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Effect of specialized bathing systems on resident cleanliness and water quality in nursing homes: a randomized controlled trial

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ABSTRACT

A randomized controlled trial evaluated the impact of different methods of water agitation on clinical and microbiological outcomes in 31 nursing home residents. Four conditions were tested: a) whirlpool tub, jets on, using standard soap products; b) ultrasound tub, ultrasound on, using the standard soap products; c) ultrasound tub, ultrasound on, using specialized soap and skin conditioner; and d) either tub (randomized), water circulation off, using standard soap products (the control condition). Outcomes of interest included skin microbial flora, water microbial flora, skin condition, time spent bathing, and staff satisfaction.

Resident skin condition and skin microbial flora did not differ between the four treatments. The tubs also did not differ in terms of bacterial colonization; however, there was a non-statistically significant trend for the highest counts to occur in whirlpool tubs after being idle overnight. The ultrasound and whirlpool tubs were preferred by staff over the control treatment (still water) in terms of sound and overall suitability. In addition, staff reported that the ultrasound tub using enhanced skin cleansers made bathing residents easier and faster than the same tub using standard cleansers.

Key words | bacteria, bathing, long-term care, nursing home, tub, whirlpool

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INTRODUCTION

Bathing in nursing homes is an important and challenging activity. Nearly all nursing home residents require assistance with the task, and that assistance is usually provided by nursing assistants who have little training or workplace longevity. Furthermore, about two-thirds of nursing home residents have Alzheimer's disease or a related dementia. Thus, a very intimate activity is performed by strangers on physically impaired older persons, many of whom have cognitive impairment. Therefore it is not surprising that bathing is the single activity most likely to lead to resident agitation and aggression in nursing homes (Burgener *et al.* 1992; Namazi & Johnson 1996). In one study, 41% of nursing home residents were reported to hit, kick, strike out at, or threaten caregivers during bathing (Whall *et al.* 1992).

In an attempt to better understand and guide the care of nursing home residents during bathing, our research team, in collaboration with colleagues from the Oregon Health and Sciences University, have conducted a series of studies

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involving the bathing process. An early study (Sloane *et al.* 1995) identified that the majority of "baths" were actually showers, though we still do not know whether this is because showers are speedier, provide better caregiver access, or are thought to make residents cleaner. Subsequent studies worked with caregivers around improving their approach, culminating in a randomized trial that demonstrated dramatic decreases in resident agitation with the use of individualized, person-centered showering techniques, and with a special type of in-bed bathing method, using a warm, damp towel and no rinse soap (Sloane *et al.* 2004). As a result of these studies, we concluded that the goal should be for care providers to have available a variety of bathing approaches, which they could then individualize to the resident's physical status and preferences (Barrick *et al.* 2001). In order to learn more about the variety of bathing approaches, we decided to focus some effort on learning about tub bathing, which is a method commonly preferred by many residents.

Two types of specialized bathing tubs are particularly popular in nursing homes. One type is a whirlpool (water jet) tub (Hollyoak *et al.* 1995*a*). The design of many whirlpool tubs causes the water circulation to concentrate near the water jets and therefore not distribute evenly throughout the tub. This peripheral water circulation leads to the need for increased manual cleaning of the resident, thus raising the potential for skin irritation and uneven cleansing (Clever *et al.* 2002; Sibbald *et al.* 2003). A second type of tub used to bathe nursing home residents employs low frequency ultrasound to propagate pressure waves in the water. The pressure waves create microscopic bubbles, which then agitate the water when they implode. The water circulation created by an ultrasound tub is potentially more evenly distributed and is theorized to lead to a reduced need for manual cleaning of the resident.

The impact of bathing on resident skin condition is a serious concern in nursing homes. Excessively dry skin, pressure ulcers, and infection are common skin problems in physically frail nursing home residents. Impaired skin integrity is associated with morbidity, ranging from mild discomfort to severe skin and systemic infections. Risk factors for dry skin in long-term care (LTC) residents include too-frequent bathing with too-hot water, low humidity, and the use of harsh soaps or detergents (Frantz *et al.* 1986; Hardy 1990; Uriri *et al.* 2002). The probability of developing pressure sores is influenced by resident factors, such as impaired sensory perception, incontinence, and inability to move to relieve pressure, and care-related factors, such as hygiene, immobility, and inadequate nutrition (Bergstrom *et al.* 1987; Horn *et al.* 2002).

Because multiple residents are bathed in nursing home tubs, infection control is also a primary concern. In attempts to limit infection risk, all tubs that are used in nursing homes must be disinfected after each bath, making a quick and effective disinfection method highly desirable (Sloane *et al.* 1995; Sloane & Carnes 2002). Cleaning whirlpool tubs requires the circulation of disinfectant through the tubing system, and there is concern that over time this tubing may harbor pathogenic bacteria not eliminated by routine disinfection. Case reports from other tub settings (e.g. hot tubs) indicate that tubs can harbor pathogens and cause morbidity (Embil *et al.* 1997; Anonymous 2000; Rickman *et al.* 2002). In addition, numerous reports have identified increased bacterial concentrations, specifically in whirlpool bathtubs, as associated with patient infection (Hollyoak et al. 1995*a*, *b*; Berrouane *et al.* 2000). Because tubs utilizing ultrasound technology contain no additional tubing, they may allow for easier disinfection and subsequent reduced risk of resident infection.

