EXECUTIVE SUMMARY

THE EFFECT OF A WATER FLOW TIMER ON FOODSERVICE FOOD HANDLERS' HANDWASHING BEHAVIOR

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1. INTRODUCTION

Importance of proper handwashing

- Poor personal hygiene is one of five risk factors contributing to foodborne illness in foodservice and retail food stores, and thus proper handwashing is critical (FDA, 2010, 2017; Green et al., 2006, 2007).
- However, compliance with proper handwashing is still problematic (e.g., only 24% in full service restaurants; FDA, 2010).

Passive/indirect intervention strategies for behavioral change

- Mounting evidence suggests that classical education strategies of knowledge transfer are not sufficient to drive behavioral change (Evans & McCormack, 2008; Schroeder et al., 2016).
- Instead, *active/direct* interventions involving motivational or behavior-based training (Pellegrino, Crandall, O'Bryan, & Seo, 2015; Yu, Neal, Dawson, & Madera, 2017) are gaining interest and found effective in improving hand hygiene practices.
- In comparison, *passive/indirect* interventions with only a subtle change in the environment or system (FDA, 2010; Green et al., 2007; Pellegrino et al., 2015; Viator, Blitstein, Brophy, & Fraser, 2015) may also help behavioral changes with less time/cost commitment and fewer financial obligations for restaurant operations.

Water flow timer

- Sufficient duration (≥ 20 sec; ServSafe®) is an important component in proper handwashing to reduce the number of microorganisms on hands (CDC, 2015).

- The presence of a water flow timer may lead food handlers to be more involved in a proper handwashing duration by providing immediate, continuous, real-time, and personalized feedback.

1.1. Purpose of the study

The purpose of this study was to address whether:

(1) the presence of a water flow timer improves foodservice food handlers' handwashing behavior;

(2) the presence of a water flow timer in conjunction with an informational poster facilitates the effect; and

(3) the effects are affected by high consumer volume.

2. METHODS

Site Selection and Sample

- A student-operated *a la carte* restaurant on a large Midwestern university campus was the site of the experiment.
- The intervention hand sink was centrally located within the kitchen and was most frequently used.
- Sample included sophomore and senior hospitality students (n = 70) and non-student employees (n = 9), more than 90% of whom were certified with ServSafe® Food Protection Manager Examination.

Design/Instruments/Data Collection

- A within-group, multiple-intervention experiment was conducted over the course of four weeks from September 12th to October 6th, 2017.

- Multiple-intervention included:
  - Week 1) baseline phase;
  - Week 2) a single intervention phase using a water flow timer (SaniTimer®);
  - Week 3) multiple intervention phase using the water flow timer and an informational poster (developed based on ServSafe®); and
  - Week 4) withdrawal phase.
- The water flow timer was attached to a faucet and had a digital display face approximately 2" in diameter, which enabled food handlers to observe a thirty second countdown on a display that begins when the water starts flowing and continues until thirty seconds have passed.
- The informational poster highlighted proper five-step handwashing procedures and the minimum duration of scrubbing with soap as well as total five steps.
- Data were collected from Tuesday to Friday, 7:30am to 2:30pm, using a small motion-detecting video camera (AUKEY DR-01 Dash Cam) that included a date and time stamp for recordings.
- The motion-detecting video camera was installed on the top of a sink with the lens directed at the faucet only, thereby capturing handwashing instances without person-identifiable information.

Behavioral measures

- **Quantitative**
  - Frequency of handwashing instances
  - Overall duration of handwashing instances

- **Qualitative**
  - Compliance to proper scrubbing duration (≥ 10 sec or not)
  - Compliance to proper five-step handwashing sequence (wetting, soaping, scrubbing, washing, and drying)
  - Compliance to complete proper handwashing (meeting both proper scrubbing duration and five-step handwashing sequence or not)

3. RESULTS

- A total of 839 handwashing instances were observed over 112 hours (see Table 1 for detailed frequencies and descriptive statistics of all measures).
- The analysis of variance (ANOVA) results showed that frequency of handwashing instances did not significantly vary across the weeks (p = .43).
- The ANOVA results showed that, despite the highest consumer traffic, duration of handwashing instances significantly increased in week 2 over week 1 (14.9 sec vs. 11.6 sec; p = .002) and significantly dropped in week 4 in comparison to week 3 (12.8 sec vs. 15.7 sec; p = .02).
- Although not definitive, the logistic regression results suggested that the compliance rates for proper scrubbing duration (p = .095) and complete proper handwashing varied across the weeks (p = .071; i.e., higher percentages in week 2 and week 3 than in week 1 and week 4), and that the compliance rate for following the proper five-step sequence increased in week 2 over week 1 (49.1% vs. 40.7%; p = .076) despite the high consumer volumes in week 2 and week 3.

- Point-biserial correlation results showed that increased handwashing duration was positively associated with proper scrubbing duration (r_{pb} = .51, p < .001), proper sequence (r_{pb} = .41, p < .001), and complete proper handwashing (r_{pb} = .45, p < .001).

Table 1. Handwashing behavioral measures and consumer volume

Week	**Frequency$^{ns.}$**	**Duration*****	**Proper scrubbing duration†**	**Proper sequence$^{ns.}$**	**Complete proper handwashing†**	**Consumer volume**
1	204	11.6	8.3%	40.7%	6.4%	152
2	234	14.9	12.0%	49.1%	10.7%	244
3	186	15.7	11.3%	39.8%	8.1%	187
4	215	12.8	5.6%	46.0%	4.2%	158

Notes. Week 1. Baseline; Week 2. Timer; Week 3. Timer + Poster; Week 4. Withdrawal.
Duration is in seconds.
Complete proper handwashing indicates compliance to both proper sequence and scrubbing.
In the consumer volume, one day of the week 2 included special banquet for 100 consumers, greater than an average daily volume.
Superscripts indicate the significance testing across four weeks.
$^{***}p < .001$. $^{\dagger}p < .1$. $^{ns}p \geq .1$.

4. CONCLUSION

- This study provided reliable and quantifiable data about food handlers' handwashing practices.
- Findings provided useful information about whether *passive/indirect* intervention strategies in handwashing practices such as the mere presence of a water flow timer are effective in driving behavioral changes of food handlers.
- If coupled with an *active/direct* training for providing the rationale, the effect of the *passive/indirect* intervention in its constant reinforcement may become even stronger.

NOTES

1. This report is an executive summary of a manuscript in preparation for journal submission.
2. The authors acknowledge the support provided by SaniTimer®.

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Research Paper

Quantifying the Effects of Water Temperature, Soap Volume, Lather Time, and Antimicrobial Soap as Variables in the Removal of *Escherichia coli* ATCC 11229 from Hands

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ABSTRACT

The literature on hand washing, while extensive, often contains conflicting data, and key variables are only superficially studied or not studied at all. Some hand washing recommendations are made without scientific support, and agreement between recommendations is limited. The influence of key variables such as soap volume, lather time, water temperature, and product formulation on hand washing efficacy was investigated in the present study. Baseline conditions were 1 mL of a bland (nonantimicrobial) soap, a 5-s lather time, and 38°C (100°F) water temperature. A nonpathogenic strain of *Escherichia coli* (ATCC 11229) was the challenge microorganism. Twenty volunteers (10 men and 10 women) participated in the study, and each test condition had 20 replicates. An antimicrobial soap formulation (1% chloroxylenol) was not significantly more effective than the bland soap for removing *E. coli* under a variety of test conditions. Overall, the mean reduction was 1.94 log CFU (range, 1.83 to 2.10 log CFU) with the antimicrobial soap and 2.22 log CFU (range, 1.91 to 2.54 log CFU) with the bland soap. Overall, lather time significantly influenced efficacy in one scenario, in which a 0.5-log greater reduction was observed after 20 s with bland soap compared with the baseline wash ($P = 0.020$). Water temperature as high as 38°C (100°F) and as low as 15°C (60°F) did not have a significant effect on the reduction of bacteria during hand washing; however, the energy usage differed between these temperatures. No significant differences were observed in mean log reductions experienced by men and women (both 2.08 log CFU; $P = 0.988$). A large part of the variability in the data was associated with the behaviors of the volunteers. Understanding what behaviors and human factors most influence hand washing may help researchers find techniques to optimize the effectiveness of hand washing.

Key words: Antimicrobial soap; Chloroxylenol; Hand hygiene; Hand washing; Soap volume; Water temperature

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The U.S. Food and Drug Administration (FDA) Food Code *(70)* includes recommendations regarding hand washing frequency, duration, and technique; however, the scientific support for many of those recommendations is not always clear nor based on recent evidence. Section 2-301.12 of the Food Code requires the use of a "cleaning compound" (soap) during hand washing. The type of compound is not specified, and facilities may elect to use either bland (soap without an antimicrobial agent) or antimicrobial soap.

Recently, the FDA Center for Drug Evaluation and Research *(71)* issued a final rule establishing that over-the-counter consumer antiseptic washes (soaps) with specific active ingredients may not be marketed in the United States after 6 September 2017. The FDA indicated that the companies that produce these antimicrobial soaps have not provided sufficient evidence to prove that they are safe for daily use and are more effective than bland soap and water. This final rule covers 19 specific active ingredients, including triclosan. However, the FDA has deferred the rule for three ingredients: benzalkonium chloride, benzethonium chloride, and chloroxylenol. This rule does not extend to hand sanitizers or antiseptic wipes and does not address antimicrobial soap sold for use in food service or food processing facilities.

The active ingredients used in antimicrobial soaps disrupt bacterial cell function by either destroying the cell (bactericidal) or inhibiting reproduction (bacteriostatic). These compounds are antiseptics and are not considered antibiotics *(17, 60)*. The literature suggests that antimicrobial soaps provide a greater reduction in bacteria than do bland soaps *(25, 28, 30, 53, 62, 65)*. However, in some studies minimal differences were found *(15, 50, 67)*. A hand soap meta-analysis revealed that use of antimicrobial soaps, when accounting for all types of bacteria and formulations, tended to result in ~0.5-log greater reduction in microorganisms than did use of bland soap *(53)*. Product formulation plays a key role in the effectiveness of antimicrobial agents and soaps, and many active antimicrobial compounds are available for use in soaps, and surfactants in addition to

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other ingredients in soaps or lotions can impede or enhance the activity of these compounds and the overall antimicrobial effect *(14, 26, 69)*.

The combined literature on soap volume (i.e., the dose or amount used per hand washing event) indicates no significant interactions between soap volume and the effectiveness of the soap *(28, 43, 53)*. These data can be confusing and often conflicting when many brands and formulations are compared. Fuls et al. *(28)* found that higher amounts of foaming 0.46% triclosan antimicrobial soap (1.5 to 3 g or two to four pumps of soap) increased the reduction of microorganisms by ~0.7 log units ($P < 0.001$) but did not observe a significant increase in microbial reduction when using a bland soap ($P = 0.2$). Larson et al. *(43)* found that a control wash with bland soap was not significantly affected by the amount of soap used (1 versus 3 mL). However, these researchers also suggested that a higher volume of soap could contribute to skin damage and suggested that the minimal amount of soap required for a thorough wash should be used to reduce the likelihood of skin damage.

The temperature of the wash water required for effective hand washing has not been extensively evaluated and still generates interest. Wash water temperatures have an upper limit; very high temperatures that would rapidly destroy bacterial cells would also severely injure human skin *(42, 68)*. The temperature of the water used during comfortable hand washing would not by itself inactivate resident microbes. Higher temperatures may still affect hand washing by increasing solvation or temperature dependent reaction rates. Boyce and Pittet *(17)* recommended avoiding use of hot water to wash hands because repeated exposure to hot water may increase the risk of dermatitis (damaged skin). Temperatures higher than 55°C can lead to scalding, and the recommended water temperature for human skin comfort is ≤43°C *(42, 68)*. Results of a hand washing survey revealed that hand comfort and personal beliefs played key roles when persons choose the water temperature for hand washing *(19)*. In two studies, Michaels et al. *(49, 50)* found no difference in microbial reductions after hand washing performed at various temperatures (4.4 to 48.9°C). However, the data in these two studies were obtained from only four volunteers, and only one study *(50)* included an antibacterial soap. Courtenay et al. *(21)* measured the differences in microbial reduction between a ServSafe recommended wash (which includes soap), a cool rinse, and a warm rinse. Only minor differences in microbial reduction were found between the cool rinse (26°C) and the warm rinse (40°C), but the interaction between temperature and soap could not be inferred from these data. In a study of various ways to sample bacteria from hands, no significant difference in bacteria recovered was found for sampling solutions at 6 or 23°C *(45)*. Although in all of these studies the temperature of the wash water had no significant antimicrobial effect, the limited replicates *(21, 49, 50)*, comparisons of a wash without soap *(21)*, and lack of actual hand washing *(45)* indicate that more work on the effect of wash water temperature is needed.

