Effectiveness of a Training Program in Reducing Infections in Toddlers Attending Day Care Centers

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The objective of this study was to assess the effectiveness of a hygiene program in reducing the incidence of respiratory and diarrheal diseases in toddlers attending day care centers. A randomized field trial was conducted in 52 day care centers in Québec, Canada, between September 1, 1996 and November 30, 1997. Absences for any reasons and the daily occurrence of colds and/or diarrhea in toddlers were recorded on calendars by the educators. The number of fecal coliforms on children's hands and on educators' hands was measured during three unannounced visits. Overall, 1,729 children were followed in 47 day care centers for a total of 153,643 child-days. The incidence rate of diarrhea was considerably reduced by the effect of monitoring (IRR = 0.73, 95% CI = 0.54,0.97), and the intervention reduced the incidence rate of upper respiratory tract infections (IRR = 0.80, 95% CI = 0.68,0.93). Monitoring alone also had an important effect in reducing the level of bacterial contamination on children's and educators' hands. The results indicate that both an intervention program and monitoring alone play a role in reducing infections in children attending day care centers. (Epidemiology 1999;10:219–227)

Keywords: bacterial contamination, Bayesian hierarchical model, child day care center, effectiveness, infectious diseases, intervention, monitoring, randomized trial.

The increased demand for child care services in industrialized countries reflects current labor and societal trends that are only expected to increase in the foreseeable future.[1–4] It is widely recognized that the risk of infection among children attending day care centers (DCCs) is higher than among children being cared for in the home.[5–25] Furthermore, this risk is greatest in children less than 36 months of age.[6,13,26–29] The impact of these infections directly affects the child's health and also generates important costs to parents and society.[30–34]

As increasing constraints are placed on public financial resources in contemporary societies, it becomes essential to develop an inexpensive, easily implementable and practical program to reduce illness incidence in the ever-growing population of toddlers attending DCCs.

Handwashing is undoubtedly the most effective method to control enteric and respiratory illnesses[35–38] that are spread through hand contact.[39,40] To date, four trials evaluating the effectiveness of hygiene and surveillance programs in reducing DCC infections have provided conflicting results.[28,41–43] Although epidemiologic and statistical methods varied, in all four studies, however, the incidence of illness decreased over time, even though it could not be shown if this decrease was due to underreporting of illness incidence, to a Hawthorne effect[44] or to a true effect of the surveillance program and/or intervention. The effect of the intervention itself on the bacterial contamination of the environment, which is a more objective measure, has not previously been assessed. The objective of this study was to assess the effectiveness of a practical, inexpensive, and easily implementable hygiene program in reducing bacterial contamination in the DCC environment and the incidence of respiratory and diarrheal illnesses in toddlers attending DCCs. The study methodology was designed to disentangle the effect of the monitoring alone from the effect of the intervention and to take into account the clustering effect of DCCs in the analysis.

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Editor's Note See related editorial on p 209 of this issue.

Subjects and Methods

Setting

From a list of a total of 466 licensed DCCs having more than 40 places located in the regions of Montréal, Laval, Lanaudière, and Laurentides, in south-central Québec, 150 DCCs were randomly selected. Of these, 75 met the study eligibility criteria (presence of at least one sandbox and one play area and of at least 12 available toddler places) and were invited to participate in the study. A total of 52 DCCs (69%) offering care to one or two toddler groups (18–36 months of age) agreed to participate in the trial, which spanned 15 months (September 3, 1996 to November 28, 1997). Children were followed until they "graduated" to an older group or until they left the DCC. Five DCCs were excluded from the analysis: two for-profit DCCs closed; one was sold; data from one DCC was unreliable, and one failed to provide data after a change in administrative staff. In addition, data could not be collected in six classrooms during Fall 1997: two (one intervention, one control) were closed because of insufficient registration, and in four (one intervention, three control), data had not been collected by the educators. Therefore, complete data was available for 47 DCCs (83 toddler classrooms). Only children that attended the DCC for more than 5 days each Fall were kept in the analysis (43 children were excluded).

Further analyses compared preintervention (September 3, 1996 to January 31, 1997) and postintervention periods (March 1, 1997 to November 28, 1997), excluding summer holidays (July–August). The classrooms and DCCs included were the same as above and children followed less than five days were excluded (18 and 36 children during the preintervention and postintervention periods, respectively).