The purpose of this study was to compare ultrasound tubs with traditional whirlpool tubs in bathing physically impaired nursing home residents. Specifically, we wanted to compare both tubs to using a tub with no water circulation, and to investigate whether a moisturizing cleanser improved skin care. The outcomes of interest included skin microbial flora, water microbial flora, skin condition, time spent bathing residents, and staff satisfaction with the tub. Our primary hypothesis was that the ultrasound system, because it had no internal water circulation, would be easier to keep consistently clean. Secondary hypotheses were that baths in the tubs would take equal amounts of time and that staff satisfaction with the tubs would be equivalent.

METHODS

Facilities

The study was conducted in two skilled nursing facilities owned and operated by a county hospital system in the

Southeastern United States. Study site A was a 125-bed urban facility that contained LTC, rehabilitation, and assisted living beds. Study site B was a 417 bed facility that housed short-term rehabilitative and LTC residents. Prior to the study, both facilities had tubs but rarely used them; instead, showering was the primary bathing method. Participating facilities did not receive monetary reimbursement; however, they were allowed to keep the tubs after the study was completed.

Subjects

Nursing home residents

The primary study subjects were adult residents of the two study facilities. Inclusion criteria were: a) high risk for skin breakdown, as defined by a score of 16 or less on the Braden Scale for Pressure Sore Risk (Bergstrom *et al.* 1987) and/or the presence of fecal incontinence; and b) willingness to be tub bathed. Potential participants were excluded from the study for the following reasons: a severe chronic skin condition, such as widespread eczema or psoriasis; hospitalization, death, or discharge anticipated within four months; or medical contraindication as determined by the attending physician.

Informed consent was obtained by the project coordinator, who was unaffiliated with the study facilities. Eligible residents who were judged by facility staff to have the cognitive capacity to provide their own consent were approached directly; for subjects who were judged incapable of providing consent, the guardian or responsible party was approached for consent and assent was obtained from the resident. Participants did not receive monetary compensation. All materials involved in the consent process were approved by the Institutional Review Boards (IRBs) of both the University of North Carolina School of Medicine and the Carolinas Health System.

Of 47 potential subjects who met selection criteria, 40 were approached (six were not approached because the guardian/responsible party could not be contacted during the enrollment period, and one became too ill to be approached). Of these 40 potential subjects who were approached, 38 consented to participate in the study, and two refused. Of the 38 consented subjects, 37 were enrolled in the study (one died before the study began). During the first treatment cycle, prior to data collection, six subjects withdrew (four expressed a dislike for tub baths and two suffered physical decline such that facility staff felt that they were unlikely to be able to complete the study), producing a final sample size of 31. Figure 1 provides a flow diagram of participant enrollment.

Nursing assistants

Certified nursing assistants employed by the study facilities were enrolled as research nursing assistants (RNAs). Potential RNAs, identified by their director of nursing as being experienced, reliable, and likely stable during the four-month study period were approached by the project coordinator for consent. In Facility A, six potential RNAs were identified, and all consented; of these, five were assigned residents, and the other served as a backup (bathing residents according to protocol when the primary RNA was not available). In Facility B, 12 potential RNAs were identified, and all consented; of these, two withdrew before the study began, eight were assigned residents, and the other two served as backups. Each RNA was assigned two or three resident subjects, for whom the RNA performed all baths (except when absent) and reported outcome and satisfaction data. The RNAs had their work assignments altered to carry out study-related tasks but they received no reimbursement for participation.

Intervention protocol

Each participating resident received each of four study conditions for a standard study period of three (facility A) or four (facility B) weeks. Four interventions were studied: whirlpool (WP; whirlpool tub, jets on, using the standard soap products the facility employs for all other bathing); ultrasound/standard (USS; ultrasound tub, ultrasound on, using the standard soap products); ultrasound/enhanced (USE; ultrasound tub, ultrasound on, using specialized soap and skin conditioners sold by the tub company); and a still water control condition (still; either tub (randomized), water circulation off, using standard soap products). Each consented participant was randomized by the study biostatistician to receive one of four treatment sequences:

