

## The Sports Ball as a Fomite for Transmission of *Staphylococcus aureus*

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**Abstract** Outbreaks of methicillin-resistant *Staphylococcus aureus* (MRSA) are becoming increasingly frequent in the athletic community. Skin-fomite contact represents a putative mechanism for transmission of MRSA. The objective of this study was to demonstrate the prevalence and transmissibility of *S. aureus* in three surfaces commonly encountered in the gymnasium setting: the court floor, the sports ball, and the athlete's hands. Three sports scenarios were simulated by dribbling a sports ball within a designated area; the surfaces were cultured before and after play using media selective for *S. aureus*. There was significant transfer of *S. aureus* from the native, contaminated surface towards two disinfected surfaces. In a fourth experiment, survival of *S. aureus* on sports balls was evaluated over time. *S. aureus* was found to be viable on the ball for at least 72 hr. This study demonstrates the significance of the sports ball as a vector for pathogen transmission. Interventions aimed at reducing athletic outbreaks should therefore include routine disinfection of sports balls during and after play.

### Introduction

Methicillin-resistant *Staphylococcus aureus* (MRSA) has received growing attention because of its widespread prevalence and virulence in healthcare and sports environments (Cohen & Kurzrock, 2004). Community-associated MRSA (CA-MRSA) infections are commonly distinguished from other staphylococcal infections by the absence of predisposing patient risk factors or recent attendance at a healthcare institution. CA-MRSA infections are often aggressive, necrotizing, antibiotic-resistant, and sometimes fatal (Centers for Disease Control and Prevention, 2016). MRSA is genetically characterized by

the presence of the arginine catabolic mobile element, the SCCmec IV gene complex, and the gene encoding Panton-Valentine leukocidin. The latter element is a recognized cytotoxic virulence factor implicated in a number of severe infections and necrotic cutaneous lesions (Lina et al., 1999).

Athletes are at particular risk of skin infection due to a high degree of skin maceration (breaking down of skin resulting from prolonged exposure to moisture) and abrasive contact between players. Over one quarter of the academic literature concerning sports infections describes outbreaks of MRSA, suggesting a growing recognition of MRSA as

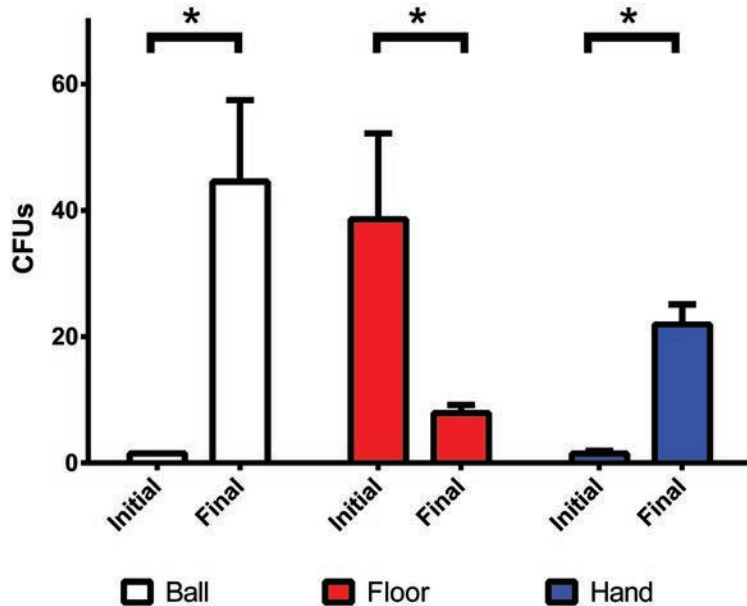
an epidemic risk to players (Grosset-Janin, Nicolas, & Sarau, 2012). While the environmental prevalence of MRSA appears to vary widely between surfaces and institutions, athletic environments pose a considerable risk to active athletes and their trainers (Oller, Province, & Curless, 2010). In one study, nearly 90% of wrestling mats in rural high schools were found to harbor MRSA isolates (Stanforth, Krause, Starkey, & Ryan, 2010).

The first outbreak of MRSA infection in the athletic community was reported in 1998 (Stacey, Endersby, Chan, & Marples, 1998). Since then, numerous investigations of CA-MRSA outbreaks have been documented in participants of football, wrestling, rugby, soccer, and other sports (Turbeville, Cowan, & Greenfield, 2006). The financial, clinical, and emotional ramifications of these infections cannot be overemphasized; for example, in one professional U.S. football team, a total of 17 missed days of game or practice were accumulated due to a single outbreak (Kazakova et al., 2005).

