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(Research Paper)

Prevalence of *Staphylococcus aureus* Nasal Carriage in Athletes Across Varying Body Mass Index Categories

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Abstract:
Obesity is associated with an increased risk of infection in athletes, and *Staphylococcus aureus* nasal colonization is a particular concern. This study aimed to investigate whether different BMIs are associated with *S. aureus* colonization in athletes. *S. aureus* colonization was assessed using nasal swab cultures from 510 male and female athletes, aged 14–55 years, in a population-based study conducted in Zakho City between 2021 and 2022. Height and weight were measured, and demographic information was analyzed using GraphPad Prism. The nasal carriage rate of *S. aureus* was 30.8% (157 out of 510 individuals). This rate was higher in obese individuals (46.4%), though this difference was not statistically significant ($p<0.113$). The highest nasal carriage rate in males was observed in obese individuals (53.85%), while the highest rate in females was observed in the overweight group (46.15%). Our results suggest that an increase in BMI may increase the likelihood of *S. aureus* nasal colonization in athletes. Future research should focus on the role of obesity in different age groups and genders.

Keywords: *Staphylococcus aureus*, nasal carriage rate, athletes, BMI

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Introduction

Staphylococcus aureus are gram-positive, spherical bacteria with a grape-like arrangement. This bacterium is known to cause various clinical manifestations, including mild to severe bloodstream infections that can lead to death [1]. The clinical importance of *S. aureus* is due to its ability to thrive in a variety of conditions, produce a wide range of virulence factors, spread rapidly and develop antibiotic resistance [2]. Approximately 30% of healthy individuals and 65% of patients with staphylococcal skin infections carry *S. aureus* in their anterior nares [3]. Community- and hospital-acquired infections are common, and treatment is challenging due to multi-drug resistant strains, such as MRSA [4]. Transmission occurs through direct contact with people and objects [5].

MRSA (Methicillin-resistant *Staphylococcus aureus*) is a group of staphylococcal strains that are resistant to multiple antibiotics, including common beta-lactam and macrolide antibiotics. Recent reports have shown that MRSA is becoming increasingly prevalent in the community, despite it traditionally being considered a hospital-only issue [6-8]. MRSA infections in the community are common where people have prolonged person-to-person contact (for example, in schools, nurseries, colleges and professional athletes involved in contact sports) or share sleeping or changing facilities. According to the Centers for Disease Control and Prevention (CDC), the risk of community-associated methicillin-resistant *S. aureus* (CA-MRSA) transmission is summarized by the "5 Cs":1) frequent skin-to-skin contact, 2) contaminated objects and surfaces, 3) crowding, 4) compromised skin integrity, and 5) poor hygiene [9]. It is therefore not surprising that athletes are at greater risk of developing CA-MRSA infections due to frequent skin contact and disruption of the skin barrier through cuts and abrasions (e.g. turf burns or abrasions caused by sports equipment) [10].

Interestingly, the National Health and Nutrition Examination Survey found that obesity was associated with increased nasal prevalence of *S. aureus* in both genders [11]. Studies have shown a positive association between high body mass index (BMI) and nasal carriage of *S. aureus* [12]. Thus, the role of BMI as an independent risk factor for *S. aureus* colonization in the community in general and in the athletic population in particular is unclear and studies on this topic in the Kurdistan Region of Iraq are limited. Therefore, this study aimed to investigate the differences in the composition of *S. aureus* between obese, overweight and average weight in the athletic population of the Zakho community.

Materials and Methods

Study setting and design

This study design was a cross-sectional study conducted among athletes in the city of Zakho, located in the Kurdistan Region of Iraq. This study was conducted from September 2021 to February 2022. A total of 510 samples were collected from different sports teams. Of these, 245 were from gyms, 24 from boxing teams, 56 from football clubs and 185 from student groups (106 from the Sports Instituteof Zakho University and 79 from the Department of Physical Education). The participants ranged in age from 18 to 55 years, with an average age of 22.33 years.

The sample size for the study was determined using an online calculator (http://www.raosoft.com/samplesize.html) with the following parameters: a 99% confidence interval; a 5% margin of error; a population size of 950,000 athletes; and a response distribution of 50%. The calculator recommended a minimum sample size of 385. However, a total of 510 athletes participated in the study, which is more than the recommended sample size. To minimize bias and increase the reliability of the data, the study enrolled a sample size that exceeded this calculation.