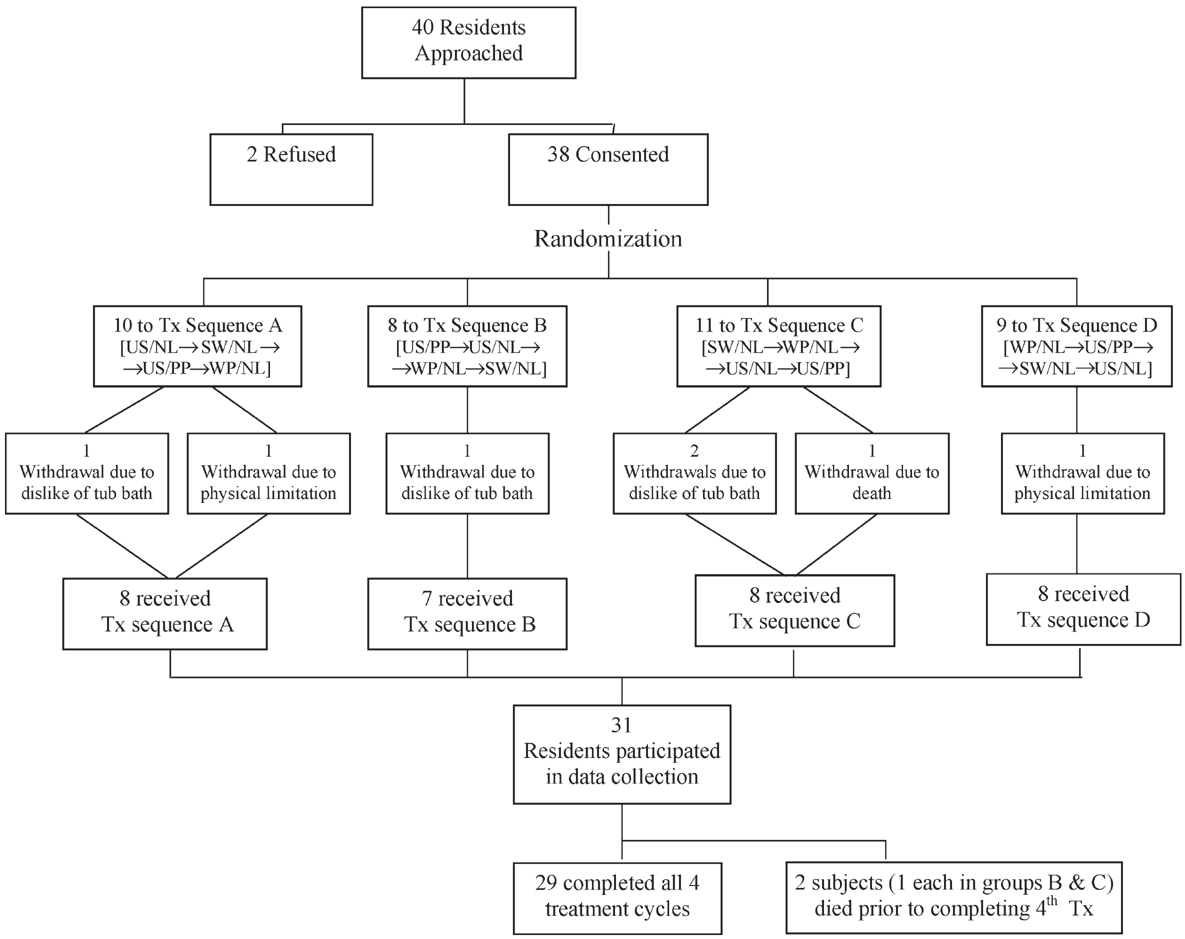

Figure 1 | Flow diagram of subject enrollment and participation (Treatment conditions are abbreviated as follows: US/NL = ultrasound water agitation with standard bathing products; SW/NL = still water with standard bathing products (control); US/PP = ultrasound water agitation with enhanced bathing products including cleanser and skin conditioner; WP/NL = whirlpool jets with standard bathing products).

USS→still → USE → WP; USE → USS → WP → still; still → WP → USS → USE; or WP → USE → still → USS.

Both participating facilities received two new specialized tubs: an Arjo Rhapsody P220 Hydromassage (whirlpool or water jet) tub, and an Arjo Rhapsody P220 Hydrosound (ultrasound) tub, and the corresponding lift devices. Tubs were delivered approximately three months prior to initiation of the study, and facility staff members were trained in the proper use of the tubs by corporate representatives. During the study, participants were bathed twice a week and the tubs cleaned by facility staff according to standard facility and industry protocols.

Each facility's assistant director of nursing, with assistance from the system's LTC quality improvement officer, oversaw intervention adherence. In order to increase compliance to individual protocols, each bathing condition was assigned a color code. At the beginning of each treatment period: a) each resident received an armband with the appropriate color code, b) each resident's care record book and the care records were color coded to correspond to the treatment being received; and c) an icon was placed on each participant's medical directives board (in his/her room) representing the appropriate bathing condition for that resident. To remind nursing assistants of the meaning of the color codes, a code key was posted in the bathing areas at all times except when the data collector was in the facility (to maintain blinding of the data collector). To assess protocol adherence, the site coordinator conducted a process evaluation during the second week of each treatment cycle. Study subjects were not bathed at other times during the study; however, as is customary in such settings, routine local cleaning was performed when needed; for example, to the perineum after an incontinent episode.