Skin-to-skin contact among players with traumatic lesions or abscesses has tentatively emerged as the primary mechanism of CA-MRSA transmission between athletes, although equipment sharing and poor hygiene have also been implicated in the spread of contagions (Cohen, 2005; Turbeville et al., 2006). Regardless, the risk of CA-MRSA transmission through an intermediary fomite is not well understood (Benjamin, Nikore, & Takagishi, 2007). Given the relative uncertainty underlying the mechanisms of CA-MRSA transmission, we sought to investigate the role of the sports ball as a potential reservoir and vector in the communication of *S. aureus*.

FIGURE 1

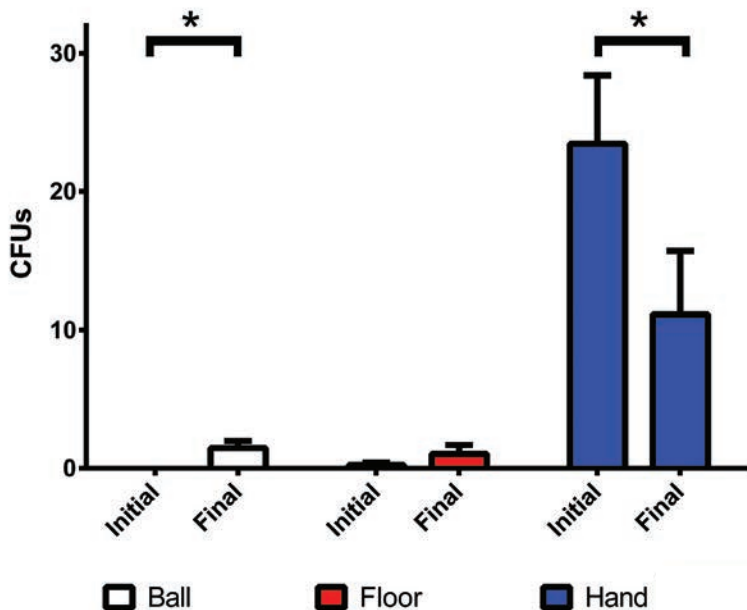
**Staphylococcus aureus Transfer From Floor to Ball and Hand for Simulation #1**



\* $p < .05$ .

FIGURE 2

**Staphylococcus aureus Transfer From Hand to Ball and Floor for Simulation #2**



\* $p < .05$ .

The purpose of this study is twofold: 1) to demonstrate the prevalence of *S. aureus* on sports balls circulating through a university gym that was open to student athletes, and 2) to establish that sports balls can act as vehicles for the transmission of *S. aureus* between the gym floor and athlete's hands. We elected to study the transmission of *S. aureus* as a model for CA-MRSA, as the greater environmental prevalence of *S. aureus* provides a more abundant reservoir from which large-scale microbial transmission can be studied. To our knowledge, this study is the first designed to explore in situ transmission between sports surfaces through simulated play. The elucidation of in-play transmission dynamics could be a vital factor in the design of future prevention efforts aimed at ameliorating infectious outbreaks in organized sports.

**Methods**

This study was conducted in the Anteater Recreation Center (ARC), the student gymnasium at the University of California, Irvine. All protocols were approved by the university institutional review board. The contact transfer of *S. aureus* between three surfaces—the gym floor, the sports ball, and the athlete's hands—was measured by means of simulated play in three different scenarios. In each scenario, two of the three surfaces were disinfected prior to play, while one was left in its native state. Each simulation was repeated 6 times with a basketball and 6 times with a volleyball for a total of 12 independent trials. In a fourth experiment, the viability of *S. aureus* on 6 sports balls was evaluated by serial cultures over a period of 72 hr.

**Specimen Sampling**

In each scenario, the following surfaces were sampled before and after play: the volar (or palm) surfaces of each hand, two random sites within a designated area of the gym floor, and two random sites on the sports ball. Sampling was carried out by means of contact "stamping" of the designated surface with an agar plate consisting of Baird-Parker agar (Hardy Diagnostics), a medium selective for *S. aureus*. All sample sites were subsequently marked to avoid sampling the same region twice in a single simulation. In each scenario, trials were excluded if either of the two disinfected surfaces cultured more than 10 CFUs



Sampled sports balls on disinfection stands. Photo courtesy of Brandon Haghverdian.

before play (as a means of controlling for inadequate pre-simulation disinfection).