Intervention

The DCC was used as the unit of randomization. The DCCs were stratified according to the median of the incidence rate (IR) of upper respiratory tract infection (URTI) observed during September-October 1996 and block randomized by geographical region to either the intervention or control group. The control DCCs continued to follow their usual hygiene policies and practices. The intervention DCCs were given a one-time comprehensive hygiene training session and materials and documents that could be used throughout the study.

The entire DCC staff in the intervention group, and especially the educators of participating classrooms, were invited to attend the complete day of training offered in February 1997. The research team reimbursed the equivalent of one full-time educator's salary to encourage participation. The content of the training session was largely based on what had previously been developed and used in a surveillance study.[28] The session ended with the following recommendations: (1) clean the toys in toddler classrooms at least once every 2 days with bleach (diluted 1:10); (2) wash hands using the proper technique at least after arrival at the DCC, after playing outside, after going to the bathroom and before lunch; (3) be creative in using reminder cues for handwashing; (4) open the windows at least 30 minutes every day; (5) clean the sand in the sandbox and the play area at least biweekly with bleach (diluted 1:10). Each DCC was provided with additional training material.

The director of one DCC randomized to the intervention group refused to send his staff to the training session. This DCC was kept within the intervention group since the aim of this study was to evaluate the effectiveness of the intervention (intent-to-treat).

Measurement of Illness Frequency

Day care educators were given calendars on which to indicate the daily occurrence of illness, the days each child was expected to attend DCC (especially for part-time children) and absences (with their causes when known). Instructions for filling in the calendars were personally given by the research staff during a baseline visit, 2 weeks before the project started. The instructions were reiterated at each of the three visits of the follow-up period. Educators were asked to return completed calendar pages monthly in a prestamped envelope. In addition, the DCC director was called monthly to obtain the number of absences and their causes, when known, for the whole DCC.

The definitions used for the illnesses have been used in previous day care research.[28] They were:

Cold

The presence of nasal discharge (runny nose) accompanied by one or several of the following symptoms: fever, sneezing, cough, sore throat, ear pain, malaise, irritability. A URTI was defined as the presence of a cold for 2 consecutive days.

Diarrhea

The presence of twice the normal number of stools or a change in the consistency of stool to watery. For a study illness to be considered as a new episode, it had to be preceded by seven illness-free days. The definitions of the two study illnesses were printed on the top of each calendar page.

Measurement of Potential Confounders

Telephone questionnaires to the DCC director and on-site visits were used to measure potential confounding variables largely based on the comprehensive listing of risk factors for infections in DCC developed by an international expert committee.[45] The questionnaires were pretested, translated into English, and back-translated into French.

Measurement of Fecal Contamination

The bacterial contamination of both the indoor and outdoor environments was measured by fecal coliform (FC) count. Contamination was assessed during three unannounced visits in Fall 1996 (September–October 1996), Spring 1997 (May–June 1997) and Fall 1997 (September–October 1997). The visits took place Monday through Thursday. Three DCCs were visited each day. The day of the week, the week of the month, and the time at which the DCCs were visited were exactly the same during the two Fall seasons. The indoor and outdoor sampling strategies have been described elsewhere [Carabin H, Gyorkos TW, Joseph L, Payment P, Soto JC. Comparison of methods to analyse imprecise fecal coliform count data from environmental samples (submitted)].

Follow-Up Questionnaire

The DCC directors were invited to participate in a follow-up telephone questionnaire in July 1997 to assess if there had been any changes in hygiene policies since the last telephone questionnaire. This questionnaire was also used to evaluate if the DCCs in the intervention group had followed the training recommendations.

Statistical Analysis

We analyzed the data separately for cold and diarrhea symptoms, even though some symptoms might have co-occurred. We computed the overall incidence rates of illness as the sum of new episodes divided by the sum of child-days at risk for that illness. We then multiplied rates by 100 to give a measure of the number of episodes per 100 child-days at risk. We considered a child at risk for an illness if he or she had not shown any symptoms of that illness in the preceding 7 days. We excluded from the denominator days when the child was not at risk.