The Food Code (section 2-301.12-B-3) *(70)* requires lathering for 10 to 15 s during hand washing. Although specific studies of lather time as a variable have been published, the added friction (from a brush) has been evaluated *(46, 59)* with different results. Price *(59)* found greater microbial reduction with more scrubbing (constant and time dependent), but Loeb et al. *(46)* found no difference in microbial reduction between hand washing with or without a brush. A meta-analysis of the hand washing literature suggested that more studies are needed to understand the importance of wash duration *(53)*. However, many researches who have studied total wash time have suggested that longer wash times are correlated with greater microbial reductions *(25, 28, 34, 47, 55)*. However, results of some studies surprisingly suggest that extended wash times, i.e., >30 s, may result in less effective reduction of transmissible microbes, which would diminish the intended purpose of hand washing *(40, 50, 53)*. One research group hypothesized that extended washing (>30 s) loosens but does not remove resident flora from hands, and these loosened microbes are now more easily transferred to other surfaces, resulting in a reduced overall benefit from removing microorganisms from hands *(50)*. Extended washes and frequent washing can lead to damaged skin *(4, 27, 29, 37–39, 57, 63, 66, 73, 74, 77)*, which promotes colonization by more dangerous microbes and reduces the ability of hand washing to remove bacteria from the (damaged) skin *(40, 42, 44)*. Bidawid et al. *(16)* observed that when finger pads inoculated with hepatitis A virus were rinsed with 15 mL of water, no transfer of virus to lettuce pieces was detected, but when fingers were rinsed with only 1 mL of water, a 0.3% transfer was detected, suggesting that exposure to a greater volume of water may play a key role in hand washing. These conflicting results indicate that more research is needed to determine which hand washing step(s) can be lengthened to increase microbial reduction.

The literature on hand washing includes a tremendous amount of misinformation, and data on many issues are missing. Many hand washing recommendations are being made without scientific backing, and agreement among these recommendations is limited, as indicated by the major inconsistencies among hand washing signs *(35)*. The goal of the present study was to close knowledge gaps in the hand washing literature pertaining to soap volume, water temperature, and lather time. The findings from this work will contribute to valid, evidence-based, helpful decisions concerning personal hygiene policies and practices.

MATERIALS AND METHODS

Volunteers. Twenty-one volunteers were selected from Rutgers University (New Brunswick, NJ) and surrounding communities. Approval from the Rutgers Institutional Review Board was obtained via the standard process before volunteers were enrolled in this study. Volunteers were asked to refrain from using any type of antimicrobial hand soap and non–alcohol-based hand sanitizers for the duration of the study to avoid buildup of active antimicrobial ingredients on the skin, which could have interfered with the results *(2, 12, 28, 54, 56, 64)*. Exclusion criteria included taking antibiotics or being ill during the 6 weeks before the start of the experiment, cuts or abrasions on the hands, self-identification as immunocompromised, or self-identification of discomfort with the experiment and a desire to be removed. One volunteer asked to be removed and did not complete the study. The remaining volunteers (ages 24.5 ± 3.9 years [mean ± SD]) included 10 men (ages 26 ± 2.2 years) and 10 women (ages 23 ± 4.7 years).

Questionnaire. Volunteers were asked to fill out a questionnaire before participation in the experiments. The questionnaire included questions that may account for external variables that could affect skin quality and skin bacterial profiles. The answers were used to parse the volunteers into groups to evaluate whether log reduction data differed significantly between the groups. The demographic variables analyzed were age, sex, moisturizer use, facial cleanser use, medication use, hand washing frequency, recent illnesses, and lotion use.

Experimental design. Four variables (lather time, soap volume, water temperature, and product formulation) were evaluated using a fractional design. One set of conditions (5 s of lather time, 38°C water temperature, and 1 mL of product volume) served as the baseline, and the effect of each variable was studied while holding the other two variables constant. Each unique set of conditions was replicated 20 times such that the total number of experiments was 20 baseline + (3 × 20 lather time) + (2 × 20 water temperature) + (2 × 20 product volume) = 160 hand washes. The entire design was repeated for bland soap and antimicrobial soap containing chloroxylenol, for a total of 320 hand washes. Each volunteer completed 16 hand washes. The target variables to be tested were randomly selected for each experiment. A volunteer performed only one wash per day until there were no more of the 16 sets for a volunteer to perform.

Lather time. Lather times of 5, 10, 20, and 40 s were evaluated. Lather time was defined as the length of time the volunteer lathered soap on their hands (by rubbing hands together) during a hand wash. Lather time did not include initial hand wetting (<1 s), soap application, hand rinsing (held constant at 10 s), or hand drying. Volunteers were instructed to lather their hands in a way that felt most comfortable.

Water temperature. Water temperatures of 38, 26, and 15°C (100, 80, and 60°F, respectively) were evaluated, and the water temperature was verified using a Thermapen with ±0.4°C accuracy (ThermoWorks, Lindon, UT). The temperature of the water was set prior to volunteer arrival and needed to be within ±2°F at the target temperature for at least 60 s. The highest temperature used (38°C) was selected because the FDA Food Code (section 5-202.12) *(70)* indicates that a hand washing sink shall be equipped to provide water at a temperature of at least 38°C. The lowest temperature used (15°C) was deliverable by the existing plumbing and judged by the authors to be the lowest tolerable temperature for comfort.

Estimation of energy consumption. The energy consumption related to heating the water for hand washing was calculated with the following thermodynamic formula:

$$Q = M \cdot C_p \cdot dT/\eta$$

where Q is the amount of heat (kJ); M is mass (kg), representing the amount of water used for a hand wash where a flow of 1 gal (3.8 L) per minute is considered the average water flow with an aerator *(1)* and 10 s is assumed as the rinse time; C_p is the specific heat of water (kJ/kg K) at 4.19; dT is the temperature difference between the heated and ambient water, where an average temperature of 10°C was assumed as the normal temperature for cold tap water and calculations were made for all three temperatures (38, 26, and 15°C); and η is the efficiency of the electric water heater, with an average efficiency of 0.92 based on guidance from the U.S. Office of Energy Efficiency and Renewable Energy *(72)*.

Soap volume. Three volumes of soap were evaluated: 0.5, 1.0, and 2.0 mL. An automatic dispenser (GOJO Industries, Inc., Akron, OH) with a 0.5-mL output was used to dispense the soap. The dispenser was nondescript, had no timer, and did not reveal the formulation being used. This soap dispenser was validated before use each day by catching an aliquot of the foam solution from the dispenser and measuring this aliquot with a scale (Ohaus Scout Pro, Parsippany, NJ). This aliquot was compared with a 0.5-mL volume of the soap that was not converted to foam.

Soap product formulation. Two foaming soap formulations were used for all experiments, one bland soap (i.e., no antimicrobial active ingredients) and one antibacterial soap containing 1.0% chloroxylenol. Both soaps are commercially available (GOJO Industries) and used commonly in a variety of settings, including food service. The soaps were typical in formulation except for the antimicrobial agent and primarily contained a blend of amphoteric and anionic surfactants to remove soils, preservatives, and skin conditioners to soften the skin and balance the effects of the cleansing agents, which can be drying and irritating to the skin. Both soaps were slightly acidic; the pH was 5.2 for the bland soap and 5.5 for the antibacterial soap.

Prewash procedure. Volunteers performed a prewash before beginning the experiment. They were invited into the laboratory and shown the location of the sink but were not given any directions other than to simply wash their hands. No direction was given on how to wash hands or how long to wash. The researcher used a stop watch to discretely measure the amount of soap used, when the hands first touched the water, lather time, rinse time, and total wash time. Volunteers were given paper towels, one at a time, to dry their hands after washing and were given as many towels as requested.

Challenge bacteria. A nonpathogenic strain of *Escherichia coli* (ATCC 11229) served as the challenge bacterium for this experiment. Use of this strain is in accordance with current ASTM International hand washing protocols *(8, 10)*. This strain is a well-established surrogate for transient bacteria transferred to hands during handling of raw foods. Cultures were made followed ASTM method E2946 *(10)*. The *E. coli* was cultured in 10 mL of soybean-casein digest broth for 24 ± 4 h at 35 ± 2°C. This 24-h culture was harvested by centrifugation (Micro 12, Thermo Fisher Scientific, Waltham, MA) at 7,000 × *g* for 10 min and then washed in phosphate-buffered saline (PBS; 0.1 M, pH 7.2). The wash process was repeated three times, and cell pellets were resuspended in PBS to form a challenge suspension of ~8 log CFU/mL.

Hand contamination. One milliliter of the *E. coli* challenge suspension was added to each volunteer's hands. Volunteers were instructed to rub their hands together (10 to 20 s) to cover all surfaces of their hands. Hands were held parallel to the floor to avoid unnecessary contamination of the forearms or elbows. The hands were allowed to dry until they did not appear visibly moist (~40 to 60 s). A sample was collected from the nondominant hand

TABLE 1. *Mean, median, and range of log reductions of microorganisms after various hand washing treatments*

		Microbial reduction (log CFU)					
Treatment[a]	Soap formulation	Mean	SD	Median	Maximum	Minimum	Range
All data	Antimicrobial	1.94	0.78	1.92	4.42	0.06	4.36
	Bland	2.22	0.74	2.22	4.40	−0.04	4.44
Baseline	Antimicrobial	1.92	0.68	1.87	3.13	0.69	2.44
	Bland	1.91	0.64	1.76	2.99	0.82	2.17
Lather time, 10 s	Antimicrobial	2.03	0.64	2.00	3.30	0.89	2.41
	Bland	2.16	0.74	2.22	3.60	1.03	2.58
Lather time, 20 s	Antimicrobial	1.95	1.00	1.82	4.39	0.35	4.03
	Bland	2.54	0.62	2.48	3.75	1.63	2.12
Lather time, 40 s	Antimicrobial	1.91	0.98	2.00	3.47	0.13	3.34
	Bland	2.43	0.71	2.25	4.09	1.57	2.52
Water temp, 15°C	Antimicrobial	1.88	0.62	1.91	3.34	0.76	2.57
	Bland	2.34	0.54	2.33	3.22	1.08	2.15
Water temp, 26°C	Antimicrobial	1.90	0.89	1.77	4.42	0.28	4.14
	Bland	1.98	0.71	1.99	3.07	0.80	2.27
Soap vol, 0.5 mL	Antimicrobial	2.10	0.77	2.18	3.24	0.06	3.18
	Bland	2.25	0.86	2.25	4.03	−0.04	4.07
Soap vol, 2.0 mL	Antimicrobial	1.83	0.65	1.81	3.34	0.64	2.69
	Bland	2.15	0.93	1.97	4.40	0.70	3.70

[a] Baseline treatment was 5-s lather time, 38°C water temperature, and 1-mL soap volume. Other treatments were identical to baseline except as noted. Sample size was 160 for the "all data" category, i.e., $n = 20$ per treatment.

before the hand wash, and that sample was used to calculate the prewash bacterial level.

Bacteria recovery procedure. A modification of the glove juice procedure *(9, 11)* was used to recover bacteria from volunteers' hands. A nitrile glove (powder-free nitrile examination gloves, Thermo Fisher Scientific) filled with 20 mL of PBS was placed over each hand, and the gloved hand was massaged for 60 s to dislodge the bacteria. The glove was then carefully removed, and the rinsate was poured into a collection tube (Falcon 50 mL Conical Centrifuge Tubes, Corning, Inc., Corning, NY). Tween 80 (10%) was used as a neutralizer in the sampling buffers for the antimicrobial soap experiments *(7)*. Neutralization of the antimicrobial agent was confirmed using ASTM method E1054-08, section 9 (neutralization assay with recovery in liquid medium) *(6)*.

Sample dilution and plating. PBS (pH 7.2 ± 0.1) was used for serial dilutions and contained the neutralizer when necessary. Samples were plated onto MacConkey agar (BBL, BD, Sparks, MD), and the CFUs were enumerated after incubating for 24 h at 35°C. The medium contained 4-methylumbelliferyl-β-D-glucuronide (Sigma-Aldrich, St. Louis, MO) to allow identification of *E. coli* without affecting colony morphology or viability *(52)*.

Hand washing. Volunteer hand washing experiments were focused on the four variables: lather time, water temperature, soap volume, and soap formulation. Volunteers were given additional instructions as to how much soap to use (number of pumps), when to wet their hands, when to stop lathering, and when to stop rinsing. Volunteers were not told what formulation they were using or the water temperature. Volunteers did not dry their hands to avoid removal of bacteria with the paper towel *(20, 32–34, 75)*.