**Simulation #1: Transfer From Floor to Ball and Hand**

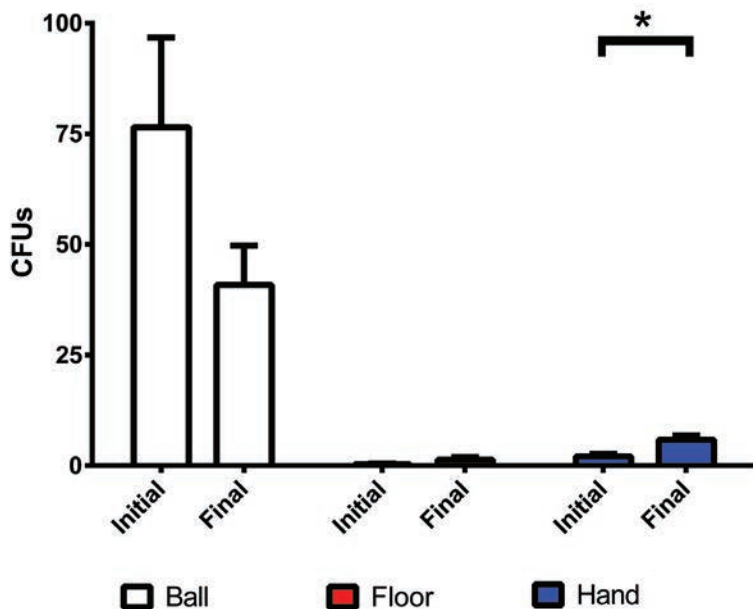
A 2 x 2 ft (0.6 x 0.6 m) zone within the free throw lane of an indoor basketball court was sectioned off immediately after a student basketball pick-up game (a spontaneous game as compared with a scheduled team game). The hands of a volunteer athlete were disinfected with commercial antimicrobial soap and warm water for 30 s. A leather basketball or volleyball, which was disinfected off site by 10 min of exposure to germicidal ultraviolet C (UV-C) light using a commercially available sports ball cleaner (GermNinja, Jaypro Sports), was handed to the player using a sterile surgical drape to avoid contamination. The participant was then instructed to stand stationary with his or her feet outside the designated area and dribble the ball inside the designated area for 5 min, alternating hands with each bounce.

**Simulation #2: Transfer From Hand to Ball and Floor**

Student athletes were recruited after at least 30 min of basketball or volleyball practice. A 2 x 2 ft (0.6 x 0.6 m) zone within the gym floor was sectioned off and disinfected using 70% ethyl alcohol. The floor was allowed to air dry for 10 min before simulated play. A leather basketball or volleyball, previously disinfected using UV-C light, was delivered to the participant using a sterile surgical drape to avoid contamination. The participant was then instructed to stand stationary with his or her feet outside the designated area and dribble the ball inside the designated area for 5 min, alternating hands with each bounce.

FIGURE 3

**Staphylococcus aureus Transfer From Ball to Floor and Hand for Simulation #3**



\**p* < .05.

**Simulation #3: Transfer From Ball to Floor and Hand**

A leather basketball or volleyball was checked out from the ARC's ball rental center within one hr following use in a student pick-up game. The hands of a volunteer athlete were disinfected with commercial antimicrobial soap and warm water for 30 s. A 2 x 2 ft (0.6 x 0.6 m) zone within the gym floor was sectioned off and disinfected using 70% ethyl alcohol. The floor was allowed to air dry for 10 min before simulated play. The participant was then instructed to stand stationary with his or her feet outside the designated area and dribble the ball inside the designated area for 5 min, alternating hands with each bounce.

