ARTICLE

Hand-Washing and Diapering Equipment Reduces Disease Among Children in Out-of-Home Child Care Centers

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ABSTRACT

OBJECTIVE. The objective of this study was to determine whether the installation of equipment for diaper-changing, hand-washing, and food preparation that is specifically designed to reduce the transmission of infectious agents would result in a decrease in the rate of diarrheal illness among children and their teachers in child care centers.

METHODS. Twenty-three pairs of child care centers were matched on size and star-rated license level. One member of each pair was randomly assigned to an intervention group and the other to a control group. Intervention centers received new diaper-changing, hand-washing, and food-preparation equipment, and both intervention and control centers received hygiene and sanitation training with reinforcement and follow-up as needed. Families with children in participating classrooms were called biweekly to ascertain the frequency and severity of any diarrheal illness episodes. Staff attendance was monitored, and staff hygiene and sanitation behaviors were observed and recorded monthly.

RESULTS. Although hygiene and sanitation behaviors improved in both intervention and control centers, there was a significant difference favoring the intervention centers with respect to frequency of diarrheal illness (0.90 vs 1.58 illnesses per 100 child-days in control centers) and proportion of days ill as a result of diarrhea (4.0% vs 5.0% in control centers) among the children. Staff in those same classrooms were reported to have a significantly lower proportion of days absent as a result of any illness (0.77% in treatment centers versus 1.73% in control centers).

CONCLUSION. Diapering, hand-washing, and food-preparation equipment that is specifically designed to reduce the spread of infectious agents significantly reduced diarrheal illness among the children and absence as a result of illness among staff in out-of-home child care centers.

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Key Words
child care centers, diarrhea prevention and control, hand-washing, hygiene

Abbreviations
UNC-CH—University of North Carolina at Chapel Hill
CCHC—child care health consultant
df—degrees of freedom

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THE NUMBER OF children who are younger than 6 years in out-of-home child care in the United States has steadily increased in the past 30 years. According to the National Association for the Education of Young Children, 70% of US children are in nonparental child care and early education settings, spending at least part of their day with caregivers other than their parents and in groups of children other than their siblings.[1]

When children are cared for in nonfamily groups, there is an increase in the transmission of infectious agents.[2] Otitis media,[3–7] upper respiratory tract infection,[5,8–10] and diarrhea[5,10–14] are early childhood illnesses that may be acquired in this manner. These illnesses cause more morbidity[15] and occur more commonly in children who are in group child care environments than in children who are reared in their own homes.

Several studies have found that the incidence of illness episodes decreases with age,[14,16–18] suggesting that early childhood is a "sensitive period" for contracting infectious illness. Numerous studies have also found that rates of illness in child care settings can be reduced by implementing simple hygiene measures such as a hand-washing program.[18–22] Carabin et al[23] demonstrated that the incidence rate of diarrhea was reduced by a hygiene training and monitoring program and that monitoring alone reduced the level of bacterial contamination on children's and caregivers' hands. Unlike health care providers, caregivers in child care settings are not provided extensive training and retraining in the correct method of dealing with potential pathogens.[21] This deficiency is compounded by the high turnover of child care center staff and emphasizes the need for continuous training in sanitation and hygiene.

Infection-control programs that have been successful in reducing child care illnesses have had other benefits. Krilov et al[24] reported that the implementation of an infection-control program resulted in downward trends in respiratory and gastrointestinal illnesses, number of physician visits, antibiotic use, and school days missed. Uhari et al[25] reported similar results in a treatment group of children who had fewer infections and prescriptions for antimicrobial agents than did control subjects. Furthermore, infection-control programs in child care have reduced the costs that are incurred by parents of sick children and their employers. Cost/benefit analysis has found a net savings resulting from decreased spending on alternative child care, physician visits, medication, and costs that are associated with parents' time lost from work.[22]

Although many studies have established a positive relationship between hygiene training of caregivers and the reduction of illness, few have examined the contribution of physical factors to the prevalence of diarrheal illness in child care. Deficiencies in equipment surfaces, food-preparation areas, diapering locations, and sink and toilet availability in child care settings may affect the transmission of pathogenic organisms. In fact, Laborde et al[26] found that faucet handles were among the most contaminated sites in child care centers. Other surfaces that are porous, cracked, or damaged increase the likelihood that pathogens will escape disinfection and allow transmission, especially when contact with these surfaces is frequent.