Fall-to-Fall Comparison

The primary analysis was concerned with the assessment of the effectiveness of the intervention and the monitoring alone in reducing illness. Monitoring alone consisted of the daily recording by educators of the study illnesses and is used here as a measure of the Hawthorne effect. To disentangle the two effects, only Falls were compared with control for seasonal variation. We calculated crude estimates of the effectiveness of the intervention and the monitoring alone as incidence rate differences (IRDs) between the intervention and control groups (Fall 1997 IR - Fall 1996 IR). We computed the variances for the 95% confidence intervals (95% CI) of the crude effectiveness using the sum of the variances of the IRDs calculated for the control and the intervention groups, assuming a normal distribution.[47]

One of the major challenges in DCC epidemiologic research is to fit a model using observations that are statistically dependent, since children are clustered within classrooms and DCCs. In addition, it might be of interest to introduce, in a single statistical model, the effect of several factors measured at different levels of clustering. For example, at the individual child level, it is well recognized that age and gender have an important effect on IR of diarrhea[6,13,26-29] while our intervention was applied at the DCC level. Bayesian hierarchical models allow this type of analysis.[48,49] In the DCC example, there are three levels: the child, the classroom, and the DCC. The full model is detailed in the Appendix.

The regression coefficients and their 95% Bayesian credible intervals (95% BCI) were computed, then their exponential was taken to obtain incidence rate ratio (IRR) estimates. We used a multiplicative model because the IRR between the groups was more stable than the IRD. In addition, educators usually underestimate the IR of URTI and diarrhea when compared with parents [Carabin H, Gyorkos TW, Soto JC, Joseph L, Collet J-P. Agreement between parents and educators in reporting cold and diarrhea symptoms in toddlers attending daycare centres (submitted)]. Therefore, the IRR is probably a more valid measure than the IRD.

Preintervention/Postintervention Periods Comparison

The secondary analysis focused on the effectiveness of the intervention alone, adjusting for the seasonal effect. This approach further assessed the effectiveness of the intervention by using the preintervention period to evaluate the baseline IR and the postintervention period as the comparison period. The generalized linear model described above was applied for each illness. This analysis improves the precision of the intervention estimate, and the "seasonal effect" estimate indicates the effect of both the monitoring alone and the seasonal effects.

Environmental Contamination

We also measured the effectiveness of the intervention on environmental contamination. The FC counts were $\log_{10}$-transformed to normalize their distribution.[51] Because the unit of analysis was the DCC and because the group sizes of children and number of educators per group varied, we used weighted averages to calculate mean log(FC counts) for children's and educators' groups within each DCC. We calculated the geometric means ($10^{\log(FC)}$) and 95% BCI using the number of FC per pair of hands for the educators' and children's hands, the number of FC per toy, and the number of FC per milliliter in the sandbox and the play area. We used multiple imputation to handle the imprecise FC counts.[52] This method has been described elsewhere [Carabin H, Gyorkos TW, Joseph L, Payment P, Soto JC. Comparison of methods to analyse imprecise fecal coliform count data from environmental samples (submitted)]. We assessed effectiveness using a multiple linear model to estimate the coefficients of the intervention and the monitoring and their 95% BCI on the log(FC), controlling for the baseline log(FC) during Fall 1996. A separate model was fit for the log(FC) on each of the children's hands, the educators' hands, the sandbox, and the play area. Only variables that were different between Fall 1996 and Fall 1997 were assessed as potential confounding factors. The estimates of the effects of monitoring and of the intervention and their 95% BCI did not change considerably when these factors were included in the model. Therefore, we report only crude estimates, adjusted for the baseline level.

While we used a Bayesian statistical approach for its flexibility in modeling and handling of missing data, we used noninformative prior densities throughout so that the final inferences were based solely on our data.

