

Tea and Coffee Consumption and MRSA Nasal Carriage

Eric M. Matheson, MD, MS

Arch G. Mainous III, PhD

Charles J. Everett, PhD

Dana E. King, MD, MS

Department of Family Medicine, Medical University of South Carolina, Charleston, South Carolina

ABSTRACT

PURPOSE Hot tea and coffee have been found to have antimicrobial properties. The purpose of this study was to determine whether the consumption of tea, coffee, or both is associated with less frequent nasal carriage of methicillin-resistant *Staphylococcus aureus* (MRSA).

METHODS We performed a secondary analysis of data from the 2003-2004 National Health and Nutrition Examination Survey to investigate the relationship between the consumption of coffee, hot tea, cold tea, and soft drinks, and MRSA nasal carriage among the noninstitutionalized population of the United States.

RESULTS An estimated 2.5 million persons (1.4% of the population) were MRSA nasal carriers. In an adjusted logistic regression analysis controlling for age, race, sex, poverty-income ratio, current health status, hospitalization in the past 12 months, and use of antibiotics in the past month, individuals who reported consuming hot tea were one-half as likely to have MRSA nasal carriage relative to individuals who drank no hot tea (odds ratio = 0.47; 95% confidence interval, 0.31-0.71). Similarly, individuals who reported consuming coffee had about a one-half reduction in the risk of MRSA nasal carriage relative to individuals who drank no coffee (odds ratio = 0.47; 95% confidence interval, 0.24-0.93).

CONCLUSIONS Consumption of hot tea or coffee is associated with a lower likelihood of MRSA nasal carriage. Our findings raise the possibility of a promising new method to decrease MRSA nasal carriage that is safe, inexpensive, and easily accessible.

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INTRODUCTION

Infection with methicillin-resistant *Staphylococcus aureus* (MRSA) is a major source of morbidity and mortality in the United States. In 2005, more than 278,000 Americans were hospitalized for MRSA-related infections, and there were more than 6,500 MRSA-related deaths.¹ Studies have suggested that nasal carriage of MRSA may significantly increase the risk of a MRSA infection, although this finding has not been universal.²⁻⁴

In an effort to both prevent and treat MRSA, researchers have examined the antimicrobial effects of several commonly consumed plants and plant extracts.⁵⁻⁷ Two of the most promising and ubiquitous are tea and coffee.⁸⁻¹⁰ Tea has been found to have antimicrobial activity against several types of pathogenic bacteria, including *Vibrio cholerae*, *Escherichia coli*, *Sbigella*, *Salmonella*, and *S aureus*.¹¹⁻¹³ Like tea, coffee appears to have antimicrobial properties against *Escherichia coli*, *Salmonella*, and *S aureus*.^{10,14} Both in vivo and in vitro studies have demonstrated that tea or tea-based extracts have antimicrobial properties when applied topically.^{9,15} What remains unclear is whether tea and coffee have systemic antimicrobial activity when consumed orally as beverages.

The purpose of this study was to evaluate the relationship between oral consumption of tea and coffee, and MRSA nasal carriage in a nationally representative sample of Americans.

Conflicts of interest: authors report none.

CORRESPONDING AUTHOR

Eric M. Matheson, MD, MS
Department of Family Medicine
Medical University of South Carolina
295 Calhoun St
Charleston, South Carolina 29425
Matheson@musc.edu

METHODS

Study Design and Participants

We analyzed data from the 2003-2004 National Health and Nutrition Examination Survey (NHANES) sample,¹⁶ a nationally representative sample of the non-institutionalized population of the United States.¹⁷ The NHANES uses a complex survey design that allows for the determination of population estimates. To enable these estimates, the survey uses sampling weights that are calculated by taking into account the unequal probabilities of selection resulting from sample design, nonresponse, and planned oversampling of minorities.

