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original research

Recommendations for Best Disinfectant Practices to Reduce the Spread of Infection via Wrestling Mats

Linda Mull Young, PhD*; Vicki Abram Motz, PhD*; Emily R. Markey, BS*; Suzanne C. Young†; Ronald E. Beaschler, MEd‡

*Department of Biological and Allied Health Sciences, †Department of Nursing, and ‡Department of Human Performance and Sports Sciences, Ohio Northern University, Ada

Context: At the request of the National Wrestling Coaches Association and the head wrestling coach at our university, we conducted a study of infection transmission in collegiate wrestlers.

Objective: To examine disinfectant effectiveness and develop best-practice guidelines for minimizing the spread of skin infections via wrestling mats.

Design: Controlled laboratory study and crossover study.

Setting: Laboratory and two 15-college wrestling invitational meets.

Patients or Other Participants: A total of 231 collegiate wrestlers and 8 officials.

Intervention(s): In the laboratory-based part of the study, we measured the bacterial load of mats disinfected with 10% bleach, OxiTitan, Benefect, eWater, and KenClean and inoculated with *Staphylococcus epidermidis* (strain ATCC 12228) at a concentration of 6.5×10^4 bacteria/cm^2. In the empirical part of the study, we used these disinfectants during 2 invitational meets and measured mat and participant bacterial load during competition. Participants were swabbed at weigh-in and after their last bout. Mat bacterial load was monitored hourly.

Main Outcome Measure(s): We determined total colony counts and species.

Results: With controlled testing, we observed that products claiming to have residual activity reduced bacterial load by 63% over the course of competition compared with nonresidual agents. Only 4 of 182 participating wrestlers tested positive for methicillin-resistant *Staphylococcus aureus*, which is the normal population occurrence. The predominant species on mats were skin bacteria (*Staphylococcus epidermidis*) and substantial levels of respiratory bacteria (*Streptococcus pneumoniae*), as well as several soil species and a surprisingly low incidence of fecal bacteria (*Escherichia coli*). Disinfectant effectiveness during the meets was consistent with controlled study findings. Cleaning mats with residual disinfectants reduced the average bacterial load by 76% compared with nonresidual cleaners. Using a footbath did not reduce the bacterial load compared with a bleach-cleaned mat, but using alcohol-based hand gel reduced it by 78%.

Conclusions: Best practices based on these data include backward mopping of the mats with a residual disinfectant pulled behind the cleaner, allowing mats to dry before walking on them, having wrestlers use hand gel before each bout, and strongly recommending that all wrestlers receive annual influenza vaccinations.

Key Words: best practices, bacterial transmission, disinfection, infection prevention, decontamination

Key Points

- Best-practice recommendations to minimize the spread of skin infections via wrestling mats are that all wrestlers should receive annual influenza vaccinations, all mats should be mopped backward with a residual disinfectant, and all wrestlers must use alcohol-based hand-sanitizing gel before each bout.
- The incidence of respiratory bacteria on the mats was high.
- Residual disinfectants had long-term bacteria-killing action.
- Backward mopping of mats reduced the occurrence of soil bacteria.
- Using an alcohol-based hand-sanitizing gel reduced bacterial load on the hands.

Wrestling is an ancient sport dating to prehistoric times. It was especially popular in Greco-Roman and early Asian cultures. The first National Collegiate Athletic Association men's wrestling championship was held in 1928. Whereas skin infections have long been documented to spread among wrestlers,[1] pathogen transmission continues to be a concern during practices and competitive meets.[2] Agel et al[3] reported that approximately 20% of wrestling injuries from 1988 to 2004 were skin infections, and Turbeville et al[4] reported 59 outbreaks of infectious disease in competitive sports from 1966 to 2005. Infection can be spread by skin-to-skin contact[5] or through wrestling gear and mats (fomites).[6] Pathogens associated with wrestling injuries include bacteria, viruses, and fungi. Bacteria include *Staphylococcus aureus* and *Streptococcus pyogenes* that result in infections, such as impetigo, folliculitis, erysipelas, and furuncles. Viruses, such as herpes simplex, cause contagious rashes, and fungi, such as *Trichophyton* and *Epidermophyton*, cause ringworm. Although wrestlers with visible skin infections are banned from competition, considerable evidence has suggested that skin-to-skin transmission[4,7,8] and fomite transmission still occur during meets.[9] Therefore, we sought to determine the

sources of contaminants on mats and develop best-practice guidelines for eliminating them.

To minimize the spread of skin infections and promote athlete safety, wrestling mats and equipment are cleaned regularly with a variety of products. Water dilutes infectious agents, and oxidizing agents (eg, bleach, OxiTitan* [Eco Applications, Hudson, OH], ProKure [ProKure Solutions, LLC, Phoenix, AZ], and eWater [eWater Health Emporium, Carrollton, TX]) destroy bacteria by denaturing bacterial proteins. Both quaternary ammonium compounds (KenClean; Kennedy Industries, Horsham, PA) and phenolic compounds (Benefect; Benefect, Ontario, CA) kill bacteria by disrupting the plasma membrane. All of these products except for water are claimed to be bactericidal, and OxiTitan and KenClean also demonstrate residual activity, continuing to kill bacteria beyond the time of application.