**Survival of *S. Aureus* on a Sports Ball**

Three basketballs and three volleyballs were sequestered from the ARC's ball rental center within one hr following use in a student pick-up game. Each ball was sampled three times for the presence of *S. aureus*. The balls were then situated on disinfected stands in a ventilated equipment storage room adjacent to the ball rental center (see photo above). The

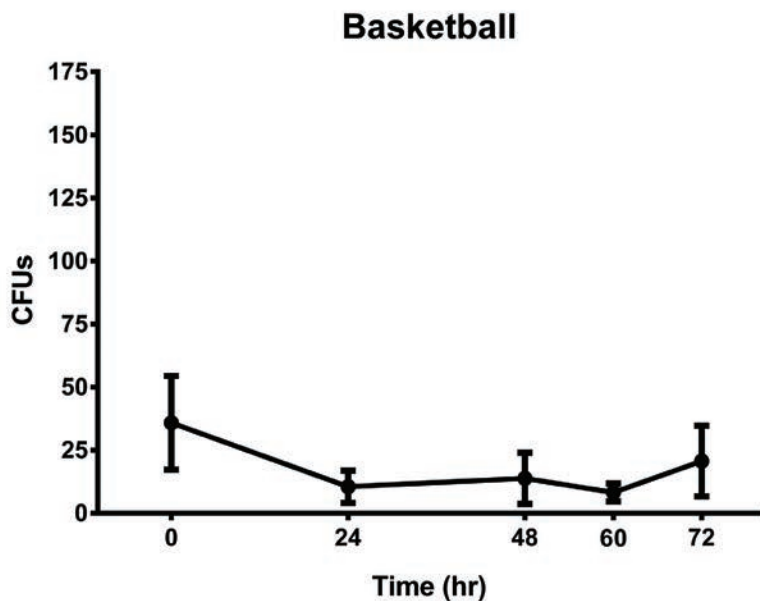
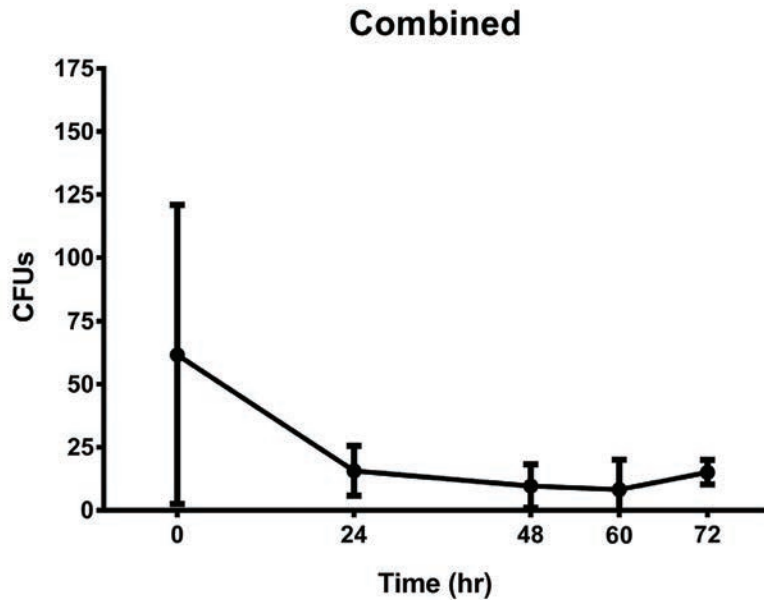
sports balls were not disturbed and were not allowed to touch any other surface. Serial cultures were subsequently obtained at two locations in different regions of the ball at 24 hr, 48 hr, 60 hr (basketball only), and 72 hr. Ambient room temperature (20–25 °C) was maintained for the duration of the experiment.

**Specimen Incubation, Colony Identification, and Statistical Analysis**

Culture plates used in sample collection were incubated aerobically using room air at 35 °C for 48 hr, consistent with manufacturer guidelines. The plates were checked for growth and counted by two different observers, with each individual observer counting the plate twice for accuracy. If the colony counts varied by more than 10% between observers, the plate was counted an additional time by a third observer; the three counts were then averaged. We assessed transmission between surfaces by comparing the average number of CFUs counted on the plate before and after play. Two-tailed, paired *t*-tests (*p* < .05) were used to statistically compare CFUs. Data were analyzed using IBM SPSS Statistics 23.

FIGURE 4

**Survival of *Staphylococcus aureus* on the Sampled Sports Balls**



continued ▶

**Results**

**Simulation #1: Transfer From Floor to Ball and Hand**

Two trials (one basketball, one volleyball) were excluded due to high CFU counts cultured on disinfected surfaces before play. The number of CFUs cultured from the floor significantly decreased following play, while the number of CFUs significantly increased in both the sports ball and the athlete's hand (Figure 1). The average change in CFUs following play was greatest in the sports ball (44.5 CFUs), followed by the floor (-32 CFUs), and the hand (20 CFUs). Interestingly, the average change in CFUs in the hand was significantly greater following play with basketballs compared with volleyballs (basketball:  $27.3 \pm 9.3$  CFUs; volleyball:  $15.3 \pm 10.0$  CFUs;  $p = .041$ ).