The objective of this study was to determine whether the installation of diaper-changing, hand-washing, and food-preparation equipment that was specifically designed to reduce the transmission of infectious agents in child care centers would result in a decrease in the rate of diarrheal illness among children and reduce their teachers' absences as a result of illness while controlling for caregiver hygiene training. The study was approved by the Institutional Review Board on Research Involving Human Subjects of the School of Public Health of the University of North Carolina at Chapel Hill (UNC-CH).

METHODS

The Quality Enhancement Project for Infants and Toddlers of UNC-CH was funded by the North Carolina Division of Child Development to improve the health and safety of infants and toddlers in child care facilities through its support of child care health consultation; grants to child care providers for health and safety enhancements; and provision of information, resources, and training for child care health consultants (CCHCs). A CCHC is a health professional who has interest in and experience with children, has knowledge of resources and child care regulations, and is comfortable linking child care settings with health resources and facilities that provide primarily education and social services.[27]

Thirteen CCHCs who were supported by the Quality Enhancement Project for Infants and Toddlers recommended 72 child care centers for participation in the study. Inclusion criteria were having an infant or toddler classroom with at least 5 infants or toddlers and a center director and staff who were willing to (1) complete all of the paperwork required by the study and (2) allow data collectors into their programs once a month. Five centers requested removal from consideration for various reasons (eg, director illness, environmental limitations). The remaining centers were matched in pairs by North Carolina's star-rated licensing level[28] and size. After matching, 23 pairs of centers located in 21 counties of North Carolina were randomly selected. From each pair, 1 center was randomly selected as the intervention center, the other as the control. All centers participated for the duration of the study. For the purpose of testing the success of randomization, 2 different statistical tests were used, depending on the nature of the variables used in the comparison. When comparing dichotomous variables such as classroom type × experimental group, we used χ^2 statistics. When comparing continuously measured variables such as age × group, we used F statistics, which are analogous to *t* values. No control variables are included in these descriptive comparisons.

Most of the centers had only 1 infant and 1 toddler classroom. Directors were requested to choose 1 classroom for the study. In the case of centers with >1 classroom, the center director selected for the study the infant or toddler classroom with the highest number of children of an appropriate age who would likely remain in the classroom for the entire 7 months of the study. This process resulted in 2 instances of an infant classroom in the treatment group being paired with a toddler classroom in the control group. Nevertheless, there were no statistically significant differences between the treatment and control groups with respect to infant or toddler age group ($\chi^2 = 2.30$, degrees of freedom [*df*] = 1,44, $P = .13$). Of importance, at the end of the study, the mean ages of the children in the intervention and control classrooms were similar (21.26 and 21.41 months, respectively), and the difference was not significant (F = 0.04, *df* = 1,361, $P = .84$).

The diapering, hand-washing, and food-preparation equipment that was supplied for the study was unique (the Sabre Group, Inc, Winterville, NC; www.sabregrp.com/Hatteras/hatteras_collection.htm), incorporating cast polymer tabletops with impermeable, seamless surfacing for food preparation, diaper-changing, and hand-washing. In addition, automatic faucets and foot-activated, rollout waste bins for diaper disposal minimized contact with the equipment by soiled hands, thereby reducing the potential spread of infectious agents. Providing separate equipment for food preparation, diaper-changing, and toddler hand-washing helped segregate these activities and reduce the risk for contamination. The equipment was installed in intervention centers before data collection commenced. Control centers received the same equipment at the completion of the study.

After the equipment was installed in the intervention centers, staff in all 46 centers were trained using the *Keep It Clean* training module.[29] New staff were trained within 1 week of their being hired. *Keep It Clean* was specifically developed for the study on the basis of successful sanitation and hygiene training activities identified by the CCHCs. The training was intended to improve and standardize the hand-washing, sanitation, diapering, and food-preparation procedures in both intervention and control centers by addressing knowledge, attitudes, and behaviors of child care providers. Pretests and posttests were collected, and follow-up training was provided by each center's CCHC whenever deficits in knowledge, attitude, or behavior were observed during monthly visits that were conducted by trained, objective data collectors.