Measures and data collection

During the last week of each treatment period (immediately after one bath), a nurse data collector who was blinded to each participant's treatment condition conducted standardized skin assessments and post-bath swabs for laboratory culture. Also, during the last week of each tub treatment, the staff care providers completed a self-administered questionnaire to assess their satisfaction with the tub. In addition, at various times during the study, water samples were collected from each tub in each facility for microbiological analysis.

Skin condition was assessed using a modification of the Hardy Skin Condition Data Form (Hardy 1990), in which the degree of presence of eight characteristics (debris, eruptions, fissures/cracking, maceration, redness, scaling, tears/abrasions, and ulcers) was assessed for each of 18 body areas; details of the skin assessment methodology have been published elsewhere (Sloane *et al.* 2004). A skin problem index score was computed as the average percent of the 18 body areas affected by any of the eight skin conditions.

Skin cultures were collected from the right web space (between the fourth and fifth toes; in case of right leg amputation, the left was substituted) and right groin (fold between perineum and upper leg) using sterile cotton swabs. Specimen swabs were placed immediately into transfer media, stored in a cooled container, and delivered to the hospital laboratory. Each sample was cultured using standard laboratory techniques, and assessed for the following microorganisms: *Streptococcus pyogenes* (group A or B), *Streptococcus viridans*, *Enterococcus*, *Staphylococcus aureus*, *Escherichia coli*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, other gram negative rods, *Corynebacterium* species, and yeast. Colony counts for each type of microorganism were reported on a 5-point scale, ranging from 0 (absent) to 4 (heavy growth). In addition, a Potentially Pathogenic Bacteria Scale (PPBS) was constructed by summing the ratings of group A or B *Streptococci*, *Streptococcus viridans*, *Enterococcus*, *Staphylococcus aureus*, *Escherichia coli*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, and other gram negative rods. Scores on the PPBS had a possible range from 0 to 32.

To measure the microbiological content of water from the tubs, eight water samples were collected from each of the four study tubs during randomly selected days over the course of the intervention period. On the designated days, two samples were collected from each of the facility's two tubs – one before the first bath (approximately 5:00 a.m.) and the other after multiple baths had been conducted (approximately 4:00 p.m.). Water samples were collected as follows: the tub was filled with water, the agitation (ultrasound or whirlpool) was turned on and allowed to run for approximately one minute, and then the specimen was taken. Samples were collected in pre-sterilized one-liter containers, immediately cooled on ice, and transported to the University of North Carolina (UNC), School of Public Health (SPH) Environmental Virology Laboratory for evaluation. Water samples were quantitatively assessed for total (heterotrophic) bacteria, total coliforms, *Escherichia coli*, and *Pseudomonas aeruginosa*. The UNC SPH Environmental Virology Laboratory specializes in evaluating water quality.

All bacteriological analyses of water samples were conducted using standard microbiological methods (Clesceri *et al.* 1998). To enumerate total coliform bacteria and *Escherichia coli*, four 200 ml, two 10 ml, and two 1 ml aliquots of each water sample were filtered through 0.45 um pore-sized 47 mm diameter membrane filters. The membranes were placed on m Endo LES agar plates, and incubated at 37° for 18–24 hours. All red colonies possessing a green metallic sheen were counted as total coliforms. Any sample membranes exhibiting total coliform colonies were subsequently transferred to plates containing nutrient agar supplemented with 100 ug/ml 4-methylumbelliferyl-B-D-glucuronide and re-incubated at 37° for 4 hours. Colonies that produced blue fluorescence when exposed to 366 nm ultraviolet light were counted as *Escherichia coli*.

Pseudomonas aeruginosa were enumerated by membrane filtration using the same series of water sample volumes described above. The membrane filters were placed on M-PA-C agar, and incubated at 41° for 3 days.

All colonies with brownish to greenish black centers were counted as *Pseudomonas aeruginosa*.

Heterotrophic plate count bacteria were enumerated by a spread plate technique. Duplicate 0.1 ml aliquots of sample water and dilutions of sample in phosphate-buffered saline were spread on R2A agar plates, and incubated in the dark at room temperature for 7 days. All visible colonies were counted.

During the final week of each tub treatment, RNAs completed two brief questionnaires that assessed their level of satisfaction with the tub treatments they had been using. One questionnaire included closed and open-ended questions about the experience of bathing a particular resident participant in the tub. The second questionnaire asked questions to elicit general opinions from the RNAs about each treatment condition. Across these two questionnaires, RNA responses to three questions were used to measure their perceptions and experiences after using each of the four tub treatments. RNAs were asked questions regarding the ease of cleaning residents using each of the four tub treatments, their perceptions of the sounds made by the tubs, and how suitable they thought each of the tub treatments were for bathing residents. Each of these questions was rated on a scale of one to five, where lower scores corresponded to more positive answers.

In order to describe the study subjects, basic demographic and medical/functional information was collected. Medical and functional status information (e.g., continence, cognitive status, activities of daily living) on nursing home residents was obtained from the most recent Minimum Data Set (Hawes *et al.* 1995). Basic demographic data (gender, age, race, ethnicity, and length of time at facility) on the RNAs was gathered by questionnaire.