Postwash sampling. Samples were collected from volunteers' hands immediately after the wash (<5 s). Both hands were sampled using the modified glove juice method *(9, 11)*, and these samples were used to calculate the postwash bacterial levels.

Postexperiment decontamination protocol. Before leaving the testing area, volunteers washed their hands under running water for 20 s using bland soap and dried their hands with paper towels. One pump of alcohol-based hand sanitizer (Purell, GOJO Industries) was then applied to the volunteers' hands, and volunteers were asked to rub their hands together until the sanitizer was completely dry. The volunteers were then asked to leave the testing area.

Data analysis. Microbial reduction data gathered from the experiment were log transformed to achieve a normal distribution *(61)*. The log reduction was determined by taking the logarithm of the prewash bacterial level on the nondominant hand (multiplied by 2 to estimate the level on both hands) and subtracting from that the logarithm of the sum of the postwash level on both hands.

A repeated-measures analysis of variance (ANOVA) and Tukey's range test and honest significant difference (HSD) test (Prism, GraphPad Software, La Jolla, CA) were used to determine whether multiple means were significantly different and whether any significant interactions existed between the variables. Differences were considered significant at $P < 0.05$. For scenarios in which only two variables were being compared, including when comparing groups from the questionnaires, a two-tailed t test was used to calculate P values (Excel, Microsoft, Redmond, WA) to determine whether significant differences existed between samples.

RESULTS

Table 1 shows the overall log reductions for all treatment conditions tested and the mean log reductions overall for the antimicrobial soap containing chloroxylenol and the bland soap. Overall, the antimicrobial soap produced a mean (SD) 1.94 (0.78)-log CFU reduction in microbial levels (range, 1.83 to 2.10 log CFU). The bland soap produced a mean (SD) 2.22 (0.74)-log CFU reduction

TABLE 2. *ANOVA of scenarios and volunteers*

Variable	Soap formulation	SD	Degrees of freedom	Mean square
Between volunteers	Antimicrobial	0.9985	7	0.1426
	Bland	6.465	7	0.9235
Between scenarios	Antimicrobial	27.37	19	1.441
	Bland	26.2	19	1.379
Residual	Antimicrobial	68.08	133	0.5119
	Bland	54.5	133	0.4098
Total	Antimicrobial	96.45	159	
	Bland	87.17	159	

(range, 1.91 to 2.54 log CFU). The analysis revealed a significant effect for soap formulation ($P = 0.00025$).

An ANOVA was performed to observe differences within the data sets and between volunteers (Table 2). The analysis revealed a significant difference between volunteers ($P < 0.0001$) (person-to-person variability factors). The post hoc Tukey HSD test on the individual volunteer's mean log reduction data revealed significant differences ($P < 0.05$, data not shown). Multiple mean log reduction differences $\geq$0.5 log CFU were found between the volunteers, which suggests that a large part of the variability in the data sets were due to variability between the volunteers. A subsequent Tukey HSD test was performed to determine differences between the individual scenarios (Table 3) to make sure that differences between scenarios were not overlooked when the two groups were combined. The analysis included lather time, water temperature, and soap volume as independent variables; the data were separated by soap formulation. For the bland soap, significant differences were found for lather time ($P = 0.01$). A post hoc HSD test revealed that the bacterial reductions with the 20-s lather time were significantly different from those achieved with the baseline lather time of 5 s ($P = 0.01$) but were significantly different from reductions achieved with the 10- and 40-s lather times. For bland soap, no significant effects on bacterial reduction were found for soap volume ($P = 0.23$) and water temperature ($P = 0.08$). For the antimicrobial soap, no significant effects on bacterial reduction were found for lather time ($P = 0.85$), water temperature ($P = 0.97$), and soap volume ($P = 0.22$). However, for the antimicrobial soap data, the P values were higher for lather time and water temperature (lather time, $P = 0.85$; temperature, $P = 0.97$) than for the bland soap data (lather time, $P = 0.01$; temperature, $P = 0.08$).

Higher water temperature entails greater energy consumption (see Fig. 1). The energy consumption associated with heating water for 1,000 hand washes is 22.35 kWh for a water temperature of 38°C but only 12.77 kWh for a water temperature of 26°C, which is a reduction of 42%. The

TABLE 3. *Tukey multiple comparison test results for antimicrobial and bland soap*

Comparison	Antimicrobial			Bland[a]		
	Mean difference	q	95% CI	Mean difference	q	95% CI
Baseline vs lather 10 s	−0.110	0.687	−0.8079 to 0.5880	−0.244	1.708	−0.8689 to 0.3800
Baseline vs lather 20 s	−0.030	0.188	−0.7280 to 0.6679	−0.628*	4.384*	−1.252 to −0.003004*
Baseline vs lather 40 s	0.010	0.064	−0.6877 to 0.7082	−0.521	3.641	−1.146 to 0.1034
Baseline vs temp 15°C	0.033	0.207	−0.6648 to 0.7311	−0.427	2.982	−1.051 to 0.1977
Baseline vs temp 26°C	0.011	0.072	−0.6865 to 0.7094	−0.071	0.497	−0.6956 to 0.5533
Baseline vs vol 0.5 mL	−0.182	1.134	−0.8794 to 0.5165	−0.339	2.369	−0.9635 to 0.2854
Baseline vs vol 2 mL	0.083	0.518	−0.6151 to 0.7808	−0.233	1.625	−0.8571 to 0.3918
Lather 10 s vs lather 20 s	0.080	0.500	−0.6180 to 0.7779	−0.383	2.676	−1.008 to 0.2414
Lather 10 s vs lather 40 s	0.120	0.752	−0.5777 to 0.8182	−0.277	1.933	−0.9012 to 0.3478
Lather 10 s vs temp 15°C	0.143	0.895	−0.5548 to 0.8411	−0.182	1.274	−0.8068 to 0.4421
Lather 10 s vs temp 26°C	0.122	0.759	−0.5765 to 0.8194	0.173	1.211	−0.4512 to 0.7977
Lather 10 s vs vol 0.5 mL	−0.072	0.447	−0.7695 to 0.6265	−0.095	0.661	−0.7191 to 0.5299
Lather 10 s vs vol 2 mL	0.193	1.205	−0.5051 to 0.8908	0.012	0.082	−0.6127 to 0.6363
Lather 20 s vs lather 40 s	0.040	0.252	−0.6576 to 0.7383	0.106	0.743	−0.5181 to 0.7308
Lather 20 s vs temp 15°C	0.063	0.395	−0.6347 to 0.7612	0.201	1.402	−0.4238 to 0.8252
Lather 20 s vs temp 26°C	0.042	0.260	−0.6564 to 0.7395	0.556	3.887	−0.06816 to 1.181
Lather 20 s vs vol 0.5 mL	−0.151	0.947	−0.8494 to 0.5465	0.288	2.015	−0.3360 to 0.9129
Lather 20 s vs vol 2 mL	0.113	0.706	−0.5850 to 0.8109	0.395	2.758	−0.2296 to 1.019
Lather 40 s vs temp 15°C	0.023	0.143	−0.6751 to 0.7209	0.094	0.659	−0.5301 to 0.7188
Lather 40 s vs temp 26°C	0.001	0.008	−0.6967 to 0.6992	0.450	3.143	−0.1745 to 1.074
Lather 40 s vs vol 0.5 mL	−0.192	1.199	−0.8897 to 0.5062	0.182	1.272	−0.4424 to 0.8065
Lather 40 s vs vol 2 mL	0.073	0.454	−0.6253 to 0.7706	0.289	2.015	−0.3360 to 0.9129
Temp 15°C vs temp 26°C	−0.022	0.136	−0.7196 to 0.6763	0.356	2.484	−0.2688 to 0.9801
Temp 15°C vs vol 0.5 mL	−0.215	1.342	−0.9126 to 0.4833	0.088	0.613	−0.5367 to 0.7122
Temp 15°C vs vol 2 mL	0.050	0.311	−0.6482 to 0.7477	0.194	1.356	−0.4303 to 0.8186
Temp 26°C vs vol 0.5 mL	−0.193	1.206	−0.8909 to 0.5050	−0.268	1.872	−0.8924 to 0.3566
Temp 26°C vs vol 2 mL	0.071	0.446	−0.6266 to 0.7694	−0.162	1.128	−0.7860 to 0.4630
Vol 0.5 mL vs vol 2 mL	0.264	1.652	−0.4336 to 0.9623	0.106	0.743	−0.5181 to 0.7309

[a] * $P < 0.05$.

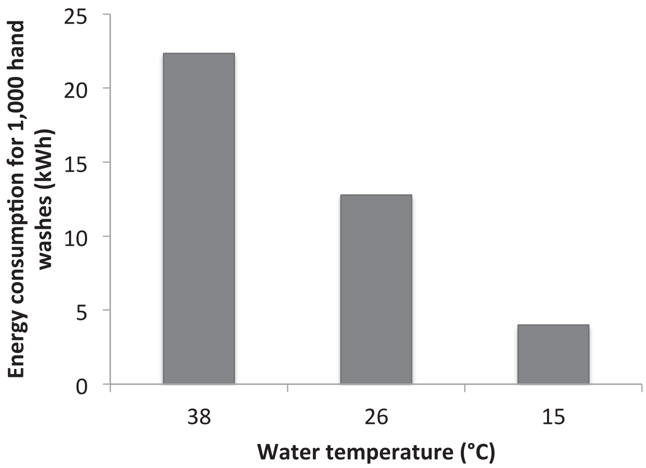

FIGURE 1. *Energy consumption related to water heating for hand washing.*

energy consumption associated with heating water for 1,000 hand washes is only 3.99 kWh for a water temperature of 15°C, which is a reduction of 68% compared with the baseline of 38°C.

Questionnaire results. No significant differences in bacterial reductions were found for volunteers who did versus did not use acne medication ($P = 0.14$) or facial cleanser ($P = 0.62$). Volunteer age also did not have an effect on mean log reductions ($r^2 = 0.009$, $P = 0.09$).

Lotion use. The questionnaire results indicate a significant difference in mean log microbial reduction ($P = 0.02$) for volunteers based on high use of lotion (2.15 log CFU) versus low use of lotion (1.95 log CFU). The difference between volunteers who used lotion and those who did not use lotion was ~0.2 log CFU.

Hand washing frequency. Sixteen volunteers indicated that they typically washed their hands more than four times per day, and four volunteers indicated that they washed their hands fewer than four times per day. The prewash mean total wash time differed significantly between these two groups ($P = 0.012$); the high frequency hand washers washed for an average of 18.2 s, and the low frequency hand washers washed for an average of 15 s. Further analysis revealed that the difference in wash times was due to lather time, not rinse time. No significant difference was found for mean rinse times ($P = 0.714$), but a highly significant difference in mean lather time was found ($P = 0.000022$); frequent hand washers lathered for 6.8 s, and less frequent hand washers lathered for 4.0 s. Washing was significantly more effective for the low frequency hand washers than for the high frequency hand washers ($P = 0.0008$) with an mean log reduction of 2.37 log CFU for low frequency washers and 2.01 log CFU for high frequency washers. This difference was still significant when accounting for formulation (antimicrobial soap, $P = 0.048$; bland soap, $P = 0.0045$). The four low frequency hand washers also reported the highest usage of lotion (more than twice per day), which improved hand washing efficacy.

Men versus women. No significant difference in mean log reductions was found for men (2.08 log CFU) and women (2.08 log CFU) ($P = 0.988$). The P value did not change for the antimicrobial or bland soap. However, a significant improvement in mean log reduction (2.34 log CFU) was found for men who used lotion versus men who did not use lotion (1.90 log CFU) ($P = 0.0003.9$). This same comparison for women was not possible because all of the women volunteers reported using lotion at least once per day (high lotion usage).