TABLE 1. Distribution of Potential Confounding Factors for the Effect of the Intervention

Factor	No of Observations	Intervention Group	Control Group
Average age in months (SD)*	1574†	26.17 (7.4)	25.72 (6.3)
Gender (% female)	1593	381 (45.2)	337 (44.9)
Average follow-up duration in days (SD)	1593	44.65 (20.1)	44.25 (20.4)
Children coming part time‡ (%)	1593	436 (51.7)	396 (52.8)
Average experience of the educator in years (SD), 1996	83	7.1 (4.9)	6.42 (4.8)
Educator has an early childhood training (%), 1996	83	37 (86.1)	30 (75.0)
Change of educator Fall 1997 (%)	83	24 (55.8)	20 (50.0)
Ratio educator:children (%)	83		
1:4 or 1:5		3 (7.0)	3 (7.5)
1:6 or 1:7		22 (51.2)	21 (52.5)
1:8 or 1:9		18 (41.9)	16 (40.0)
Average volume per person in m^3 (SD)	83	9.02 (3.87)	8.00 (2.88)
Average level of CO_2 in ppm (SD), 1996	83	1,008.1 (586.9)	1,253.8 (549.8)
Presence of a sink in the room (%)	83	31 (72.1)	36 (90.0)
Presence of a changing table in the room (%)	83	26 (60.5)	29 (72.5)
The children share the bathroom with others (%)	83	33 (76.7)	33 (82.5)
Infants room (%)	47	14 (58.3)	15 (65.2)
Stated policy of exclusion for diarrhea (%)	47	11 (45.8)	14 (60.9)
Stated policy of exclusion for fever (%)	47	15 (62.5)	16 (69.6)
Stated policy of exclusion for vomiting (%)	47	6 (25.0)	8 (34.8)
Non-profit (%)	47	19 (79.2)	20 (87.0)
Region (No. DCCs)	47		
Montréal		11	12
Laval		4	4
Lanaudière		3	1
Laurentides		6	6
Presence of a mechanical ventilation system (%)	47	16 (66.7)	9 (39.1)
Electrical heating (%)	47	11 (45.8)	14 (60.9)
Bleach diluted 1:10 used to clean the toys (%)	47	14 (58.3)	13 (59.1)
Frequency of toy cleaning (No. DCCs)	47		
≥ once a week		5	3
once a week		9	9
< once a week		6	9
no policy		2	4
Non-monetary payment for services (%)§	47	10 (41.7)	17 (73.9)

* Age at September 3, 1996 and September 1, 1997, for children attending the DCC during the Fall 1996 and the Fall 1997, respectively.
† 19 missing values for age, 10 in the intervention group, 9 in the control group.
‡ Children coming part-time: child present at the DCC less than 75% of the maximum follow-up period (68 days each season).
§ Nonmonetary payment for services (%): Provincial government program to compensate for unpaid bills. These citizens are generally asked to help the staff in cleaning the toys and the environment.

All Bayesian analyses were conducted using the BUGS (Bayesian inference Using Gibbs Sampling) package.[53] All the programming and data management was conducted using STATA for Windows 95®.[54]

Ethics Review

The study was approved by the Montreal General Hospital Ethics Review Committee and the Cité de la Santé de Laval Ethics Research Review Committee.

TABLE 2. Crude Effectiveness* and 95% Confidence Interval of the Intervention in Reducing the Incidence Rate† of Upper Respiratory Tract Infections (URTI) and Diarrhea, for Different Units of Analysis (Child, Classroom, and Day Care Center)

		Intervention Group			Control Group			
Illness	Unit of Analysis	Fall 1996	Fall 1997	Difference‡	Fall 1996	Fall 1997	Difference‡	Crude Effectiveness
URTI	Child	2.53	2.02	−0.50 (−0.84,−0.16)	2.69	2.44	−0.26 (−0.65,0.14)	−0.24 (−0.76,0.28)
	Classroom	2.92	2.43	−0.48 (−1.21,0.24)	3.63	3.75	0.12 (−1.40,1.65)	−0.60 (−2.28,1.08)
	Day care center	2.87	2.21	−0.66 (−1.48,0.17)	3.42	3.05	−0.37 (−1.51,0.76)	−0.28 (−1.65,1.08)
Diarrhea	Child	0.55	0.31	−0.24 (−0.38,−0.01)	0.74	0.51	−0.23 (−0.41,−0.05)	−0.01 (−0.23,0.21)
	Classroom§	0.58	0.35	−0.23 (−0.49,0.03)	0.94	0.67	−0.27 (−0.78,0.23)	0.04 (−0.52,0.60)
	Day care center§	0.56	0.32	−0.24 (−0.51,0.04)	0.78	0.67	−0.11 (−0.55,0.33)	−0.13 (−0.64,0.38)

* The crude effectiveness was computed as the incidence rate difference for the intervention group minus the incidence rate difference for the control group.
† All incidence rates are reported as the number of episodes per 100 child-days at risk.
‡ Incidence rate difference between Fall 1996 and Fall 1997 (95% confidence interval): this difference corresponds to the monitoring effect.
§ Average incidence rates are reported.

