Journal of Food Protection, Vol. 73, No. 12, 2010, Pages 2306–2320

Review

Outbreaks Where Food Workers Have Been Implicated in the Spread of Foodborne Disease. Part 11. Use of Antiseptics and Sanitizers in Community Settings and Issues of Hand Hygiene Compliance in Health Care and Food Industries

EWEN C. D. TODD,[1]* JUDY D. GREIG,[2] BARRY S. MICHAELS,[3] CHARLES A. BARTLESON,[4] DEBRA SMITH,[5] AND JOHN HOLAH[5]

[1]Department of Advertising, Public Relations and Retailing, Michigan State University, East Lansing, Michigan 48824, USA; [2]Public Health Agency of Canada, Laboratory for Foodborne Zoonoses, 160 Research Lane, Unit 206, Guelph, Ontario, Canada N1G 5B2; [3]The B. Michaels Group Inc., 487 West River Road, Palatka, Florida 32177, USA; [4]6100 Troon Lane S.E., Olympia, Washington 98501, USA; and [5]Campden BRI, Chipping Campden, Gloucestershire GL55 6LD, UK

MS 10-009: Received 8 January 2010/Accepted 21 April 2010

ABSTRACT

Hand washing with soap is a practice that has long been recognized as a major barrier to the spread of disease in food production, preparation, and service and in health care settings, including hospitals, child care centers, and elder care facilities. Many of these settings present multiple opportunities for spread of pathogens within at-risk populations, and extra vigilance must be applied. Unfortunately, hand hygiene is not always carried out effectively, and both enteric and respiratory diseases are easily spread in these environments. Where water is limited or frequent hand hygiene is required on a daily basis, such as for many patients in hospitals and astronauts in space travel, instant sanitizers or sanitary wipes are thought to be an effective way of preventing contamination and spread of organisms among coworkers and others. Most concerns regarding compliance are associated with the health care field, but the food industry also must be considered. Specific reasons for not washing hands at appropriate times are laziness, time pressure, inadequate facilities and supplies, lack of accountability, and lack of involvement by companies, managers, and workers in supporting proper hand washing. To facilitate improvements in hand hygiene, measurement of compliant and noncompliant actions is necessary before implementing any procedural changes. Training alone is not sufficient for long-lasting improvement. Multiactivity strategies also must include modification of the organization culture to encourage safe hygienic practices, motivation of employees willing to use peer pressure on noncompliant coworkers, a reward and/or penalty system, and an operational design that facilitates regular hand hygiene.

This is the 11th article in a series on food workers, foodborne illness, and worker hygiene. The first six described the types of outbreaks involving workers, how workers contributed to these outbreaks, infective doses, pathogen carriage, sources of contamination, pathogen excretion by infected persons, and transmission and survival of pathogens in food environments *(34, 100–104)*. The next set of four articles considered physical barriers to contamination, glove use, and hand hygiene with different kinds of soaps and sanitizers *(105–108)*. In this article, we examine the promotion of hand hygiene in various settings where there are many opportunities for person-to-person spread of pathogens and discuss the observed lack of compliance with hand hygiene programs in the health care and food industries. The article concludes with different strategies that can be used to encourage hand washing and use of sanitizers among employees.

* Author for correspondence. Tel: 517-355-8371; Fax: 517-432-2589; E-mail: todde@msu.edu.

Food workers have been implicated in outbreaks of foodborne illness, and hands contaminated by human or animal feces are a well-recognized mode of pathogen transfer; sneezes, coughs, infected skin lesions, and vomitus also have transmitted pathogens from workers to food, patrons, and fellow workers. Physical barriers such as food shields, utensils, and appropriate protective clothing have value but are insufficient to completely prevent contamination of food or food contact surfaces by body secretions. Thus, hand hygiene is vital for reducing pathogen spread, and although gloving can reduce the risk of food contamination, it is not a substitute for hand washing. Washing, scrubbing, rinsing, and drying are critical components of the hygiene process that removes soil encountered by workers during their regular duties both at work and at home. Because these operations take time to be effective (15 to 20 s), they are often not carried out properly. A quick rinse with water followed by shaking of hands to dry them can actually loosen any trapped microorganisms on the skin, facilitating transfer during hand contact with individuals or objects such as food contact surfaces. Poor

hand washing compliance results from a combination of factors, including a lack of facilities, worker education, training, and motivation by managers. In response to the need for a shorter hand hygiene process, alcohol-based instant sanitizers (hand antiseptics) were developed years ago for use in hospitals and other health care settings. These hand antiseptics are now increasingly being used in other settings such as hotels, schools, child care centers, and other public places. These sanitizers also can increase the effectiveness of food worker hand hygiene programs, provided that hands are first thoroughly washed and free of soil. Improving hand washing compliance, deciding where and how instant hand sanitizers can be used, and improving other important food safety behaviors in food preparation environments requires an effective management plan and continual monitoring that goes beyond occasional training.

USE OF SOAPS AND ALCOHOL-BASED SANITIZERS AND ANTISEPTICS IN SCHOOLS, CHILD CARE CENTERS, LONG-TERM CARE FACILITIES, HOSPITALS, FAIRS, THE COMMUNITY, AND DURING SPACE TRAVEL

Schools and fairs. Children contract gastrointestinal and respiratory diseases through contact with secretions from other children and surfaces in closed, crowded facilities such as child care centers and schools. The numbers of children exposed are large. In 2004, 31.1 million children were enrolled in elementary schools in the United States *(88)*. Elementary school–age children are particularly vulnerable to infections. Although hand washing is the best method for preventing infections, many elementary schools are housed in buildings that have barriers to effective hand hygiene. Meadows and Le Saux *(65)* conducted a systematic review of six studies on the use of antimicrobial rinse-free hand sanitizers in elementary schools and found that the quality of the research reported was low. Given the potential to reduce student absenteeism, teacher absenteeism, school operating costs, health care costs, and parental absenteeism through the spread of transmitted illnesses, Meadows and Le Saux recommend a well-designed and analyzed trial to optimize this hand hygiene technique.

Research has suggested that even a one-session intervention can be effective for improving hand washing behavior in elementary school children by incorporating videos, drawing activities, and demonstrations and installing sanitizers in the classrooms *(36, 38, 94, 118)*. Morton and Schultz *(71)* developed a 45-min intervention for elementary school students (kindergarten through grade 3) called the ''germ unit.'' Teachers demonstrated proper technique using the GlitterBug device, and signs were posted reminding the children to wash with hand sanitizer. The researchers found a 43% reduction in absenteeism for students in the intervention classes. More recent work supported these conclusions with a multifactorial intervention that included hand sanitizer and sanitizing desk wipes and resulted in reduced absenteeism caused by gastrointestinal illness in elementary school students *(88)*. Norovirus was the only virus detected and was found less frequently on classroom surfaces in the intervention group than in the control classrooms (9 versus 29%). However, the intervention did not impact absenteeism from respiratory illness, suggesting differences in sanitizer efficacy for different viruses. The differences in effect may not be associated with the sanitizer; we know that alcohol-based hand rubs (ABHRs) are less effective against nonenveloped viruses such as norovirus and hepatitis A virus than against enveloped viruses such as influenza virus *(10, 96)*. Increased hand washing also was effective for reducing absenteeism in grade 2 children after an intervention that included class discussions and hand washing demonstrations in a controlled study in Illinois *(109)*. In a recent study in Utah, the combination of a visual clue (the teacher hand washing) and a verbal clue (''Wash your hands'') improved hand washing rates, as did a guest educator talking about hand washing and germs *(94)*.

Commercial products and downloadable programs are freely available on the Internet; however, most of these programs and products have not been evaluated for their effectiveness. Several programs have been promoted by government, industry associations, and coalitions in the United States. The Scrub Club *(73)*, produced by NSF International, is a fun, interactive, and educational Web site that teaches children the proper way to wash their hands. The site consists of a Webisode with interactive games, educational music, downloadable activities for kids, educational materials for teachers, and program information for parents. Fight BAC! *(74)*, which was developed by Partnerships for Food Safety Education, is aimed at children and youth and includes kits and brochures on how to clean hands properly.

More than two-thirds (32 million) of school-age children (ages 5 to 17 years) in the United States missed school in 2007 because of illness or injury *(13)*. Diarrhea is second only to the common cold as a cause of lost working time, with about 25 days lost from work or school each year for every 100 Americans *(90)*. In response, the Centers for Disease Control and Prevention (CDC) and the Soap and Detergent Association promoted Healthy Schools, Healthy People—It's a SNAP (School Network for Absenteeism Prevention) *(90)*. This program is a school-based, education-based effort to improve health by making hand cleaning an integral part of the school day. SNAP is designed to motivate the entire school community to talk about clean hands by providing tools for incorporating hand hygiene into multiple subject areas and activities.

Washington State University *(115)* developed Germ City: Clean Hands, Healthy People as an educational multistate project to enhance awareness and improve the effectiveness of hand washing. The project goals are to (i) enhance awareness of the importance of hand washing, (ii) improve effectiveness and frequency of hand washing among children, youth, adults, senior citizens, and at-risk groups in rural and urban settings, (iii) modify attitudes, enhance personal motivation, and facilitate behavior change, and (iv) evaluate the effectiveness of the hand washing education program. Germ City is a science-based, interac-

tive education program for elementary and middle school students. The presentation includes a hands-on opportunity to learn about the importance of frequent and effective hand washing, with supporting resource materials and assessments to supplement the learning experience. The Germ City unit includes a lightproof tunnel or tent equipped with two black lights. A UV light–sensitive lotion is applied to hands as pretend germs. Participants go through the tunnel to observe the amount of germs on their hands, wash their hands normally, and revisit Germ City to assess how well they washed their hands. The traveling, interactive exhibit is shown at school events, county fairs, health fairs, and employee training events. Self-evaluations for the program were conducted in 2003 *(110)*; 48,995 youth and adults in Alabama, Hawaii, Idaho, West Virginia, and Washington were reached through the Germ City program, with an 86.6% completion rate reported in a behavior change exit survey. For adults, 15.6% changed their behavior after coughing and/or sneezing, 18.54% changed their behavior after playing and/or working outside, 21.3% changed their behavior before eating and/or preparing food, 12% changed their behavior after using the restroom, and 27.4% changed their behavior after playing with animals; 4.8% did not change their behavior. For youth (ages 5 to 18 years), 13.7% changed their behavior after coughing and/or sneezing, 13.6% changed their behavior after playing and/or working outside, 24.8% changed their behavior before eating and/or preparing food, 22.3% changed their behavior after using the restroom, and 23.9% changed their behavior after playing with animals; 5.6% did not change their behavior. Although these percentages indicate that behavioral changes were made by most participants, there was no way to confirm that these changes actually occurred or to determine whether the changes were temporary or long lasting.