Data analysis

All data were entered twice, and duplicate entries were compared for accuracy and errors corrected. Statistical analyses were conducted using SAS Software (SAS Institute, Cary, North Carolina). Prior to assessing treatment effects, statistical testing established the absence of period and carryover (period-by-treatment interaction) effects for each outcome (Tudor *et al.* 2000). Throughout, statistical significance is defined at the $p < .05$ level.

Primary analyses evaluated the effects of treatment condition on skin microbiological flora and skin condition. Specifically, rank scores for the outcome variable skin microbial flora were compared across treatment types, using a stratified Wilcoxon-Rank sum test. A Mantel-Haenszel test was conducted to evaluate within-resident differences in skin condition between treatments (Landis *et al.* 1998; Stokes *et al.* 2000).

Additional analyses evaluated the relationship between treatment condition and the secondary outcomes of staff satisfaction and bacteriological colonization of the tub. A Mantel Haenszel testing procedure using rank scores was used to examine differences in RNA responses between the four tub treatments. The relationship between treatment condition and time taken to bathe the resident was analyzed using a linear mixed model with a random effect of resident nested within nursing assistant. The relationship between treatment condition and bacteriological colonization of the tub was assessed with a Wilcoxon rank test using exact p-values.

RESULTS

Study subjects

Of the 31 resident study participants, 29 (93%) were female, 23 (74%) were white, and 8 (26%) were African American. The mean age was 85.6 (SD 8.7) years. On average, resident subjects had lived in the facilities 3.2 years (SD 3.3). The majority (90%) had moderate (score: 2–4), severe (score: 5–8), or very severe dementia (score: 9–10), as assessed by the Minimum Data Set Cognition Scale (Hartmaier *et al.* 1994). Most participants were incontinent of urine on a daily basis (81%) and stool at least twice a week (74%). The mean score on the Braden scale was 14 (SD 3.3), indicating moderate to high risk for skin breakdown. Twenty-four study participants (77%) required total assistance with bathing, six (19%) required partial assistance, and one (3%) required supervision only.

Thirteen research nursing assistants (RNAs) participated in the study; demographic information was collected on 11. Of these, ten were women (90%), and nine were African American (82%). The mean age of the RNAs was 45.1 years (SD 10.3). On average, RNAs had worked in the facility for 5.1 years (SD 5.1), with a range from nine months to 15 years.

Skin assessment

Skin microbial flora

Bacterial colony counts from the toe webspace and inguinal regions are displayed in Table 1. A stratified Wilcoxon rank sum test revealed no significant differences in the potentially pathogenic bacteria summary scores or *Corynebacterium* levels across the four treatments. Specifically, the p-values were 0.48 for the inguinal summary score, 0.72 for the toe summary score, 0.61 for the inguinal *Corynebacterium* cultures, and 0.45 for the toe *Corynebacterium* cultures.

Skin condition

A skin problem index score was computed by taking the average percent of the 18 body areas affected by any of the eight skin conditions: debris, eruptions, fissures/cracking, maceration, redness, scaling, tears/abrasions, and ulcers. The mean percent of body areas affected by any of the eight skin conditions was 7.11% (SD 3.77) for the ultrasound/-standard treatment, 6.67% (SD 2.83) for the ultrasound/enhanced treatment, 6.70% (SD 3.30) for the whirlpool treatment, and 7.33 (SD 4.72) for the control condition. A stratified Wilcoxon rank sum test showed no significant differences across the four treatments ($p = .81$).

Staff satisfaction

Nursing assistant responses to the staff satisfaction questions are presented in Table 2. With respect to ease of cleaning residents, RNA's reported that the ultrasound/enhanced tub treatment was easier for cleaning residents than the ultrasound/standard treatment ($p = .02$). All other pairwise comparisons of this question were non-significant.

When RNAs were asked about their perception of the sounds made by the tub, they rated all treatments involving water agitation as preferable to the control treatment (still water) ($p = .02$, .006, and $<.0001$ for ultrasound/standard, ultrasound/enhanced, and whirlpool, respectively). In addition, RNAs rated the whirlpool tub as making significantly more pleasant sounds than either ultrasound treatment ($p = .04$ and $p = .02$ for the ultrasound/standard and ultrasound/enhanced treatments, respectively).

Regarding the overall suitability of each tub for bathing their residents, the RNAs rated the ultrasound/standard treatment as significantly more suitable than the control treatment ($p = .02$). In addition, they rated the whirlpool tub as marginally more suitable than the control treatment ($p = .07$).

RNAs reported that the control treatment required an average of 29.7 minutes (SD 2.7), the whirlpool treatment 30.4 minutes (SD 2.6), the ultrasound/standard 34.4 (SD 3.2), and the ultrasound/enhanced 28.8 minutes (SD 2.7). The bathing times for the ultrasound/standard treatment were marginally significantly greater than those for the ultrasound/enhanced tub treatment ($p = .07$). No other pairwise comparisons approached statistical significance.