Body Mass Index (BMI)

The Body Mass Index (BMI) of all participants was calculated according to WHO guidelines [13]. Individuals were classified into four groups based on their BMI: underweight (BMI < 18), normal weight (BMI between 18.5 kg/m^2 and 24.9 kg/m^2), overweight (BMI between 25.0 kg/m^2 and 29.9 kg/m^2) and obese (BMI $\geq$ 30.0 kg/m^2).

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Sample collection

Samples were collected from both nostrils of all enrolled athletes. The swabs were first moistened with sterile normal saline to avoid allergy and irritation that might result from dry swabs and then gently rolled in both nostrils for a few seconds. All samples collected were fully labelled with an identification number, age, gender, date and time of collection. After inoculation in transport media with Brain Heart Infusion (BHI) broth (Neogene, UK), swabs were immediately transported to the microbiology laboratory for further processing.

Isolation and identification

Traditional methods for isolating bacteria include culturing and biochemical testing. Collected samples stored in transport media (Brain Heart Infusion broth) (Neogen, UK) were directly cultured on selective media (Mannitol Salt Agar) (Neogen, UK) by proper streaking on the surface of the medium, followed by incubation at 37 °C for 1 to 2 days. *S. aureus* isolates were identified and isolated from our previous studies [14,15]. For isolation and identification bacterial colonies were first classified by Gram's staining of bacterial colonies and then bacteria were identified based on phenotypic colony characteristics (mannitol salt agar fermentation), morphology and biochemical tests including catalase and coagulase tests [14, 16].

Inclusion and Exclusion criteria

The inclusion criteria for the study were individuals actively involved in athletics, aged over 18 years, and who gave consent to participate. Conversely, individuals not involved in athletics, those who had received antibiotics within the previous three months, and those who refused to participate were excluded from the study.

Ethics statement

All volunteers provided verbal informed consent. The study design and methodology were approved by the Ethics Committee of the Faculty of Medicine,University of Zakho, Kurdistan Region, Iraq. Ethical considerations, in particular the protection of personal data, were taken into account at all stages of the study.

Statistical analysis

All statistical analysis of the recorded data were performed using GraphPad Prism version 8. Data were calculated as mean ± standard deviation for continuous data and frequency (%) for categorical data. Student t-test was used to analyze quantitative data and chi-square (Fisher's exact test) was used to analyze qualitative variables. P-value <0.05 was considered significant and higher was considered non-significant.

Results

Prevalence of *S. aureus* among athletes

A total of 510 nasal swabs (392 males and 108 females) were included in this study. The overall nasal carriage rate of *S. aureus* among athletes was 30.8% (157/510). The mean age of the subjects was 22.21 years (± 6.29) and the mean body mass index was 22.78 (± 3.52).

Prevalence of *S. aureus* according to BMI

After calculating the BMI for all 510 people in the study, the people were divided into four groups: 28 obese people with a BMI (≥ 30 kg/m²); 148 overweight people with a BMI (between 25.0 and 29.9 kg/ m²); 289 normal weight people with a BMI (between 18.5 and 24.9 kg/m²) and 45 underweight people. The total distribution of nasal *S. aureus* among athletes in different BMI groups was 157 (30.8%). Of 28 obese subjects, 13 (46.45%) were positive for *S. aureus*. In addition, 48 (32.4%) of the overweight subjects carried *S. aureus*, which was higher than the carriage rate of nasal *S. aureus* in the normal weight group, 87 (30.1%), and 9 (20%) of the underweight groups. However, these differences were not statistically significant ($p > 0.05$) (Fig 1/Table 1).

In males, the nasal carriage rates of *S. aureus* in obese, overweight, normal weight, and underweight individuals were 53.85% (7/13), 29.51% (36/122), 32.75% (75/229) and 17.86% (5/28), respectively. The results indicate that the nasal carriage rate of *S. aureus* was highest in the obese male group compared to other male groups, whereas the underweight males had the lowest prevalence rate. However, these differences were not statistically significant in male athletes ($p = 0.12$) (Fig 1(A)/Table 2).