Child care centers and homes with young children attending child care. The same results were obtained with child care centers. In a recent review article on recommendations for controlling enteric infections in child care settings *(55),* the appropriate times for workers to wash hands was emphasized, i.e., upon arrival, after outside activity, after touching the nose, after using the toilet, after changing a diaper, and before eating. During a randomized, controlled trial in which child care staff were trained about transmission of infection and hand washing (544 children observed for 9 months), episodes of diarrhea were reduced to 1.9 per child-year compared with 2.7 per child-year in control centers *(85).*

Children in child care who are younger than 3 years of age are 3.5 times more likely and children ages 3 to 5 are twice as likely to have an acute gastrointestinal illness than are home-reared children *(49).* Recorded outbreaks have most often involved *Shigella, Giardia,* and enteric viruses *(70, 97).* Kotch et al. *(50)* found that diapering, hand washing, and food preparation equipment specifically designed to reduce the spread of infectious agents significantly reduced diarrheal illness among children and absence as a result of illness among staff in out-of-home child care centers. This special food preparation equipment included cast polymer tabletops with impermeable, seamless surfaces for food preparation, automatic faucets or foot-activated faucets for hand washing, and rollout waste bins for diaper disposal. These items were installed in the intervention centers before data collection and resulted in minimized contact with 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 reduced the risk for contamination. A significant difference was found that favored the intervention centers with respect to frequency of diarrheal illness (0.90 versus 1.58 illnesses per 100 child-days in control centers) and proportion of days ill as a result of diarrhea (4.0 versus 5.0% in control centers) among the children. Staff in these same classrooms were reported to have a significantly lower proportion of sick days due to any illness (0.77% in treatment centers versus 1.73% in control centers).

This type of specific equipment modification is not possible for most centers. Nevertheless, some basic hand hygiene activities in the home also can reduce illness. In a study of children (0.5 to 5 years of age) who were enrolled in 26 out-of-home child care centers for >10 h/week, the intervention centered on increased use of alcohol-based hand sanitizer *(89).* Intervention families received a supply of hand sanitizer and biweekly hand hygiene educational materials for 5 months; control families received only materials promoting good nutrition. After the 5-month period, the secondary gastrointestinal illness rate per susceptible person-month was significantly lower in intervention families than in control families (0.17 versus 0.35). This intervention was less effective against respiratory illnesses, in contrast to the observations of Lee et al. *(54).* These authors deduced that in homes with young children enrolled in child care illness transmission to family members occurred frequently, and alcohol-based hand gel use was associated with reduced respiratory illness transmission in the home. Clearly, issues related to respiratory viruses are different from those for enteric viruses; these may be related to the type of ABHRs used or other undetermined factors.

Although child care personnel may be concerned about situations in which children put their fingers into their mouth or eyes after using a hand gel, no significant amount of alcohol is absorbed from this source *(47).* Gibson et al. *(28)* suggested that the more than 3 million cases of infectious disease associated with child care facilities each year could be reduced by washing hands with soap after diaper changing. These authors used a microbial risk assessment approach to quantify the infectious disease risk by determining the amount of feces in an average diaper, the level of bacteria per gram of feces, the transference of bacteria from one soiled diaper to the hands, the reduction in bacterial counts by hand washing, hand-to-mouth transfer rates, and dose-response estimates. Using the model, the authors estimated that the probability of infection ranged from 24 to 91 cases per 100 persons for those who changed diapers of babies with symptomatic shigellosis and who used a control product (soap without an antibacterial

ingredient), 22 to 91 cases per 100 persons for those who used an antibacterial soap (4% chlorhexidine), and 15 to 90 cases per 100 persons for those who used a triclosan (1.5%) antibacterial soap. Those persons who diapered babies with asymptomatic shigellosis and who used a nonantibacterial control soap had a risk of 49 per 100,000 to 53 per 100, those who used the 4% chlorhexidine–containing soap had a risk of 43 per 100,000 to 51 per 100, and those who used a 1.5% triclosan soap had a risk of 21 per 100,000 to 43 per 100. These authors concluded that adequate washing of hands after diapering reduced the risk of infection and that the risk could be further reduced by 20% by the use of an antibacterial soap.

Long-term care facilities and hospitals. In a recent review of enteric outbreaks in long-term care facilities with recommendations for prevention, several studies were cited that supported the effectiveness of hand washing for controlling transmission of enteric infections *(33).* Makris et al. *(60)* reported that during a 2-year comprehensive infection control program, with education emphasizing hand washing, environmental cleaning, and disinfection, gastrointestinal infections were reduced by 68% in four intervention long-term care facilities compared with 10% in four control facilities, although the difference was not significant. In response to another comprehensive infection control program in a hospital (emphasizing education, hand washing, surveillance, contact isolation, and environmental disinfection), there was a significant decline in vancomycin-resistant *Enterococcus* transmission *(12).* After promoting the use of alcohol-based hand sanitizers by providing pocket-size 4-oz. (120-ml) containers to health care workers in an acute care hospital, nosocomial infection rates decreased by 36% over 10 months *(42).* In another extended care facility, use of alcohol-based gel hand sanitizers by health care workers for 34 months decreased nosocomial infection rates by 30% *(26).*

The community. Bloomfield et al. *(9)* reviewed existing literature on the effectiveness of hand hygiene procedures, including hand washing and the use of alcohol-based hand sanitizers, for reducing the risks of infections in home and community settings and concluded that (i) hand hygiene is a key component of good hygienic practice in the home and community and can produce significant benefits in terms of reducing the incidence of infection, most importantly gastrointestinal infections but also respiratory tract and skin infections; (ii) decontamination of hands can be carried out either by hand washing with soap or by use of waterless hand sanitizers; (iii) the impact of hand hygiene on reducing infectious disease risks could be increased by convincing people to wash or disinfect their hands properly and at the appropriate times; and (iv) promotion of hand hygiene should be accompanied by hygiene education.

To quantify the effect of hand hygiene interventions on rates of gastrointestinal and respiratory illnesses and to identify interventions that provide the greatest efficacy, Aiello et al. *(1)* conducted meta-analyses to generate pooled rate ratios across interventions for 30 hand hygiene trials published from January 1960 through May 2007. These authors grouped the trials by specific intervention on the basis of seven categories: (i) hand hygiene education alone, (ii) nonantibacterial soap with hand hygiene education, (iii) antibacterial soap with hand hygiene education, (iv) antibacterial soap alone, (v) alcohol-based hand sanitizer alone, (vi) alcohol-based hand sanitizer with hand hygiene education, and (vii) non–alcohol-based hand sanitizer containing benzalkonium chloride. For all hand hygiene interventions combined, 31% of gastrointestinal illness cases were prevented. The use of nonantibacterial soap with education prevented 39% of cases compared with no intervention in a control group. The next greatest impact was the pooled estimate for the effectiveness of hand hygiene education alone compared with no intervention (31% of gastrointestinal illness cases prevented). The use of benzalkonium chloride–based hand sanitizer prevented 41% of both respiratory and gastrointestinal illness cases. Alcohol-based hand sanitizer alone prevented 26% of these combined illness cases, and the combined use of alcohol-based hand sanitizer with hand hygiene education prevented 21% of illness cases. None of the other interventions were associated with significant prevention of combined illness outcomes (i.e., antibacterial soap compared with nonantibacterial soap and nonantibacterial soap compared with hand hygiene education). The authors were surprised that the use of alcohol-based hand sanitizers combined with hand hygiene education was not strongly associated with reduced rates of gastrointestinal or respiratory illnesses. This finding was unexpected because alcohol-based sanitizers containing 60 to 80% (wt/vol) alcohol have been effective against a range of viruses and bacteria, including agents that cause diarrhea or respiratory infections. However, Steinmann et al. *(96)* and others have pointed out that the virucidal activity depends on the type of alcohol selected and the target virus (enveloped versus nonenveloped). Aiello et al. *(1)* concluded that the most beneficial intervention was hand hygiene education with use of nonantibacterial soap. Use of antibacterial soap produced little added benefit compared with use of nonantibacterial soap.

Hand hygiene is clearly effective against gastrointestinal and, to a lesser extent, respiratory infections. However, studies of hygiene practices during respiratory illness and interventions targeting aerosol transmission also are needed. Schools and child care centers should consider incorporating simple infection control interventions to reduce the number of days lost due to common illnesses. Homes with young children attending child care centers or elementary schools also may benefit from the use of sanitizing gels. Implementation of effective interventions early in life may increase the likelihood of meaningful behavioral changes and encourage good hand hygiene to become a regular, well-practiced habit *(109).* Unfortunately, in some regions there is no encouragement for individuals to wash their hands after visiting washrooms. Comer et al. *(19)* found that although posters to promote hand washing were displayed in child care facilities and food operations in two counties in North Carolina, as is the law, similar advertisements were

not on display in public restrooms specifically targeting consumers.

Sanitation during space travel. Sanitizing wipes are most valuable as quick, convenient cleaners, especially in locations where other means of hygiene are unavailable. An extreme situation is space travel in cramped quarters. Much of the research derived from experiments in space may be useful in other situations, including extended exploration in submersibles and submarines, troops in the field under lengthy combat or siege conditions, and long-term bed-bound patients who cannot have full-body washes. Where individuals must work, relax, and sleep with limited opportunities for changing clothes and washing, pathogens build up on the skin and in orifices. Pathogens encountered by astronauts include *Staphylococcus aureus,* beta-hemolytic streptococci, *Pseudomonas aeruginosa,* and enteric viruses *(5, 6, 27, 98).*

Lotter et al. *(58, 59)* and Lotter and Horstman *(56, 57)* observed healthy men who were confined in a simulated aerospace environment and given diets of various foods or exposed to elevated cabin temperature. In one experiment, four men were confined for 6 weeks with various set diets. Swab samples were taken from all parts of the body, and the bacterial isolates were typed. These individuals were not permitted to bathe, shave, groom hair, clean or cut their nails, or change or remove clothes, and wipes were used only for personal hygiene. The authors noted that the subjects did not become more susceptible to staphylococcal infections under stressful space-travel conditions, but transfer of *S. aureus* occurred between the environment and the men.

Sponge baths have been evaluated *(82),* but for space shuttle flights, disposable antiseptic moist wipes containing moisturizers are the main means of cleansing the hands and body as an adjunct to sponge bathing *(40)*; five moist wipes per day were adequate to prevent excessive bacterial colonization of the skin *(57).*

Despite concerns over potential development of antibiotic-resistant skin strains and skin irritation with long-term usage of antiseptic moist wipes, these wipes are still in use today, without adverse effects *(22, 99).* Because showering is time-consuming and laundering is currently not feasible in space, full body cleanliness is best accomplished using moist and dry wipes and prewetted and dry towels, e.g., one wet towel and two dry towels per day *(69).* The International Space Station now employs antiseptic towelettes for multiple uses, including wiping of contact surfaces, cleaning crew silverware, and personal hygiene *(78).* Hand and body hygiene compliance should not be a problem for motivated astronauts but may be an issue in other settings.