**Simulation #2: Transfer From Hand to Ball and Floor**

Two trials (one basketball, one volleyball) were excluded due to high CFU counts cultured on disinfected surfaces before play. The number of CFUs cultured from the athlete's hand significantly decreased after the simulation, whereas the number of CFUs significantly increased in the ball (Figure 2). There was no significant change in CFUs sampled from the floor after play, although both the pre- and post-simulation counts were relatively low when compared with the hand. The average change in CFUs following the simulation was greatest in the hand (-14 CFUs) compared with the sports ball (1.5 CFUs). The average change in CFUs in the sports ball was also significantly greater in the volleyball compared with the basketball (basketball:  $0.5 \pm 0.7$  CFUs; volleyball:  $2.1 \pm 2.9$  CFUs;  $p = .043$ ), although the practical importance of this comparison likely is not substantial.

**Simulation #3: Transfer From Ball to Floor and Hand**

Three trials (two basketball, one volleyball) were excluded due to high CFU counts cultured on disinfected surfaces before play. There was a significant increase in CFUs cultured from the hand following the simulation, although there was no significant effect of play on either the sports ball or the floor (Figure 3). The average change in CFUs was greatest in the ball (-44 CFUs) compared with the floor

(1.6 CFUs) and the hand (4.8 CFUs). There were no significant differences between the volleyball or the basketball with respect to colony transmission before and after play.

### Survival of *S. aureus* on a Sports Ball

Six standard rental basketballs and volleyballs were serially cultured over a period of 72 hr. Baseline cultures (time = 0 hr) yielded significantly more CFUs on the volleyball than on the basketball (volleyball:  $96 \pm 76.9$  CFUs; basketball:  $35.9 \pm 19.4$  CFUs;  $p = .02$ ). Although cultures on both the basketball and volleyball decreased over the ensuing time points (time = 24, 48, 60, 72 hr), none of these cultures differed significantly compared with baseline (Figure 4). At the final time point (time = 72 hr), the average number of CFUs did not differ significantly between the volleyball and basketball (volleyball:  $9.5 \pm 7.9$  CFUs; basketball:  $20.7 \pm 14.0$  CFUs;  $p = .29$ ).