Michael Moyer, executive director of the National Wrestling Coaches Association, and Professor Ronald Beaschler, head wrestling coach at Ohio Northern University and a coauthor of this study, requested development of evidence-based best practices to reduce the transmission of skin infections among wrestlers at competitions. Therefore, the purposes of our study were to (1) identify sources of bacterial pathogens in the wrestling environment; (2) determine the most effective, practical methods of bacterial disinfection; and (3) develop guidelines that wrestling coaches can implement to minimize infections. We expected that skin bacteria would predominate in the wrestling environment. We also expected that 10% bleach, the long-used standard for microbial decontamination, would be as effective or more effective than other cleaning agents in killing bacteria but would have no residual effects.

METHODS

We used a 2-tiered study to develop appropriate bacterial-reduction methods. A controlled study in the laboratory allowed us to determine the effective use of disinfectants over time with a known inoculant load. Data collected during invitational meets in 2013 and 2014 were evaluated to determine the killing effectiveness of disinfectant methods on mats that were used during 6 hours of competition with constant reinoculation by successive wrestlers. All participants provided written informed consent, and the study was approved by our institutional review board (protocol LY-AS-100114-1).

Controlled Study

A controlled laboratory study was conducted inside a biohazard hood. New 30- × 30-cm mat squares (provided by Resilite Sports Products, Inc, Sunbury, PA) were divided into quadrants and disinfected according to the manufacturer's specifications using 1 of 5 cleaning agents: 10% bleach, OxiTitan, Benefect, eWater, and KenClean (n = 4 replications for all treatments). To determine surface sterilization by each agent, we sampled mat squares by rubbing a rayon swab moistened with Stuart medium over the mat surface for 30 seconds. Bacteria were extracted by placing the swabs in tubes containing 2 mL of Mueller-Hinton broth and agitated in an Eppendorf thermoagitator (ThermoMixer C; Eppendorf AG, Hamburg, Germany) at 1000 revolutions per minute for 5 minutes at 37°C. A 10-μL sample of each extract was inoculated on trypticase soy agar with 5% sheep red blood cells, or blood agar plates (BAPs), and incubated for 24 hours at 37°C in 5% CO_2. Initial sterile conditions were confirmed.

Each sterilized mat quadrant was inoculated with 100 μL of a 0.5 McFarland standard of *Staphylococcus epidermidis* (strain ATCC 12228; 1.5×10^7 cells/quadrant = a concentration of 6.5×10^4 bacteria/cm^2) that were distributed evenly using a sterile spreader and allowed to dry. To determine a time course of bacterial growth, 2.5- × 15-cm strips of inoculated mats were sampled at 0, 1, 2, 6, and 24 hours. Swabs were handled as described, and bacterial colonies were counted after 24 hours of incubation.

All Ohio Northern University wrestlers were screened monthly (September 2013–March 2015) for methicillin-resistant *S aureus* (MRSA). Appropriately trained personnel (L.M.Y., V.A.M., E.R.M., S.C.Y., and trained students) performed nasal swabs on the wrestling participants using culturettes with Stuart medium. Specimens were inoculated on chromID MRSA medium (bioMérieux, Marcy l'Etoile, France) and incubated for 24 hours at 37°C in 5% CO_2. Any specimens demonstrating growth of blue-green colonies after 24 hours were subcultured onto BAPs and incubated as described. Beta-hemolytic samples were gram stained and tested for the presence of coagulase. Specimens testing positive for coagulase, demonstrating gram-positive staining with clustered cocci morphology, and demonstrating growth on Mueller-Hinton agar with 4% oxacillin were reported as positive for MRSA.

2013 Invitational Meet

We swabbed the nostrils, hands, and anterior surfaces of the forearms of the home team (N = 24) and 5 volunteers from each of 5 guest teams at the beginning of the 2013 invitational meet and repeated the hand and forearm swabs when athletes were eliminated from competition. In addition, the hands and lateral forearms of the officials (N = 8) were swabbed at the beginning and end of the meet. We tested mat disinfectants, including 10% bleach, OxiTitan, KenClean, and ProKure (alone and in combination). Mats were disinfected according to the manufacturer's specifications and were swabbed hourly throughout the meet by a trained team (L.M.Y., V.A.M., E.R.M., S.C.Y., and trained students). Swabs were plated on BAPs, mannitol salt agar (MSA) plates, and eosin methylene blue agar using a quadrant-based streaking technique designed for bacterial quantification. Given that the bacterial colony count was so high, load was approximated using a single decimal scale so the whole number represented the last quadrant in which bacteria grew, and the decimal fraction represented the relative abundance of colonies in that quadrant.