ISSUES SURROUNDING HAND HYGIENE COMPLIANCE

Measuring worker hand washing compliance. Hand washing compliance is a measure of how well hands are washed and how often they should be washed; determination of these factors is based on activities resulting in contamination of hands and the risk of transmission of foodborne illness. Hand hygiene, one of the earliest activities a child learns both at home and at school, is important after playing outside and particularly after using the toilet and before eating. Primary schools in the United Kingdom teach hand washing and other aspects of personal hygiene by oral instruction, demonstrations, making posters, watching videos, role playing, and carrying out microbiology experiments *(7).* However, hand washing is not practiced by responsible adults as often as is perceived by the general public. In a study of 100 people in Wales, 87% of people believed that to prevent foodborne illness it was important to wash hands before preparing food, before eating, and after touching chicken *(17).* Although most respondents (95%) believed it was very likely that washing and drying hands would help prevent foodborne disease, no one admitted to doing it adequately on every appropriate occasion (85% complied after handling raw foods and 55% complied before touching ready-to-eat foods). Although consumers in the United States were knowledgeable about hand washing, cleaning, and using different utensils for raw and cooked foods, their knowledge did not lead to adequate implementation of the practices *(4, 23, 119).*

Because the maintenance of high compliance rates and high standards of personnel hygiene is critical to food safety, the systems employed to achieve compliance should be routinely evaluated and updated to incorporate the most effective approaches for preventing foodborne illness. An important approach is frequent hand washing during all phases of food preparation. Hand washing compliance in health care situations is notoriously lax. In two separate hospital studies, average hand washing compliance ranged from 30 to 56% *(81, 116).* In the Watanakunakorn et al. *(116)* survey, the prevalence of hand washing in a teaching hospital was not extensive but was higher in surgical units (56.4%) and medical intensive care units (39.2%) than in intermediate units (30.0%) or general units (22.8%). Fewer studies have been conducted in food operations, and although compliance rates in food manufacturing are generally thought to be acceptable, in other food handling settings compliance is a continuing issue.

For larger scale industrial food manufacturing facilities, anecdotal evidence suggests good compliance rates, primarily because the food industry is highly concerned about this issue. Based on the observations in food factories in the United Kingdom recorded for many years by two of the present authors (D. Smith and J. Holah) *(43),* compliance with good hand washing practices within food processing areas is very high, probably in excess of 95%. Hand washing is seen as a critical step for preventing transient microorganisms on the hands (e.g., pathogens or food spoilage organisms) from entering the food processing area, with attendant risks of economic loss to the company through foodborne outbreaks and/or product recalls. Thus, hand washing forms an essential part of food safety induction training in food operations. Observations from another of the present authors (B. S. Michaels) *(78)* indicate that compliance in food processing plants in the United States during the last 5 years has generally been good, but

there is room for improvement. The following are examples. In a plant manufacturing precooked and flash frozen poultry patties for fast food and grocery distribution, compliance at the entrance was excellent but was extremely minimal at almost every other hand washing station in the plant (based on soap usage at each station). The cold temperatures in the processing areas were considered a major deterrence to compliance. In a poultry processing plant, compliance was also excellent at the entrance but was minimal for workers wearing gloves covered with food residues for long periods of time. Minimal hand washing occurred at breaks and between glove changes. In a beverage bottling plant, hand hygiene was generally good, and mixed use of gloves, alcoholic hand sanitizers, and hand washing with soap helped provide rapid and appropriate hand hygiene. In food service bakery operations, food workers' bare hands were frequently exposed to dough for long periods with little hand hygiene but also minimal risk of foodborne transmission because of the subsequent baking process. Nevertheless, gloves should be worn to reduce this exposure, especially for preparation of uncooked cookie dough.

Many international food retailers also require their suppliers to prominently display at all hand washing stations posters in all the dominant languages that describe appropriate hand washing steps for the workforce. However, inquiries into the *Escherichia coli* O157:H7 infection outbreaks in Scotland and Wales and investigations into the peanut butter–associated outbreak and multiple recalls in the United States have revealed flagrant disregard for basic hygienic practices *(14, 76, 77).* Hence, all companies must remain vigilant in this area, and employees must not become lax in carrying out routine hand washing procedures. Monitoring of hand washing practices in processing areas includes direct management supervision and recording, the use of closed-circuit television monitors and automated hand washing and compliance systems, and the conducting of random hand hygiene compliance assessments, e.g., by taking periodic hand swabs. Hand washing monitoring programs are not mandated in the United Kingdom to satisfy the requirements of all the major worldwide food retailers' audit schemes. A hand hygiene survey of food processing companies in the United Kingdom revealed that 60% of respondents monitor hand hygiene compliance in high-risk food preparation areas, and the most popular methods are observation by a supervisor and closed-circuit television *(93).* A typical strategy used by food manufacturing companies is a ''hand hygiene week'' sponsored by management when food workers would be reminded of correct hand hygiene procedures and would subsequently be monitored for compliance. As an additional check, management also could monitor the use of soap and paper towels. If the amount of these items consumed were to decrease over some period (as advised by the company buyers), management could then repeat the ''hand hygiene week.'' However, this measurement of compliance is only a general one, and management does not always check how frequently or thoroughly workers wash their hands not only on a regular basis but also after touching their faces and clothing, waste materials, the floor, or other potentially contaminated areas, even though workers are trained to do so. In some factories management has tried to encourage compliance by placing ABHRs or alcohol wipe dispensers close to food work stations, following the concept of hand disinfection at the point of patient contact utilized in the health care sector. Studies have documented an increase in compliance when workers know that they are being monitored *(21, 43).*

In studies of hand washing among food workers in food service facilities, compliance generally ranges from 5 to 60% *(3, 25, 111).* In one study, Emery *(25)* found that 60% of food service personnel failed to wash their hands after using the toilet. In a United Kingdom Food Standards Agency study *(44),* one-third of caterers failed to wash their hands after using the toilet, and 53% of food workers in catering facilities appeared not to wash their hands before preparing food. Inadequate hand washing by food workers was cited as a contributory factor in 31% of outbreaks occurring in Washington State from 1990 to 1999 *(20).*

Clayton and Griffith *(16)* studied 115 food workers from 29 catering businesses that produced high-risk foods in Wales, for a total of 31,050 food preparation and hygiene actions in this workplace. Hand hygiene practices were carried out adequately on only 31% of the required occasions and were not even attempted 55% of the time. Touching potentially contaminated objects or surfaces and improper handling of potentially contaminated foods were identified. Hand hygiene actions after touching potentially contaminated objects or surfaces were observed on only 25% of required occasions. Hand washing was carried out on only 9 and 14% of the occasions when food workers touched their face and/or hair and entered the kitchen, respectively. Two main hand hygiene errors were identified: (i) a failure to use soap (39% of attempts) and (ii) a failure to dry hands adequately (42% of attempts). Caterers' failure to use soap accounted for 39% of failed hand hygiene attempts. A total of 87 failures to use soap occurred despite soap being available, but on 44 occasions there was no soap available in the kitchen. Food workers both failed to use soap and failed to appropriately dry their hands on 19% of attempts. Cleaning of surfaces and equipment was not carried out adequately 77% of the time, and on 60% of occasions cleaning was not even attempted. Cleaning of surfaces or equipment following contact by potentially contaminated foods, objects, and hands was performed adequately on 85, 22, and 10% of required occasions, respectively. Cleaning actions were only judged to be adequate for worktops, chopping boards, and food containers 29, 47, and 3% of the time, respectively. Cleaning also was often neglected after potential contamination of telephones, cupboards, and shelves, and none of these surfaces were adequately cleaned during the observation period. Infrequent cleaning of food containers, equipment, and door handles coupled with a failure to wash hands may help explain the high bacterial counts noted on these same surfaces in other studies.

One compliance issue is the risk of skin damage from excessive washing or scrubbing, which can lead to inflammation of the epidermis. New information on the

resident microflora is starting to help us understand the natural anti-inflammatory properties that counteract skin redness. *S. aureus* is a pathogen that can cause wound infections and produce enterotoxins in foods and should be removed by proper hand hygiene using either soap and water or ABHRs. However, the normal skin microflora includes staphylococcal species that will induce inflammation when present below the dermis but are tolerated on the epidermal surface without initiating inflammation. The two principal normal stimuli of inflammation are injury and infection. During infection, the detection of microbes is accomplished in part by Toll-like receptors, which are best known as stimuli of inflammation *(51).* However, the mechanisms involving the Toll-like receptors that regulate inflammation during skin injury are linked to staphylococcal lipoteichoic acid acting selectively on keratinocytes to inhibit skin inflammation *(51).* These findings indicate that the skin epithelium requires Toll-like receptors for normal inflammation after wounding and that the microflora can modulate specific cutaneous inflammatory responses *(51).* Although essential for recovery from injury, the ability to limit inflammation is important to prevent skin diseases such as psoriasis. Unlike ABHRs, triclosan also has anti-inflammatory properties *(92).* Inflammation in human skin caused by intradermal administration of histamine can be reduced by the application of triclosan *(48).* For this reason triclosan soaps may have benefits outweighing the somewhat remote possibility of production of antibiotic-resistant strains through regular use of these antimicrobial soaps. Moisturizers applied to affected skin support the regeneration of the skin barrier and reduce the likelihood of occupational hand dermatitis *(39),* although their efficacy is not confirmed *(45).* Therefore, based on the specific task, workers have choices concerning what hygienic steps to take, e.g., glove use with frequent changes, responsible skin care with low-impact moisturizing and anti-inflammatory soaps, and perhaps a change in the regimen occasionally, alternating soaps with gels.