TABLE 3. Incidence Rate Ratio* Estimates and Their 95% Bayesian Credible Intervals between the Intervention and the Monitoring and the Rate of Upper Respiratory Tract Infection (URTI) and Diarrhea, Adjusted for the Baseline Incidence Rates Clustered by Day Care Center

	URTI		Diarrhea	
	Crude	Adjusted†	Crude	Adjusted‡
Intervention	0.89 (0.72, 1.10)	0.86 (0.70, 1.06)	0.76 (0.50, 1.15)	0.77 (0.51, 1.18)
Monitoring	0.91 (0.78, 1.06)	0.96 (0.82, 1.11)	0.72 (0.54, 0.96)	0.73 (0.54, 0.97)

* The incidence rate ratios were computed by taking the exponential of the multiple linear regression coefficients for the effect studied.
† Adjusted for age.
‡ Adjusted for age and gender.

Results

Overall, we observed 54,138 and 79,477 child-days during the preintervention and postintervention periods, respectively. Children in the intervention and control groups were followed for 28,983 and 25,155 child-days during the preintervention period, respectively, and 41,648 and 37,829 child-days during the postintervention period, respectively.

There were 805 and 788 children followed for more than 5 days during Fall 1996 and 1997, respectively. During Fall 1997, 414 children attended 43 classrooms at the 24 DCCs in the intervention group whereas 374 children attended the 40 classrooms at the 23 DCCs in the control group. A total of 224 children were followed both during Fall 1996 and Fall 1997.

The distribution of some of the potential confounders is presented in Table 1. Overall, they were well balanced between the two groups, even though there was some attrition over the study period. In addition, the potential confounding factors remained the same or only slightly changed from 1996 to 1997. Only one DCC randomized to the control group changed its hygiene policies during the 2nd year. Only one DCC in the intervention group had consulted public health authorities for a problem of chicken pox between February 1997 and July 1997. The average age of children was similar between the intervention (26.17 months) and control groups (25.72 months) and during the two Fall periods (25.7 months in 1996 and 26.2 months in 1997). A larger proportion of boys were followed in both the intervention (54.8%) and control (55.1%) groups and was comparable between the two Falls (53.9% in 1996 and 56.0% in 1997).

The crude estimates of the intervention effectiveness, unadjusted for the clustering effect, age, and gender, are reported in Table 2. This method of analysis showed no considerable effect of the intervention, regardless of the unit of observation used. In the intervention group, monitoring alone showed a considerable effect when the child was used as the unit of analysis. As expected, when we used the classroom or the DCC as the unit of analysis, the 95% CI over the estimates increased. In the control group, the effects of monitoring alone was less important, even when the child was used as the unit of analysis.

Fall-to-Fall Comparison

In Table 3 we report the crude and adjusted IRR estimates for monitoring and intervention effects obtained with the Bayesian hierarchical model. The variance explained by the classroom effect was negligible. Therefore, we included only the DCC level of clustering in both models. The crude and adjusted estimates of the Poisson regression coefficients for the intervention and monitoring effects were similar since the distribution of age and gender was similar in both groups and in both Falls. The adjusted effectiveness of the intervention in reducing the IR of URTI and diarrhea was not important (IRR = 0.86, 95% BCI = 0.70, 1.06 and IRR = 0.77, 95% BCI = 0.51, 1.18, respectively). The monitoring effect contributed to reducing the IR of diarrhea by 37% (IRR = 0.73, 95% CI = 0.54,0.97). The effect of the monitoring in reducing the IR of URTI was negligible (IRR = 0.96, 95% BCI = 0.82, 1.11).

Preintervention/Postintervention Comparison

Table 4 shows the results of the Bayesian hierarchical model for evaluating the effectiveness of the intervention while adjusting for the seasonal effect and for the baseline IR within each DCC. Again, the adjusted and crude estimates were similar, even though the effect of season was slightly confounded by age. The intervention reduced the IR of URTI by 25% (IRR = 0.80, 95% BCI = 0.68, 0.93) whereas it showed little effect on the IR of diarrhea (IRR = 1.10, 95% BCI = 0.81, 1.50). As expected, there was a seasonal effect for both the IR of URTI and diarrhea (IRR = 0.78, 95% BCI = 0.70, 0.87 and IRR = 0.69, 95% BCI = 0.55, 0.86), respectively.