Prewash data. Breakdown of the prewash data is shown in Table 4. During the prewash phase, the mean recorded lather time was 6.3 s, the mean rinse time was 11.4 s, and the mean total wash time was 17.7 s. The temperature of the wash water did not change the observed lather ($P = 0.76$), rinse ($P = 0.31$), and overall wash ($P = 0.70$) times. For both men and women, no effect of water temperature on the observed wash times was found, and the respective P values remained roughly the same. Men lathered and rinsed their hands for a longer time (~2 s) than did women (lather time: men = 7.4 s, women = 5.4 s, $P = 0.006$; rinse time: men = 12.3 s, women = 10.5 s, $P = 0.04$), which resulted in a longer overall hand washing times for men ($P = 0.002$). Minimal correlation was found between length of lather time and rinse time ($R^2 = 0.03$) for all volunteers. The mean (SD) volume of soap used was 0.6 (0.25) mL (Fig. 2; approximately one pump of soap) for both men and women. Although the difference between men and women for volume of soap used was not significant ($P = 0.39$), further analysis revealed a significant difference in volume of soap used across all volunteers ($P = 0.000000135$), suggesting that personal behavior dictated choice of soap volume; 71% of volunteers used one pump, 26% used two pumps, 1% used three pumps, and 2% used no pumps of soap. These percentage differences did not noticeably change with water temperature. A volunteer did not change the number of pumps of soap used for each prewash and would routinely use the same amount of soap. A weak correlation (low R^2) was found between total wash time and pumps of soap used ($P = 0.001$, $R^2 = 0.07$), and 43.4% of volunteers used water before applying soap, whereas 56.6% applied soap before using water. For the men, 56.8% used water first and 43.2% used soap first; for the women, 31.1% used water first and 68.9% used soap first.

DISCUSSION

Lather time (length of wash). The 30-s wash (20 s of lathering and 10 s of rinsing) with bland soap produced a significantly different mean log reduction in bacterial counts compared with the baseline 15-s wash. Results of several other studies have indicated that a longer wash time can provide a greater microbial reduction benefit *(25, 28, 34, 47, 55)*. However, these studies involved an overall wash time of <30 s and did not break the wash event into separate parts (lather versus rinse). In a meta-analysis of hand

TABLE 4. *Prewash data*[a]

Group	Total no. of washes	Mean wash time (s) Lather	Rinse	Total	% volunteers using: No soap	One soap pump	Two soap pumps	Three soap pumps	Water first	Soap first
All	198	6.3	11.4	17.7	2.0	70.7	26.3	1.0	43.4	56.6
15°C	31	7.0	10.6	17.6	0.5	11.1	4.0	0.0	6.6	9.1
26°C	47	6.1	12.5	18.6	0.5	16.7	6.1	0.5	9.1	14.7
38°C	120	6.3	11.1	17.4	1.0	42.9	16.2	0.5	27.8	32.8
Men	95	7.4	12.3	19.7	3.0	62.0	29.0	1.0	56.8	43.2
15°C	19	7.6	11.4	19.0	1.0	12.0	6.0	0.0	11.6	8.4
26°C	20	6.2	13.3	19.5	1.0	14.0	5.0	0.0	11.6	9.5
38°C	56	7.8	12.2	19.9	1.0	36.0	18.0	1.0	33.7	25.3
Women	103	5.4	10.5	15.9	1.0	78.0	23.0	1.0	31.1	68.9
15°C	12	6.0	9.3	15.3	0.0	10.0	2.0	0.0	1.9	9.7
26°C	27	6.3	11.9	18.0	0.0	19.0	7.0	1.0	6.8	19.4
38°C	64	4.9	10.2	15.1	1.0	49.0	14.0	0.0	22.3	39.8

[a] Percentages are of 198 washes for the "all" group, 95 washes for the men, and 103 washes for the women. Some of the prewash data were compromised (equipment malfunction), resulting in a different number of prewashes for men and women. Each pump of soap provided 0.5 mL of foaming product.

washing, 120-s washes resulted in a lower log reduction than did 30-s washes *(53),* suggesting that wash times >30 s may not be more effective. These results are consistent with our findings and suggest that microbial reduction will not increase significantly beyond 10- to 20-s lather times. One hypothesis to explain this finding is that microbes that are easier to remove are lifted from the hands by the wash in <30 s; however, microbes that are embedded in deeper layers or pores or are biochemically attached to skin will not be removed regardless of longer hand washing time.

Water temperature. In our study, no significant difference in washing effectiveness was found at different temperatures (15 to 38°C). This finding agrees with those of Michaels et al. *(49, 50),* who tested a wider range of water temperatures (4.4 to 48.9°C) but found mean microbial reductions of ~2 to 2.5 log CFU, very similar to our mean reductions of 1.9 to 2.3 log CFU. Courtenay et al. *(21)* found a small but significant difference (94 versus 99%; $P < 0.05$) in microbial reduction between a cool rinse (26°C) and a warm rinse (40°C), but because none of these experimental washes included the use of soap, the relevance to a hand washing following the recommendation of the FDA Food Code *(70)* is unclear. Because Courtenay et al. studied hands inoculated with a ground beef matrix, the saturated fats in the meat may have been more easily removed at warmer water temperatures. Warmer water does not enhance antimicrobial activity but have a negative environmental impact (i.e., energy consumption); therefore, policy requirements for warm water hand washing (e.g., the Food Code) should be reconsidered.

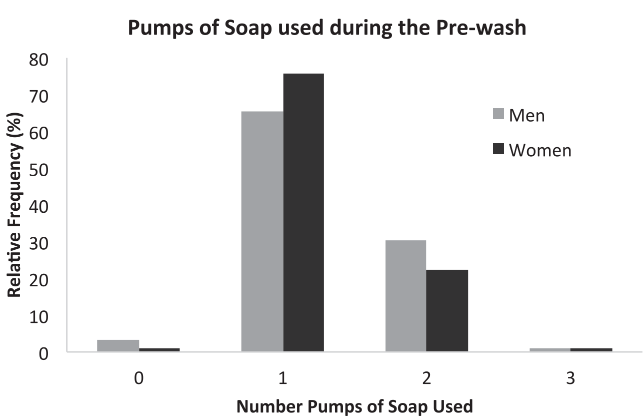

FIGURE 2. *Number of pumps of soap used by women (solid) and men (shaded) during the prewash. Each pump delivered 0.5 mL of soap.*

Volume of soap. No significant difference for volume of soap used was found for either kind of soap (bland soap, $P = 0.48$; antimicrobial soap, $P = 0.41$). Both Fuls et al. *(28)* and Larson et al. *(43)* found no significant increase in microbial reduction when using bland soap. However, in contrast to our findings, Fuls et al. and Larson et al. did find that increasing the volume of the antimicrobial soap increased the log reductions. Both sets of authors suggested increased exposure to more antimicrobial agent as the explanation for increased microbial reduction. The difference in mean log reductions for a higher volume of antimicrobial soap may be due to the types of active agents being tested because formulation effects efficacy *(14, 69).* We used a 1% chloroxylenol antimicrobial soap, Larson et al. used a 4% chlorhexidine gluconate antimicrobial soap, and Fuls et al. used a 0.46% triclosan antimicrobial soap. The minimum volume of soap needed should also consider the soil removal required by the users, which is also likely to be significantly affected by soap formulation (especially surfactant choices).

Antibacterial and bland soaps. A significant difference in microbial reduction was found between soap formulations ($P = 0.0003$). However, the difference in mean log reductions between the antimicrobial and bland soap (Table 1) was only ~0.3 log CFU, which is within the range of error for microbiology data (i.e., a clinically insignificant difference). In several studies, greater microbial reductions were achieved with antimicrobial soaps than with bland soaps *(25, 28, 30, 62, 65),* and the effectiveness of antimicrobial soaps increased with repeated use by building up the antimicrobial agent on the skin *(2, 12, 28, 54, 56).* This effect can also be seen with hand sanitizers made with antimicrobial agents that remain on the skin *(64),* unlike those made with alcohol, which is not readily absorbed *(13, 18).* Given the FDA 1-year extension for soaps containing chloroxylenol *(71),* future work with the antimicrobial soap used in this study should take into consideration the need for buildup on the skin to improve efficacy and formulation style. In their meta-analysis of hand soaps, Montville and Schaffner *(53)* suggested that overall, accounting for all types of bacteria, antimicrobial soap should have a ~0.5-log greater reduction (mean, 2.4 log CFU) than bland soap (mean, 1.9 log CFU). We did not see a greater difference, but the bland soap data and the antimicrobial soap data both fell within the meta-analysis's range of mean log reductions *(53).* Future studies should take into consideration the surfactant profile of an antimicrobial soap, which can have a significant effect on the results *(14, 69).* We used two formulations that were both commonly used by the public and designed to be mild to the skin and similar in use. Highly efficacious antimicrobial soaps are made by designing the ingredient matrix around the antimicrobial active ingredient to create a formulation that does not inhibit but ideally highly activates the antimicrobial agent *(14, 69).* Future work should take into consideration the variety of antimicrobial soaps available and the various methods for testing these soaps.

Lotion use. Although the mean differences were small (~0.2 log CFU) between lotion users and non–lotion users, lotion use could affect several analyses. Skin damage from frequent hand washing is a well-established phenomenon *(4, 27, 29, 37–39, 57, 63, 66, 73, 74, 77),* and lotion often is used to repair this damaged skin *(5, 41, 48).* Damaged skin is more difficult to wash *(40, 42, 44),* so a slight, yet higher log reduction for the volunteers who indicated regular lotion use is not surprising. Although all women indicated using lotion more than once per day, not all men used lotion regularly (~0.5 log CFU greater mean reduction for men who were lotion users). This study did not provide sufficient evidence to draw a strong conclusion about the effect of lotion use on hand washing. However, the available evidence is enough to warrant more precisely controlled and designed investigations to measure the effect of hand lotion use on hand washing. Use of lotion to improve skin quality *(5, 41, 48)* and reduce pathogen colonization of damaged skin *(40, 42, 44)* would be an advantage to both health care workers and food handlers.

Person-to-person variability. A large part of the variability in the data sets was due to variability between the volunteers (Table 2). This finding is not uncommon for in vivo hand washing research, and large variability in results can be found both within and between hand washing studies *(53).* Microbial reductions >4 log CFU have been consistently reported in hand sanitizer research, with limited variability *(3, 22–24, 31, 36, 51, 58, 76),* suggesting that hand soap and hand sanitizer effectiveness may be more influenced by human behavior and/or physiological hand differences than by the effectiveness of the soap and/or sanitizer, which is not surprising considering the number of steps recommended for proper hand washing *(35).* No published work was discovered that links physiological differences, such as skin moisture levels, skin sensitivity, hair density, scar tissue, and hand size, to hand washing outcomes. How these physiological differences affect microbial loads, reductions, and health risks would be an interesting topic for future hand hygiene research.

Other observations. Similar to our work, Larson et al. *(43)* also recorded the mean amount of soap (mL) used by health care workers. They observed that health care workers used ~ 2.7 mL of soap when attending to high-risk patients, ~2 mL when attending to low-risk patients, and ~1 mL when not attending to patients. Our volunteers, who were not health care workers, used a much smaller amount of soap than did the participants in the study by Larson et al. (mean, 0.6 mL for the prewash; Fig. 2); 65% of men used one pump of soap, and 75% of women used one pump of soap. Larson et al. did not use a foaming soap but rather a liquid soap in a syringe dispenser and asked the volunteers to use an amount of soap they would normally use for hand washing. In our study, soap was released in 0.5-mL increments from a dispenser. Similar to the Larson et al. study *(43),* we found that volunteers used different amounts of soap, and each volunteer routinely used the same amount of soap for each of hand wash, i.e., consistently following their individual habits.

The results of this study indicate that water temperature is not a critical factor for the removal of transient microorganisms from hands. Combining these results with those of other studies of water temperature as a variable *(49, 50),* water temperature does not have a strong effect on hand washing. Therefore, it may be time to remove water temperature recommendations for hand washing from regulations and promote recommendations aimed at skin comfort *(42, 68).* Overall, the length of lather time and volume of soap used did not make a large difference, but a minimum of 0.5 mL of soap and 10 s of lather time is recommended based on our findings. Lotion use by the volunteers had an effect on the results; microbial reduction was greater for volunteers that used lotion regularly. One of the key findings from this study is that variability exists between people in both microbial reduction after hand washing and hand washing behavior. Understanding which behaviors, human factors, and physiological differences influence hand washing the most may allow future studies to focus on which techniques can optimize the effectiveness of hand washing and thereby reduce infection transmission risk and improve food safety.

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Hand Washing Practices in a College Town Environment

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Abstract **Many people do not wash their hands when the behavior in which they engage would warrant it. Most research of hand washing practices to date has taken place in high-traffic environments such as airports and public attraction venues. These studies have established a persistent shortcoming and a gender difference in hand washing compliance. Using field observations of 3,749 people in a college town environment, the research described in this article replicates and extends earlier work while identifying potential environmental and demographic predictors of hand washing compliance. Additionally, the authors' research suggests that proper hand washing practices, as recommended by the Centers for Disease Control and Prevention, are not being practiced. Finally, the authors' research raises a question as to the accuracy of earlier measurements of "proper" hand washing practices, suggesting that compliance rates are inflated. The results can help increase hand washing rates for the general public and thus decrease the risk of transmitting disease.**

Introduction

Many individuals take hand washing for granted and do not consider how essential hand washing is in the prevention of infections and disease. Thus they often fail to wash their hands when they engage in activity that would warrant or require hand washing. Research has established that people generally overstate the degree to which they wash their hands; that women are much more likely to wash their hands than men; and that while hand washing compliance appears to have increased in recent years much room for growth still exists. According to the Centers for Disease Control and Prevention (CDC) (Mead et al., 1999), failing to wash or insufficiently washing hands contributes to almost 50% of all foodborne illness outbreaks. Additionally, Curtis and Cairncross (2003) performed a meta-analysis that suggests that hand washing with soap can reduce diarrheal disease risks by more than 40% and that hand washing interventions could save one million lives annually. Yet we do not know why people fail to wash their hands at recommended rates and in the proper fashion. Our research attempted to establish predictors of hand washing that can be used to induce higher rates of hand washing compliance.