To evaluate the marginal utility of microbial testing for minimizing potential risks of foodborne outbreaks in restaurants, swab samples were taken from hand washing sink faucets, freshly cleaned and sanitized food contact surfaces, and cooler or freezer door handles in 70 of 350 category 3 (high risk) food service operations in Toledo, OH *(46).* The swabs were inoculated onto various selective media, and standard procedures were used to identify pathogenic and nonpathogenic bacteria. Microbiological evaluations of the sampled food service operations were compared with visual inspection reports, using a numeric rating scale. Enteric bacteria (which may indicate fecal contamination) were found on food contact surfaces, on cooler or freezer door handles, and on hand washing sink faucets in 86, 57, and 53% of the food service operations, respectively. Approximately 27, 40, and 33% of the restaurants received visual ratings of very poor to poor, fair, and good to very good, respectively. In comparison, 10, 17, and 73% of the restaurants received microbiological rating scores of very poor to poor, fair, and good to very good, respectively. Restaurants with trained personnel received significantly higher visual rating scores than did restaurants without trained personnel ($P < 0.01$). Although more restaurants received poor rating scores by visual inspection than by microbiological evaluation, the presence of fecal bacteria from various sites in more than 50% of the food service operations indicated that visual inspection alone might not be sufficient. Therefore, the authors recommended periodic microbiological evaluation of high-risk food service operations in addition to visual inspection for minimizing the risk of foodborne disease outbreaks. Sagoo et al. *(87),* however, did confirm that microbial counts were linked to poor hygiene in a study of the microbiological status of surfaces used in the preparation of ready-to-eat foods.

Green et al. *(32)* stated that improvement of food worker hand washing practices is dependent upon a clear understanding of these practices by those involved. These authors observed food worker hand washing practices in 333 randomly selected restaurants in Colorado, Connecticut, Georgia, Minnesota, Oregon, and Tennessee as a part of EHS-Net (Environmental Health Specialists Network, CDC), using the methodology of Clayton and Griffith *(16).* Results indicated that workers engaged in approximately 8.6 work activities per hour for which hand washing is recommended. However, workers made hand washing attempts (i.e., removed gloves if worn and placed hands in running water) for only 32% of these activities and washed their hands appropriately (i.e., removed gloves if worn, placed hands in running water, used soap, and dried hands) for only 27% of these work activities. Hand washing attempts and appropriate hand washing rates differed by work activity. Appropriate hand washing was significantly higher in conjunction with food preparation than for other work activities (41 versus $\leq$30%) but was significantly lower in conjunction with touching the body than for other work activities (10 versus $\geq$23%). Appropriate hand washing rates were significantly lower when gloves were worn (16%) than when gloves were not worn (30%). These findings suggest that the hand washing practices of food workers need to be improved, glove use may reduce hand washing, and restaurants should consider reorganizing their food preparation activities to reduce the frequency with which hand washing is needed.

Employee behavior in Nevada catering firms was observed on and off premises *(41).* Hand washing was less likely to occur off premises, but neither situation was acceptable. Before work began, hands were not washed 70.3% of the time off premises and 29.8% of this time on premises. Hands were not washed after touching the body, uniform, etc., 60.6% away from the home base and 39.4% on site. These findings agree with those of the EHS-Net observational studies in food service operations *(32).*

Unsupervised hand washing will never be completely compliant in any setting. Lack of time and laziness were cited as reasons for not always washing hands in a Welsh consumer study *(17),* and knowledge and compliance both in the work place and at home continue to be inconsistent. According to Coleman and Roberts *(18),* lack of compliance is due not only to time constraints, staff shortages, and

poorly designed facilities but also to a sense of overconfidence among managers and owners because they see their operations as low risk. Food service personnel must be trained and supervised for washing their hands after touching raw foods, after toilet use, and at other times after possible hand contamination.

Pittet *(80)* reviewed 11 studies of hand hygiene compliance in health care facilities between 1981 and 1999, and in every case compliance was almost universally low. Among the reasons given for poor compliance were inaccessible supplies, inconveniently located or insufficient numbers of sinks or use of an automated sink, interference with worker-patient relationship when patient needs were perceived as a priority, working in an intensive care unit, high work load and/or insufficient time, forgetfulness, lack of knowledge of the guidelines and/or protocols or disagreement with them, being male, being a physician rather than a nurse, lack of good role models, and lack of administrative sanction of noncompliers or rewards for compliers with identified strategies for successful promotion of hand hygiene in hospitals based on previous research. Specifically for hands, issues were skin irritation and a belief that glove use obviates the need for hand hygiene. Pittet *(80)* expanded the reasons for glove use being a barrier for hand hygiene compliance by noting (i) a failure to remove gloves after patient contact or between dirty and clean body site care for the same patient and (ii) a tendency to wash and reuse gloves between patient contact. Pittet recommended that hand washing or disinfection be strongly encouraged after glove removal; in a study involving artificial contamination, organisms were cultured from 4 to 100% of the gloves and observed counts were up to 4.7 log units on hands after glove removal.

Because irritation was a main barrier to hand hygiene, Pittet *(79)* emphasized that (i) alcohol-based formulations for hand disinfection (isopropyl, ethyl, or n-propanol, 60 to 90%, vol/vol) are less irritating to skin than are antiseptic or nonantiseptic detergents; (ii) alcohols, with the addition of appropriate emollients, are at least as tolerable and as efficacious as detergents; (iii) emollients may even be protective against cross-infection by keeping the resident skin flora intact; and (iv) hand lotions help to protect skin and may reduce microbial shedding. The major focus for improvement in health care facilities was on systems modifications including availability of alcohol gels, education, and motivation, but results of several studies indicated that all three areas must be promoted for hand hygiene practices to be successful *(80)*. All these lack-of-compliance issues can be translated into food handing scenarios, where the main source of contamination is likely to be the workers themselves and raw food of animal origin. However, alcohol gels are less useful for workers preparing foods because of the higher soil level on the hands.

Risk of contamination in a food processing or food service establishment resides with those individuals who handle food most and wash hands least. In these facilities, bacteria are easily transferred during commonly performed tasks during food service operations *(15),* and hand washing is critical to limit this transfer. Food workers who regularly fail to wash hands when they should are termed refractory noncompliers *(79)*. In a study of 97 hepatitis A virus–infected food service workers, only 23% were rated as executing acceptable hand hygiene *(91)*; 77% of those with greatest risk used successful intervention methods the least. In both health care and food service hand hygiene studies, high demand for hand cleansing reflected high workload and was associated with low compliance *(30, 53, 81, 95),* driving the risk to higher levels when the hand washing regime was not followed. This finding is supported by a focus group study on knowledge, practices, and barriers related to hand washing in Oregon restaurants *(83)*. The most important barriers were time pressure, inadequate facilities and supplies, lack of accountability, lack of involvement of managers and coworkers, and organizations that were not supportive of hand washing. Although food service operators periodically receive citations for violations, the real motivation for proper hygiene in food service facilities is a commitment by management and employees to protect the public by serving patrons uncontaminated food.

Compliance by sanitation and maintenance employees. Another group of typically ignored workers who are responsible for maintaining facilities in a good hygienic state are the cleaning and sanitizing crews. Professional contract cleaning is a basic service occupation that is carried out worldwide in many different environments, including food facilities. Sanitation (cleaning) staffs represent a sizeable proportion of the total workforce (3% in the United States, 4% in Finland, and 10% of the female working population in Spain) *(121)*. Although many contract cleaners are well-trained professionals, some individuals in this profession are extremely transient, have low occupational skills, and belong to the less advantaged educational and socioeconomic groups. These workers may have to clean a wide variety of buildings and may not be specialists in food establishments. Because their work is typically performed during off-hours under minimal supervision, contract cleaners often escape regulatory control, health surveillance, and risk prevention oversight and must be therefore considered a risk factor for inadvertently spreading contamination through cross-contamination or lack of proper personal hygiene. When employed directly by a food establishment (predominantly the case in the United Kingdom), cleaners tend to be permanent staff members who are trained specifically for sanitation roles, including basic food and hand hygiene.

Other persons who are not regular food worker staff include engineers and other equipment maintenance staff, whose knowledge of food and hand hygiene may be limited *(106)*. These workers are a particular risk because their daily duties take them to both interior and exterior parts of the food establishment and raw and finished product sides of the facility, where their clothing and tools may become contaminated. Maintenance workers are focused on a quick turnaround for ensuring that the food processing and food service equipment is functioning correctly in response to a maintenance or repair call and are less concerned about the risk of cross-contamination by tools, overalls and other

clothing, and work boots. In larger plants, these workers are full-time staff; in smaller operations, they may be brought in on demand. All such workers should be cautioned to be as diligent in hygienic practices as the operation's food workers and should be monitored by supervisory staff for any risky practices. As an extra precaution, all equipment and utensils should be sanitized after any maintenance activity involving touching or working with food contact surfaces.

Improving worker compliance. Many approaches exist for improving hand hygiene compliance, mainly in health care settings, but none of these approaches has been successful enough to be considered the ideal model. The best examples require much time commitment and effort on the part of management and workers, and monitoring must be ongoing. More than 50 published articles indicate that more than training is needed to convince people to wash their hands to protect health *(66, 67)*. Because barriers to hand washing are multidimensional, educational and training programs for managers and coworkers should include (i) a hands-on orientation training program for new employees on hand washing procedures and knowledge of the causes of foodborne illness, (ii) involvement of both managers and coworkers in the training, (iii) easily accessible hand washing facilities regularly stocked with necessary supplies, (iv) ongoing career-long refresher hand washing training and a support structure involving the whole food service industry, and (v) advice from local health departments and their inspectors to improve hand washing practices. A management system that monitors and ensures compliance will help to reduce barriers to hand washing *(112)*. These strategies are similar to those suggested for successful promotion of hand hygiene in hospitals *(80)*, which include educational campaigns; routine observation and feedback; making hand hygiene easy and convenient; reminders in the workplace; well-engineered facilities; avoiding overcrowding, understaffing, and excessive workload; ensuring an institutional climate of safety among employees; periodic change in hand hygiene agents; making ABHRs available; facilitating skin care for workers' hands; administrative sanctions and/or rewards; obtaining active participation at the individual and institutional level; and enhancing individual and institutional self-efficacy. These program areas are consistent with the requirement to link the science (how do I wash my hands?) with personal values (why should I wash my hands?) and shared group or cultural values (the organization's policy on washing hands: why do we wash our hands?) *(75)*.

To improve compliance, hand washing monitors are now being attached to automatic sinks and to alcohol gel dispensers. These monitors determine soap and antiseptic usage and may provide detailed records concerning employee hand washing behavior *(11, 61)*. Those monitoring soap volume are able to provide information on washing and rinsing times. Broughall et al. *(11)* described a hand washing monitoring system that enabled accurate measurements of the frequency of hand washing by nursing and medical staff during the course of their duties. This system recorded hand washing frequency with 93% accuracy, with a measured hand washing frequency of 5 to 10 washes per nurse per shift. This frequency was far lower than that claimed by the nurses, indicating a lack of compliance.