The centers' directors were responsible for recruiting children into the study by providing the parents or guardians of children in the selected classrooms with a written summary of the study and a verbal description of study procedures. At least 5 children at each center were recruited. Eligibility criteria included that the child be expected to remain in the classroom throughout the 7-month study period and be <36 months of age at the end of data collection and that at least 1 family contact could participate in a telephone survey in English. Siblings were allowed to participate when they also attended the study center and met the eligibility criteria. Between September 1, 2002, and January 31, 2003, cooperating center directors recruited a total of 487 potential subjects into the study. Of these, 70 lacked usable consents and an additional 11 could not be contacted. Eighteen potential subjects who were contacted had to be dropped from the study for reasons such as "left center" or "ineligible" (because of age, other, or unknown reasons). Therefore, illness and attendance data are based on at least 1 completed parent or guardian interview for 388 infants and toddlers (Fig 1).

Telephone interviewing began on December 3, 2002, while recruiting was still in progress. There was no statistically significant difference between experimental groups in the proportion of subjects recruited after interviewing began. The mean ages of children in the treatment and control groups whose parents were interviewed in the first interview cycle (F = 1.05, *df* = 1,185, $P = .31$) did not differ significantly from those whose parents' first interviews were after the first interview cycle (F = 1.85, *df* = 1,160, $P = .18$). We know that, on average, control children participated in the study 125.4 days and intervention children 119.0 days. This difference was not significant (F = 1.29, *df* = 1,369, $P = .26$). Neither was there any significance difference between the 2 groups in the number of subjects (59 control and 62 intervention) who were lost to follow-up ($\chi^2 = 121$, *df* = 1,369, $P = .46$).

Children's illnesses and child care attendance were monitored by parent or guardian telephone interview. Participating families were contacted biweekly by the Survey Research Unit of the Department of Biostatistics of UNC-CH. The family contact was asked whether, during the previous 2 weeks, the participating child(ren) (1) had attended the center; (2) had changed rooms; and (3) had experienced any illness and, if so, what the associated symptoms were. Vouchers for reduced-cost diapers that were contributed by a major supermarket chain were provided by the study to child care providers who used them to purchase diapers for use by child subjects during the course of the study, saving the parents the expense of supplying diapers for their children in child care and possibly reducing the import of pathogens from homes into both intervention and control centers.

For each of the 30 weeks of the study, a caregiver weekly attendance form was completed by the center director and mailed to the study office using a self-addressed, stamped envelope. The caregiver weekly at-