Current Hand Washing Practices

Recent surveys establish that U.S. adults claim to wash their hands after using public restrooms at very high rates. In 2009, 94% (*N* = 2,516) suggested that they consistently wash their hands (QSR Magazine, 2009), while in 2010, 96% (*N* = 1,006) stated that they always wash their hands after using a public restroom (Harris Interactive, 2010). Self-reports of hand washing behavior have been criticized as unreliable as hand washing is a socially desirable activity (Judah, Aunger, Schmidt, Granger, & Curtis, 2009) and observational research suggests these high self-report rates are inflated (Harris Interactive, 2010).

The potential discrepancy aside, it is important to note that hand washing rates have trended upwards in recent years. The American Society for Microbiology and the American Cleaning Institute have studied hand washing practices since 1996. Most recently they reported on hand washing in restrooms at public attractions in five cities across the U.S. The restroom locations included Turner Field in Atlanta, the Museum of Science and Industry and Shedd Aquarium in Chicago, Penn Station and Grand Central Terminal in New York, and the Ferry Terminal Farmers Market in San Francisco (Harris Interactive, 2010). All locations experience high volumes daily, and at the composite level, the 2010 data (*N* = 6,028) establishes that 85% of the observed adults wash their hands after using a public restroom. This is an increase from 77% in 2007 (*N* = 6,076), which was somewhat lower than the 2005 rate of 83% (*N* = 6,336). With the exception of the Shedd Aquarium, which has seen a 3% dip in hand washing rates since 2005, all the venues saw a slight upward trend in observed hand washing rates (Harris Interactive, 2010). In 2003, hand washing rates were also observed across six North American airports, averaging 74% compliance (*N* = 4,046). The highest hand washing rates were obtained in Toronto with 95% while Chicago had the lowest rate at 62% (American Society for Microbiology, 2003).

The research consistently finds a gender bias in hand washing practices. Women wash their hands more frequently than men. In the 2003 study (American Society for Microbiology) it was observed that 83% of women washed their hands after using the restroom, whereas only 74% of the men did so. In a multi-year study across public attractions, women consistently wash more than men across all years and venues (Harris Interactive, 2010). The average observed hand washing rates for women were 93% in 2010, 88% in 2007, and 90% in 2005. The equivalent rates for men were 77%, 66%, and 75%, respectively.

A study of 120 secondary school students (Guinan, McGuckin-Guinan, & Sevareid, 1997) found that 58% of female students and 48% of male students washed their hands after using the restroom, although only 28% of the female students and 8% of the male students used soap. In a university campus public restroom study (Johnson, Sholoscky, Gabello, Ragni, & Ogonosky, 2003), 61% of women and 37% of men (N = 175) were observed washing their hands, while the hand washing rate climbed to 97% for women and fell to 35% of men when a sign was introduced to encourage hand washing. Similarly, in a British 32-day study of highway service station restrooms (N = 198,000) that observed entry and soap use with electronic sensors, it was found that 65% of women and 32% of men washed their hands, but that the hand washing rate increased to as much as 71% for women and 35% for men when messages designed to encourage hand washing were displayed using electronic dot matrix screens (Judah et al., 2009).

A study of the hand washing practices of university students living in a dormitory found that women wash their hands after urinating 69% of the time and after bowel movements 84% of the time, whereas the corresponding figures for males were 43% and 78% (Thumma, Aiello, & Foxman, 2008). In a study of restaurant food workers (Green et al., 2006), food handlers washed their hands only 32% of the time when their behaviors made such hand washing required.

A review of the literature on foodborne disease outbreaks from 1975 to 1998 identified 81 foodborne disease outbreaks involving 14,712 people within which 93% of the foodborne outbreaks involved infected food workers transmitting pathogens to the food with their unwashed hands (Guzewich & Ross, 1999). An observation of 80 women in a bar bathroom (Hayes, 2002) found that only 40% washed their hands; when the researcher engaged the subject and modeled hand washing, the hand washing rate increased to 56%, while it dropped to 27% when the researcher appeared to be simply talking on her cell phone. This research also noted that the female subjects were less likely to wash their hands later in the night than earlier in the evening (r = -.44, p < .01).

It is evident from the reviewed research that room for improvement exists in hand washing practices. Additional research is needed to further understand how and why hand washing rates differ and if such rates can be influenced by environmental factors within the restroom. Gender is associated with marked differences in hand washing rates. Are other demographic variables such as age also associated with hand washing rates? Furthermore, evidence exists that environmental variables such as signage and posters influence hand washing rates and other health-related behaviors (Etter & Laszlo, 2005; Judah et al., 2009). Do other environmental variables, such as sink conditions and type of faucet impact hand washing rates? Does the hand washing rate on campus differ from the rate off campus?

It is unclear from the reviewed literature whether the various reported rates of hand washing reflect hand washing with soap as recommended by the CDC or if the rates incorporate practices somewhat inconsistent with the established recommendations. As such, our study used three measures of hand washing, defined as 1) no washing—leaving the restroom without washing or rinsing hands, 2) attempted washing—wetting hands but not applying soap, and 3) washing hands with soap, in addition to measuring the duration of washing. This added distinction is important because Burton and co-authors (2011) reported that washing with soap and water is more effective at removing fecal bacteria from hands than washing with water alone.

Methods

Participants and Procedures

Direct observations of hand washing behaviors were conducted by 12 research assistants in restrooms located across a college town. Observers were instructed to be unobtrusive and disguise their observation of hand washing behaviors. To ensure this and ensure accurate measurement and coding consistency, each of the observers met researchers individually for training and attended training meetings as a group.

All observations were recorded according to a standard coding form. The coding form consisted of the subject ID, date, subject's age group, observation time, gender, hand washing behaviors, the type and availability of drying mechanisms (i.e., not available, hot air, paper towel, or both), location of restrooms (off campus versus on campus), type of faucet (standard faucet versus motion detection), the cleanliness of sink conditions, and availability of hand washing signage.

Washing behaviors were recorded into three categories: no washing (leaving the restroom without washing or rinsing their hands), attempted hand washing (wetting hands without using soap), and washing hands with soap. Observers also discreetly measured the total length of time in terms of the number of seconds subjects' hands were placed under running water during washing, lathering, and rinsing. The time of observation was collected and nominal time categories were formed for the purpose of analyses. Due to the unobtrusive nature of our observations, the subject's age group was estimated using the trained observers' subjective evaluations and the subject was placed into one of two groups: college age or younger and older than college age. The cleanliness of sink conditions had three categories including dirty, reasonable, and clean, which was also based on the subjective evaluation of observers. The presence of a hand washing sign was added to the coding form later based on observer feedback.

Statistical Analysis

Descriptive data were compiled and further analyzed using Chi-square analysis and ANOVA. Specifically, Chi-square analysis was used to identify statistically significant differences in subjects' demographic variables, environmental variables in the restrooms, and among hand washing behaviors. ANOVA was used to establish mean differences in the length of time hands were placed under running water across the above specified variables. Kappa and paired t-test statistics were calculated, using a subsample (n = 90) to evaluate inter-rater reliability.

Results

Inter-Rater Reliability

Evaluation of inter-rater agreement is an important step in ensuring reliability in observational studies, especially when studies involve multiple observers. We selected four different restrooms (n = 44, located in two off-campus restrooms; and n = 46, located in two on-campus restrooms) to determine the inter-rater reliability among observers. The observers agreed 100% on the environmental variables. For the two dependent variables, the time spent washing time and other washing behaviors, paired-samples t-tests (Fleiss, 1981), and Cohen's Kappa (Cohen, 1960) were used. A Kappa statistic of more than .8, more than .6, and more than .4 is considered to have "almost perfect," "substantial," and "moderate" agreement, respectively (Landis & Koch, 1971). Excellent inter-rater reliability was demonstrated as indicated by nonsignificant paired t-test result in estimating washing time ($p > .01$) and Kappa of .89 in evaluating washing behaviors.

TABLE **1**

Characteristics of Sample and Restroom Settings (*N* = 3,749)

Variables	*n*	%
Observation time		
Morning	538	14.4
Afternoon	2,326	62.0
Evening/night	885	23.6
Gender		
Male	1,479	39.5
Female	2,270	60.5
Age		
College group and younger than college group	2,310	61.6
Older than college group	1,439	38.4
Drying		
Not available	47	1.3
Only paper	2,799	74.7
Only air dryer	331	8.8
Both paper and air dryer	572	15.3
Faucet		
Standard faucet	2,889	77.1
Motion detection	860	22.9
Sink condition		
Dirty	219	5.9
Reasonable	1,779	47.5
Clean	1,750	46.7
Location		
On campus	1,755	46.8
Off campus	1,994	53.2
Sign		
Sign	1,548	63.7
No sign	882	36.3

Characteristics of Sample and Overall Findings

Table 1 presents characteristics of the sample and observation settings. Of the 3,749 subjects observed, approximately 54% of observations took place in restrooms located off campus. Sixty-two percent of observations took place in the afternoon, followed by evening/night (23.6%) and morning (14.4%). Of all subjects, 60.5% of the observed subjects were women. About 62% (61.6%) of the subjects were estimated as college age or younger, with the remainder estimated to be older than college. Nearly all restrooms had a mechanism for drying hands (98.7%). About 64% of the restrooms in the study contained signs encouraging hand washing. Seventy-seven percent of the restrooms were equipped with a standard faucet while 22.9% had motion detection faucets.

Overall, 66.9% of the subjects used soap when washing their hands. Of these, 1.2% did not dry their hands, but left the restrooms with wet hands. About 23% attempted to wash their hands, that is, they wet their hands but did not use soap. A total of 10.3% did not wash their hands *at all* after using the restroom. CDC (2012) recommends that people should rub their soaped hands for 15 to 20 seconds before rinsing thoroughly. Our measure of duration included the length of time placed under running water while subjects were washing, rubbing, and rinsing their hands. Nonetheless, as shown in Table 2, only 5% or so spent more than 15 seconds in combined washing, rubbing, and rinsing of their hands.

Results From Chi-Square Analysis

The Chi-square analysis revealed statistically significant differences in hand washing behaviors across time of observation, gender, age, sink condition, and hand washing signage (Table 3). For example, 12.4% observed during evenings did not wash their hands while the morning and afternoon rates of leaving the restroom without attempting to wash were 8.6% and 9.4%, respectively. Subjects washed their hands significantly more with soap during mornings (70.6%) than during afternoons (66.4%) and evenings (67%). The gender difference was confirmed with women using soap and engaging in proper hand washing behavior significantly more (77.9%) than men (50.3%). About 7% of the women and 14.6% of the men did not wash their hands at all, while 15.1% of the women and 35.1% of the men simply wet their hands with water. Those estimated to be older than college (70.3%) washed their hands with soap significantly more than the college age and younger group (64.8%).