Although automated systems can detect usage, they cannot improve compliance without additional actions by management. When observation and verbal feedback systems with or without automatic counting systems were implemented in health care settings, no improvement in compliance was noted *(8, 62)*, but when automated systems were combined with positive deviance initiatives, hand washing compliance increased substantially *(63)*. Positive deviance initiatives are based on the observation that in every community there are certain individuals or groups whose uncommon behaviors and strategies enable them to find better solutions to problems than are found by their peers even though they have access to the same resources and face similar or more difficult challenges *(64)*. This approach has been used to combat such intractable problems as childhood malnutrition, poor infant health, and reduction of infections with methicillin-resistant *S. aureus* (MRSA). Marra et al. *(63)* used the positive deviance approach to focus on promoting compliance with hand hygiene protocols at all opportunities by all health care workers who come into contact with patients and their environment. All heath care workers in the study met twice monthly to express their feelings about hand hygiene, to discuss what needed to be improved, and to note good examples. The positive deviant workers were those who wanted to change and to develop new ideas for improving hand hygiene and who stimulated coworkers, including physicians, to use alcohol gel products. The positive deviant workers spontaneously decided to count hand hygiene episodes during their shifts to assess the performance of their colleagues. They also created and edited videos that were shown during positive deviance meetings. The program became a great source of pride for these positive deviant workers, which was a motivating factor.

Alcohol-based products, compared with other commonly used antiseptics such as chlorhexidine, reduce the time spent on hand hygiene while achieving even higher rates of hand decontamination and thus reducing the number of health care–associated infections *(114)*. Positive deviance programs for hand hygiene were effective when alcohol gel use was promoted in step-down units from intensive care units in a large Brazilian hospital *(63)*. During a 3-month period, hand hygiene episodes were counted by use of electronic hand washing counters. A positive deviance strategy was implemented in one step-down unit (A) and no strategy was implemented in another step-down unit (B). A total of 62,000 hand hygiene episodes occurred per 1,000 patient-days in unit A and 33,570 occurred per 1,000 patient-days in unit B ($P < 0.01$). The incidence of health care–associated infections was 6.5 per 1,000 patient-days in unit A and 12.7 per 1,000 patient-days in unit B ($P = 0.04$). There was a nearly twofold difference in the amount of alcohol gel dispensed between the intervention unit (A) and the control unit (B) (62,000 versus 33,570 aliquots per 1,000 patient-days; $P < 0.01$). However, no significant

difference was found in the number of liters of chlorhexidine used between the intervention unit and the control unit (63.5 versus 49.9 liters per 1,000-patient days; $P = 0.18$). It would be interesting to determine whether this approach is sustainable over a long period of time. Although the same goal (sole use of ABHRs versus other antiseptics) may not apply to food processing and food service settings, the concept of positive deviance should be considered with a reward system for those positive deviant workers that take such initiative.

Continued employment can be based on regular hand washing, with established daily quotas. In health care situations, Queensland Health *(84)* recommended that Health Service Districts and facilities focus initially on achieving very high hand hygiene compliance for high-risk activities. Once the ward, unit, or department has reached ≥50% compliance with high-risk hand hygiene activities, such as care of indwelling devices inserted into sterile body sites (e.g., a catheter inserted into a patient) or contact with patients known to have transmissible pathogens (e.g., MRSA, vancomycin-resistant enterococci, and norovirus), the focus should move to medium-risk activities (e.g., sponging the skin of a sick patient) and then to low-risk activities (e.g., after coughing, sneezing, or visiting the toilet). Queensland Health acknowledged that this process is incremental and that several years may be needed to achieve high levels of hand hygiene compliance for low-risk activities.

Equivalent activities most likely encountered in food service situations would be medium risk (handling of raw meats) and low risk (personal hygiene). High-risk activities would be avoiding contamination of infant formula with *Chronobacter sakazakii* or contamination of other foods with any enteric organisms, especially for at-risk persons such as organ transplant patients. Hand hygiene compliance can be measured using a hand hygiene audit tool *(113).* Observations are recorded, e.g., 5 to 10 30-min periods every 3 months in each area or ward, and compliance is defined as either washing hands with soap and running water or decontaminating hands with an ABHR in accordance with a hand hygiene opportunity.

Another approach to assessing hand washing compliance is to observe and report practices. One such study involved 100 female college students *(24).* Most students (63%) washed their hands, and 38% used soap; 32% washed with soap for 5 or more seconds, but only 2% washed their hands with soap for 10 or more seconds. Fewer students left without hand washing when someone else was present in the sink area (9%) than when they were alone (45%). High bacterial populations were found on a female bathroom sink faucet and toilet seat, confirming the need for programs that will increase hand washing compliance. Another possibility to be evaluated is more frequent janitorial services to disinfect toilet seats, stall door handles, and sink faucets. Potential strategies considered to optimize infection control included using peer pressure to encourage hand washing, installation of motion-activated faucets, use of disposable toilet seat covers, and exit doors that can be pushed open.

Changes in compliance can occur. The following is an example for general hygienic conditions, not necessarily hand washing. As a follow-up to their study in which high microbial counts were linked to poor hygienic food handling *(86),* Sagoo et al. *(87)* conducted a microbiological survey of open, ready-to-eat prepared salad vegetables from catering or retail premises and salad vegetables from food service areas or customer self-service bars and found improvements in hygienic conditions. Overall, 97% of the products tested were of satisfactory microbiological quality (no *Campylobacter, Salmonella,* or *E. coli* O157 detected in 25 g, and no *E. coli, Listeria* spp., or *Listeria monocytogenes*) or acceptable microbiological quality (20 to <100 CFU/g for *E. coli, Listeria* spp., or *L. monocytogenes*); only 3% had *E. coli* levels in the range of 10^2 to 10^5 CFU/g. Most of the display and preparation areas (95%) and self-service salad bars (98%) that were visited were judged to be visibly clean by the sampling officer. Most self-service bars (87%) were regularly supervised or inspected by staff during open hours, and designated serving utensils were used in most salad bars (92%) but in only a minority of food service areas (35%). A hazard analysis system (based on guidance documents that included hazard analysis critical control point principles) was on site in most premises (80%), and in 61% of the premises the system was documented (information pertinent to the specific operations was recorded for verification purposes). Most managers (90%) had received food hygiene training. A direct relationship was found between increased confidence in food business management and the presence of food safety procedures and the training of management in food hygiene.

A similar relationship also was found by Gormley et al. *(29)* in a survey of catering establishments in the United Kingdom. Of the premises where staff washed and dried their hands after contact with eggs or pooled egg mixtures, a higher number had a documented food safety management system in place (82.0%) in comparison with those premises that did not have such a system (60.8%). On the premises where staff did not wash their hands, knowledge of the safe use of eggs was significantly less common (54.6%) than it was on the premises where staff did wash and dry their hands (80.3%). Hand washing also was clearly not feasible when there were no facilities in place and available for use, as occurred on 6.2% of premises.

Campaigns about hand hygiene may be useful for reducing contamination and illnesses *(117).* Students in four campus residence halls who were exposed to a message campaign and provided with ABHRs increased their knowledge about the potential health benefits of hand washing and sanitizer use and reported higher rates of hand washing and use of the antiseptic than did the control group. These students also experienced fewer cold and flu illnesses during the study than did those in the control group and missed fewer classes or work assignments because of colds or flu. Presumably, this campaign also would impact enteric illnesses, although these were not tracked.

Allwood et al. *(3)* found that supervisors as role models were effective in a food service setting. These authors

conducted a survey of retail food establishments in Minnesota to investigate the effect of hand washing training, availability of hand washing facilities, and the ability of the person in charge (PIC) to describe hand washing protocols according to the Minnesota Food Code on workers' ability to demonstrate code-compliant hand washing. Only 52% of the PICs could describe the hand washing procedure outlined in the Food Code, and only 48% of workers could demonstrate code-compliant hand washing. The most common problems observed were failure to wash for 20 s and failure to use a fingernail brush. For PICs, a strong positive association was found between being a certified food manager and being able to describe the Food Code hand washing protocol, and an even stronger association was found between the ability of the PIC to describe hand washing and the ability of workers to demonstrate code-compliant hand washing. Significant associations were detected among correct hand washing demonstration, physical infrastructure for hand washing, and the hand washing training methods used by the establishment. These results suggest that improving hand washing practices among food workers will require interventions that address PIC knowledge of hand washing requirements and procedures and the development and implementation of effective hand washing training methods. This process must be continual; otherwise, long-term effects on hand washing frequency will be minimal despite employee feedback, education, and increased sink automation *(52)*.

Workers must change gloves and wash their hands when moving from one job to another, and workers must follow this practice even when their job description requires multiple task changes in a given period *(75)*. A reason for personal hygiene not being considered as a critical control point has been the lack of effective monitoring techniques. However, some aspects of hygiene can be checked in a very definite way, and corrective action can be taken. For instance, wearing of gloves has been advocated precisely because their use can be monitored by both management and the health department, although the quality of glove hygienic practice is not as easy to determine *(37)*. To identify factors related to food worker hand hygiene practices, Green et al. *(31)* collected observational data on food worker hand hygiene practices (hand washing and glove use) and observational and interview data on factors related to hygiene behavior, such as worker activity, restaurant characteristics, worker food safety training, and the physical and social environment. Results indicated that hand washing and glove use were more likely to occur in conjunction with food preparation than with other activities (e.g., handling dirty equipment) and when workers were not busy. Hand washing was more likely to occur in restaurants whose food workers received food safety training, in restaurants that had more than one hand sink, and in restaurants where the hand sink was in the observed worker's sight. Glove use was more likely to occur in chain restaurants and in restaurants with glove supplies in food preparation areas. As previously stated, hand washing and glove use were also related to each other; hand washing was less likely to occur with activities in which gloves were worn.

These findings indicate that a number of factors are related to hand hygiene practices and support suggestions that food worker hand hygiene improvement requires more than food safety education. Improvement programs must be multidimensional and must address factors such as those examined in this study. Although hand hygiene is the most effective measure for interrupting the transmission of microorganisms that cause illness, both in the community and in the health care setting, using hand hygiene as a sole measure to reduce infection is unlikely to be successful when other factors, such as environmental cleanliness, employee working conditions, staffing levels, and education, are inadequate *(2)*. Compliance with hand hygiene recommendations is poor worldwide. Although the techniques involved in hand hygiene are simple, the complex interdependence of factors that determine hand hygiene behavior makes the study of hand hygiene complex. Akyol et al. *(2)* stated that improved compliance with hand hygiene recommendations depends on altering human behavior, which requires input from behavioral and social scientists to design studies to investigate compliance. Interventions to increase compliance with hand hygiene practices also must be appropriate for different cultural and social needs.