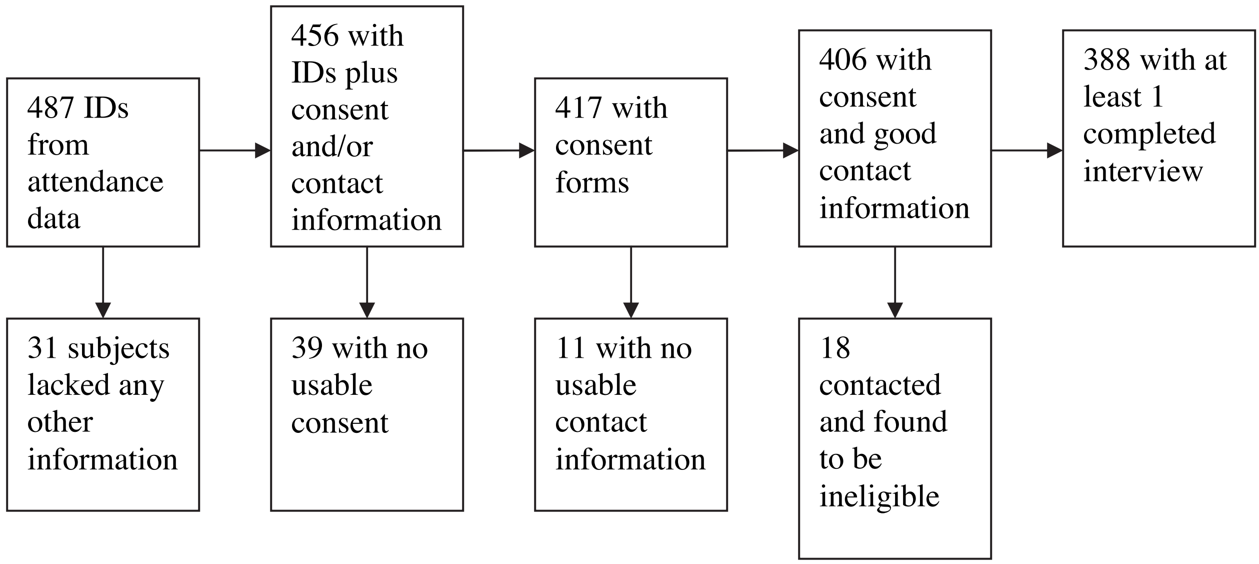

FIGURE 1
Description of recruitment of the sample ($N = 388$) in 46 child care centers: September 1, 2002, to January 31, 2003.

tendance form tracked the attendance of the caregivers and volunteers in the study classroom.

To ensure that sanitation and hygiene practices remained standard, field data collectors recorded baseline and 7 monthly observations of the diapering or toileting of the children and the preparation of food (including hand-washing in both cases) using a standard form, the event sampling form. This form had 8 observable caregiver behaviors for diapering/toileting and 9 behaviors for food preparation. The behaviors followed the recommended steps as presented in the *Keep it Clean* training. Most items were scored according to whether the behaviors were performed "adequately," "inadequately," or "not at all" on a 3-point scale (except for behaviors that logically could be scored only "yes" or "no"), and the scores were averaged. The observations were communicated to the center's CCHC, who would visit the center, if necessary, within the subsequent 2 weeks to provide corrective guidance. The reliability of the field data collectors and the event sampling form was checked by comparing the scores of 2 data collectors who were rating the same events concurrently. Initial reliability was >85%, and reliability remained at this high level.

Before hypothesis testing, the success of random assignment of classrooms to the intervention or control conditions was assessed. The data analysis for this purpose was generated using SAS/STAT 8.02 of the SAS system for Windows.[30] Multivariate analysis of variance was conducted to determine whether significant group differences were detected for 14 key characteristics of the centers and classrooms that could affect the outcomes: (1) teacher/child ratio, (2) center's star-rated license type, (3) total center enrollment, (4) total classroom enrollment, (5) age of youngest child in classroom, (6) age of oldest child in classroom, (7) number of children in classroom enrolled in the study, (8) number of subsidized children in classroom, (9) number of subsidized children enrolled in study from each classroom, (10) number of boys in classroom, (11) number of boys enrolled in study from each classroom, (12) number of caregivers in classroom, (13) number of relief caregivers per week, and (14) number of potential caregivers per week. Four of the 14 variables—mean classroom enrollment ($P < .01$), mean number of children participating in the study per classroom ($P < .05$), mean number of boys enrolled in the classroom ($P < .001$), and mean number of boys participating in the study per classroom ($P < .05$)—were significantly different between intervention and control classrooms. Because the direction of the differences—more boys and more total children in intervention classrooms—would mitigate against the intervention's succeeding, these variables did not need to be controlled for in the models (Table 1).

Incidence density scores were computed for all episodes of diarrhea (defined as any loose, watery stool that if contained would assume the shape of the container). A separate episode of diarrhea was defined by an interval of 7 diarrhea-free days. Review of the distribution of incidence density scores for all incidences of diarrhea (mild, moderate, and severe) indicated extreme skewness with an inflated proportion of no (0) incidences. Proportions for 3 additional variables—number of days child sick, number of full days child absent from child care because of illness, and number of full days parent missed work because of child's illness—computed by dividing the number of days by the number of biweekly telephone interviews times 14 were also highly skewed with an inflated proportion of no incidences. Therefore,

TABLE 1 **Comparison of Center, Classroom, and Child Characteristics for Control and Treatment Groups at Baseline: September 1, 2002, to January 31, 2003**