When restrooms contained hand washing signs, subjects used soap more (68.5%) than subjects in restrooms that had no such signs (60.5%). Sink cleanliness influenced hand washing behaviors as well. When sinks were clean, 73.9% washed their hands using soap, while the rate for reasonably clean and dirty sinks was 61.2% and 59.4%, respectively. No

TABLE **2**

Overall Hand Washing Behavior and Length of Hand Washing Time (*N* = 3,749)

Variables	*n*	%
Washing behavior		
Not washing	384	10.3
Wetting hands without soap	856	22.8
Washing hands with soap	2,509	66.9
Length of hand washing time		
0 seconds	384	10.3
1–4 second(s)	824	22.0
5–8 seconds	1,432	38.2
9–14 seconds	911	24.2
15 seconds or longer	198	5.3

TABLE **3**

Chi-Square Test: Comparison of Hand Washing Behavior by Sample Demographics and Restroom Settings (*N* = 3,749)

Variables	Not Washing	Wetting Hands Without Soap	Washing With Soap	χ^2
	10.3% (*n* = 384)	**22.8% (*n* = 856)**	**66.9% (*n* = 2,509)**	
	%	**%**	**%**	
Observation time				13.2*
Morning	8.6	20.8	70.6	
Afternoon	9.4	24.2	66.4	
Evening/night	12.4	20.6	67.0	
Gender				311.3*
Male	14.6	35.1	50.3	
Female	7.1	15.1	77.9	
Age				12.9*
College group and younger than college group	10.6	24.6	64.8	
Older than college group	9.7	20.0	70.3	
Faucet				0.8
Standard faucet	9.8	22.9	67.3	
Motion detection	10.8	23.0	66.2	
Sink condition				91.2*
Dirty	19.6	21.0	59.4	
Reasonable	10.7	28.1	61.2	
Clean	8.1	17.9	73.9	
Location				4.8
On campus	10.3	24.3	65.4	
Off campus	9.7	21.6	68.6	
Sign				17.4*
Sign	9.7	21.7	68.5	
No sign	10.7	28.8	60.5	

*$p < .01$.

statistically significant differences in subjects' hand washing behavior were found across faucet type (standard faucet versus motion detection) or restroom location (on campus versus off campus).

Results From ANOVA

Multi-way ANOVA was conducted to evaluate the mean differences among identified factors in terms that may influence the length of washing time (Table 4). Statistically significant differences were found for gender, age group, type of faucet, sink condition, and hand washing signage. The average washing time for men and women, although short for both, was 6.27 seconds for men and 7.07 seconds for women. The gender effect persists. The age group older than college spent significantly more time washing their hands (mean = 6.93 seconds) than did college group and younger than college group (mean = 6.48 seconds). The presence of a sign also influenced washing time; the mean score in the presence of a sign was 7.08 seconds and 6.50 seconds without. Subjects spent significantly more time washing their hands when the sink condition was clean (mean = 7.20 seconds), compared to when the sink appeared reasonably clean (mean = 6.36 seconds) or dirty (mean = 6.16 seconds). No significant differences in hand washing time were found across time of observation or restroom locations.

Discussion

Hand washing is the most effective thing one can do to reduce the spread of infectious diseases according to CDC (CDC, 2012; Mead et al., 1999). Our study provided detailed information about how long and in what environments different groups engaged in various hand washing behaviors. While earlier research reported that not all wash their hands, prior studies have not identified factors associated with proper hand washing behaviors. Additionally, previous studies did not clearly distinguish between washing with and without soap. Our study recognizes the importance of environmental factors that promote proper hand washing behaviors. To our knowledge, our study was one of the first studies to focus on hand washing behaviors and the length of time spent washing while incorporating environmental factors and the time of observation.

The observed hand washing behaviors and the length of time washing hands relate differently to different factors. Our study supports earlier work in observing that men need more encouragement than women to engage in proper hand washing behaviors, although most men and women do wash their hands using soap. Nonetheless, the percentages who simply wet their hands was significantly higher for men (35.1%) than for women (15.1%).

While our study was not specifically designed to test for the intervention effect of a hand washing sign, the study did find that the presence of a sign influenced both hand washing behaviors and the length of washing time. This is an important finding as a high percentage of people fail to wash their hands properly, and signs that include messages highlighting correct hand washing or reminders to use soap may increase compliance. It appears that this kind of explicit reminder may be particularly useful in men's restrooms, given that more than one-third of men simply wet their hands without using soap.

In previous studies the automated and sequenced phases of the device/sink resulted in significant improvement in hand washing practices (Larson, Bryan, Adler, Lee & Blane, 1997; Larson, McGeer, & Quiaishi, 1991). Our study showed that the type of faucet itself (standard faucet versus motion detection) did not impact hand washing behaviors. Care must be taken in the interpretation of washing time, as it is possible to equate washing time with the motion-detected dispensing of water, much as our study did in terms of manual water flow.

More importantly, the findings of our study showed that it is important to maintain clean sink conditions, as clean sinks promoted proper hand washing procedures as well as increased length of time washing hands. When sinks are dirty, some may choose not to wash their hands, despite knowing they should. Studying the effect of time of day on hand washing behavior, a relatively new research focus, showed that hand washing generally decreased as the evening progressed.

The most important findings of our research relate to the distinctions among hand washing behaviors and the length of time hands were washed. Specifically, less than 6% of the sample approached the recommended hand washing duration. Furthermore, our study identified that a large proportion of subjects engaged in hand washing behavior that did not involve the use of soap. It is interesting to note that if the proportion of people who were observed using soap when washing their hands were combined with those who only used water, the hand washing rates reach the higher levels reported in other studies. This raises the question of whether hand washing compliance rates have been inflated by way of definition in earlier work.

TABLE **4**

Multi-Way ANOVA: Hand Washing Time by Demographics and Restroom Settings (*N* = 3,749)

Variables	Hand Washing Time Mean (Seconds)	*F*	η^2
Observation time		.92	.022
Morning	6.50		
Afternoon	6.81		
Evening/night	6.77		
Gender		25.21*	.082
Male	6.27		
Female	7.07		
Age		8.14*	.058
College group and younger than college group	6.48		
Older than college group	6.93		
Faucet		49.29*	.114
Standard faucet	6.45		
Motion detection	7.74		
Sink condition		15.76*	.091
Dirty	6.16		
Reasonable	6.36		
Clean	7.20		
Location		2.23	.024
On campus	6.63		
Off campus	6.86		
Sign		7.97*	.057
Sign	7.08		
No sign	6.50		

Note. Total mean = 6.75 (*SD* = 4.76), mean = 7.52 (*SD* = 4.41).
*$p < .01$.

Limitations and Future Research

While the data from our study are informative, it should be noted that observations only took place in one college town environment. Care should be therefore taken in generalizing the findings.

As an alternative to the self-reporting method, direct and unobtrusive observations of hand washing were used as a way to enhance reliability and validity. It should be recognized, however, that even an apparent unobtrusive observation may influence hand washing behaviors, as the simple presence of others in a restroom may lead to increased compliance (Bittner, Rich, Turner, & Arnold, 2002; Drankiewicz & Dundes, 2003; Edwards et al., 2002; Nalbone, Lee, Suroviak, & Lannon, 2005).

While our study attempted to investigate the role that a hand washing sign would have on hand washing behavior, the subjects were not asked whether they recalled seeing the sign or whether they could recall the messages. Future research should consider sign content, design, and placement.

In our study the act of drying was measured. Approximately 2% of subjects who attempted to wash their hands (i.e., wetting hands without soap) or washed hands with soap did not dry their hands at all, but we do not know if those who attempted to dry their hands achieved dry hands. This would be good to include in future studies as studies have demonstrated that the transfer of microorganisms is more likely to occur from wet skin than from dry skin (Mackintosh, & Hoffman, 1984; Merry, Millder, Findon, Webster, & Neff, 2001; Patrick, Miller, & Findon, 1997).

Conclusion

Our study replicated and extended earlier work on hand washing practices. While past studies have focused on high-traffic venues such as transportation hubs and stadiums, our study focused on hand washing behaviors in a college town environment. Field observations by trained observers in a variety of restrooms provided a sample of 3,739 people who were unobtrusively watched to note their hand washing behaviors.

The findings were consistent with earlier research in that a significant gender bias was found. Women wash their hands significantly more often, use soap more often, and wash their hands somewhat longer than men. Both men and women fell far short, however, of CDC-recommended hand washing durations, averaging 6.27 and 7.07 seconds, respectively. Only 5.3% of the sample washed their hands for 15 seconds or more. Considering the definition of hand washing and the careful training of observers, this particular finding raises the specter of significant inflation in earlier reported hand washing compliance rates. Future studies need to measure hand washing compliance carefully.

Additionally, our study established that restroom environmental conditions and signage are important. Specifically, hand washing compliance was greater when restroom sinks were clean and when signs encouraging hand washing were posted.

Hand washing compliance and practices as reported in this and previous studies fall short of the ideal. The public needs to be continuously encouraged to engage in proper hand washing practices. In addition, careful attention to restroom environmental conditions and signage may help increase compliance. Given the established gender bias, consideration should be given to the content of the messages targeting men and women. Perhaps men and women would respond differently to gender-targeted messages.

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Factors Related to Food Worker Hand Hygiene Practices†

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ABSTRACT

To identify factors related to food worker hand hygiene practices, we collected (i) observational data on food worker (*n* = 321) hand hygiene practices (hand washing and glove use) and (ii) 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, with more than one hand sink, and with a hand sink 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. 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. Instead, improvement programs must be multidimensional and address factors such as those examined in this study.

Many reported foodborne illness outbreaks originate in food service establishments *(25),* and sporadic foodborne illnesses have been associated with having eaten outside the home *(11, 19).* Additionally, food workers' poor personal hygiene is an important contributor to foodborne illness outbreaks *(15, 25).* For example, Olsen et al. *(25)* found that annually from 1993 to 1997, poor personal hygiene of food workers was a contributing factor in 27 to 38% of foodborne illness outbreaks, and Guzewich and Ross *(15)* found that in 89% of outbreaks caused by food contaminated by food workers, pathogens were transferred to food by workers' hands.

The U.S. Food and Drug Administration's (FDA) Food Code for retail establishments includes guidelines on prevention of food contamination by workers' hands *(15, 29).* Hand washing is one of the FDA's recommended prevention methods, for it can significantly reduce transmission of pathogens from hands to food and other objects *(15, 22, 24).* The Food Code indicates that proper hand washing should take at least 20 s and include running warm water, soap, friction between the hands for 10 to 15 s, rinsing, and drying with clean towels or hot air. In addition, the Food Code specifies situations in which hands should be washed, such as before food preparation and after handling raw meat or poultry. The FDA also recommends that bare-hand contact should be prevented when working with ready-to-eat (RTE; i.e., safe to eat without further cooking) food and minimized when working with non-RTE food, because hand washing may not always be sufficient to prevent the transmission of pathogens from hands to other items, such as food *(3, 9, 22).* The Food Code suggests that barriers, such as deli tissue, tongs, and disposable gloves, be used for this purpose. Gloves are commonly used as barriers in food service establishments, and anecdotal evidence suggests that glove use for this purpose may be increasing. Proper glove use can decrease the transfer of pathogens from hands to food *(22, 23),* but some researchers and practitioners have argued that glove use may lead to less safe hand washing practices *(10, 15, 21).*

Research on the prevalence of hand washing and glove use in food-service establishments indicates that these hand hygiene practices do not occur as often as they should. For example, food workers have reported that they sometimes or often do not wash their hands and/or wear gloves when they should, do not always wash their hands after touching raw meat, and do not always change their gloves after touching raw meat *(6, 13).* Additionally, observational studies have found low rates of hand hygiene practices. For example, the FDA observed improper hand washing in 73% of restaurants and failure to prevent bare-hand contact with RTE foods in 57% of restaurants *(28).* Additionally, both Clayton and Griffith *(5)* and Green et al. *(14)* found that observed food workers washed their hands in only a third of the instances in which they should have washed them.

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† The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.

TABLE 1. *Observed activities for which hand washing is recommended*

When hand washing should occur	Activity	Description
Before the activity	Food preparation	Engaging in food preparation, including working with exposed food, clean equipment and utensils, and unwrapped single-use articles
	Putting on gloves for food preparation	Putting on gloves in order to engage in food preparation (see above)
After the activity and before beginning another activity	Preparing raw animal product	Preparing raw animal product (animal products that have not been cooked or processed; uncooked eggs, meat, poultry, and fish)
	Eating, drinking, tobacco use	Eating, drinking, or using tobacco (unless from a closed beverage container handled to prevent hand contaimination)
	Coughing, sneezing, tissue use	Coughing, sneezing, or using a handkerchief or disposable tissues
	Handling dirty equipment	Handling dirty equipment, utensils, or cloths
	Touching body	Touching human body parts other than clean hands and clean, unexposed arms

These findings, along with evidence that poor personal hygiene frequently contributes to foodborne-illness outbreaks, indicate that improvement of food workers' hygiene practices is needed. Researchers and practitioners contend that a range of personal, social, and environmental factors influence food worker practices and that these factors need to be addressed to successfully change food workers' behavior *(8, 26, 27)*. Thus, the purpose of this study was to identify factors related to food worker hand hygiene practices.

This article is the second one based on a study we conducted on food worker hand hygiene practices. For this study, we observed food workers for an extended period and recorded specific information on their work activities and the hygiene practices associated with those activities. We also collected data on possible factors related to hygiene behavior through interviews with restaurant managers and observations of restaurant environments. In the first article on this study, we presented descriptive data on food worker hand washing and glove-use practices across different work activities *(14)*. In this article, we present data on the relationships between hand washing and glove use and factors proposed to be related to hygiene behavior. These factors include worker activity (e.g., worker busyness), restaurant characteristics (e.g., ownership: chain versus independent), worker training, physical environment (e.g., number of sinks), and the social environment and management (e.g., management encouragement of hand hygiene). These factors were chosen because existing theories or data suggest that they may affect hygiene behavior (*1, 6–8, 12, 13, 16–18, 20, 26*).