Water microbiological cultures

Water sample cultures

The results of the cultures of water samples from the study were expressed as colony forming units (cfu) per 100 milliliters of water. Distributions of heterotrophic plate counts and *Pseudomonas aeruginosa* cultures from the study tubs are displayed in Figures 2 and 3, respectively. The median heterotrophic plate counts for the whirlpool tub samples were 19,369 in the morning ($n = 7$) and 1,126 in the afternoon ($n = 8$); for the ultrasound tub samples the corresponding counts were 1,802 in the morning ($n = 6$) and 901 in the afternoon ($n = 7$). A Wilcoxon rank test using exact p-values showed that heterotrophic plate count values did not significantly differ as a function of time of day or tub type ($p = .14$ and $p = .74$, respectively). The median *Pseudomonas* culture results for the whirlpoool tub samples were 0.45 in the morning ($n = 7$) and 0 in the afternoon ($n = 8$); for the ultrasound tub samples the *Pseudomonas* counts were 0.58 in the morning ($n = 6$), and (0.20) in the afternoon ($n = 7$). The morning *Pseudomonas* counts were significantly higher than the afternoon counts, irrespective of the type of tub ($p = .05$), however there were no significant differences between tub types ($p = .99$). Neither *E. coli* nor total coliforms were found in any of the water samples from either tub.

Table 1 | Mean intertriginious bacteria cultures (N = 120)

Bacteria	Control		Whirlpool		Ultrasound/Standard		Ultrasound/Enhanced	
	Inguinal fold	Toe webspace	Inguinal fold	Toe webspace	Inguinal fold	Toe webspace	Inguinal fold	Toe webspace
Group A or B *Streptococcus*[a]	0	0	.07 (.37)	0	0	0	0	0
Streptococcus viridans[a]	.77 (1.26)	.23 (.73)	.33 (.80)	0	.61 (1.05)	.10 (.56)	.25 (.59)	.07 (.38)
Enterococcus[a]	.61 (1.17)	0	.47 (1.01)	.17 (.66)	.29 (.90)	.10 (.56)	.46 (1.00)	0
Staphylococcus aureus[a]	.10 (.55)	.31 (.93)	.10 (.56)	.08 (.40)	.14 (.35)	.41 (1.05)	0	.15 (.78)
Escherichia coli[a]	.32 (.94)	.13 (.43)	.37 (.96)	0	.13 (.50)	0	.36 (.78)	.04 (.19)
Proteus mirabilis[a]	.84 (1.29)	.47 (.90)	1.00 (1.29)	.52 (1.02)	.90 (1.11)	.45 (.74)	.93 (1.15)	.39 (.99)
Pseudomonas aeruginosa[a]	0	0	.33 (.84)	.28 (.84)	.26 (.68)	.03 (.19)	.32 (.86)	.21 (.79)
Other gram negative rods[a]	.90 (1.11)	.07 (.25)	.87 (1.14)	.48 (.87)	.52 (.77)	.14 (.44)	.54 (.84)	.32 (.72)
Yeast[a]	.10 (.54)	0	0	0	0	0	0	0
Diphtheroids[ac]	1.68 (1.60)	1.13 (1.41)	1.20 (1.47)	1.38 (1.63)	1.13 (1.43)	.79 (1.29)	1.25 (1.48)	1.32 (1.59)
Potentially Pathogenic Bacteria Scale (PPBS)[bc]	3.55 (2.92)	1.20 (1.35)	3.53 (2.92)	1.52 (2.23)	2.84 (2.03)	1.21 (1.76)	2.86 (2.19)	1.18 (1.76)

[a]Cultures were reported on a 5-point scale, with 0 representing no growth and 4 indicating heavy growth.
[b]Potentially Pathogenic Bacteria Scale: sum of group A or B *Streptococcus*, *Streptococcus viridans*, *Enterococcus*, *Staphylococcus aureus*, *Escherichia coli*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, and other gram − rods. Possible range = 0 to 32.
[c]No significant differences in PPBS or *Diphtheroid* levels across four tub treatments, as assessed with a stratified Wilcoxon rank sum test. Overall p-values of 0.48 for inguinal PPBS, 0.72 for toe PPBS, 0.61 for inguinal *Diphtheroid* culture, and 0.45 for toe *Diphtheroid* culture.

Table 2 | Unadjusted mean responses to nursing assistant bathing experience questionnaire

Question (number of responses)	Control	Whirlpool	Ultrasound/Standard	Ultrasound/Enhanced	p-value[a]
Ease of cleaning resident (n = 122) [Range: 1 = very easy to 5 = very difficult]	2.03 (.19)	2.00 (.17)	2.13 (.17)	1.70 (.17)	0.18
Nursing assistant perception of sounds made by tub (n = 114) [Range: 1 = very pleasant to 5 = very bothersome]	2.00 (.10)	1.48 (.16)	1.93 (.15)	2.00 (.16)	< .001
Overall suitability of tub for bathing resident (n = 121) [Range: 1 = excellent to 5 = poor]	1.94 (.16)	1.60 (.16)	1.58 (.12)	1.79 (.16)	0.16
Time required for bathing, in minutes, including tub cleaning (n = 122)	29.65 (2.72)	30.43 (2.60)	34.35 (3.23)	28.80 (2.71)	0.20

[a]Overall p-value comparing between the four treatments obtained using Mantel Haenszel testing procedure using rank scores. The relationship between treatment condition and time required for bathing analyzed using a linear mixed model with a random effect of resident nested within nursing assistant. See text for pairwise comparisons.