Characteristic	Control Group, Mean (SD)	Treatment Group, Mean (SD)	F
Teacher/child ratio	0.27 (0.092)	0.24 (0.083)	1.83
Center's license type	2.91 (0.95)	2.87 (0.76)	0.03
Center enrollment	59.74 (25.63)	64.15 (34.56)	0.24
Children enrolled per classroom	7.74 (2.18)	11.48 (5.21)	10.08[a]
Age of youngest child in classroom, mo	10.13 (5.77)	10.35 (7.54)	0.01
Age of oldest child in classroom, mo	19.24 (7.31)	21.61 (8.96)	0.33
Children in classroom participating in study	7.35 (2.17)	9.13 (3.57)	4.19[b]
Subsidized children in classroom	4.22 (3.66)	6.78 (5.69)	3.31
Subsidized children participating in study	4.07 (3.58)	5.65 (4.04)	1.93
No. of boys in classroom	3.61 (1.70)	6.39 (3.34)	12.68[c]
No. of boys participating in study	3.48 (1.81)	4.87 (2.10)	5.82[b]
No. of caregivers in classroom	2.13 (1.01)	2.59 (1.19)	1.96
No. of relief caregivers per week	1.30 (1.02)	1.09 (0.85)	0.62
No. of potential caregivers per week	2.74 (2.40)	2.87 (2.12)	0.04

[a] $P < .01$.
[b] $P < .05$.
[c] $P < .001$.

to assess significant group differences in diarrheal frequency, days ill, full days absent, and full days missed from work, a Poisson regression procedure in the LIMDEP (limited dependent variable model) software package was used.[31]

Three characteristics of the Poisson distribution that make it appropriate for this analysis are that (1) there are no negative values, (2) the data are highly skewed, and (3) the variance increases as the mean increases. Although our outcomes were entered as raw counts, Poisson regression automatically uses a log transformation that adjusts for skewness and prevents the model from producing negative predicted values. This procedure also allows controlling for group differences in length of exposure to the intervention between children in treatment centers and children in control centers. The distribution of differences that was created by some children's leaving during the study and others' beginning their center attendance after the intervention had begun was controlled for by including a variable that was equal to the log transformation of the number of days of data collection for each child as a predictor in the regression models. Data from children within the same classroom were assumed to be nonindependent. An adjustment in the covariance structure was made to account for this nonindependence by estimating a random effect for classroom.

RESULTS

Four Poisson regression models were estimated. In each case, the predictors included the estimated intercept of the line (where all of the predictors were equal to 0), the log transformation of the number of data collection days, and the dichotomous variable for treatment versus control group. The dependent variables were (1) frequency of severe diarrhea, (2) number of days ill with diarrhea, (3) number of full days the child was absent from child care because of diarrhea, and (4) number of full days a parent missed work because of child's illness. Maximum likelihood estimates of the effects of these predictors indicated that the children in the intervention group experienced significantly fewer episodes of diarrhea (0.90 vs 1.58 diarrhea illnesses per 100 child-days; $P < .001$) and were sick with diarrhea a lower proportion of days (4.0% vs 5.0%; $P < .001$) than the children in the control group. No significant differences were found between the intervention and control groups for number of full days absent from child care or number of full days parents missed work because of child's illness.

A similar analysis using data from the caregiver weekly attendance form was conducted to determine whether caregivers who were working in the intervention sites experienced fewer sick days than those who were working in the control sites. The predictors in the model were the number of days the caregiver worked at the site, the number of days the site was open for children to attend, and the dichotomous group variable. Estimates were generated controlling for clustering by estimating a random effect for centers. In this analysis, the caregivers in intervention sites reported a significantly lower proportion of days absent from work as a result of any illness than did the caregivers in the control sites (0.77% vs 1.73%; $P < .001$; Table 2).

The final analysis was conducted on the event sampling data to determine whether the diapering and food-preparation behaviors of the caregivers differed in the 2 groups of classrooms during the intervention period. A score was developed from the event sampling measure. First, the reverse score for each item was averaged across the multiple events sampled at each observation session.