*In April 2015, the US Environmental Protection Agency issued an order to stop the sale, use, or removal of OxiTitan, which contains the active ingredient zinc nanoparticle. The order included several trade names and any related products containing the same formulation (https://www.epa.gov/newsreleases/epa-takes-action-protect-public-unregistered-pesticideepa-issues-order-stop-sale).

2014 Invitational Meet

Given the results of the 2013 study, mats were cleaned during the 2014 invitational meet by mopping backward with 10% bleach, isopropanol, OxiTitan, KenClean, 0.25% thymol, or Benefect. To accomplish this mopping technique, the cleaner walked backward, pulling the mop so that he or she did not walk on the clean, wet surface. Mats were allowed to dry before use. Nasal swabs for MRSA screening and hand swabs were conducted at weigh-in for all wrestlers on all teams (N = 182); their hands were swabbed again after elimination by second loss. We extracted swabs as previously described. Mats were swabbed uniformly by a trained team (L.M.Y., V.A.M., E.R.M., S.C.Y., and trained students) at the beginning of the meet and hourly thereafter. The team pulled the swabs across the starting line, rubbing the entire area with 1 side of the swab and then rubbing in the perpendicular direction with the opposite side of the swab, and extracted them as previously described. Extract was inoculated on BAPs and MSAs. Plates were read after a 24-hour incubation at 37°C in 5% CO_2. Species identification was performed by visual screening followed by gram staining, use of differential media and serologic analysis, and confirmation via the Vitek 2 (bioMérieux) microbial identification system as necessary.

One set of 3 mats was used to determine the value of the auxiliary cleaning methods. All 3 mats were disinfected with 10% bleach. Mat 1 served as the control; mat 2 was used to monitor the effect of shoe disinfection, as we required wrestlers to wipe their feet through a bath containing 10% bleach before entering; and mat 3 was used to analyze the effect of hand antisepsis, as we required wrestlers to clean their hands with a pump-dispensed alcohol-based hand gel (62% ethanol; Member's Mark Hand Sanitizer; Vi-Jon Laboratories, Inc, St Louis, MO) before their bouts.

For each mat, we recorded the time of each bout, the participating wrestlers, and the hand bacterial colony counts for the first and final bouts of each wrestler. Wrestlers (N = 182) from 15 schools competed in a total of 385 bouts. Bouts were conducted over a 9-hour period, evenly spread over 8 mat conditions, with a mean of 48.1 ± 3.2 bouts per mat and an hourly average of 12.0 ± 3.4 wrestlers per mat. The mean number of bacterial colonies counted (representing 1% of swabbed load) on the hands of each wrestler was 50.3 ± 11.5. For each hour, the total bacterial load of the wrestlers on each mat was calculated by multiplying the average load of participating wrestlers by the number of wrestlers who used the mat during that time. The load on each mat during each hour was determined by directly swabbing mats. We counted 8976 representative colonies, representing 1% of swabbed bacteria.

Statistical Analysis

For the controlled study, we used analysis of variance with post hoc *t* tests. Invitational meet data were grouped by treatment. We calculated means and standard deviations (SDs) and paired *t* tests. Change in load over time was grouped by hour within the treatment group. We calculated means, SDs, analysis of variance, and post hoc *t* tests. For the 2013 invitational meet, we devised an arbitrary system to compare bacterial load. Dilution streaking of the 4 quadrants was performed, and plates were assigned a number *x.y*, where *x* was the last quadrant in which colonies were found and *y* was the relative growth in that quadrant, which was scored as 1 (*light*), 2 (*moderate*), 3 (*heavy*), or 4 (*dense*). These were analyzed by means and SDs and then graphed; comparisons were relative and expressed as percentages. For the 2014 invitational meet, we quantified bacteria using a technique that delivered a consistent 1% of plated bacteria, which were counted directly; calculated the means and SDs; and used analysis of variance and post hoc *t* tests. We performed regression analysis with Excel (version 2016; Microsoft Corpo, Redmond, WA) to examine the relationship between bacterial loads on the mat and wrestlers. The α level was set at .05.

RESULTS AND DISCUSSION

Controlled Study

Using rayon swabs and a thermoagitator resulted in consistent retrieval of 1% of bacteria from the swabbed specimens. In their study of bacterial-swabbing methods, Moore and Griffith[10] indicated that great inconsistency existed in recovery rates. Whereas we recovered a small proportion, it was within the range reported by others and most importantly was consistent, producing more reliable data.

