294</td>
<td>12 child-months</td>
<td>5.95 (5.68–6.24)</td>
</tr>
</tbody>
</table>

*Denominator values were multiplied by appropriate constants to convert the denominator units to child-year at risk.
Method 4 the least. Using Method 1 leads to finding the intervention having a significant impact in reducing the IR of diarrhea, which was not the case with the other 3 methods. The smaller variance obtained with Method 1 is due to the use of larger numbers as denominators (child-days). For the impact of monitoring, Method 4 leads to estimates 18.6 times and 15.6 times higher than those obtained with Method 1 for diarrhea and colds, respectively. Methods 2 and 3 gave intermediate estimates. Again, the estimates were most precise using Method 1, with Method 4 being the least precise.

For both intervention and monitoring, the estimated impact was smallest with Method 1, and also the most precise. Conversely, Method 4 gave the largest estimate of impact, but the least precise. Methods 2 and 3 were intermediate.

**DISCUSSION**

In comparing various definitions of IR parameter estimates, we found that IRs and IRDs are substantially affected, and IRRs less so. This agrees with results from a study in Australia, although those authors did not report separate IRs and IRDs.\(^\text{18}\)

Common measures of incidences rates use the same numerator. Hence, the observed variation among the 4 methods is dictated by the definition and unit of the denominator. In general, the larger the at-risk time unit, the smaller the estimated IR. When the time unit is small, the estimation of the number of child-days at risk is more exact, leading to a smaller denominator (by excluding days when children are sick or during the lag time). Conversely, using a less exact measure leads to a larger denominator because ill children, or those in lag time, remain in the denominator. There were more episodes of colds than diarrhea, leading to more variation in the time at risk and in the estimation of IRs for colds.

The lack of variation in the estimation of IRR is expected because the IRR is a ratio of 2 incidence rates, both of which use the same unit for their denominators. Consequently, less variation is seen in IRRs across the methods. However, substantial differences were observed in IRDs. This finding has implications for public health policy and decision-making since IRDs are used to measure the impact of a preventive intervention or program.

In general, the larger the at-risk time unit, the larger the IRD point estimate and the smaller the precision. Method 1 gives a more conservative estimate of the IRD with a narrower 95% Bayesian credible interval that is likely to be closer to the actual preventive effect. Conversely, Method 4, with the least exact denominator, has a wider Bayesian credible interval, and results in a serious and more uncertain overestimation of the potential preventive effect of the intervention and monitoring.

Infectious disease occurrence in day care centers is important from both a public health and economic point-of-view. Illnesses associated with out-of-home child care put a financial burden on families, businesses, and the health care system.\(^\text{19,31}\) We have demonstrated that variation in the definition of an illness episode and person-time at risk can greatly modify the IRD estimate. In 2 other day care center studies, the authors used IRDs to estimate the cost-savings and cost-effectiveness of interventions and type of child care.\(^\text{19,32}\) Because of different numerator and denominator definitions, conclusions from these types of analysis can be in doubt.

One methodologic issue related to our model is the assumption of a constant incidence rate within each child, which does not explicitly model the transmission dynamics of the infection. However, we did try to take this into account in the hierarchical model by having each child cluster within themselves and the day care center.

Another issue is that the choice of numerator and denominator definitions is made during a study’s design stage and is often influenced by other factors (eg, frequency of observation [daily versus weekly]). We recommend careful attention to such measurement issues at study design and data collection stages.

Most parents do not have an acceptable alternative to day care center despite the higher risk of infection in these settings. The influence of different definitions of numerators and denominators on IRs and IRDs limit the evidence base on which public health recommendations for day care centers are formulated. Development of a more standard approach to the measurement and reporting of IRs may be warranted.

**TABLE 3.** Incidence Rate Ratios (95% Bayesian Credible Intervals) for Monitoring and Intervention for Diarrhea and Colds in Children Attending Day Care Centers

<table>
<thead>
<tr>
<th>Methods Number</th>
<th>Monitoring IRR (95% Credible Interval)</th>
<th>Intervention IRR (95% Credible Interval)</th>
<th>Monitoring IRR (95% Credible Interval)</th>
<th>Intervention IRR (95% Credible Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.67 (0.49–0.89)</td>
<td>0.75 (0.48–1.18)</td>
<td>0.85 (0.74–0.97)</td>
<td>0.95 (0.79–1.14)</td>
</tr>
<tr>
<td>2</td>
<td>0.65 (0.48–0.89)</td>
<td>0.76 (0.49–1.22)</td>
<td>0.78 (0.68–0.88)</td>
<td>0.98 (0.82–1.18)</td>
</tr>
<tr>
<td>3</td>
<td>0.65 (0.47–0.87)</td>
<td>0.77 (0.50–1.21)</td>
<td>0.78 (0.68–0.92)</td>
<td>1.03 (0.84–1.26)</td>
</tr>
<tr>
<td>4</td>
<td>0.67 (0.50–0.91)</td>
<td>0.73 (0.48–1.16)</td>
<td>0.84 (0.74–0.95)</td>
<td>0.96 (0.80–1.16)</td>
</tr>
</tbody>
</table>
REFERENCES