The causes of absences recorded for all children attending the participating DCCs were available for 20 and 22 DCCs in the control and intervention groups, respectively. The proportion of absences caused by ill-

TABLE 4. Incidence Rate Ratio* Estimates and Their 95% Bayesian Credible Intervals between the Intervention and the Rate of Upper Respiratory Tract Infection (URTI) and Diarrhea, Adjusted for the Season Effect

	URTI		Diarrhea	
	Crude	Adjusted†	Crude	Adjusted‡
Intervention	0.80 (0.68, 0.93)	0.80 (0.68, 0.93)	1.10 (0.81, 1.49)	1.10 (0.81, 1.50)
Season	0.70 (0.62, 0.79)	0.78 (0.70, 0.87)	0.63 (0.51, 0.78)	0.69 (0.55, 0.86)

* The incidence rate ratios were computed by taking the exponential of the multiple linear regression coefficients for the effect studied.
† Adjusted for age.
‡ Adjusted for age and gender.

TABLE 5. Geometric Mean of Fecal Coliform Counts and Their 95% Bayesian Confidence Interval Isolated from the Indoor and Outdoor Environment Samples during Fall 1996 and Fall 1997

	Intervention Group			Control Group		
	n	Fall 1996	Fall 1997	n	Fall 1996	Fall 1997
Children's hands*	24	35.01 (8.55,95.96)	3.23 (1.92,5.12)	23	110.00 (26.00,315.90)	2.61 (1.53,4.19)
Educators' hands*	23	6.50 (2.69,13.39)	2.07 (0.85,4.28)	23	27.82 (11.59,57.56)	4.42 (1.81,9.19)
Indoor toys†	24	1.86 (0.69,4.10)	0.42 (0.33,0.52)	22‡	3.13 (1.09,7.2)	0.38 (0.30,0.48)
Outdoor toys†	22‡	13.84 (2.00,48.86)	3.11 (0.93,7.68)	23	11.71 (178,40.97)	4.61 (1.45,11.16)
Sandbox§	24	11.89 (2.90,31.86)	7.30 (1.48,22.02)	23	16.71 (4.34,45.11)	12.68 (2.43,40.04)
Play area§	24	8.60 (1.61,26.04)	6.10 (1.86,15.22)	23	34.81 (6.95,104.20)	6.99 (2.05,17.78)

* Reported as the average number of fecal coliforms per pair of hands.
† Reported as the average number of fecal coliforms per toy.
‡ One outdoor toy sampling bag and two indoor toy sampling bags were empty when they arrived at the laboratory.
§ Reported as the average number of fecal coliforms per milliliter of sand.

ness was similar in the intervention and control groups during Fall 1997 (36.90, 95% CI = 26.89, 46.90, and 32.79, 95% CI = 26.14, 39.43, respectively) and Fall 1996 (35.68, 95% CI = 26.44, 44.91, and 41.61, 95% CI = 31.61, 51.60, respectively). The difference in the proportion of absences due to illness between the postintervention and preintervention periods was small in either the intervention or the control group (1.2, 95% CI = −9.9, 12.3, and −8.8, 95% CI = −22.1, 4.5, respectively).

Environmental Contamination

We report the number of FC isolated from the indoor and outdoor environmental samples in Table 5. The level of FC contamination was lower for all environmental samples in Fall 1997 compared with Fall 1996, the decrease being larger in indoor samples. Children's hands were more contaminated than educators' hands during Fall 1996 but not during Fall 1997. Outdoor toys were more contaminated than indoor toys in both years.

The effect of the intervention and monitoring alone on the FC counts is reported in Table 6. All multiple linear coefficients were negative, with considerable effects of the monitoring in reducing FC on children's (−1.36, 95% BCI = −1.73, −0.99) and educators' hands (−0.62, 95% BCI = −1.03, −0.23). The effect of the intervention on the FC counts in the outdoor environment was negligible.