We observed 2 distinct patterns of bacterial growth that were associated with characteristics of the disinfectants used (Figure 1). Mats disinfected with nonresidual products (eWater, 10% bleach) had high rates of bacterial growth in the first 2 hours after inoculation and peaked during that time. Growth decreased as bacteria depleted available nutrients, and loads slowly rose again as the surviving bacteria used the remains of dead microbes for nourishment. Mats disinfected with products advertising residual effects (OxiTitan, KenClean) had a slower rate of bacterial growth than those disinfected with nonresidual agents ($t_4 = 2.86$, $P = .02$); growth peaked at 3 to 4 hours and declined to very low levels at 24 hours. The thyme-based disinfectant (Benefect) demonstrated residual growth patterns similar to those of residual disinfectants ($t_4 = -1.774$, $P = .08$) and different from those of nonresidual disinfectants ($t_4 = 2.96$, $P = .02$; Figure 1).

2013 Invitational Meet

Data from the 2013 invitational meet yielded information on both the processing of pathogens during a meet and their transmission. We determined that MSA plates yielded only 55.8% of the bacterial count found on BAPs; eosin methylene blue agar, only 4.2%. Given that bacterial counts were greater on BAPs, they are used as the standard for reporting results in this paper unless otherwise specified.

We observed no difference in the bacterial load between the officials and the wrestlers at the beginning of the meet ($t_{10} = -0.84$, $P = .20$). The mean initial bacterial load on the officials' hands (2.40 ± 0.81) and forearms (2.27 ± 0.93) did not rise by the end of the meet (2.27 ± 0.83 and 2.27 ± 0.78, respectively; $t_8 = 1.25 \times 10^{-16}$, $P = .83$). This lack of change was consistent for all media tested, suggesting that officials have little effect on bacterial spread. The wrestlers' hands (N = 49 in 2013) had higher bacterial loads than their

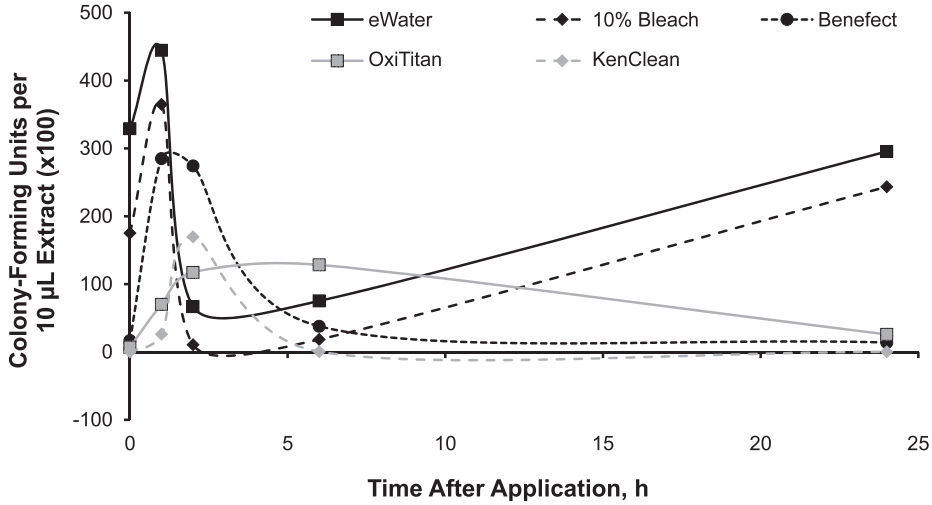

Figure 1. Time course of bacterial load on mats in the controlled study compared by treatment. Products: eWater, eWater Health Emporium, Carrollton, TX; Benefect, Benefect, Ontario, CA; OxiTitan, Eco Applications, Hudson, OH; KenClean, Kennedy Industries, Horsham, PA.

forearms at the beginning (1.80 ± 0.91) and end of the meet (2.30 ± 1.14; $t_{34} = -5.83$, $P < .001$). Their hands had higher loads at the end (2.83 ± 1.18) than at the beginning of the meet (2.37 ± 0.93; $t_{33} = -7.32$, $P < .001$), indicating that mat conditions (heat, sweat) are conducive to bacterial incubation.

The fairly high initial bacterial load on mats at the onset of the meet (0.41 ± 0.56) can be ascribed to contamination during warm-up and a mat-cleaning protocol that included the cleaner walking on freshly cleaned mats that had not yet dried. We observed a rise based on the quadrant-scaling method (2.1 ± 0.0; $F_{1,5} = 8.99$, $P < .001$), with post hoc t tests showing a rise after the first 2 hours of competition ($t_7 = -3.78$, $P = .003$) and another rise after 2 more hours of competition (2.35 ± 1.08; $t_7 = 3.41$, $P = .005$; Figure 2). The increase in bacterial count was not different beyond that point ($t_7 = -1.52$, $P = .09$). This observation implied that bacterial growth from early bouts, which may have peaked, was replaced by new inoculants from later bouts, maintaining a consistently high load.