TABLE 2 **Poisson Regression Results Predicting Effects of Special Equipment on Child and Caregiver Outcomes According to Experimental Group: December 2002 to May 2003**

Parameter	Child Diarrhea Frequency per 100 Child-Days	% of Days Child Ill per 100 Child-Days	Days Child Absent From Child Care per 100 Child-Days	Days Parent Missed Work Because of Child Illness per 100 Child-Days	% of Days Caregiver Absent Because of Illness
Control	1.58	5.0	1.30	0.84	1.73
Treatment	0.90	4.0	0.91	0.62	0.77
P	<.001	<.001	NS	NS	<.001

NS indicates not significant.

Then a mean across all of the observations was computed for each item. An item analysis was conducted on the 17 items, and they were found to have adequate internal consistency (Cronbach's $\alpha = .73$). On the basis of this evidence, the items were averaged to form an overall score for diapering and food preparation for each caregiver. Review of the distribution of this variable indicated adequate normality for an analysis of variance. No group differences were detected ($F = 0.74$. $df = 1{,}45$, $P = .3941$; Fig 2).

DISCUSSION

We believe this to be the first study to investigate the impact that physical equipment in child care centers may have on the occurrence and the duration of infectious illness among both children and staff. In preparation for the study, the study staff examined commercially available diaper-changing and hand-washing equipment that was actually available for use in child care centers in North Carolina. This informal investigation revealed a lack of durable, high-quality options. Additional explo-