The NHANES sampling procedure consists of 4 stages. Stage 1 entails selection of primary sampling units (PSUs), which are mostly single counties or, in a few cases, groups of contiguous counties with probability proportional to a measure of size. In stage 2, the PSUs are divided into segments (generally city blocks or their equivalent). In stage 3, households within each segment are listed and a sample is randomly drawn. In geographic areas where the proportion of age, ethnic, or income groups selected for oversampling is high, the probability of selection for those groups is greater than in other areas. In stage 4, individuals are chosen to participate in NHANES from a list of all persons residing in selected households. The individuals are drawn at random within designated domains of age, sex, and race/ethnicity. Each individual is assigned a sample weight, a measure of the number of people in the population represented by that individual in NHANES, reflecting the unequal probability of selection, adjustment for nonresponse, and adjustment to individual population controls. The 30 PSUs included in the 2003-2004 NHANES were selected from a frame of all US counties, using the 2000 census data.

More information on the methods of the 2003-2004 NHANES survey, including laboratory assessments, can be found elsewhere.¹⁶ Nasal carriage of *S aureus* was assessed in all participants aged 1 year or older, but many of the other variables were not included for individuals younger than age 2. Consequently, we included in our study only participants aged 2 years old or older.

Assessment of MRSA Nasal Carriage

Nasal cultures were collected and plated on mannitol salt agar (MSA). The MSA plates were incubated at 37°C for 48 hours. Mannitol-fermenting colonies were selected and subcultured to plates with trypticase soy agar containing 5% sheep blood, that is, blood agar plates (BAPs), and incubated at 37°C overnight. MSA plates with little or no growth were reincubated at 37°C overnight, and plates with non-mannitol-fermenting growth were held at room temperature. The

plates were reexamined the next day, and any yellow or gold colonies were subcultured to BAPs.

Overnight cultures on BAPs were first screened using Staphaurex, a rapid latex kit for the identification of *S aureus* (Remel Laboratories, Lenexa, Kansas). A tube coagulase test using rabbit plasma with EDTA was then performed both on Staphaurex-negative isolates from BAPs with morphology consistent with *S aureus* and on Staphaurex-positive isolates with morphology inconsistent with *S aureus*. Staphaurex-positive isolates and Staphaurex-negative, tube coagulase-positive isolates were identified as *S aureus* and saved for further testing.

Determination of Methicillin Resistance

S aureus isolates were screened for methicillin resistance by the disk diffusion method. Overnight cultures from BAPs were plated on Mueller-Hinton agar, and a 1- μ g oxacillin disk was placed on the inoculated plate. Zone diameters were measured and recorded after a 24-hour incubation at 37°C; on the basis of the results, isolates were classified as sensitive (≥ 13 mm), intermediate (11-12 mm), or resistant (≤ 10 mm). For the purposes of this study, *S aureus* isolates with a zone diameter of 10 mm or less were considered MRSA and all other *Staphylococcus* isolates were considered methicillin sensitive (MSSA).

Beverage Consumption

Beverages evaluated were hot tea, iced tea, coffee, soda consumed during the summer, and soda consumed during the remainder of the year as ascertained with 6 questions. The first question was, "How many cups of hot tea, caffeinated or decaffeinated, did you drink (over the past 12 months)?" The second question was, "How many glasses of iced tea, caffeinated or decaffeinated, did you drink (over the past 12 months)?" The third question was "How many cups of coffee, caffeinated or decaffeinated, did you drink (over the past 12 months)?" Responses to these 3 questions were categorized as (1) none or (2) less than 1 cup a month or more for coffee, tea, and iced tea. Participants were also asked, "Over the past 12 months, did you drink soft drinks, soda, or pop?" Those who answered yes were then asked, "How often did you drink soft drinks, soda, or pop in the summer?" and subsequently asked, "How often did you drink soft drinks, soda, or pop during the rest of the year?" Because of the very small number of individuals who did not consume any soft drinks, answers for soft drink consumers were classified as (1) never to 2 to 3 times per month or (2) 1 to 6 times per week or more.

Control Variables

We evaluated numerous variables previously associated with MRSA nasal carriage as potential confounding variables in the relationship between MRSA carriage

and beverage consumption. They included age, race, sex, poverty status, health status, recent hospital stay, and recent antibiotic use.