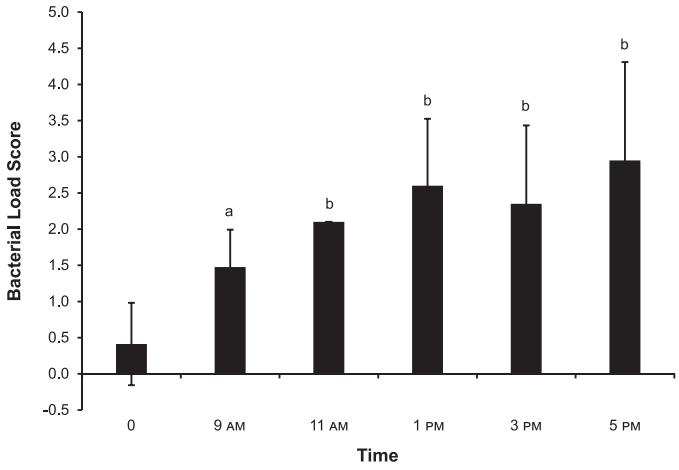

Figure 2. Bacterial load on mats over the course of a meet showing significant increases after a, 2 hours of grappling and b, then again after another 2 hours but not thereafter.

We found high counts of skin bacteria (relative count is reported here because very high plate counts rendered quantification of individual bacterial species impractical for these 2013 data); low counts of fecal coliforms; and high counts of respiratory species, including *Streptococcus pneumoniae* on the mats (Table). Given that *S pneumoniae* is associated with developing postinfluenza infection, we recommended that wrestlers receive the influenza vaccine to avoid influenza transmission and complications. A surprisingly large representation of soil bacteria was also present. Whereas these are not normally pathogenic, they

Table. Categories of Representative Bacterial Contaminants Found on Mats

Category	Contaminant
Respiratory bacteria	*Streptococcus pneumoniae*
	Klebsiella pneumoniae
Skin bacteria	*Staphylococcus epidermidis*
	Staphylococcus aureus
	Micrococcus luteus
	Kocuria varians
	Staphylococcus capitis
	Staphylococcus lugdunensis
Soil bacteria	*Bacillus* spp
	Paracoccus yeei
	Micrococcus luteus
	Brevundimonas spp
Fecal coliforms	*Escherichia coli*
	Enterobacter aerogenes
	Pantoea spp
	Enterococcus casseliflavus
Opportunistic bacteria	*Pseudomonas aeruginosa*
	Kocuria rosea
	Serratia marcescens
	Alloiococcus otitis
	Cronobacter sakazakii group
	Alcaligenes faecalis
	Acinetobacter spp

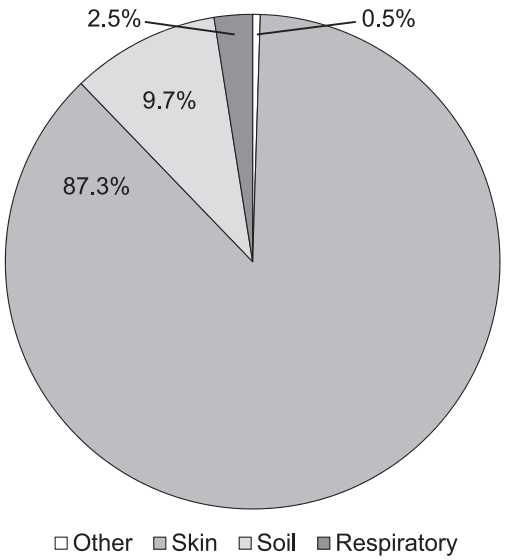

Figure 3. Representative sources of bacteria on mats expressed as a percentage of the total bacterial load.

can be infectious when they penetrate the skin through abrasions, such as those received during contact sports.

These findings suggest that a disinfecting agent with residual activity should be used to kill bacteria throughout an invitational meet and that alternative mat-cleaning protocols, such as dragging the mop behind the cleaner (mopping backward) and allowing mats to dry completely before walking on them, should be used.

2014 Invitational Meet

The data from the 2014 meet reflected implementation of some recommendations made after the 2013 meet and benefitted in design from the results of the controlled study to improve quantification of bacterial load. Mats were cleaned by mopping backward, and all Ohio Northern University wrestlers received influenza vaccines. A set of mats was dedicated to testing the bacteriocidal potential of auxiliary cleaning using an alcohol-based hand-sanitizing gel or foot bath. In addition, MRSA screening was continued monthly for our wrestlers and was also conducted for all participants at the 2014 invitational meet.

Soil bacteria were reduced to 9.7% of total mat load (307 out of 3155 colonies identified) presumably due to mopping backward (Figure 3).