York et al. *(120)* also found that training alone is not sufficient to improve the safety of employee behavior in food service establishments. They found that repeated measures analyses of variance indicated training improved hand washing knowledge, but intervention was necessary to improve overall behavioral compliance and hand washing compliance. These authors suggested that registered dietitians and food service managers should implement a combination of training and interventions to improve knowledge and compliance with food safety behaviors rather than relying on training alone; they also stated that most so-called interventions are merely additional training. York et al. based their conclusions on the theory of planned behavior, which states that perceived barriers, attitudes, and subjective norms influence intentions to perform a behavior. If an individual perceives barriers to, has unfavorable attitudes about, or perceives that others who are important to them do not approve of a certain behavior, it is unlikely that the individual will perform that behavior. For hand washing, several of these barriers have been identified, such as lack of facilities and soap, bare hand versus glove use, chafing of hands, the busyness of the operation, and management lack of interest in food safety *(105, 106, 120)*. Employees showed little difference in knowledge of food safety behaviors concerning hand washing, thermometer usage, and proper use of work surfaces to avoid cross-contamination after (i) the three stages of baseline understanding, (ii) 1 week posttraining (ServSafe) *(72)*, and (iii) an intervention strategy 8 months later. For this intervention strategy, the researchers used financial incentives for employees with the best food safety compliance records and posted persuasive messages in high-traffic areas stressing serious consequences (illness or death) for patrons and employees who ignored the food safety guidelines. Newspaper articles on recent outbreaks involving food service employees in well-known restaurant chains also were posted. This knowledge

background indicated that employees were familiar with the rationale and the need for hand washing in food service establishments. However, training and intervention increased actual compliance for hand washing at the start of the study (37.5%), after training (44.7%), and after intervention (57.6%).

York et al. *(120)* concluded that in each establishment responsible and trained personnel (managers, registered dietitians, and dietetic technicians) should identify perceived barriers to food safety practices among employees by asking about factors that make it difficult to comply with food safety guidelines. Employees also should be asked to describe unfavorable outcomes that may result from complying with guidelines. After determining barriers and attitudes to target, those responsible can develop interventions to meet employees' needs. Management should continuously monitor employees' compliance with food safety guidelines and provide ongoing training and interventions to improve the safety of food and decrease the risk of foodborne illnesses.

CONCLUSION

Hand hygiene is not a new concept for prevention of disease spread, either at home or work, although how to best achieve more complete compliance has not been resolved even after many years of study and research. The fact that foodborne outbreaks occur because of lapses in hand hygiene in food operations, particularly food service facilities, has been well established over many decades *(34)*. Yet, employees continue to forget to wash their hands or do so ineffectively, and illnesses continue to occur. Michaels et al. *(67)* suggested that the key components affecting risk of transmission are hand hygiene compliance, hygiene efficiency, and cross-contamination. Compliance reflects (i) the frequency of the cleansing process, (ii) the willingness to adhere to the recommended procedures, (iii) hygiene efficiency through the combined effects of washing, brushing, rinsing, drying, sanitizing, gloving, etc., (iv) prevention of cross-contamination by having more hands-free operations, (v) handling less raw and more processed food, and (vi) working on sanitized surfaces. Our experience indicates that compliance can be improved only with multiactivity strategies. Training and increased knowledge of food safety issues, including hand hygiene, are important components of a strategy but must be considered in addition to monitoring of the actual practices. Monitoring can be accomplished by direct observation and recording of positive and negative behaviors or by some automated system of recording use of water and soaps or other antiseptics such as ABHRs. These automated systems can be for total worker use or can be modified for individuals when a personal identification component, such as a radio frequency identification tag, can be included and the information stored in a database.

A major consideration is the ability to alter human behavior by peer pressure, such as positive deviance, or through rewards and penalties applied to both management and other employees. These issues lead into the critical impact of the cultural values of both society and workers' organizations. The climate of an institution is a key element in promoting positive change. This is a new area for food safety research promoted by Griffith and others *(35)*. Individual food handler behavior is linked directly to the culture of the food business. How management creates and supports the food safety culture within a business may be the most important factor for determining whether that business can avoid violations on inspection, foodborne illness of its patrons, or costly recall of its products. The more confident the business is in the production and/or service of its food, the more likely it will implement proper hygienic measures and institute effective training of the staff, both managers and other employees. Policies should be in place to enhance both individual and institutional self-efficacy. The PIC of the workers on the line needs complete knowledge of food safety risks in the company's operations and why hand hygiene, including adequate washing, is necessary to avoid contamination of the food and its contact surfaces. Hand washing is less likely to occur when gloves are worn than when bare hand contact occurs; yet, there are risks for contamination of food from both gloves and hands *(105)*.

The PIC is an authority for training and advice in specific conditions of the operation. The presence of a well-trained PIC provides a system for routine observation and feedback and for making hand hygiene easy and convenient with necessary supplies regularly stocked, putting reminders in the workplace, requesting better engineered facilities, avoiding overcrowding, understaffing, and excessive workload, facilitating skin care for workers' hands, and implementing administrative sanctions and/or rewards. PICs should participate actively in policy decisions that affect workers. Unfortunately, PICs have many tasks to carry out, especially in small operations, and it is difficult not to let the economic driver of profit block time and effort spent on food safety and hand hygiene. Collaboration and advice from local health departments and their inspectors should be encouraged, because these departments are more involved in education than in regulation. One obvious action is to determine the most risky practices in any operation and insist on very high hand hygiene compliance with the highest risk activities. More research into motivation for correct procedures may give new directions for improving compliance. Vigilance must be maintained at all times to ensure operations are as safe as possible, and any change in operational practices must be carefully monitored to determine whether new risks may arise.

REFERENCES

1. Aiello, A. E., R. M. Coulborn, V. Perez, and E. L. Larson. 2008. Effect of hand hygiene on infectious disease risk in the community setting: a meta-analysis. *Am. J. Public Health* 98:1372–1381.
2. Akyol, A., H. Ulusoy, and I. Ozen. 2006. Handwashing: a simple, economical and effective method for preventing nosocomial infections in intensive care units. *J. Hosp. Infect.* 62:395–405.
3. Allwood, P. B., T. Jenkins, C. Paulus, L. Johnson, and C. W. Hedberg. 2004. Hand washing compliance among retail food establishment workers in Minnesota. *J. Food Prot.* 67:2825–2828.
4. Altekruse, S. F., B. B. Timbo, M. L. Headrick, and K. C. Klontz. 1995. Associations between diet and health behavior: results from