Age was categorized into groups (2-6, 7-19, 20-64, and ≥ 65 years old). Race/ethnicity was classified as non-Hispanic white, non-Hispanic black, or Hispanic. We did not include individuals categorized as Other Race or Multiracial in our study because there were too few with MRSA (unweighted $n = 4$). Poverty status was determined using the poverty-income ratio. This ratio is calculated by dividing a family's income by a poverty threshold income that is based on family size.¹⁸ The poverty threshold is determined each year by the US Office of Management and Budget. Poverty-income ratios ranged up to 5, with values of less than 1 indicating poverty. Current health status was based on self-report and was classified as either (1) excellent, very good, or good, or (2) fair or poor. Recent hospitalization was determined by participants' response to the question, "During the past 12 months were you a patient in a hospital overnight? Do not include an overnight stay in the emergency room."

Recent antibiotic use was evaluated in the NHANES by examining the individual's prescription medications. Participants were asked to bring the containers for all the prescription medications taken during the past month and to report any medications taken for which the container was not available. These medications were then matched by trained survey interviewers to an annually updated comprehensive database of all prescription drugs in the US market.

Missing Data

For the purposes of this analysis, we excluded individuals who were missing data on any variable. A total of 3,172 individuals were missing data. Of these individuals, the majority were missing data on coffee consumption (2,654), tea consumption (2,658) or poverty-income ratio (449).

Analysis

We used SUDAAN software (Research Triangle Institute, Research Triangle Park, North Carolina) for all analyses to account for the complex sample design used in NHANES. The analyses incorporated both the stratification and clustering aspects of the sampling design. The proper weighting procedures include adjustments for basic probability of selection and nonresponse. Because minorities were oversampled, and the sampling design was complex, we used sampling weights provided by the NHANES to compute population estimates based on weighted parameter estimates and standard errors.

We computed descriptive statistics for the study sample. Because there were relatively small numbers

of MRSA carriers within each beverage consumption group, it was necessary to use a binary categorization (drinker or nondrinker) for the beverage groups to gain a standard error of less than 30%, conforming to recommendations of the National Center for Health Statistics (which conducts NHANES) for small sample sizes. We performed a χ^2 analysis to determine that none of the standard errors exceeded 30% on population estimates, as recommended by the Center. We computed unadjusted and adjusted logistic regression models to determine the odds ratios (ORs) and 95% confidence intervals (CIs) for MRSA nasal carriage according to beverage consumption. In addition to hot tea and coffee, iced tea and soft drink consumption were examined to determine if the antimicrobial properties of hot tea and coffee differed from that of other types of beverages. The adjusted models controlled for age, race/ethnicity, sex, poverty-income ratio, current health status, hospitalization in the past year, and antibiotic use in the past month. A statistical level of $P < .05$ was considered significant for all analyses.

RESULTS

The sample included 5,555 individuals, which is equivalent to a weighted sample size of 182,100,249. Their characteristics are shown in Table 1.

Overall, 1.4% of the individuals in the sample had nasal carriage with MRSA. An estimated 88.6 million persons (48.6% of the population) reported consuming hot tea, and 93.7 million (51.4% of the population) reported consuming no hot tea over the past month. An estimated 110.7 million (60.8% of the population) reported consuming coffee, and 71.4 million (39.2% of the population) reported consuming no coffee over the past month.

In an unadjusted logistic regression model (Table 2), individuals who consumed hot tea had a slightly more than one-half reduction in the likelihood of MRSA nasal carriage relative to their counterparts who reported consuming no hot tea (OR = 0.47; 95% CI, 0.31-0.70). Furthermore, after adjusting for age, race/ethnicity, sex, poverty-income ratio, current health status, hospitalization in the past 12 months, and use of antibiotics in the past month, individuals who reported consuming hot tea still had a lower likelihood of MRSA nasal carriage (OR = 0.47; 95% CI, 0.31-0.71).

Coffee consumption was also associated with a one-half reduction in the odds of MRSA nasal carriage, but only in the adjusted logistic regression model (OR = 0.47; 95% CI, 0.24-0.93) (Table 2).