High amounts of respiratory flora, most notably *S pneumoniae*, were found on the mats. These microbes were presumably transferred from wrestlers to mats by forceful exhalations during competition. These findings are very important for 2 reasons. First, *S pneumoniae* is a marker for other respiratory pathogens that we could not monitor in this investigation. These pathogens include the viruses that cause colds and influenza, indicating that wrestlers may be at higher risk of acquiring these infections. Second, the prevalence of the H1N1 influenza virus was at its highest level since the 2009 pandemic.[11] The H1N1 virus leads to more severe illness in individuals aged 18 to 25 years, and the greatest concern in this cohort is the complication of pneumonia caused by *S pneumoniae*. Given that *S pneumoniae* was consistently found contaminating mats, wrestlers are not only at high risk of acquiring the H1N1 infection but also face dangerous *S pneumoniae* complications. Mandatory influenza vaccinations implemented by our wrestling team in 2014 reduced the team influenza infection rate from approximately 40% before 2014 to 0% (R. Beaschler, oral communication, April 2015). Thus, influenza vaccinations should be recommended for all wrestlers to prevent avoidable complications from infection.

The MRSA tests were positive in 2.2% of invitational athletes (4 of 182), which was equivalent to the national average of 2% in 2014,[12] and confirmed the observation of Lindenmayer et al[13] that the spread of MRSA during a meet does not appear to be a major concern.

Three organisms (*Pseudomonas aeruginosa, Kocuria rosea*, and *Serratia marcescens)* were regularly collected from the mats. These microbes are opportunistic pathogens. Although not usually infectious, wrestlers who are immunocompromised due to other infections, type I diabetes, or certain drug therapies are potentially at risk for acquiring an infection caused by these microorganisms, emphasizing the need for adequate mat disinfection.

All tested cleaners killed bacteria. During the meet, mats cleaned with residual disinfectants reduced the mean total bacterial contamination by 76.3% of load (mean colony count of mats = 437.25 ± 231.30) compared with mats cleaned with nonresidual products (mean colony count of mats = 1844.50 ± 423.50; $t_2 = 2.68$, $P = .05$; Figure 4).

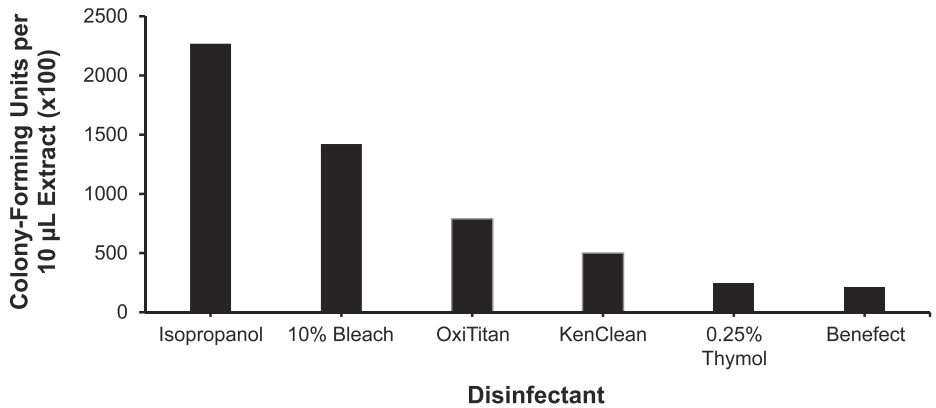

Figure 4. Comparison of total bacterial load on mats cleaned with different disinfectants shows the effectiveness of residual disinfectants. Products: OxiTitan, Eco Applications, Hudson, OH; KenClean, Kennedy Industries, Horsham, PA; Benefect, Benefect, Ontario, CA.