MATERIALS AND METHODS

Restaurants. This study was conducted by environmental health specialists (specialists) affiliated with the Environmental Health Specialists Network (EHS-Net), a collaborative project of the Centers for Disease Control and Prevention (CDC), the FDA, the U.S. Department of Agriculture, and 9 states (California, Connecticut, New York, Georgia, Iowa, Minnesota, Oregon, Rhode Island, Tennessee; Colorado participated until 2005). EHS-Net is focused on the investigation of environmental antecedents of foodborne illness, including food preparation and hygiene practices.

The study comprised randomly selected restaurants located in designated geographical areas in six of the 2004 EHS-Net states (Colorado, Connecticut, Georgia, Minnesota, Oregon, Tennessee; see Green et al. *(14)* for more information on the sample). While there is variability in these states' adoption of the FDA Food Code, all had similar hand washing guidelines and none prohibited bare-hand food contact at the time of the study.

Data collection. The study was conducted over 3 months in the fall of 2004. Before the start of the study, the study protocol was reviewed and approved by CDC's Institutional Review Board (IRB) and the appropriate IRBs in the participating states. Additionally, all specialists participated in training designed to increase data collection consistency. (See Green et al. *(14)* for more information.)

In each restaurant, a specialist first interviewed the restaurant manager, owner, or other employee to collect data on restaurant characteristics, food preparation training and policies, manager certification, food preparation processes, and hand washing encouragement. The specialist then conducted a 10- to 15-min observation of the kitchen to collect information on the environment, such as the number of hand sinks with warm water, soap, and towels or hot-air drying methods. Then, using an observation method similar to the one designed by Clayton and Griffith *(5)*, the specialist conducted a 45- to 50-min observation of one worker who was preparing food. Workers were chosen on the basis of the specialist's ability to observe them relatively unobtrusively (e.g., without interfering with their work). To limit the influence of the specialist's presence on worker behavior, the specialist observed the worker for 10 to 15 min before beginning the 45- to 50-min data collection period to allow the worker time to adjust to the specialist's presence. Additionally, workers were not made aware of precisely which aspects of their behavior were being recorded during the observations.

During this observation, the specialist recorded data on specific activities that required hand washing (according to the Food Code; see Table 1) and the hand hygiene behaviors associated with those activities. For the activities of food preparation and putting on disposable gloves for food preparation, hand washing should occur before each activity. For the remaining activities (preparing

TABLE 2. *Variables used in logistic regression models of appropriate hand washing and glove use*

Variable	Variable values	Hand washing model	Glove use model
Worker activity			
Actity type	Food preparation; putting on gloves for food preparation; preparing raw animal product; eating, drinking, using tobacco/coughing, sneezing, using tissue; handling dirty equipment; touching the body	✓	✓
Worker busyness	Yes (worker engaged in ≥8.6 [median] activities) vs no (worker engaged in <8.6 activities)	✓	✓
Hands washed appropriately with activity	Yes vs no		✓
Gloves worn during activity	Yes vs no	✓	
Restaurant characteristics			
Restaurant ownership—chain	Yes vs no	✓	✓
Complex food preparation processes	Yes vs no	✓	✓
Worker training			
Hand hygiene taught to workers	Yes vs no	✓	✓
Workers provided with food safety training	Yes vs no	✓	✓
Management certification required	Yes vs no	✓	✓
Physical environment			
Multiple hand sinks	Yes (>1 sink) vs no	✓	
Hand sink close to worker	Yes (<10 ft from sink) vs no (≥10 ft from sink)	✓	
Hand sink in worker's sight	Yes vs no	✓	
Hand washing supplies at hand sinks	Yes (all hand sinks had warm water, soap, and recommended drying methods) vs no	✓	
Glove supplies in food preparation areas	Yes vs no		✓
Social environment/management			
Worker visibility to manager	Yes (manager could see worker some/most of the observation) vs no	✓	✓
Worker visibility to customers	Yes (worker somewhat/fully visible) vs no	✓	✓
Management encouragement of hand washing	Yes (respondents said hand washing was encouraged) vs no	✓	

raw animal products; eating, drinking, or using tobacco; coughing, sneezing, or using tissues; handling dirty equipment or utensils; and touching human body parts other than clean hands and arms), hand washing should occur after each activity and before beginning another activity. Data were also collected on the activity of preparing raw produce. However, because of inconsistencies in the way specialists identified raw produce, these data were excluded from analysis.

The specialist also collected data on hand hygiene behaviors in which the worker engaged along with each of the observed activities. The specialist recorded whether the worker placed his or her hands under running water, whether the worker used soap, whether and how the worker dried his or her hands (e.g., paper towel, cloth towel, clothes), and whether the worker wore and removed his or her gloves. Data were also recorded on whether hand sanitizer was used, but those data are not discussed here. Finally, the specialist recorded data on the physical environment during the observation, such as proximity of the observed worker to the nearest sink.

Data analysis. We used multivariate logistic regression models to determine the combination of factors that best explained hand hygiene practices. Stepwise regression procedures were used to guide the determination of the explanatory variables included in the final models. A model was conducted for appropriate hand washing, which entailed (i) removing gloves, if worn; (ii) placing hands under running water; (iii) using soap; and (iv) drying hands with paper towels, cloth towels, or hot air. A model was also conducted for glove use, which entailed wearing gloves during work activities. For these models, the level of analysis was activity; thus, the outcome variables were dichotomous and indicated whether the hygiene practice (hand washing or glove use, depending on the model) occurred with each observed activity for which hand washing is recommended. Because the observed worker in each restaurant engaged in multiple activities during the observation, activity was treated as a repeated measure in all analyses. The state in which data collection took place was included as a control variable in both regression models. Preliminary forward stepwise regression analyses were conducted with the SAS software package (SAS, Cary, N.C.); all other regression analyses were conducted with the SUDAAN software package (RTI International, Research Triangle Park, N.C.) to account for the repeated measures aspect of these data.

Table 2 describes the explanatory variables included in the regression models. These fell into the categories of worker activity

(activity type, worker busyness, hands washed, gloves worn), restaurant characteristics (ownership: chain versus independent, complex food preparation processes [i.e., holding, cooling, reheating or freezing of foods]), worker training (hand hygiene taught to food workers, food safety training provided to food workers, management certification required), physical environment (multiple hand sinks, hand sink closeness to worker, hand sink in worker's sight, hand washing supplies at hand sinks, glove supplies in food preparation areas), and social environment and management (worker visibility to manager, worker visibility to customers, management encouragement of hand washing). All explanatory variables were included in the initial regression model of appropriate hand washing. All explanatory variables, except those expected to only be related to hand washing (multiple hand sinks, hand sink closeness to worker, hand sink in worker's sight, hand washing supplies at hand sinks, and management encouragement of hand washing) were included in the glove-use model. Additionally, whether gloves were worn in conjunction with the activity was included as an explanatory variable in the hand washing model and whether hands were washed appropriately in conjunction with the activity was included as an explanatory variable in the glove-use model. Odds ratios (ratios above 1 indicate that the hygiene behavior was more likely to occur with the activity; ratios below 1 indicate that the hygiene behavior was less likely to occur with the activity) and Wald F test probability values (values at 0.05 or lower are considered significant) are provided for each explanatory variable included in the final regression models.

RESULTS

Descriptive analyses. Of the 1,073 establishments we contacted, 808 were eligible to participate (i.e., met our definition of a restaurant, were open for business, and did not belong to a chain with an already participating restaurant). Of these, 333 agreed to participate, yielding a response rate of 41%. Because of missing information, data are reported on only 321 restaurants. Sixty-one percent (196) of the restaurants were independently owned, 38% (121) were chains or franchises, and 1% (4) had missing data concerning ownership.

The median duration of individual worker observations was 48 min (25% quartile = 45; 75% quartile = 48). Observed workers engaged in a total of 2,195 activities falling into one of the defined activity categories. The estimated median number of activities observed per hour per worker was 8.6 (25% quartile = 5; 75% quartile = 12.3). The most frequent activity, accounting for 36% of all activities (786 activities), was handling dirty equipment, followed by food preparation (23%; 514 activities); preparing raw animal product (17%; 384 activities); putting on gloves for food preparation (10%; 224 activities); touching the body (9%; 197 activities); eating, drinking, or using tobacco (3%; 77 activities); and coughing, sneezing, or using tissue (1%; 13 activities). Because of the low frequency of the last two groups of activities, they were combined into one category called "eating/coughing" for the remaining analyses.

Workers washed their hands appropriately (i.e., removed gloves, if worn; placed their hands under running water; used soap; and dried their hands with paper or cloth towels or hot air) in conjunction with 27% (588 of 2,195 activities) of all activities. They wore gloves during 28% (608 of 2,195 activities) of all work activities. More detailed descriptive data on these hand hygiene activities can be found in Green et al. *(14).*

TABLE 3. *Logistic regression model of appropriate hand washing* (n *= 2,149)*

Hand washing	Odds ratio[a]	Lower 95% Cl[b]	Upper 95% Cl
Worker activity			
Activity type			
Food preparation (reference)	—	—	—
Putting on gloves for food preparation	0.64	0.34	1.22
Preparing raw animal product	0.44*[c]	0.31	0.61
Eating/coughing	0.48*	0.31	0.74
Handling dirty equipment	0.13*	0.07	0.23
Touching body	0.39**	0.20	0.74
Worker was busy	0.45*	0.30	0.66
Worker wore gloves during the activity	0.41*	0.26	0.67
Worker training			
Workers provided with food safety training	1.81***	1.06	3.12
Physical environment			
Multiple hand sinks	1.63***	1.07	2.47
Hand sink in worker's sight	1.93**	1.15	3.23

[a] Odds ratios above 1 indicate that hand washing was more likely to occur with the activity; odds ratios below 1 indicate that hand washing was less likely to occur with the activity.
[b] CI, confidence interval.
[c] Wald F test probability values: * $P < 0.001$, ** $P < 0.01$, *** $P < 0.05$.

Appropriate hand washing. The final regression model for appropriate hand washing was comprised of the variables that best accounted for the variance in appropriate hand washing ($R^2 = 0.142$). Those included activity type, worker busyness, glove use, food safety training provided to food workers, multiple sinks, and hand sink in worker's sight (Table 3). Appropriate hand washing was more likely to occur with food preparation activities than with all other activities except putting on gloves. Appropriate hand washing was also more likely to occur in restaurants where food workers received food safety training, where there were multiple hand sinks, and where a hand sink was in the observed worker's sight. Appropriate hand washing was less likely to occur when workers were busy and when gloves were worn at the point at which hand washing should occur.

Glove use. The activities of food preparation and putting on gloves for food preparation were combined for these analyses. Specifically, all activities categorized as putting on gloves for food preparation were recategorized as food preparation activities in which gloves were worn. The final regression model for glove use was composed of the variables that best accounted for the variance in glove use ($R^2 = 0.235$). Those included activity type, worker busyness, hand washing, restaurant ownership, and glove supplies in food preparation areas (Table 4). Glove use was more likely

TABLE 4. *Logistic regression model of glove use* (n = 2,160)

Glove use	Odds ratio[a]	Lower 95% CI[b]	Upper 95% CI
Worker activity			
Activity type			
Food preparation (reference)[c]	—	—	—
Preparing raw animal product	0.69	0.41	1.18
Eating/coughing	0.17**[d]	0.05	0.62
Handling dirty equipment	0.42*	0.27	0.67
Touching body	0.52*	0.30	0.92
Worker was busy	0.51**	0.31	0.83
Worker washed hands along with activity	0.37*	0.23	0.58
Restaurant characteristics			
Restaurant ownership—chain	3.41*	1.91	6.09
Physical environment			
Glove supplies in food preparation areas	5.47*	2.88	10.38

[a] Odds ratios above 1 indicate that glove use was more likely to occur with the activity; odds ratios below 1 indicate that glove use was less likelty to occur with the activity.

[b] CI, confidence interval.

[c] The activities of food preparation and putting on gloves for food preparation were combined for this analysis.

[d] Wald F test probability values: * $P < 0.001$, ** $P < 0.01$, *** $P < 0.05$.

to occur during food preparation activities than during activities involving eating/coughing, handling dirty equipment, and touching the body. Glove use was also more likely to occur in chain restaurants and in restaurants with glove supplies in the food preparation areas. Glove use was less likely to occur when workers were busy and during activities with which workers washed their hands appropriately.