the 1992 Rhode Island Behavioral Risk Factor Survey. *J. Behav. Med.* 18:225–232.
5. Berry, C. A. 1969. Preliminary clinical report of the medical aspects of Apollo 7 and 8. NASA TMX-58027. National Aeronautics and Space Administration, Manned Spacecraft Center, Houston.
6. Berry, C. A. 1970. Summary of medical experience. 1. The Apollo 7 through 11 manned spaceflights. *Aerosp. Med.* 41:500–519.
7. Bielby, G., B. Egan, A. Eves, M. Lumbers, M. Raats, and M. Adams. 2006. Food hygiene education in UK primary schools: a nation-wide survey of teachers' views. *Br. Food J.* 108:721–731.
8. Bittner, M. J., E. C. Rich, P. D. Turner, and W. H. Arnold, Jr. 2002. Limited impact of sustained simple feedback based on soap and paper towel consumption on the frequency of hand washing in an adult intensive care unit. *Infect. Control Hosp. Epidemiol.* 23:120–126.
9. Bloomfield, S. F., B. Cookson, F. Falkiner, C. Griffith, and V. Cleary. 2007. Methicillin-resistant *Staphylococcus aureus, Clostridium difficile,* and extended-spectrum beta-lactamase–producing *Escherichia coli* in the community: assessing the problem and controlling the spread. *Am. J. Infect. Control* 35:86–88.
10. Boyce, J. M., and D. Pittet. 2002. Guideline for hand hygiene in healthcare settings: recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA hand hygiene task force. *Morb. Mortal. Wkly. Rep.* 51: 1–45.
11. Broughall, J. M., C. Marshman, B. Jackson, and P. Bird. 1984. An automatic monitoring system for measuring handwashing frequency in hospital wards. *J. Hosp. Infect.* 5:447–453.
12. Byers, K. E., A. M. Anglim, C. J. Anneski, T. P. Germanson, H. S. Gold, L. J. Durbin, B. M. Simonton, and B. M. Farr. 2001. A hospital epidemic of vancomycin-resistant *Enterococcus*: risk factors and control. *Infect. Control Hosp. Epidemiol.* 22:140–147.
13. Centers for Disease Control and Prevention. 2008. Summary health statistics for U.S. children: National Health Interview survey, 2008. Available at: http://www.cdc.gov/nchs/fastats/children.htm. Accessed 6 April 2010.
14. Centers for Disease Control and Prevention. 2009. Multistate outbreak of *Salmonella* infections associated with peanut butter and peanut butter–containing products—United States, 2008–2009. *Morb. Mortal Wkly. Rep.* 58:85–90.
15. Chen, Y., K. M. Jackson, F. P. Chea, and D. W. Schaffner. 2001. Quantification and variability analysis of bacterial cross-contamination rates in the kitchen. *J. Food Prot.* 64:72–80.
16. Clayton, D. A., and C. J. Griffith. 2004. Observation of food safety practices in catering using notational analysis. *Br. Food J.* 106:211–227.
17. Clayton, D. A., C. J. Griffith, and P. Price. 2003. An investigation of the factors underlying consumers' implementation of specific food safety practices. *Br. Food J.* 105:434–453.
18. Coleman, P., and A. Roberts. 2005. Food hygiene training in the UK: a time for change. *Food Serv. Technol.* 5:17–22.
19. Comer, M. M., I. Mohammad, V. Jarvis McMillan, G. G. Baker, and S. G. Patterson. 2009. Reducing the spread of infectious disease through hand washing. Article 1R1B7. *J. Extension* 47. Available at: http://www.joe.org/joe/2009february/pdf/JOE_v47_1rb7.pdf. Accessed 4 January 2010.
20. Conference for Food Protection, Council III, Science & Technology. 2002. Preventing contamination from hands, section 3-301.11. Issue 02-03-25. Report of the Council III Bare Hand Contact Committee, 1 February. Available at: http://www.foodprotect.org/media/meeting/2002_Council_III.pdf. Accessed 7 July 2009.
21. Cooper, F. 2008. Hand hygiene—lessons from the NHS. *Int. Food Hyg.* 19:11–12.
22. Czerwinski, B. S., and A. C. Toback. 1992. Skin care in the space environment. *Dermatol. Nurs.* 4:369–376.
23. Daniels, N. A., R. L. Atmar, D. A. Bergmire-Sweat, R. L. Fankhauser, R. I. Glass, K. A. Hendricks, S. S. Monore, P. Mead, A. Reddy, S. M. Rowe, and K. J. Schwab. 2000. A foodborne outbreak of gastroenteritis associated with Norwalk-like viruses: first molecular traceback to deli sandwiches contaminated during preparation. *J. Infect. Dis.* 181:1467–1470.
24. Drankiewicz, D., and L. Dundes. 2003. Handwashing among female college students. *Am. J. Infect. Control* 31:67–71.
25. Emery, H. C. 1990. Changing poor handwashing habits—a continuing challenge for sanitarians. *Dairy Food Environ. Sanit.* 10:8–9.
26. Fendler, E. J., Y. Ali, B. S. Hammond, M. K. Lyons, M. B. Kelley, and N. A. Vowell. 2002. The impact of alcohol hand sanitizer use on infection rates in an extended care facility. *Am. J. Infect. Control* 30: 226–233.
27. Fox, L. 1971. The ecology of micro-organisms in a closed environment. *Life Sci. Space Res.* 9:69–74.
28. Gibson, L. L., J. B. Rose, C. N. Haas, C. P. Gerba, and P. A. Rusin. 2002. Quantitative assessment of risk reduction from hand washing with antibacterial soaps. *J. Appl. Microbiol. Symp. Suppl.* 92:136S–143S.
29. Gormley, F. J., C. L. Little, E. de Pinna, J. McLauchlin, and the Food, Water and Environmental Surveillance Network. 2009. Microbiological study on *Salmonella* contamination of pooled raw shelled egg mix and environmental samples from catering establishments. Available at: http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1245309914251. Accessed 23 June 2009.
30. Gould D. 1994. Nurses' hand decontamination practice: results of a local study. *J. Hosp. Infect.* 28:15–30.
31. Green, L. R., V. Radke, R. Mason, L. Bushnell, D. W. Reimann, J. C. Mack, M. D. Motsinger, T. Stigger, and C. A. Selman. 2007. Factors related to food worker hand hygiene practices. *J. Food Prot.* 70:661–666.
32. Green, L. R., C. A. Selman, V. Radke, D. Ripley, J. C. Mack, D. W. Reimann, T. Stigger, M. Motsinger, and L. Bushnell. 2006. Food worker hand washing practices: an observational study. *J. Food Prot.* 69:2417–2423.
33. Greig, J. D., and M. B. Lee. 2009. Enteric outbreaks in long-term care facilities and recommendations for prevention: a review. *Epidemiol. Infect.* 137:145–155.
34. Greig, J. D., E. C. D. Todd, C. A. Bartleson, and B. S. Michaels. 2007. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 1. Description of the problem, methods, and agents involved. *J. Food Prot.* 70:1752–1761.
35. Griffith, C. J., K. M. Livesey, and D. A. Clayton. 2010. Food safety culture: the evolution of an emerging risk factor? *Br. Food J.* 112: 426–438.
36. Guinan, M., M. McGuckin, and Y. Ali. 2002. The effect of a comprehensive handwashing program on absenteeism in elementary schools. *Am. J. Infect. Control* 30:217–220.
37. Guzewich, J. J. 1995. The anatomy of a ''glove rule.'' *Environ. News Digest* Fall:4–13.
38. Hammond, B., Y. Ali, E. Fendler, M. Dolan, and S. Donovan. 2000. Effect of hand sanitizer use on elementary school absenteeism. *Am. J. Infect. Control* 28:340–346.
39. Hannuksela, M. 1996. Moisturizers in the prevention of contact dermatitis. *Curr. Probl. Dermatol.* 25:214–220.
40. Harding, R. 1989. Survival in space: medical problems of manned spaceflight. Routledge, New York.
41. Hertzman, J., and D. Barrash. 2007. An assessment of food safety knowledge and practices of catering employees. *Br. Food J.* 109: 562–576.
42. Hilburn, J., B. S. Hammond, E. J. Fender, and P. A. Groziak. 2003. Use of alcohol hand sanitizer as an infection control strategy in an acute care facility. *Am. J. Infect. Control* 31:109–116.
43. Holah, J. (j.holah@campden.co.uk), and D. L. Smith. 2009. Personal communication.
44. Hovey, L. 2003. One in three caterers don't wash hands after using lavatory, (UK) survey shows. *Food Prot. Trends* 23:53–54.
45. Kampf, G., and J. Ennen. 2006. Regular use of a hand cream can attenuate skin dryness and roughness caused by frequent hand washing. *BMC Dermatol.* 6:1.
46. Kassa, H., B. Harrington, M. Bisesi, and S. Khuder. 2000. Comparisons of microbiological evaluations of selected kitchen areas with visual inspections for preventing potential risk of foodborne outbreaks in food service operations. *J. Food Prot.* 64:509–513.

47. Kinnula, S., T. Tapiainen, M. Renko, and M. Uhari. 2009. Safety of alcohol hand gel use among children and personnel at a child day care center. *Am. J. Infect. Control* 37:318–321.
48. Kjaerheim, V., P. Barkvoll, S. M. Waaler, and G. Rölla. 1995. Triclosan inhibits histamine-induced inflammation in human skin. *J. Clin. Periodontol.* 22:423–426.
49. Kotch, J. B., and D. Bryant. 1990. Effects of day care on the health and development of children. *Curr. Opin. Pediatr.* 2:883–894.
50. Kotch, J. B., P. Isbell, D. J. Weber, V. Nguyen, E. Savage, E. Gunn, M. Skinner, S. Fowlkes, J. Virk, and J. Allen. 2007. Hand-washing and diapering equipment reduces disease among children in out-of-home child care centers. *Pediatrics* 120:e29–e36. Available at: http://pediatrics.aappublications.org/cgi/content/full/120/1/e29. Accessed 31 December 2009. DOI: 10.1542/peds.2005-0760.
51. Lai, Y., and R. L. Gallo. 2009. AMPed up immunity: how antimicrobial peptides have multiple roles in immune defense. *Trends Immunol.* 30:131–141.
52. Larson, E. L., C. Friedman, J. Cohran, J. Treston-Aurand, and S. Green. 1997. Prevalence and correlates of skin damage on the hands of nurses. *Heart Lung* 26:404–412.
53. Larson, E. L., and M. Killien. 1982. Factors influencing handwashing behavior of patient care personnel. *Am. J. Infect. Control* 10: 93–99.
54. Lee, G. M., J. A. Salomon, J. F. Friedman, P. L. Hibberd, D. Ross-Degnan, E. Zasloff, S. Bediako, and D. A. Goldman. 2005. Illness transmission in the home: a possible role for alcohol-based hand gels. *Pediatrics* 115:852–860.
55. Lee, M. B., and J. D. Greig. 2008. A review of enteric outbreaks in child care centers: effective infection control recommendations. *J. Environ. Health* 71:24–32, 46.
56. Lotter, L. P., and B. S. Horstman. 1967. The potential hazard of staphylococci and micrococci to human subjects in a life support systems evaluator with elevated cabin temperature. Ohio Tech. Rep. AMRL-TR-67-43. USAF Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, OH.
57. Lotter, L. P., and B. S. Horstman. 1967. The potential hazard of staphylococci and micrococci to human subjects in a life support systems evaluator while on a simulated GT-7 mission. Ohio Tech. Rep. AMRL-TR-67-45. USAF Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, OH.
58. Lotter, L. P., B. S. Horstman, and J. V. Rack. 1967. The potential hazard of staphylococci and micrococci to human subjects in a life support systems evaluator and on a diet of precooked freeze-dried foods. Ohio Tech. Rep. AMRL-TR-67-18. USAF Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, OH.
59. Lotter, L. P., B. S. Horstman, and J. V. Rack. 1967. The potential hazard of staphylococci and micrococci to human subjects in a life support systems evaluator and on a diet of liquid foods. Ohio Tech. Rep. AMRL-TR-67-21. USAF Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, OH.
60. Makris, A. T., L. Morgan, D. J. Gaber, A. Richter, and J. R. Rubino. 2000. Effect of a comprehensive infection control program on the incidence of infections in long-term care facilities. *Am. J. Infect. Control* 28:3–7.
61. Mann, J. 2003. Handwashing: technology adds a measure of management. *Foodserv. Equip. Supplies,* March. Available at: http://www.fesmag.com/article/CA6507312.html. Accessed 23 June 2009.
62. Marra, A. R., C. D'Arco, B. de Arruda Bravim, M. D. V. Martino, L. Correa, C. V. Silva, L. C. R. Lamblet, M. Silva, Jr., G. de Lima, L. R. Guastelli, L. Barbosa, O. F. Pavão dos Santos, and M. B. Edmond. 2008. Controlled trial measuring the effect of a feedback intervention on hand hygiene compliance in a step-down unit. *Infect. Control Hosp. Epidemiol.* 29:730–735.
63. Marra, A. R., L. R. Guastelli, C. M. Pereira de Araújo, J. L. Saraiva dos Santos, L. C. R. Lamblet, M. Silva, Jr., G. de Lima, R. G. R. Cal, Â. T. Paes, M. C. Neto, L. Barbosa, M. B. Edmond, and O. F. Pavão dos Santos. 2010. Positive deviance: a new strategy for improving hand hygiene compliance. *Infect. Control Hosp. Epidemiol.* 31:12–20.
64. Marsh, D. R., D. G. Schroeder, K. A. Dearden, J. Sternin, and M. Sternin. 2004. The power of positive deviance. *BMJ* 329:1177–1179.
65. Meadows, E., and N. Le Saux. 2004. A systematic review of the effectiveness of antimicrobial rinse-free hand sanitizers for prevention of illness-related absenteeism in elementary school children. *BMC Public Health* 4:50.
66. Michaels, B., and T. Ayers. 2002. Hazard analysis of the personal hygiene process, p. 191–200. *In* Proceedings of the 2nd National Sanitation Foundation International Conference on Food Safety, Savannah, GA, 11 to 13 October 2000.
67. Michaels, B., V. Gangar, A. Schultz, M. Arenas, M. Curiale, T. Ayers, and D. Paulson. 2002. Water temperature as a factor in handwashing efficacy. *Food Serv. Technol.* 2:139–149.
68. Michaels, B., C. Keller, M. Blevins, G. Paoli, T. Ruthman, E. Todd, and C. J. Griffith. 2004. Prevention of food worker transmission of foodborne pathogens: risk assessment and evaluation of effective hygiene intervention strategies. *Food Serv. Technol.* 4:31–49.
69. Mohanty, S., M. J. Rycroft, and M. Barrett. 2001. Design concepts for zero-G whole body cleansing on ISS Alpha. Part II. Individual design project NASA/CR 2001-208931. Available at: http://ston.jsc.nasa.gov/collections/TRS/_techrep/CR-2001-208931.pdf. Accessed 21 August 2009.
70. Mohle-Boetani, J. C., M. Stapleton, R. Finger, N. H. Bean, J. Poundstone, P. A. Blake, and P. M. Griffin. 1995. Communitywide shigellosis: control of an outbreak and risk factors in child day-care centers. *Am. J. Public Health* 85:812–816.
71. Morton, J. L., and A. A. Schultz. 2004. Healthy hands: use of alcohol gel as an adjunct to handwashing in elementary school children. *J. Sch. Nurs.* 20:161–167.
72. National Restaurant Association. 2010. ServSafe® food safety training program. Available at: http://www.servsafe.com/about/. Accessed 7 April 2010.
73. NSF International. 2007. The scrub club. Available at: http://www.scrubclub.org. Accessed 7 April 2010.
74. Partnerships for Food Safety Education. 2010. Fight BAC! Keep food safe from bacteria. Available at: http://www.fightbac.org. Accessed 7 April 2010.
75. Paulson, D. S. 2000. Handwashing, gloving and disease transmission by the food preparer. *Dairy Food Environ. Sanit.* 20:838–845.
76. Pennington, H. 2009. The public inquiry into the September 2005 outbreak of *E. coli* O157 in South Wales. HMSO, Cardiff, UK. Available at: http://wales.gov.uk/ecolidocs/3008707/reporten.pdf?skip=1&lang=en. Accessed 3 December 2009.
77. Pennington, T. H. 2000. VTEC: lessons learned from British outbreaks. *J. Appl. Microbiol.* 88(Suppl.):90S–98S.
78. Pierson, D. L. 2001. Personal communication to Barry S. Michaels.
79. Pittet, D. 2000. Improving compliance with hand hygiene in hospitals. *Infect. Control Hosp. Epidemiol.* 21:381–386.
80. Pittet, D. 2001. Improving adherence to hand hygiene practice: a multidisciplinary approach. *Emerg. Infect. Dis.* 7:234–240.
81. Pittet, D., P. Mourouga, and T. V. Perneger. 1999. Compliance with handwashing in a teaching hospital. *Ann. Intern. Med.* 130:126–130.
82. Pogue, W. R. 1985. How do you go to the bathroom in space? Tom Doherty Associates, New York.
83. Pragle, A. S., A. K. Harding, and J. C. Mack. 2007. Food workers' perspectives on handwashing behaviors and barriers in the restaurant environment. *J. Environ. Health* 69:27–32.
84. Queensland Health. 2007. Hand hygiene policy—clean hands are life savers. Available at: http://www.health.qld.gov.au/chrisp/ic_guidelines/appendix_A.pdf. Accessed 19 March 2010.
85. Roberts, L., E. M. Douglas, L. Jorm, C. McGilchrist, M. Patel, and W. Smith. 2000. Effect of infection control measures on frequency of diarrheal episodes in child care: a randomized, controlled trial. *Pediatrics* 105:743–746.
86. Sagoo, S. K., C. L. Little, C. Griffith, and R. Mitchell. 2003. Study of cleaning standards and practices in food premises in the United Kingdom. *Commun. Dis. Public Health* 6:6–17.
87. Sagoo, S. K., C. L. Little, and R. T. Mitchell. 2003. Microbiological quality of open ready-to-eat salad vegetables: effectiveness of food hygiene training of management. *J. Food Prot.* 66:1581–1586.