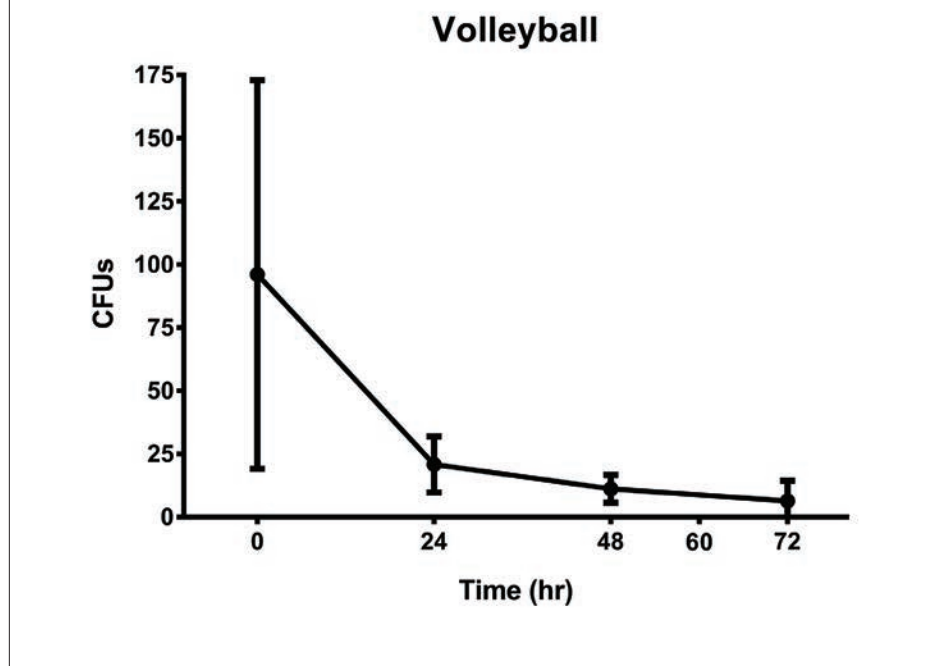
### Discussion

This study set out to demonstrate both the prevalence and transmissibility of *S. aureus* on sports surfaces commonly encountered in a university recreation center. Our results successfully affirmed both characteristics in several ways. First, in each of the three play scenarios, one surface was left in its native state (e.g., not disinfected). This surface was subsequently found to culture a substantial amount of *S. aureus* before any play took place, establishing a baseline prevalence of *S. aureus* on each of the tested sites. Following play, we demonstrated a transmission of bacteria away from the native surface and towards the remaining two interactive surfaces. For instance, in simulation #1, bacteria were found to transfer from the floor (the native surface) to the ball and hands (the previously disinfected surfaces).

Moreover, our study demonstrated the viability of *S. aureus* on sequestered sports balls for 72 hr. Although the population of bacteria declined substantially in this time frame, it was not eradicated. Our results are consistent with prior work demonstrating persistent survival of *S. aureus* for up to 12 days on inanimate surfaces (Boa, Rahube, Fremaux, Levett, & Yost, 2013). Rotation of the balls out of circulation and away from handling is therefore insufficient to fully eliminate the organisms subsisting on sports balls. It has been the experience and observation of the authors that, whereas

FIGURE 4 continued

### Survival of *Staphylococcus aureus* on the Sampled Sports Balls



weight rooms are typically equipped with disinfectant cleaners for use by patrons, the same materials are not supplied to the athletes seeking to rent sports balls.

Nonporous materials like sports balls and gym floors have a greater capacity to transfer CA-MRSA on contact, increasing the risk of spread in both the athlete and the casual gym-goer alike (Stanforth et al., 2010). As such, interventional programs have emerged to reduce transmission of CA-MRSA in the athletic community (Sanders, 2009). Interventional programs have proved to be efficacious and cost-effective by targeting the conditions that promote bacterial spread including contact, contaminated surfaces, and lack of cleanliness. Moreover, the combined cost of secondary, tertiary, and rehabilitative care for a single episode of CA-MRSA can total several hundreds of thousands of dollars (O’Laughlin & Cook, 2009). By comparison, the cost of a realistic, practical prevention program for an athletic team likely amounts to less than \$50 (O’Laughlin & Cook, 2009).

Based on this study’s results, the sports ball is an important vector for transmission of infectious organisms between the athlete’s

hands and the gym floor. While efforts are being made to improve sanitation for the athlete, to our knowledge there are few programs that routinely disinfect sports balls that players use (Fritz et al., 2012). It is conceivable that the addition of such an intervention would add minimal cost to the facility and require nominal staff involvement. Frequent disinfection of sports balls, and intermittent removal from circulation for at least 24 hr, might reduce the incidence of infectious outbreaks in athletic teams.

This study was limited in several respects. First, the media used to culture the gym surfaces was selective for *S. aureus* but not MRSA. This was intentionally done to maximize culture yield and, in turn, better study the transmissibility of *S. aureus*. As a result, little can be concluded from our study regarding the prevalence of CA-MRSA in the gym, although prior efforts have successfully demonstrated the existence of MRSA on a variety of athletic surfaces (Kazakova et al., 2005; Stanforth et al., 2010). It is also likely that the physical transmission characteristics of antibiotic-susceptible *S. aureus* are similar to CA-MRSA. Second, only two sites were sampled from each athletic

surface before and after play. The resultant sampling error could account for some of the variability in culture yield, but is unlikely to discount the consistent transmission trends observed across the play simulations.

## Conclusion

Over the last 20 years, the role of the nonclinical environment in transmission of MRSA has become increasingly recognized (Cohen & Kurzrock, 2004; Kassem, 2011). The community strain of MRSA, in particular USA 300, now accounts for between 8–20% of hospital-reported MRSA infections (McKenna, 2008).

The consequences of skin–fomite contact are gaining attention, and this type of contact likely accounts for a significant proportion of CA-MRSA outbreaks, especially in the athletic setting (Miller & Diep, 2008). Our study demonstrated the prevalence of *S. aureus* on various athletic surfaces, as well as the effect of sports play in the transmission of pathogens from one surface to another. The sports ball, in particular, was identified as a principal vector for transmission between athlete hands and the gym floor. Future efforts to reduce the incidence of infectious sports epidemics should therefore include interven-

tions with routine disinfection of the sports ball during and following play. 🐼

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