In July 1997 we determined that, among the 24 DCCs randomized to the intervention group, 22 had used the coloring book, 23 had used the poster on handwashing, 18 had listened to the videotapes about hygiene, 19 had one or several meetings to discuss the training session with all the staff, 6 had increased the frequency of toy cleaning, 17 had used the rake and shovel to clean the sand, and 14 had increased the frequency of cleaning the sandbox. Among the 43 educators that had attended the training session, 22 were still taking care of a group of toddlers in Fall 1997 (51.2%).

Discussion

This study is the first to assess the effectiveness of a practical, inexpensive, and easily implementable comprehensive hygiene training program in reducing both the IRs of diarrheal and respiratory infections and the environmental contamination in DCCs. It is also the first to disentangle the effects of intervention and of monitoring appropriately by using a model that takes into account the clustering effect of DCCs.

Comparing our results with previous studies is difficult owing, for example, to the large differences in study designs that have been used.[28,41–43]

The advantages of our study design and analysis were the introduction of the clustering effect of the DCC, the use of true IR using child-days-at-risk as the denominator and the control of confounding through the baseline IRs. It is also the largest randomized field trial ever conducted in the day care setting aimed at reducing infections through hygiene training. The statistical methods we used avoided a subjective choice for the unit of analysis and permitted adjustment of variables mea-

TABLE 6. Multiple Linear Regression Coefficient Estimates and the 95% Bayesian Credible Intervals for the Effects of the Intervention and the Monitoring for the Logarithm of the Fecal Coliform Counts during Fall 1997, for Indoor and Outdoor Environmental Samples, Using a Multiple Imputation Method for Imprecise Values and Adjusting for the Baseline Fecal Coliform Counts during Fall 1997

	Indoor Samples		Outdoor Samples	
	Children's hands*	Educators' hands†	Sandbox*	Play area*
Constant‡	1.99 (1.67, 2.31)	1.31 (1.08, 1.54)	1.05 (0.64, 1.46)	1.16 (0.78, 1.54)
Intervention	−0.19 (−0.55, 0.17)	−0.26 (−0.71, 0.20)	−0.06 (−0.76, 0.63)	−0.06 (−0.81, 0.67)
Monitoring	−1.36 (−1.73, −0.99)	−0.62 (−1.03, −0.23)	−0.23 (−1.01, 0.56)	−0.38 (−1.03, 0.27)

* n = 47.
† n = 46.
‡ Constant: intercept that controls for the baseline log(FC) during year 1.

sured at different levels of clustering. One limitation of our study is that we could only compare the monitoring-alone effect for 3 months of follow-up before and after the intervention. A full-year comparison would have increased its power.

The intervention had no important effect on reducing either the IR of URTI and diarrhea or the environmental contamination when the two Falls were compared, whereas it reduced the IR of URTI when the preintervention and postintervention periods were compared. This comparison included the immediate effectiveness of the intervention whereas the Fall-to-Fall comparison assessed only its long term effectiveness. Including more events might have contributed to improving the precision of the estimates.

The effectiveness of the intervention in reducing the IR of URTI was considerable (decrease of 25%), given the important economical impact of these illnesses in the day care setting.[33,34] One previous study had shown the effectiveness of combining an intervention including reminder visits, participation of children and a program of public health surveillance to be largely effective in reducing the IR of URTI even though the sample size was small.[28]

The intervention did not show a meaningful reduction on the IR of diarrhea or the FC contamination on the children's and educators' hands, the former being in agreement with the results obtained in two previous studies.[42,43] The only randomized prestudy/poststudy in which the intervention had had a considerable effect used a very small sample size (4 DCCs) and offered a very closely followed training that would be too expensive to be implemented widely.[41] We deliberately did not supplement our intervention with reminders during the follow-up period because our aim was to evaluate the effectiveness of a realistically implementable hygiene program.

There was almost no effect of the monitoring on the IR of URTI. Conversely, the IR of diarrhea was reduced by the simple recording of their daily occurrence combined with three on-site visits by the research team and monthly calls to the DCC directors. This finding confirms what has been suspected in a previous randomized trial during which a similar intervention was offered.[43] Our study also provides evidence that the effectiveness of the monitoring was not due to a decrease in reporting diarrhea occurrence through time since the FC contamination on children's and educators' hands was also reduced. In addition, the proportion of absences due to illness in all children attending the DCC remained similar during the 2 years in both groups. Therefore, the monitoring effect could not be attributed to the effect of a reduction of illness frequency in all DCCs during Fall 1997. Thus, observing and recording illnesses in children would seem to be a more effective method of encouraging the educators to wash their hands better and to remind them about the importance of keeping a clean environment than a one-day training session.