88. Sandora, T. J., M. C. Shih, and D. A. Goldmann. 2008. Reducing absenteeism from gastrointestinal and respiratory illness in elementary school students: a randomized, controlled trial of an infection-control intervention. *Pediatrics* 21:e1555–e1562.
89. Sandora, T. J., E. M. Taveras, M. C. Shih, E. A. Resnick, G. M. Lee, D. Ross-Degnan, and D. A. Goldmann. 2005. A randomized, controlled trial of a multifaceted intervention including alcohol-based hand sanitizer and hand-hygiene education to reduce illness transmission in the home. *Pediatrics* 116:587–594.
90. School Network for Absenteeism Prevention. 2003. Healthy schools, healthy people. Available at: http://www.itsasnap.org/index.asp. Accessed 7 April 2010.
91. Sharp, T. W. 1989. A descriptive analysis of hepatitis A in foodhandlers, Washington State, 1987–88. M.P.H. thesis. University of Washington, Seattle.
92. Skaare, A. B., G. Rölla, and P. Barkvoll. 1997. The influence of triclosan, zinc or propylene glycol on oral mucosa exposed to sodium lauryl sulphate. *Eur. J. Oral Sci.* 105:527–533.
93. Smith, D. L. 2009. Hand hygiene: guidance for best practice. Guideline 62. Campden BRI, Chipping Campden, UK.
94. Snow, M., G. L. White, Jr., and H. S. Kim. 2008. Inexpensive and time-efficient hand hygiene interventions increase elementary school children's hand hygiene rates. *J. Sch. Health* 78:230–233.
95. Sproat, L. J., and T. J. Inglis. 1994. A multicentre survey of hand hygiene practice in intensive care units. *J. Hosp. Infect.* 26:137–148.
96. Steinmann, J., B. Becker, B. Bischoff, D. Paulmann, M. Friesland, T. Pietschmann, J. Steinmann, and E. Steinmann. 2010. Virucidal activity of 2 alcohol-based formulations proposed as hand rubs by the World Health Organization. *Am. J. Infect. Control* 38:66–68.
97. Steketee, R. W., S. Reid, T. Cheng, J. S. Stoebig, R. G. Harrington, and J. P. Davis. 1989. Recurrent outbreaks of giardiasis in a child day care center, Wisconsin. *Am. J. Public Health* 79:485–490.
98. Taylor, G. R. 1974. Recovery of medically important microorganisms from Apollo astronauts. *Aerosp. Med.* 45:824–828.
99. Toback, A. C. 1991. Space dermatology: a specialty in evolution. *Cutis* 48:283–287.
100. Todd, E. C. D., J. D. Greig, C. A. Bartleson, and B. S. Michaels. 2007. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 2. Description of outbreaks by size, severity, and settings. *J. Food Prot.* 70:1975–1993.
101. Todd, E. C. D., J. D. Greig, C. A. Bartleson, and B. S. Michaels. 2007. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 3. Factors contributing to outbreaks and description of outbreak categories. *J. Food Prot.* 70:2199–2217.
102. Todd, E. C. D., J. D. Greig, C. A. Bartleson, and B. S. Michaels. 2008. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 4. Infective doses and pathogen carriage. *J. Food Prot.* 71:2339–2373.
103. Todd, E. C. D., J. D. Greig, C. A. Bartleson, and B. S. Michaels. 2008. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 5. Sources of contamination and pathogen excretion from infected persons. *J. Food Prot.* 71:2582–2595.
104. Todd, E. C. D., J. D. Greig, C. A. Bartleson, and B. S. Michaels. 2009. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 6. Transmission and survival of pathogens in the food processing and preparation environment. *J. Food Prot.* 72:202–219.
105. Todd, E. C. D., B. S. Michaels, J. D. Greig, D. Smith, and C. A. Bartleson. 2010. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 8. Gloves as barriers to prevent contamination of food by workers. *J. Food Prot.* 73:1762–1773.
106. Todd, E. C. D., B. S. Michaels, J. D. Greig, D. Smith, J. Holah, and C. A. Bartleson. 2010. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 7. Barriers to reduce contamination of food by workers. *J. Food Prot.* 73:1552–1565.
107. Todd, E. C. D., B. S. Michaels, J. Holah, D. Smith, J. D. Greig, and C. A. Bartleson. 2010. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 10. Alcohol-based antiseptics for hand disinfection and a comparison of their effectiveness with soaps. *J. Food Prot.* 73:2128–2140.
108. Todd, E. C. D., B. S. Michaels, D. Smith, J. D. Greig, and C. A. Bartleson. 2010. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 9. Washing and drying of hands to reduce microbial contamination. *J. Food Prot.* 73:1937–1955.
109. Tousman, S., D. Arnold, W. Helland, R. Roth, N. Heshelman, O. Castaneda, E. Fischer, K. O'Neil, and S. Bileto. 2007. Evaluation of a hand washing program for 2nd-graders. *J. Sch. Nurs.* 23:342–348.
110. U.S. Department of Agriculture, Research, Education & Economics Information System. 2004. The Germ City Hand Washing Program: clean hands, healthy people. Available at: http://www.reeis.usda.gov/web/crisprojectpages/190520.html. Accessed 7 April 2010.
111. U.S. Food and Drug Administration. 2000. Report of the FDA retail food program database of foodborne illness risk factors. Available at: http://www.fda.gov/Food/FoodSafety/RetailFoodProtection/FoodborneIllnessandRiskFactorReduction/RetailFoodRiskFactorStudies/ucm123544.htm. Accessed 9 July 2009.
112. U.S. Food and Drug Administration. 2009. Food Code 2009. Available at: http://www.fda.gov/Food/FoodSafety/RetailFoodProtection/FoodCode/FoodCode2009/. Accessed 11 December 2009.
113. van de Mortel, T., and M. Murgo. 2006. An examination of covert observation and solution audit as tools to measure the success of hand hygiene interventions. *Am. J. Infect. Control* 34:95–99.
114. Voss, A., and A. F. Widmer. 1997. No time for handwashing!? Handwashing versus alcoholic rub: can we afford 100% compliance? *Infect. Control Hosp. Epidemiol.* 18:205–208.
115. Washington State University. 2010. Germ city: clean hands, healthy people. Available at: http://www.germcity.wsu.edu/overview.htm. Accessed 7 April 2010.
116. Watanakunakorn, C., C. Wang, and J. Hazy. 1998. An observational study of hand washing and infection control practices by healthcare workers. *Infect. Control Hosp. Epidemiol.* 19:858–860.
117. White, C., R. Kolble, R. Carlson, and N. Lipson. 2005. The impact of a health campaign on hand hygiene and upper respiratory illness among college students living in the residence halls. *J. Am. Coll. Health* 53(4):175–181.
118. White, C. G., F. S. Shinder, A. L. Shinder, and D. L. Dyer. 2001. Reduction of illness absenteeism in elementary schools using an alcohol free instant hand sanitizer. *J. Sch. Nurs.* 17:258–265.
119. Williamson, D. M., R. B. Gravani, and H. T. Lawless. 1992. Correlating food safety knowledge with home food-preparation practices. *Food Technol.* 46:94–100.
120. York, V. K., L. A. Brannon, C. W. Shanklin, K. R. Roberts, A. D. Howells, and E. B. Barrett. 2009. Foodservice employees benefit from interventions targeting barriers to food safety. *J. Am. Diet. Assoc.* 109:1576–1581.
121. Zock, J. P. 2005. World at work: cleaners. *Occup. Environ. Med.* 62:581–584.