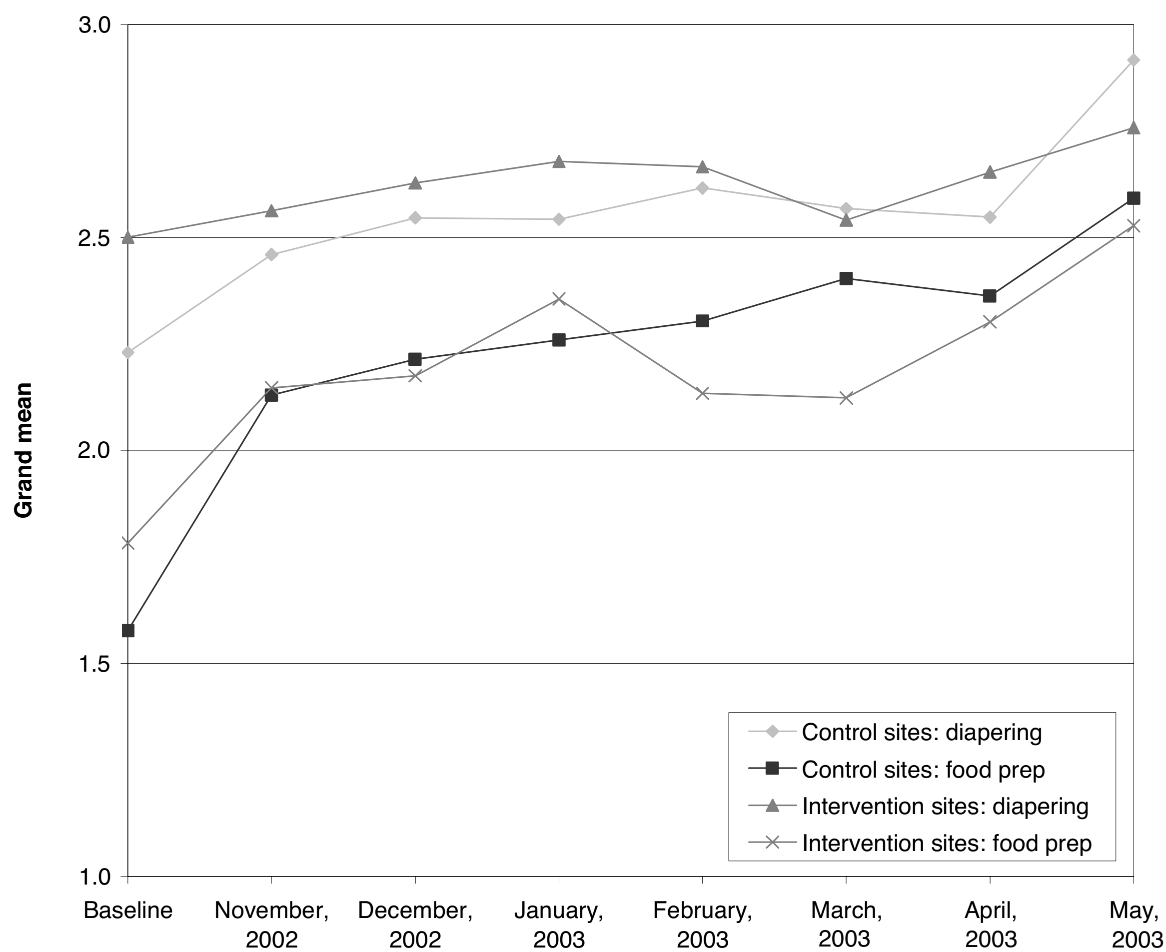

FIGURE 2
Grand means (range: 1–3) of caregiver diapering and food-preparation behavior according to month and experimental group: November 2002 to May 2003.

ration revealed that only 1 manufacturer was interested in manufacturing the necessary numbers of diaper-changing tables and food-preparation surfaces that matched the quality and the durability criteria that the study team and the state child care health consultant had developed. Other manufacturers that were contacted by the study staff declined, citing a business priority for less expensive equipment that would need to be replaced every few years.

This study has shown that high-quality equipment, characterized by seamless, impermeable countertops and touchless faucets and cabinet doors, is associated with significantly fewer episodes of diarrhea among children and fewer sick days among staff. Behavioral change strategies for reducing diarrhea in out-of-home child care may be more effective if this source of contamination is controlled. Both improved staff hygiene and sanitation behavior and state-of-the-art diapering and food-preparation equipment are necessary for optimal prevention of diarrheal illness.

Two significant differences between the 2 study groups were noted. The total number of children and the number of boys were larger in the intervention classrooms. These differences may have reduced the overall effect of the intervention, because number of children per classroom is a risk factor, and boys tend to stay in diapers longer. In addition, control centers were working hard to get their perceived reward (the free equipment that they were promised at the end of the study). These 3 factors should have reduced the difference in outcomes between the intervention and control groups, suggesting that the significant differences in illnesses and absences that were found favoring the intervention group are all the more impressive.

Long-term follow-up with reinforcement of correct sanitation and hygiene behaviors resulted in steady improvement in the correct sequence of the behaviors over 7 months in both the intervention and control centers. The impact of the equipment can add value to the impact of training in proper diaper-changing and hand-washing that was observed in previous studies. Finally, an often overlooked aspect of many investigations into sanitation and hygiene in child care is the impact that infectious illness has on the teacher-caregivers and the resulting impact on the children. Ill caregivers can increase the risk to children, not just because they are vectors of disease but also because their absence results in hiring less experienced and less well-trained substitutes. "Health status, health behaviors, and health concerns of teachers and directors are important determinants of the quality and continuity of the child care workforce, and therefore the quality of child care programs."[32] This study found that the caregivers in the intervention classrooms were absent less as a result of illness, suggesting that the combination of state-of-the-art equipment and high-quality training with follow-up will have an impact on the overall quality of care.

The study has several limitations. Classrooms were randomly matched without stratifying for classroom type. Nevertheless, only 4 of 14 classroom characteristics were significantly different. In any study of child care, a movement of children in and out of classrooms is to be expected. In the case of subjects who missed interviews, the researchers had to depend on the child care providers to follow up. Attrition from the intervention and control groups during the course of the study was comparable.

Despite the potential of our state-of-the-art diapering and food-preparation equipment, the cost of purchase and installation, averaging $10 385 ($7500 for the equipment and the rest for installation) per classroom, may be prohibitive for many child care facilities. One approach in North Carolina has been for low-interest loans to be made available for providers who wish to install the new equipment. Were equipment such as this to be mass produced, perhaps the unit cost would go down. Finally, the success of any intervention to reduce diarrhea and other infectious diseases in out-of-home child care depends, in large part, on the knowledge, skills, and availability of trained CCHCs, regardless of whether appropriate furnishings and equipment are available. Support for the training, certification, supervision, and deployment of CCHCs in the United States remains inadequate.[33]

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