The findings were similar for combined coffee and tea intake. The odds of MRSA nasal carriage were lower for individuals drinking both beverages com-

Table 1. Characteristics of the Sample (Unweighted N = 5,555; Population Estimate = 182,100,249)

Characteristic	Participants, %	Characteristic	Participants, %
Age, y		Nasal carriage status	
2-6	6.1	MRSA	1.4
7-19	18.6	MSSA	26.5
20-64	61.8	No <i>Staphylococcus</i>	72.1
≥65	13.5	Coffee	
Race/ethnicity		None	39.2
Non-Hispanic white	76.2	<1 cup per month or more	60.8
Non-Hispanic black	11.6	Hot tea	
Hispanic	12.2	None	51.4
Sex		<1 cup per month or more	48.6
Male	46.8	Coffee or hot tea	
Female	53.2	None	26.8
Poverty-income ratio		<1 cup per month or more of either	73.2
<1	14.3	Iced tea	
≥1	85.7	None	34.0
Current health status		<1 cup per month or more	66.0
Good to excellent	85.7	Soft drinks during the summer	
Fair to poor	14.3	Never to 2-3 times per month	24.4
Hospitalized in the past 12 months		1-6 times per week or more	75.6
Yes	9.2	Soft drinks during the rest of the year	
No	90.8	Never to 2-3 times per month	30.9
Use of antibiotics in the past month		1-6 times per week or more	69.1
Yes	5.6		
No	94.4		

MRSA = methicillin-resistant *Staphylococcus aureus*; MSSA = methicillin-sensitive *Staphylococcus aureus*.

pared with individuals drinking neither tea nor coffee, in both the unadjusted logistic regression model (OR = 0.41; 95% CI, 0.20-0.81) and the adjusted logistic regression model (OR = 0.33; 95% CI, 0.16-0.70).

In contrast to the associations found for hot tea and coffee, we did not find any statistically significant relationship between iced tea or soft drink consumption and MRSA nasal carriage (Table 2).

Because fewer children than adults consume coffee and tea, we conducted a separate analysis to examine the association between coffee and tea consumption and MRSA nasal carriage among individuals aged 18 years or older. The results were similar to those in the entire sample in adjusted analyses, for hot tea (OR = 0.53; 95% CI, 0.15-0.80), for coffee (OR = 0.49; 95% CI, 0.23-1.04), and for the combination of hot tea and coffee (OR = 0.35; 95% CI, 0.15-0.80).

DISCUSSION

The results of this study suggest a lower likelihood of MRSA nasal carriage among individuals who drink hot tea, coffee, or both. These findings, based on a nation-

ally representative sample of adults and children in the United States, extend the previous findings of in vitro and topical antimicrobial activity of tea and coffee to a systemic effect. The results suggest that consumption of coffee and hot tea may modify the risk of MRSA nasal carriage and potentially MRSA infection.

The mechanism behind this possible effect of coffee and tea consumption on MRSA carriage is not completely understood. There is increasing evidence to suggest that both coffee and tea have antimicrobial characteristics.^{8,10,17} Although the exact mechanisms through which the antimicrobial properties of these beverages are exerted remain to be elucidated, a few compounds have garnered particular attention. In the case of coffee, particular attention has focused on the potential antibacterial properties of trigonelline, glyoxal, methylglyoxal, and diacetyl.^{10,19} For tea, attention has focused on the antimicrobial properties of tannic acid and catechins.^{8,20,21} In addition,

consumption of both coffee and tea decrease iron absorption, which may prove important because iron is critical for the growth of *S aureus*.^{22,23}

Although most of the data on the antimicrobial properties of coffee and hot tea have come from in vitro experiments, a few clinical trials have examined the effect of hot tea and coffee in vivo. In one study conducted by Fujii et al,⁹ bedridden patients with MRSA-infected decubitus ulcers underwent debridement of their ulcers with either green tea or normal saline. After 1 month, the patients whose ulcers were treated with green tea debridement experienced a marked decrease in ulcer severity, and MRSA had disappeared in one-half. In the patients treated with normal saline debridement, ulcer severity was unchanged, and all of the ulcers were still infected with MRSA.