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In females, the nasal carriage rates of *S. aureus* in obese, overweight, normal weight and underweight individuals were 40% (6/15), 46.15% (12/26), 20% (12/60) and 23.53% (4/17), respectively. The results indicate that the prevalence of *S. aureus* was higher in obese and overweight female athletes compared to healthy weight and underweight groups, but this difference was not statistically significant (p = 0.065) (Table 2 and Fig 1B).

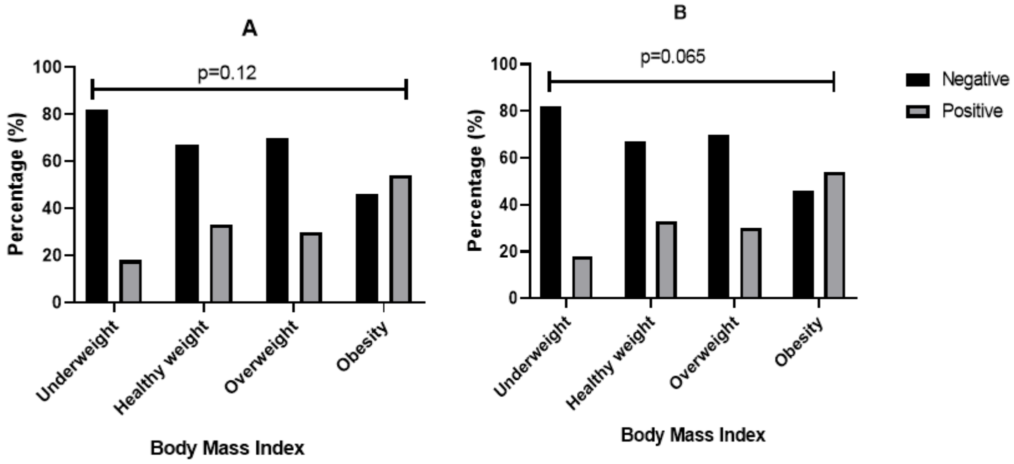

Fig 1: Distribution of nasal *S. aureus* among athletes in different BMI groups: Male (A) and Female (B). The P value was determined using the chi-square test, with p values <0.05 considered statistically significant.

Table 1: Distribution of nasal *S. aureus* in athletes with different BMI groups

Category of BMI	Total No.	Positive No.%	Negative No %	*P value
Underweight	45 (8.8)	9 (20)	36 (80)	
Healthy weight	289 (56.7)	87 (30.1)	204 (69.9)	0.113
Overweight	148 (29)	48 (32.4)	100 (67.6)	
Obesity	28 (5.5)	13 (46.4)	15 (53.6)	
Total	**510**	**157 (30.8)**	**353 (69.2)**	

*The p-value was calculated using the chi-square test to assess the differences between the different BMI categories.

Table 2: Distribution of nasal *S. aureus* among athletes with different BMI groups according to gender.

Category of BMI	Gender	Positive No.%	Mean±SD	Negative No %	Mean±SD	Total No.%
Underweight (n=45)	Male	5 (17.86)	17.96±0.198	23 (82.14)	16.84±1.41	28 62.22)
	Female	4 (23.53)	17.28±0.66	13 (76.47)	17.43±0.71	17 (37.78)
	Total	**9 (20)**		**36 (80)**		**45 (100)**
Healthy weight (n=289)	Male	75 (32.75)	21.41±1.45	154 (67.25)	21.58±1.63	229 (79.24)
	Female	12 (20)	21.71±1.77	48 (80)	21.64±1.56	60 (20.76)
	Total	**87 (30.1)**		**202 (69.89)**		**289(100)**
Overweight (n=148)	Male	36 (29.51)	26.47±1.83	86 (70.49)	26.32±1.59	122 (82.43)
	Female	12 (46.15)	26.9±1.63	14 (53.85)	26.21±1.79	26 (17.57)
	Total	**48 (32.43)**		**100 (67.57)**		**148 (100)**
Obesity (n=28)	Male	7 (53.85)	33.36±2.58	6 (46.15)	32.18±1.44	13 (46.43)
	Female	6 (40)	33.39±1.61	9 (60)	33.21±3.39	15 (53.57)
	Total	**13 (46.43)**		**15 (53.57)**		**28 (100)**

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Regarding the nasal prevalence rate of *S. aureus* in sports teams with different BMI categories, the healthy weight group had the highest rate of nasal colonization with 289 cases (56.7%). In contrast, the obesity group had the lowest colonization rate with 28 cases (5.5%). The prevalence rate was highest among healthy weight students in sports facilities (20%), followed by athletes in gyms (15.9%) and football players (14.3%). However, these differences were not statistically significant, as indicated by p-values of 0.83, 0.45 and 0.33, respectively (Table 3).