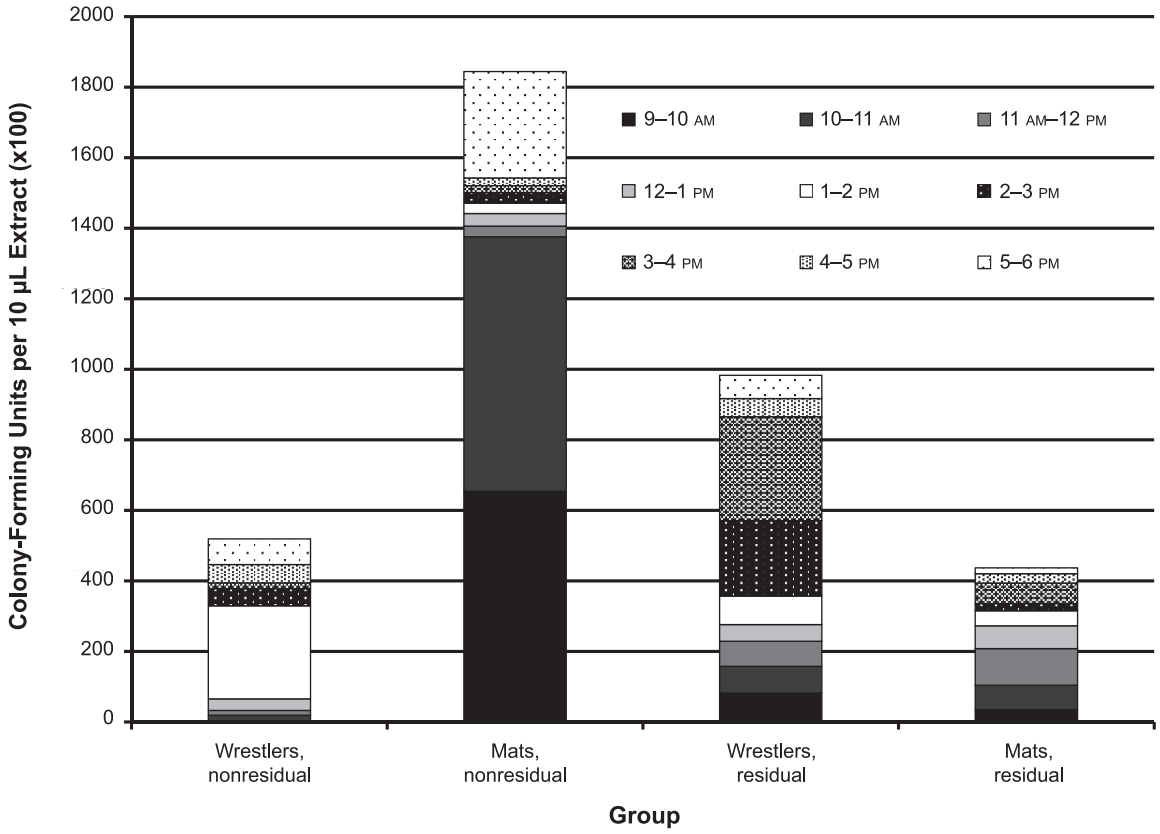

Figure 5. Comparison of average wrestler load and hourly mat load shows an inverse correlation with the swabbed load on mats cleaned with residual disinfectants.

Mats used to test auxiliary cleaning methods were not included in these data. Given that only wrestlers who were eliminated in a bout were swabbed, hourly bacterial loads were estimated by multiplying the average load of swabbed wrestlers by the total number of wrestlers who grappled on the mat during that hour. Estimated average hourly load of bacteria on wrestlers did not correlate with swabbed load on the mat during that hour. Mats cleaned with nonresidual cleaners trended toward having an equal or higher load than the contaminating wrestlers in any given hour ($F_{1,8} = 0.76$, $P = .41$, $R^2 = 0.098$). Mats cleaned with residual products, including natural thyme-based disinfectants, trended toward equal or lower bacterial loads than the contaminating wrestlers in any given hour ($F_{1,8} = 0.055$, $P = .82$, $R^2 = 0.0079$; Figure 5). This observation supports the claims of manufacturers that residual cleaners effectively decrease overall bacterial load during extended use of wrestling mats. Therefore, all mats should be cleaned with residual disinfectants.

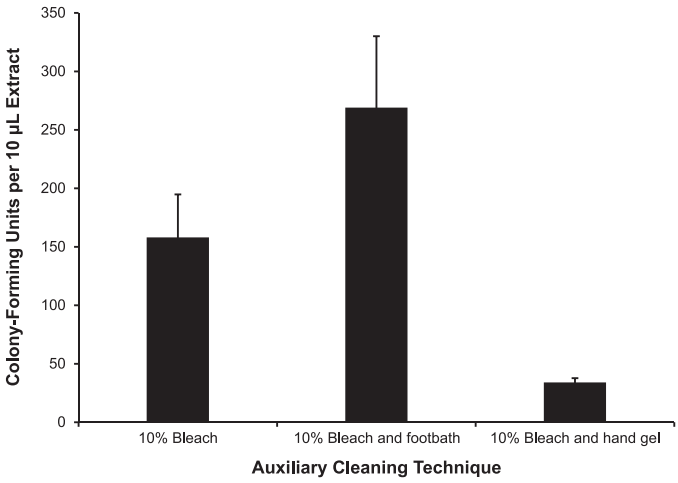

Figure 6. Comparison of auxiliary cleaning techniques shows the effectiveness of hand gel in reducing bacterial load.

For auxiliary cleaning methods, the average hourly bacterial load on the mat where wrestlers used a pump-dispensed hand gel before grappling was 78.3% lower than where hand gel was not used (34.3 ± 37.9 colonies versus 157.9 ± 45.9 for bleach alone; $t_{16} = 1.002$, $P = .16$; Figure 6) and 73.4% lower than the average of all other treatments that did not include hand gel (34.3 ± 37.9 colonies versus 128.9 ± 40.7 for others; $t_{16} = 2.34$, $P = .02$). This observation is consistent with the findings of Anderson,[14] who reported that a reduced incidence of postcompetition infection correlated with hand washing. The importance of this finding is that, if wrestlers have lower initial bacterial counts, fewer bacteria will be transmitted to the mats, reducing their effect as a fomite. We observed no improvement on the mat with the auxiliary footbath as used (269.0 ± 79.4 colonies versus 157.9 ± 45.9 for bleach alone; $t_{16} = 0.467$, $P = .32$). Although it was not part of the protocol, we noted that wrestlers wiped their shoes with a random communal towel after using the footbath, which likely negated any potential benefit of the foot-cleaning regimen (Figure 6) and is a reminder that shared equipment serves as a fomite promoting microbial

transmission. Therefore, wrestlers should use hand gel before each bout.