In another study, 24 elderly patients with cerebrovascular disease and MRSA-positive sputum were randomized and treated with either tea catechin extracts or saline as a control, each given by a nebulizer 3 times daily, for 4 weeks.¹⁵ After 1 week, 7 of the 12 patients in the tea-treated group had a decrease in MRSA concentration in their sputum, compared

Table 2. Logistic Regression Models Showing Odds of MRSA Nasal Carriage by Beverage Consumption

Beverage Consumption	Unadjusted OR (95% CI)	Adjusted ^a OR (95% CI)
Coffee		
None	1.00	1.00
<1 cup per month or more	0.53 (0.28-1.02)	0.47 (0.24-0.93)
Hot tea		
None	1.00	1.00
<1 cup per month or more	0.47 (0.31-0.70)	0.47 (0.31-0.71)
Coffee or hot tea		
None	1.00	1.00
<1 cup per month or more of either	0.41 (0.20-0.81)	0.33 (0.16-0.70)
Iced tea		
None	1.00	1.00
<1 cup per month or more	0.81 (0.39-1.68)	0.88 (0.39-1.99)
Soft drinks during the summer		
Never to 2-3 times per month	1.00	1.00
1-6 times per week or more	0.85 (0.44-1.66)	0.97 (0.48-1.96)
Soft drinks during the rest of the year		
Never to 2-3 times per month	1.00	1.00
1-6 times per week or more	1.07 (0.57-1.99)	1.28 (0.68-2.42)

CI = confidence interval; MRSA = methicillin-resistant *Staphylococcus aureus*; OR = odds ratio.

^a Adjusted for age, race/ethnicity, sex, poverty-income ratio, current health status, hospitalization in the past year, and antibiotic use in the past month.

with none of the saline control group. Perhaps even more impressive, the average length of hospitalization was 51 days in the tea-treated group vs 85 days in the saline-treated group.

Our findings reinforce and expand the findings of earlier studies by suggesting that tea has antibacterial properties not only when applied topically, but also when consumed orally. What remains less clear is why iced tea did not affect the risk of nasal MRSA carriage in the same manner as hot tea. One possible explanation is that iced tea has lower levels than hot tea of polyphenolic compounds per unit volume, because many of the compounds in tea are more soluble at higher temperatures.^{24,25} Another possibility is that the volatile antimicrobial compounds in coffee and hot tea reach the nares in vapor form.^{12,26} Hot beverages may also increase the temperature of the distal nares, which may improve the immune response.^{27,28}

Like iced tea, soda consumption did not affect the risk of MRSA nasal carriage. As many sodas are caffeinated, this finding suggests that caffeine is unlikely to be responsible for the antibacterial properties of hot tea and coffee.

Several important limitations to this study should be noted. First, the cross-sectional design of NHANES allows us to make statements only about association, not causation. Second, we excluded individuals from the study with missing values rather than using multiple

imputation, which may have increased our standard error. Third, we could not be certain when individuals last consumed coffee or tea. Finally, because an exact understanding about the biochemical constituents in hot tea and coffee that may be associated with protection against MRSA remains to be elucidated, we had to speculate on a primary theory and several alternative theories. The effect, however, appears to be robust.

Although not a specific limitation, it is important to note that the larger question of the importance of MRSA nasal carriage has yet to be resolved. Even though several studies have suggested such carriage increases the risk of systemic infection with MRSA, others have not.²⁻⁴ Given this debate, the benefits of any treatment for MRSA nasal carriage should be carefully balanced against the risk.

At present, the only way to treat MRSA nasal carriage is with antibiotics that have proven only partially successful at long-term eradication. Our findings of reduced odds of MRSA nasal carriage among tea and coffee drinkers raise the possibility of a promising new alternative to antibiotics that is safe, inexpensive, and easily accessible.

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Key words: Methicillin-resistant *Staphylococcus aureus*; MRSA; tea; coffee; disease prevention; carriers; disease reservoirs; colonization

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