In boxing, the highest nasal carriage rate of *S. aureus* was observed in the healthy weight group (12.5%), while the lowest rate was found in the underweight group (4.2%), with no statistically significant difference (p = 0.32). In gym participants, the nasal carriage rate of *S. aureus* was higher in healthy weight and overweight individuals (15.9% and 12.2%, respectively) compared to the underweight and obese groups, which had the lowest colonization rates (0.82% and 4.1%, respectively). However, these differences were not statistically significant (p = 0.45) (Table 3).

Table 3: Distribution of nasal *S. aureus* among different types of athletes with different BMI groups

Type of sport		Underweight	Healthy weight	Overweight	Obesity	p-value
		No. (%)	No. (%)	No. (%)	No. (%)	
Boxing (n=24)	Positive	1 (4.2)	3 (12.5)	2 (8.3)	2 (8.3)	0.32
	Negative	5 (20.8)	3 (12.5)	7 (29.2)	1 (4.2)	
Gym (n=245)	Positive	2 (0.82)	39 (15.9)	30 (12.2)	10 (4.1)	0.45
	Negative	11 (4.5)	79 (32.2)	60 (24.5)	14 (5.7)	
Football (56)	Positive	1 (1.8)	8 (14.3)	6 (10.7)	1 (1.8)	0.33
	Negative	4 (7.1)	25 (44.6)	11 (19.6)	0 (0)	
Sports Institutions (n=185)	Positive	5 (2.7)	37 (20)	10 (5.4)	0 (0)	0.83
	Negative	16 (8.6)	95 (51.4)	21 (11.4)	1 (0.5)	
Total Number (n=510)		**45 (8.8)**	**289 (56.7)**	**148 (29.0)**	**28 (5.5)**	

Discussion

The incidence of obesity has increased significantly, and in 2016 there were approximately 2 billion overweight and 650 million obese adults worldwide [13]. Although obesity and overweight are known risk factors for major chronic diseases, their effects on susceptibility to infection are still poorly understood [17]. Previous research has shown that obese people have a higher risk of nosocomial sepsis, bacteraemia, surgical site infections, wound site infections and community-acquired pneumonia [18]. Many of these infections are often caused by *S. aureus*. Between 20 and 30% of healthy people carry *S. aureus* in their nose, which is a significant risk factor for bacterial infections [19].

This is the first study to investigate the association between *S. aureus* and BMI among athletes in the Kurdish community. Although several studies conducted in our region have shown an increased prevalence of *S. aureus* in the general community [20], hospitals [21] and students [22]. In the present study, however, we assessed the prevalence of *S. aureus* at different BMIs in both genders and different types of sports. We observed an overall nasal carriage prevalence of *S. aureus* of 30.8% among 510 individuals from the athletic population of different sports teams in Zakho.

It is not surprising that athletes have such a high prevalence of *S. aureus* carriage,as the bacteria can be spread through shared equipment and direct skin contact. Athletes are also known to share personal sports equipment, to neglect personal hygiene and to be exposed to the outside environment while exercising. These factors may be closely related to

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community-associated MRSA (CA-MRSA) outbreaks in sports teams [23]. A recently published Italian study found that 42% of contact sports athletes had nasal carriage of *S. aureus*. In judo and wushu/kung fu athletes, the rate ranged from 23.8% to 54.8% [24]. The carriage rate in this study was higher than previously reported rates of nasal carriage of *S. aureus*; in Taiwan, the frequency of nasal carriage of *S. aureus* among college students and athletes was 21.2% and 23. 2% in the USA [25]. However, the rate of carriage in this study was lower than the rate found in French athletes (61%) [26]. This discrepancy between the results we found and those of other studies could be partly explained by differences in the size of the participant population, geographical distribution, microbial isolation methods and environmental variables during samplingand procedure, which could be a high risk factor for *S. aureus* nasal colonization in the body.

