Diarrhea and Colds in Child Day Care Centers

Impact of Various Numerator and Denominator Definitions of Illness Episodes

Mushfiqur R. Tarafder,[a] Hélène Carabin,[a] Theresa W. Gyorkos,[b] and Lawrence Joseph[b]

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.

Submitted 3 June 2008; accepted 3 February 2009.
From the [a]Department of Biostatistics and Epidemiology, College of Public Health, University of Oklahoma Health Sciences Center, Oklahoma City, OK; and [b]Division of Clinical Epidemiology, McGill University Health Centre, Montréal, Québec, Canada.
Supported by a National Scholars Award from the Québec Medical Research Council (to L.J.).
SDC Supplemental digital content is available through direct URL citations in the HTML and PDF versions of this article (www.epidem.com).
Correspondence: Hélène Carabin, Department of Biostatistics and Epidemiology, College of Public Health, University of Oklahoma Health Sciences Center, 801 NE 13th St, Room 305, Oklahoma City, OK 73104. E-mail: helene-carabin@ouhsc.edu.

ISSN: 1044-3983/09/2006-0796
DOI: 10.1097/EDE.0b013e3181ba468e

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

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

	Method Number			
	1	2	3	4
Unit of IR	No. episodes/child-day at risk	No. episodes/child-week at risk	No. episodes/child-fortnight at risk	No. episodes/child-month at risk
Measurement unit of episodes	Day of reported illness at the day care center	Week with a reported illness at the day care center	Day of reported illness at the day care center	Day of reported illness at the day care center
Episode (numerators)	1 day of illness preceded by 7 days without symptoms	1 week of illness[a] with the previous calendar week free of symptoms	1 day of illness preceded by 7 days without symptoms	1 day of illness preceded by 7 days without symptoms
Child-time at risk (denominators)	Number of children present at day care center without symptoms of illness in the past 7 days[b]	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[b]	Number of children present at day care center at least 20 hours/week (3 days) without symptoms of the illness during the present fortnight[b]	Average number of children present per month[c]

[a]One day with symptoms during that calendar week.
[b]Assuming child is free of symptoms during the weekend and on days of nonattendance.
[c]Calculated 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

	Diarrhea			Colds		
Method Number	No. Episodes (Numerator)	No. Child-Years at Risk (Denominator)[a]	Incidence Rates (No. Episodes/Child-Year at Risk) (95% Credible Interval)	No. Episodes (Numerator)	No. Child-Years at Risk (Denominator)[a]	Incidence Rates (No. Episodes/Child-Year at Risk) (95% Credible Interval)
1	309	180 (365 child-days)	1.72 (1.53–1.92)	1747	149 (365 child-days)	11.73 (11.18–12.29)
2	315	317 (52 child-weeks)	0.99 (0.89–1.11)	2065	247 (52 child-weeks)	8.35 (7.99–8.71)
3	309	286 (26 child-fortnights)	1.08 (0.96–1.21)	1747	223 (26 child-fortnights)	7.85 (7.49–8.23)
4	309	295 (12 child-months)	1.05 (0.94–1.17)	1747	294 (12 child-months)	5.95 (5.68–6.24)

[a]Denominator values were multiplied by appropriate constants to convert the denominator units to child-year at risk.

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.[30]

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

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

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

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.[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.[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.[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.