Our study is the first to describe the bacterial contamination in the outdoor environment of DCCs and to assess the effect of the monitoring and of an intervention in reducing it. Only one study had previously documented parasite (*Toxocara* spp. ova) contamination of sandboxes and play areas in the day care setting but no bacterial assessment was included.[55] At baseline, we found the bacterial contamination to be considerably high in the sandbox and the play area and possibly suggestive of a potential health risk to children. Neither the monitoring nor the intervention, however considerably reduced the FC contamination. Therefore, recommendations regarding the cleaning of the sandbox and play area are probably not sufficient to decrease the bacterial contamination in the sand.

Our study has shown that decreasing the occurrence of URTI and diarrhea in DCCs might need different prevention strategies. It would seem that asking the educators to report the occurrence of diarrhea in children attending their classroom reduces its incidence. Therefore, reducing the IR of diarrhea would require a concerted effort from DCC staff and the public health authorities.

A comprehensive 1-day training session accompanied with training material proved effective in reducing the occurrence of URTI during the first 9 months after its implementation. The duration of this effect remains uncertain. In the United States, the turnover of DCC staff has been shown to be as high as 50% over a period of 2 years,[56] whereas 50% of the staff that had received the training were taking care of another age group or had left the DCC the 2nd year of our study. Nevertheless, DCC staff are genuinely interested in acquiring information about infectious diseases.[57,58] Therefore, a yearly training program may help to control the occurrence of URTI in the day care setting.

Appendix

The major features of our model were the following:

First, we used Poisson regression model for the number of episodes of URTI and diarrhea within each child. The model included independent variables for the intervention, monitoring alone (year), DCC effects, age and gender. Since there was great between-DCC variability in IRs, we fit a separate parameter, representing the overall IR level in each DCC. We used a random effects model to account for these differences, where we assumed the collection of parameter values were normally distributed among the 47 DCCs.

Our model can be described in three stages:

At the first stage, an individual Poisson generalized linear regression model with a log link (McCullagh and Nelder, 1989) is fitted within each child I (I = 1,..,1574) attending DCC j (j = 1,..,47) during the fall k (k = 0 (1996) or k = 1 (1997). The equation is:

$$\ln(\theta_{ijk}) = \delta_j + \beta_1 * k + \beta_2 * \mathrm{Int}_j * k + \beta_3 * age_{ijk} + \beta_4 * \mathrm{gender}_{ijk}$$

where θ_{ijk} corresponds to the mean IR of child I attending the DCC j during the year k, β_1 represents the surveillance effect, β_2 is the intervention effect (Int = 0 for the control group and Int = 1 for the intervention group), β_3 and β_4 represent the specific regression coefficients for the child's age (in months) and gender (female is coded as 1) and δ_j represents the baseline rate in DCC$_j$.

The variation in baseline IRs between DCCs is modelled by placing a hierarchical (random effects) component on the δ_j where j2)

$$\delta_j \sim \text{Normal}(\mu_j, \sigma_j^2), \qquad (1)$$

Therefore, the logarithm of the baseline IRs are assumed to follow a normal distribution with mean μ_j and variance σ_j^2 In other words, the baseline IRs can vary from DCC to DCC according to σ_j^2 This represents the second stage of our hierarchical model.

At the last stage of the model, prior distributions are set for all unknown parameters, including μ_j, σ_j^2 and prior parameters for all model coefficients. We used noninformative prior distributions, so that, *a priori* all values in the feasible range have approximately equal values. Therefore, the posterior distributions, upon which all of our inferences are based, are almost exclusively influenced by the data, and not by the choice of prior distributions.

Since an analytic solution for this model is almost impossible, we followed Gelman *et al* (1995) in using the Gibbs sampler,[48] an iterative Markov-chain Monte Carlo technique to form inferences on all parameters. A sufficient number of iterations (20,000) were run to ensure accurate estimates for all parameters according to the criterion of Raftery and Lewis.[59]

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