Interestingly, the highest prevalence of *S. aureus* (46.4%) was isolated from obese athletes, followed by overweight individuals (32%), but these differences were not statistically significant (p=0.113). These findings contrasted with those of a study conducted among the general population in Norway, where they reported a positive association between BMI and *S. aureus* colonization; in addition, in the female population, each 2.5 kg/m^2 increase in BMI was associated with a 7% increase in the odds of nasal carriage of *S. aureus* (P = 0.01) [27]; which was not consistent with studies among the general US community, they detect the association between high BMI and increased odds of nasal carriage *S. aureus* in 19 years examined in 2001–04; NHANES revealed a 1.3 and 1.2 times greater odds of *S. aureus* nasal colonization among obese people (BMI 30 kg/m^2) men and women, respectively, compared with normal or overweight subjects [11]. Comparing our results with studies conducted in an athletic population, a study of *S. aureus* in French athletes found no association between BMI and carriage of *S. aureus* [26].

The current study also showed that the prevalence of nasal carriage of *S. aureus* was higher in men. This finding was consistent with previous research showing that men had higher rates of nasal carriage of *S. aureus* than women [28]. Although the nasal carriage rate of *S. aureus* in this study is insignificantly different between males and females, the microbiological differences between the genders may be partly due to the effects of reproductive hormone regulation of immune defences, microbial virulence factors, and cell physiology [29]. Increased weight gain may have a significant impact on human reproduction, as obesity is associated with 6% of primary female infertility [30]. Research showes a higher rate of nasal carriage of *S. aureus* in men than in women [15].

This study found that the difference in nasal *S. aureus* carriage rates between the obese (46.4%) and overweight (32.4%) groups was not statistically significant compared to normal weight adults (30.2%). These results contradict those of previous studies: Iraq and Baghdad [31]. One study found an association between nasal carriage of *S. aureus* and obesity, and one study found no association between nasal carriage and different body mass indexes [32]. They found a positive relation between high BMI and nasal carriage of *S. aureus*. Another study found a higher incidence of *S. aureus* in obese women compared with controls [33].

According to our research, being overweight may indicate an increased likelihood of bacterial colonization. Furthermore, this finding would suggest that *S. aureus* contributes to the increased weight gain seen in obese and overweight people. There was a considerable variation in the prevalence of *S. aureus* between BMI categories. Previous data shows that the predictors of *S. aureus* differ by sex and age, with some evidence linking the status of altered hormone levels in both sexes, such as leptin resistance and sex- specific hormone levels. Obesity has been shown to impair the ability of the immune system to respond appropriately to infection caused by some bacteria. Fat is thought to be a reservoir of inflammatory cytokines and it has been proposed that obesity may influence some diseases through this pathway [34].

Based on the findings of our study and other similar ones, there is a possible link between nasal carriage of *S. aureus* and obesity, suggesting that the presence of certain bacteria in the nose may reflect broader changes in the body's microbial environment that may influence, or be influenced by obesity. Obesity has been associated with an increased risk of *S. aureus* colonization. One study found that individuals with obesity may have a higher nasal carriage rate of *S. aureus*, possibly due to factors such as altered immune responses, skin folds or changes in skin microbiota [35]. Probiotics and prebiotics have emerged as a potential therapy for regulating weight gain in both obese and overweight people. This may replace more traditional therapies, including multi-component non-surgical methods and bariatric surgery, both of which are associated with significant side effects and costs. Obesity is a complicated multifactorial condition and there are many different and complex reasons why obesity and bacteria are linked. These relationships may be indirect and have to do with a person's diet, use of drugs or alcohol, smoking or even the physical constitution of the host [36].

In conclusion, the current study is considered primary and further research including athletes from various provinces in the Kurdistan Region of Iraq would likely be required. Further research is needed to investigate *S. aureus* in different types of contact sports, focusing on body mass index over time. Efforts should be made to prevent *S. aureus* from colonizing the nose, as this could reduce the rate of infection among athletes in our country. Furthermore, the nose was the only body site studied. However, colonization can also occur in other places, such as the throat, axillae, perineum and skin [37]. However, the nose is thought to be the main site of *S. aureus* colonization, as decolonization of the nose typically has a decolonizing effect on the skin [38]. Moreover, the epidemiology and pathophysiology of staphylococcal infection appears to be significantly influenced by nasal colonization [39]. Hence, future studies should consider different sampling sites, especially oral and skin abrasion sites in obese athletes.

Conflict of Interest Statement:
The author(s) declare that there are no conflicts of interest related to this manuscript.

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