REFERENCES

1. Lu N, Samuels ME, Shi L, Baker SL, Glover SH, Sanders JM. Child day care risks of common infectious diseases revisited. *Child Care Health Dev*. 2004;30:361–368.
2. Sempértegui F, Estrellá B, Egas J, et al. Risk of diarrheal disease in Ecuadorian day-care centers. *Pediatr Infect Dis J*. 1995;14:606–612.
3. Soto JC. Infectious disease control in daycare centers: a Canadian experience. *Can J Pediatr*. 1993;5:330–336.
4. Ford-Jones EL, Kim MH, Yaffe BA, et al. Infectious diseases in day-care centres: minimizing the risk. *Can Med Assoc J*. 1987;137:105–107.
5. Lemp GF, Woodward WE, Pickering LK, Sullivan PS, DuPont HL. The relationship of staff to the incidence of diarrhea in day-care centers. *Am J Epidemiol*. 1984;120:750–758.
6. Bartlett AV, Moore M, Gary GW, Starko KM, Erben JJ, Meredith BA. Diarrheal illness among infants and toddlers in day care centers. I: Epidemiology and pathogens. *J Pediatr*. 1985;107:495–502.
7. Staat MA, Morrow AL, Reves RR, Bartlett AV, Pickering LK. Diarrhea in children newly enrolled in day-care centers in Houston. *Pediatr Infect Dis J*. 1991;10:282–286.
8. Carabin H, Gyorkos TW, Soto JC, Joseph L, Payment P, Collet JP. Effectiveness of a training program in reducing infections in toddlers attending day care centers. *Epidemiology*. 1999;10:219–227.
9. Carabin H, Gyorkos TW, Soto JC, Joseph L, Collet JP. Comparison between two common methods for reporting cold and diarrhea symptoms of children in daycare centre research. *Child Care Health Dev*. 2000;26:471–487.
10. Last JM. *A Dictionary of Epidemiology*. 4th ed. New York: Oxford University Press; 2001.
11. Cordell RL, MacDonald JK, Solomon SL, Jackson LA, Boase J. Illnesses and absence due to illness among children attending child care facilities in Seattle-King County, Washington. *Pediatrics*. 1997;100:850–855.
12. Roberts L, Smith W, Jorm L, Patel M, Douglas RM, McGilchrist C. Effect of infection control measures on the frequency of upper respiratory infection in child care: a randomized, controlled trial. *Pediatrics*. 2000;105:738–742.
13. Collet JP, Burtin P, Kramer MS, Floret D, Bossard N, Ducruet T. Type of day-care setting and risk of repeated infections. *Pediatrics*. 1994;94:997–999.
14. Stahlberg MR. The influence of form of day care on occurrence of acute respiratory tract infections among young children. *Acta Paediatr Scand*. 1980;282(suppl):1–87.
15. Loda FA, Glezen WP, Clyde WA. Respiratory disease in group day care. *Pediatrics*. 1972;49:428–437.
16. Kotch JB, Weigle KA, Weber DJ, et al. Evaluation of an hygienic intervention in child day-care centers. *Pediatrics*. 1994;94:991–994.
17. Denny FW, Collier AM, Henderson FW. Acute respiratory infections in day care. *Rev Infect Dis*. 1986;8:527–532.
18. Roberts L, Jorm L, Patel M, Smith W, Douglas RM, McGilchrist C. Effect of infection control measures on the frequency of diarrheal episodes in child care: a randomized, controlled trial. *Pediatrics*. 2000;105:743–746.
19. Hardy AM, Lairson DR, Morrow AL. Costs associated with gastrointestinal-tract illness among children attending day-care centers in Houston, Texas. *Pediatrics*. 1994;94:1091–1093.
20. Black RE, Dykes AC, Anderson KE, et al. Handwashing to prevent diarrhea in day-care centers. *Am J Epidemiol*. 1981;113:445–451.
21. Bartlett AV, Reves RR, Pickering LK. Rotavirus in infant-toddler day care centers: Epidemiology relevant to disease control strategies. *J Pediatr*. 1988;113:435–441.
22. Rauch AM, Van R, Bartlett AV, Pickering LK. Longitudinal study of *Giardia lamblia* infection in a day care center population. *Pediatr Infect Dis J*. 1990;9:186–189.
23. Campbell RL, Bartlett AV, Sarbaugh FC, Pickering LK. Effects of diaper type on diaper dermatitis associated with diarrhea and antibiotic use in children in day-care centers. *Pediatr Dermatol*. 1988;5:83–87.
24. Sullivan P, Woodward WE, Pickering LK, DuPont HL. Longitudinal study of occurrence of diarrheal disease in day care centers. *Am J Public Health*. 1984;74:987–991.
25. Laborde DJ, Weigle KA, Weber DJ, Kotch JB. Effect of fecal contamination on diarrheal illness rates in day-care centers. *Am J Epidemiol*. 1993;138:243–255.
26. Van R, Wun CC, O'Ryan ML, Matson DO, Jackson L, Pickering LK. Outbreaks of human enteric adenovirus types 40 and 41 in Houston day care centers. *J Pediatr*. 1992;120:516–521.
27. Hjelt K, Paerregaard A, Nielsen OH, et al. Acute gastroenteritis in children attending day-care centres with special reference to rotavirus infections. I. Aetiology and epidemiologic aspects. *Acta Paediatr Scand*. 1987;76:754–762.
28. Barros AJ, Ross DA, Fonseca WV, Williams LA, Moreira-Filho DC. Preventing acute respiratory infections and diarrhoea in child care centres. *Acta Paediatr*. 1999;88:1113–1118.
29. Pickering LK, Evans DG, DuPont HL, Vollet JJ III, Evans DJ Jr. Diarrhea caused by *Shigella*, rotavirus, and *Giardia* in day-care centers: prospective study. *J Pediatr*. 1981;99:51–56.
30. Kleinbaum DG, Kupper LL, Morgenstern H. *Epidemiologic Research: Principles and Quantitative Methods*. 1st ed. New York: Wiley; 1982.
31. Carabin H, Gyorkos TW, Soto JC, Penrod J, Joseph L, Collet JP. Estimation of direct and indirect costs because of common infections in toddlers attending day care centres. *Pediatrics*. 1999;103:556–564.
32. Ackerman SJ, Duff SB, Dennehy PH, Mafilios MS, Krilov LR. Economic impact of an infection control education program in a specialized preschool setting. *Pediatrics*. 2001;108:E102.