DISCUSSION

Both appropriate hand washing and glove use were related to activity type—workers were more likely to wash their hands appropriately and wear gloves with food preparation than with most other activities. This finding is encouraging, for it suggests that at least some workers understand the need to protect food from hand contamination. Appropriate hand washing and glove use were also related to worker busyness—these hand hygiene behaviors were less likely to occur when workers were busy (i.e., engaged in relatively larger numbers of activities needing hand washing). Because food workers have identified time pressure as a barrier to engaging in safe food preparation practices *(6, 12, 20),* these results are perhaps not surprising. However, given that time pressure is also inherent to the food service industry, these results are troubling. We have previously suggested that restaurant managers ensure adequate staffing for the workload and emphasize the importance of food safety over speed to combat the effects of time pressure on safe food preparation practices *(12).* Clayton and Griffith *(5)* have proposed that restaurants evaluate their food preparation activities in light of the frequency with which hand washing is needed. A reduction in the number of needed hand washings may lessen time pressure and thereby increase the likelihood that food workers will engage in the remaining needed hand washings and don gloves when appropriate.

Hand washing and glove use were related to each other—appropriate hand washing was less likely to occur with activities in which gloves were worn than with activities in which gloves were not worn. These results suggest that workers who wear gloves do not remove them and wash their hands as they should. Although some researchers and practitioners have contended that glove use can promote poor hand washing practices *(10, 15, 21),* little data exists on this issue. More research is needed to understand the relationship between glove use and hand washing.

Appropriate hand washing was positively related to two factors associated with restaurants' hand sinks: multiple hand sinks and a hand sink in the worker's sight. These factors contribute to sink accessibility, which likely promotes hand washing. Appropriate hand washing was also more likely to occur in restaurants in which the manager reported that food workers received food safety training. This finding is consistent with other findings of an association between knowledge and training and safe food preparation practices *(4).*

Glove use was related to restaurant ownership—workers were more likely to wear gloves in chain restaurants than in independent restaurants. This finding suggests that glove use may be determined, at least in part, by restaurant management. Some types of restaurants, such as chains, may be more likely to require and institutionalize glove use. Gloves were also worn more often when glove supplies were accessible in food preparation areas. As with sinks and hand washing, glove accessibility likely promotes glove use.

The findings of this study indicate that a number of factors are related to hand hygiene practices and support those who have suggested that food worker hand hygiene improvement requires more than the provision of food safety education. Instead, improvement programs must be multidimensional and address additional factors *(8, 26, 27).* These factors may include, but are certainly not limited to, those found to be significant in this study: activity type, worker busyness, number and location of hand sinks, availability of supplies (e.g., gloves, soap, towels), restaurant ownership, and the relationship between prevention methods (i.e., glove use and hand washing).

The FDA recommends that barriers such as gloves be used to prevent hand contact specifically with RTE food. Although we examined glove use during food preparation, we did not distinguish between RTE food and non-RTE food (other than raw meat or poultry). Explanatory variables for glove use with RTE food may differ from those identified in our study. Additionally, because of concerns about data collection complexity, we did not collect data on some hand hygiene behaviors that are considered important by the FDA *(29).* For example, we did not measure how long workers washed their hands or whether they created friction between their hands. The inclusion of such factors may have affected our findings.

There are a number of factors that may impact hand hygiene behavior that we did not examine in this study. For example, we did not measure individual characteristics of the observed food workers, such as age, gender, and food safety knowledge, attitudes, and beliefs. Evidence suggests that such individual characteristics influence food safety behavior *(2, 13)*. This study also does not allow us to make causal inferences about the relationships among variables. For example, the relationship between hand washing and the presence of a hand sink in the observed worker's sight was significant and positive. However, we cannot determine if the presence of a sink in sight causes workers to wash their hands more frequently or if there is some other explanation for the relationship (e.g., workers choose to work close to a sink because they plan to wash their hands frequently). Thus, although our data indicate that there are significant relationships between a number of factors and hand hygiene behavior, more research is needed to determine the causal nature of those relationships.

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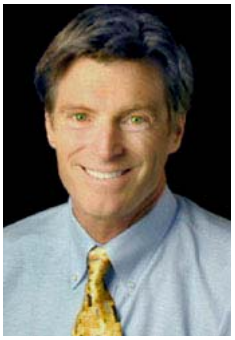
29. U.S. Food and Drug Administration. 2005. Food code, 2005. Available at: http://www.cfsan.fda.gov/~dms/fc05-toc.html. Accessed 1 April 2006.

11 HAND WASHING FACTS

Could singing Yankee Doodle save your life?



By Jay Hardy, CLS, SM (ASCP)

Jay Hardy is the founder and president of Hardy Diagnostics.

After studying microbiology at California State Universities at Fullerton and Long Beach, he completed his Medical Technology internship at Santa Barbara Cottage Hospital.

The company began in 1980, shortly after Hardy served as a Medical Technologist and microbiologist at Goleta Valley Hospital in California.

1.

80% of all infectious diseases are transmitted by touch.

According to experts, without a vaccine, the single most important thing you can do to prevent getting the flu is to wash your hands.

2.

The Solution to Pollution is Dilution.

While soap may not kill all viruses, thorough hand washing will decrease the viral counts to a point below the infectious threshold.

3.

Caught in the act (or lack of).

95% of the population says that they wash their hands after using a public toilet. However when 8,000 people were monitored across five large cities in the US, they found the actual number to be more like 67%.

Chicago topped the list at 83%. New York was the worst at less than half.

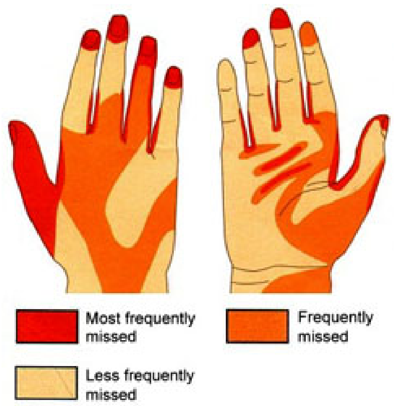
4.

Do as I say, not as I do…

A poll of pediatric ICU physicians showed that they ***claimed*** their rate of hand washing between patients was 73%, but when followed and observed, the hand washing rate was found to be less than 10%. Listen carefully and you can hear Dr. Semmelweis rolling over in his grave. The top excuses for not hand washing among doctors? Too busy and dry skin.

5.

Where's the dirt?



CDC studies show that the number of bacteria per square centimeter on the human body are as follows:

- Scalp – 1,000,000
- Forearm – 10,000
- Arm pit – 500,000
- Abdomen – 40,000
- Hands of medical personnel – 40,000 to 500,000

When it comes to hands, fingernails and the surrounding areas harbor the most microorganisms.

6.

Who has it?

A recent study showed that 21% of the health care workers in ICU had varying counts of *Staphylococcus aureus* on their hands.

7.

Too busy?

One study demonstrated that hand washing guidelines were followed 25% of the time during times when the floor was overcrowded and understaffed. Compliance rose to 70% when the floor was properly staffed and not overcrowded with patients.

8.

And the winner is…

Many studies have shown that alcohol rubs are more effective than plain or even antimicrobial soaps, unless the hands are heavily soiled. However we can't get overconfident with alcohol rubs. Despite its effectiveness against many organisms, alcohols have very poor activity against bacterial spores, protozoan oocysts, and certain non-enveloped (nonlipophilic) viruses. In addition, alcohol has no residual effect as some antimicrobial soaps do.

9.

How long is enough?

The CDC recommends at least 15 seconds. However, studies show that the reduction of skin bacteria is nearly ten times greater by washing with soap for 30 seconds rather than 15. Even so, remember that alcohol gels are even more effective than soap.

The average wash time for health care workers? 9 seconds.

Children (and why not adults?) are taught to sing "Yankee Doodle Dandy" start to finish before rinsing. This takes about 15 seconds. If you don't know the words to Yankee Doodle, the Happy Birthday song sung twice will suffice.

10.

Some like it hot.

But if they do, hot water can increase the chance of dermatitis. Hot or warm water has not been proven to increase the effectiveness of hand washing. Cold water, though not as comfortable, produces less skin damage from detergents especially with repeated washings.

11.

The two layers of bacteria.

The outer layer of bacteria found on your hands is termed "**Transient Flora**". This layer is potentially the most dangerous for transmitting disease from one person to another. Fortunately, it is also the most easily eliminated by hand washing. The deeper layer is called "**Resident Flora**". This bacterial population is more likely to be made up of innocuous bacteria such as *Staphylococcus epidermidis* and *Corynebacteria* spp. (diptheroids); and is more resistant to washing, since they occupy the deeper layers of skin cells.

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World Health Organization
REGIONAL OFFICE FOR Africa

Division of Prevention and Control of Non-Communicable Diseases
Food Safety and Nutrition

Fact Sheet 2º

Hand Washing and Food Safety

A bulk of the foodborne disease outbreaks are attributable to poor hygienic practices and improper handling of food. Undoubtedly, adequate personal hygiene practices are essential in reducing the risks of a foodborne illness. Hand washing is one of the most effective and cheapest measures against infections and foodborne diseases.

FAST FACTS

- Many foodborne diseases and pathogenic microorganisms are spread by contaminated hands.
- Foodborne pathogens, such as *salmonellosis, shigellosis, hepatitis A, giardiasis* and *campylobacteriosis* are transmitted via the faecal-oral route. These account for a substantial number of disease outbreaks in developing countries.
- Good quality drinking-water and good personal hygiene in food preparation and handling are therefore of utmost importance in preventing the spread of disease.[1]

Foodborne disease

Many foodborne diseases and pathogenic microorganisms are spread by contaminated hands. Many of these illnesses occur unnecessarily, since the faecal-oral routes of disease transmission are easily prevented.[1]

WHO reports that 90% of the annual deaths from diarrhoea are among children particularly in developing countries. A significant number of the deaths could be attributed to shigella, which causes dysentery or bloody diarrhoea. [2]

A study on the microbial quality of street foods in Accra, Ghana showed among others the significance of proper hand-washing practices, use of soap and environmental hygiene. Among the reported risk factors for street food contamination were cooking of food well in advance of consumption, exposure of food to flies, and working with food at ground level and by *hand*.[3]

Significance of proper hand washing to food safety

Judicious washing of hands can significantly reduce bacterial contamination and risk of foodborne illness.

Reports indicate that the simple act of washing hands with soap and water reduces incidents of diarrhoea from *shigella* and other causes by up to 35 percent. [2]

Proper hand washing

Hands should ideally be washed, with soap or ash, under running water. Rubbing hands vigorously 15-20 seconds until a soapy lather

[1] Healthy Villages – A guide for communities and community health workers. WHO. 2003.
[2] Water for Health: Taking Charge. WHO. 2001.
[3] Mensah *et al.* Street Foods in Accra, Ghana: How Safe Are They? Bulletin of the World Health Organization. 2002.

appears, and scrubbing between fingers and fingernails.

Where there is no system, running water can be organized by using a water butt with a tap. If there is a shortage of water, using soap with a small quantity of water in a bowl is adequate.[4]

Washing of hands should be particularly be done:

- Before food preparation;
- Before eating;
- Before serving food;
- During food preparation to avoid cross-contamination;
- Before and after handling raw meat, poultry and fish products;
- After changing diapers;
- After blowing nose/sneezing;
- After using the toilet, not just after defecation, since the pathogens can also be picked up from previous users of toilets via door handles, taps and drying towels.[5]
- After handling unsanitary objects such as waste/garbage containers;
- After contact with toxic substances or chemicals;
- After touching/handling livestock or pets

In all these activities hands may become contaminated with pathogens or toxic chemical residues that can be transferred to food.[5]

[4] Food, Environment and Health: A Guide for Primary School Teachers. WHO. 1990

[5] Basic Food Safety for Health Workers. Adams M and Mortarjemi Y. WHO. Geneva. 1999

Health education in food safety

Experience has shown that well designed and implemented educational programmes, is a feasible and cost-effective means of improving health status.[6]

Adequate food safety and hygiene education/promotion particularly in schools with the provision of adequate sanitary and hand-washing facilities are essential.

WHO technical support and actions in food safety education

A special focus is being made at collaborating with education authorities to promote food safety education in primary and secondary level, among both students and parents. Work is also underway on the promotion of participatory community-based food safety education and awareness-raising strategies.

For More Information on Food Safety and Nutrition please contact Division of Prevention and Control of Non-communicable Diseases (DNC). B.P. 6 Congo Brazzaville.

[6] Foodborne disease: a focus for health education. WHO. 2000