CONCLUSIONS

The results of this 2-year study yielded 4 best-practice recommendations.

1. Recommend annual influenza vaccinations for all wrestlers. Based on the high incidence of respiratory bacteria, both bacterial and viral respiratory pathogens can be transmitted during a meet. Given that complications from these pathogens are a concern in this demographic, we recommend that all students who participate in collegiate wrestling receive influenza vaccines.
2. Clean all mats with a residual disinfectant. All residual disinfectants that were tested had long-term bacteria-killing action compared with nonresidual cleaners, which included the standard 10% bleach treatment. Given that natural thyme-based cleaners have residual activity, they should be considered, especially when sensitivities to harsh disinfectants are a concern.
3. Encourage all coaches to use the backward-mopping technique for mat disinfection. Based on the high occurrence of soil bacteria that are potentially pathogenic when introduced into abraded areas, the person cleaning the mats should avoid walking on them after cleaning, and foot traffic on mats should be restricted to participating wrestlers who are not wearing street shoes. Options for cleaning modifications might include having the cleaners wear booties or walk backward, dragging the mop behind them. In addition, any mats rolled for storage should be recleaned before use, as they are likely contaminated with soil bacteria when the floor side of the mat contacts the top.
4. Make hand-gel use by all wrestlers mandatory before each bout. Given that the hands had the highest bacterial load and use of an alcohol-based gel reduced this load by 73.4%, we recommend that wrestlers cleanse their hands with an alcohol-based hand sanitizer before each bout and that all venues make this gel available.

In follow-up studies, researchers will examine the use of alternative shoe-cleansing methods, such as wipes containing residual cleaners, before entering the mat; additional types of hand gels, particularly those containing residual agents; and cleaning practices for wrestling equipment other than the mats themselves.

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REFERENCES

1. Selling B, Kibrick S. An outbreak of herpes simplex among wrestlers (herpes gladiatorum). *N Engl J Med*. 1964;270:979–982.
2. Habibipour R, Moradi-Haghgou L, Bayat S. Survey on dermatophytosis in wrestlers and its relationship with wrestling mats in Hamedan. *Zahedan J Res Med Sci*. 2012;14(8):38–42.
3. Agel J, Ransone J, Dick R, Oppliger R, Marshall SW. Descriptive epidemiology of collegiate men's wrestling injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 through 2003–2004. *J Athl Train*. 2007;42(2):303–310.
4. Turbeville SD, Cowan LD, Greenfield RA. Infectious disease outbreaks in competitive sports: a review of the literature. *Am J Sports Med*. 2006;34(11):1860–1865.
5. Adams BB. *Tinea corporis* gladiatorum. *J Am Acad Dermatol*. 2002; 47(2):286–290.
6. Stanforth B, Krause A, Starkey C, Ryan TJ. Prevalence of community-associated methicillin-resistant *Staphylococcus aureus* in high school wrestling environments. *J Environ Health*. 2010; 72(6):12–16.
7. Snook GA. Injuries in intercollegiate wrestling: a 5-year study. *Am J Sports Med*. 1982;10(3):142–144.
8. Adams BB. Transmission of cutaneous infections in athletes. *Br J Sports Med*. 2000;34(6):413–414.
9. Kohl TD, Martin DC, Nemeth R, Evans DL. Wrestling mats: are they a source of ringworm infections? *J Athl Train*. 2000;35(4):427–430.
10. Moore G, Griffith C. Problems associated with traditional hygiene swabbing: the need for in-house standardization. *J Appl Microbiol*. 2007;103(4):1090–1103.
11. H1N1: originally referred to as swine flu. US Department of Health and Human Services Web site. http://www.flu.gov/about_the_flu/h1n1/. Accessed June 15, 2016.
12. MRSA tracking. Centers for Disease Control and Prevention Web site. http://www.cdc.gov/mrsa/tracking/. Accessed June 15, 2016.
13. Lindenmayer JM, Schoenfeld S, O'Grady R, Carney JK. Methicillin-resistant *Staphylococcus aureus* in a high school wrestling team and the surrounding community. *Arch Intern Med*. 1998;158(8):895–899.
14. Anderson BJ. Effectiveness of body wipes as an adjunct to reducing skin infections in high school wrestlers. *Clin J Sport Med*. 2012; 22(5):424–429.

Address correspondence to Linda Mull Young, PhD, Department of Biological and Allied Health Sciences, Ohio Northern University, 525 South Main Street, Ada, OH 45810. Address e-mail to l-young@onu.edu.