DISCUSSION

This randomized controlled trial compared ultrasound tubs (both with and without specialized soap products) to traditional whirlpool tubs in bathing physically impaired nursing home residents, and also compared these tub treatments to a tub with no water circulation. Four tub treatments were tested: a) whirlpool tub using standard soap products; b) ultrasound tub using standard soap products; c) ultrasound tub using enhanced soap products (i.e. soap and skin conditioner); and d) either tub (randomized), water circulation off, using standard soap products (i.e., the control condition). The outcomes of interest included skin microbial flora, water microbial flora, skin condition, time spent bathing residents, and staff satisfaction with the tub.

The four tub treatments did not significantly differ in the microbial counts of Streptococcus pyogenes (group A

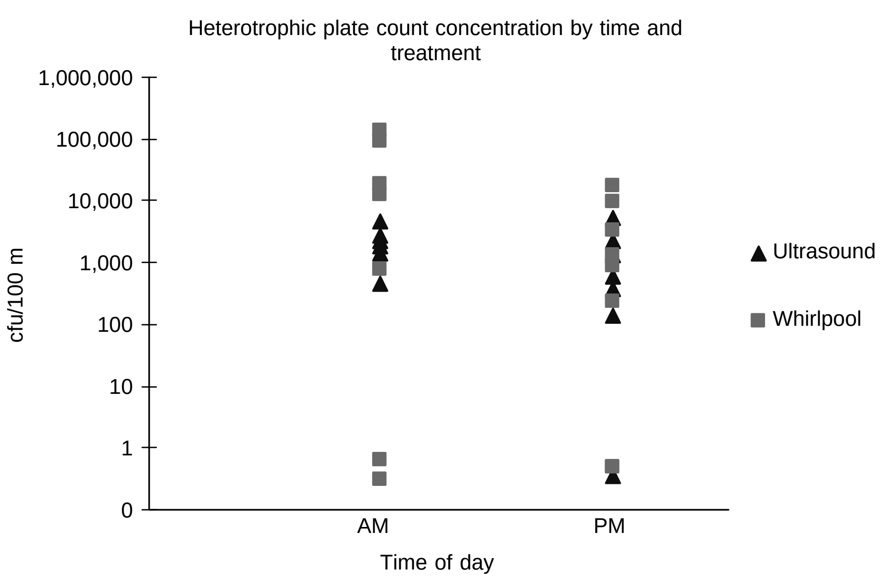

Figure 2 | Water sample cultures: Heterotrophic Plate Count Bacteria[ab] (n = 28). [a]Wilcoxon rank testing using exact p-values showed that heterotrophic plate count values did not significantly differ as a function of time of day (p = .14) or tub type (p = .74). [b]Median Ultrasound values: AM = 1,802 (n = 6) and PM = 901 (n = 7); Median Whirlpool values: AM = 19,369 (n = 7) and PM = 1,126 (n = 8).

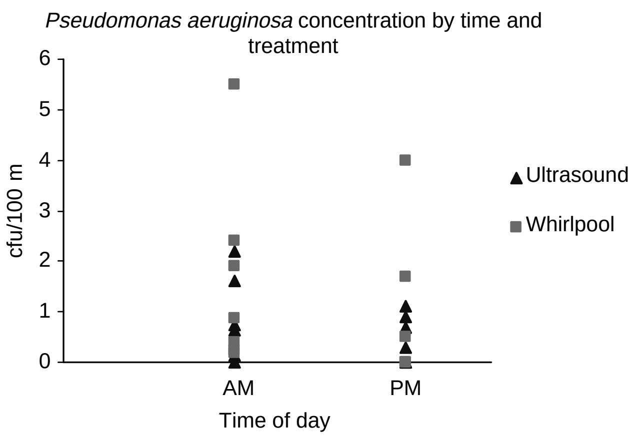

Figure 3 | Water sample cultures: *Pseudomonas aeruginosa* Bacteria[ab] (n = 28). [a]Wilcoxon rank testing using exact p-values showed that *Pseudomonas aeruginosa* values were significantly higher in the AM than in the PM (p = .05), however there were no significant differences between tub types (p = .99). [b]Median Ultrasound values: AM = 0.58 (n = 6) and PM = 0.20 (n = 7); Median Whirlpool values: AM = 0.45 (n = 7) and PM = 0 (n = 8).

or B), *Streptococcus viridans*, *Enterococcus*, *Staphylococcus aureus*, *Escherichia coli*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, other gram negative rods, *Corynebacterium* species, or yeast sampled from resident's intertriginious regions. The average percent of body areas affected by debris, eruptions, fissures/cracking, maceration, redness, scaling, tears/abrasions, and/or ulcers did not differ across tub treatments. Based on these results, skin condition and skin microbial flora did not appear to be differentially affected by the type of tub treatment received.

Differences were observed across tub treatments in terms of nursing assistant satisfaction. RNAs cited the ultrasound/enhanced treatment as easier for cleaning residents than the ultrasound/standard tub treatment (p = .02). This finding is of particular importance if "easier" cleaning can be equated with less manual scrubbing, as manual cleaning can lead to skin irritation (Clever *et al.* 2002; Sibbald *et al.* 2003). Observed resident skin condition was not significantly different when this treatment was used, however, which may indicate that RNAs did not modify their scrubbing routine even when they felt the resident was being cleaned more easily.

RNAs rated the ultrasound/standard treatment, the ultrasound/enhanced treatment, and the whirlpool treatment as making more pleasant sounds than the control treatment (still water), and they rated the whirlpool tub as making significantly more pleasant sounds than either ultrasound treatment. This finding suggests that the noisier the treatment, the more highly it is rated by staff, possibly because they equate noise with cleansing action. An alternative explanation would be that rhythmic noise reduces agitation in residents with dementia (Sloane *et al.* 1997). This hypothesis is consistent with research indicating that "white noise" reduces agitation in nursing home residents (Burgio *et al.* 1996). Another, less favorable explanation would be that the staff rated the noise favorably because it removed the need to converse with residents. This explanation would be particularly problematic because staff conversation with residents, and in particular the explanation of actions before they are initiated, has been shown to enhance resident satisfaction and comfort during bathing, and is also associated with fewer assaults against caregivers (Barrick *et al.* 2001; Somboontanont *et al.* 2004).

RNAs reported that the ultrasound/standard treatment required slightly more time for bathing the resident than the ultrasound/enhanced treatment (p = .07). The meaning of this or any finding regarding bathing times would require additional research, and perhaps videotaped analyses, as reasons for long baths could involve favorable (e.g., resident preference) or unfavorable (e.g., increased staff work) explanations.

RNAs rated the ultrasound/standard treatment as significantly "more suitable" than the control treatment (p = .02), and the whirlpool tub as marginally more suitable than the control treatment (p = .07). This finding is somewhat puzzling, given the RNAs reported the ultrasound/enhanced as more effective and time-efficient. It is possible that other, non-measured considerations, such as perceived cost of the enhanced cleansers, were responsible for this finding.

Measurements of bacterial counts in water samples from the two tubs revealed no significant differences between the ultrasound and whirlpool tubs. However, it should be noted that sample sizes were small (13 samples from the ultrasound tub and 15 from the whirlpool tub) and heterotrophic plate count ranges were wide; so, with larger sample sizes, significant differences might have been observed.

The heterotrophic plate count is a highly nonspecific test, measuring a wide range of bacteria that are grouped together based on their need for organic nutrition; these bacteria are identified using a particular method, temperature, and time (Allen *et al.* 2004). Because of the wide group of bacteria subsumed by this title, and the method used to measure their presence, it is not possible to quantify specific bacteria or determine if any are pathogenic. Of the 28 samples that were collected, however, it is noteworthy that the 5 highest heterotrophic plate count readings were from the whirlpool tub. It is possible that these high heterotrophic plate count levels (ranging from 18,182 to 137,838 cfu/100 ml, with the highest reading from the ultrasound tub being 4,504 cfu/100 ml), contained dangerous pathogenic bacteria. In addition, the highest *Pseudomonas aeruginosa* counts were observed with the whirlpool tub, suggesting that whirlpool tubs may be difficult to clean in a consistent manner. More sampling, with specific testing for individual bacteria, would be needed to definitively determine the pathogenic potential of the two tub types.

The specific bacteria that were measured in the tubs (*Pseudomonas aeruginosa*, *Escherichia coli*, and total coliforms) did not appear to pose any health threat. *Pseudomonas aeruginosa* counts were significantly higher in the morning than in the afternoon regardless of the type of tub, however the overall levels of this bacterium were well below those generally believed to have adverse health effects (Price & Ahearn 1988). However, some researchers have suggested that even small amounts of *Pseudomonas aeruginosa* can potentially cause infection in immunocompromised or other populations (Hollyoak *et al.* 1995*b*; Berrouane *et al.* 2000).

In summary, the method of water agitation does not appear to result in major observable differences in skin condition or infection risk. Facility staff appeared to prefer noisy to quiet bathing conditions, but the meaning of this finding is unclear. Staff rated enhanced skin cleansers more favorably for their cleaning ability, but this did not translate to increases in overall satisfaction. The tubs did not differ in terms of harboring bacteria; however, because the range of heterotrophic plate counts was considerably wider in whirlpool than in ultrasound tubs, consistent reductions in bacterial counts appear to be more difficult to achieve in whirlpool tubs than in ultrasound tubs.

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