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# Common Cutaneous Bacterial Infections in Competitive Swimmers: A Retrospective Study

**Eleni Sfyri *, Niki Tertipi, Vasiliki Kefala, Vasiliki-Sofia Grech and Efstathios Rallis**

Department of Biomedical Sciences, School of Health and Care Sciences, University of West Attica, GR-12243 Athens, Greece elsfiri@uniwa.gr; ntertipi@uniwa.gr; valiakef@uniwa.gr; vgkrek@uniwa.gr; erallis@uniwa.gr

* Correspondence: elsfiri@uniwa.gr (E.S.)

**Abstract: Background/Objectives:** Bacterial skin infections are common, particularly among athletes. In swimming, folliculitis, pitted keratolysis, and impetigo are among the most frequent. However, data on these infections in competitive swimmers are limited. This study aimed to evaluate the prevalence of bacterial infections in young competitive swimmers from Greek clubs. **Methods:** Ethics approval was obtained from the University of West Attica (52645/20-07-2020) and the Hellenic Swimming Federation (787/15-03-2019). An anonymous questionnaire was completed by 1047 swimmers or their parents. Data collected included gender, age, frequency and season of infections, training environment (indoor/outdoor), years of training, weekly training frequency, and hygiene-related behaviors**. Results:** Infections significantly correlated with age and years of training. Higher prevalence was observed among swimmers training in indoor facilities. Specific behaviors—such as placing towels and clothes on locker room benches—were linked to pitted keratolysis ($p=0.036$) and impetigo ($p<0.001$). Sharing equipment was associated with all three infections. Folliculitis and pitted keratolysis were less frequent and mainly affected adolescent and adult swimmers. Impetigo was more common and affected younger age groups. A strong association was found between, seasonal allergies and both folliculitis and pitted keratolysis, between skin allergies, pitted keratolysis, impetigo and viral skin infections with all bacterial manifestations. **Conclusions:** Cutaneous bacterial infections can impact swimmers' health and performance. Preventive strategies, including proper hygiene, awareness, and prompt treatment, are vital to reducing the risk of infection and limiting transmission within swimming communities.

**Keywords:** cutaneous bacterial infections; competitive swimmers; folliculitis; pitted keratolysis; impetigo

## 1. Introduction

Skin infections are frequently encountered in general population and among athletes [1]. Swimming, which is especially favored by children and young adults, poses a significant risk of cutaneous infections [2]. The incidence of cutaneous ailments in swimmers is greatly influenced by exposure to moisture, heat, cold, wind, chemicals, and sunlight [3]. Some skin infections are notably common, with primary risk factors stemming from the pool environment, swimming equipment, and the routines of swimmers [3–6]. Additionally, cutaneous bacterial infections that are usually widespread in the general population, often influenced by external factors, can interfere with swimmers' training programs and lead to more severe health issues.

Folliculitis is a common and usually benign skin condition involving inflammation of hair follicles. It typically presents as erythematous papules that may progress to pustules. The condition can be caused by bacterial, fungal, viral and parasitic infections, as well as chemical or physical irritants [7]. Staphylococcus aureus is the most frequent causative agent, while Pseudomonas-related folliculitis is often linked to poorly disinfected hot tubs, pools, and whirlpools [8]. The exact incidence of folliculitis remains unknown. However, individuals with diabetes, obesity, prolonged antibiotic

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use, immunosuppression, or frequent shaving are at higher risk. While gender does not directly affect overall prevalence, certain types may be more common in one gender. Diagnosis is primarily clinical, relying on patient history and physical examination [9]. Contributing factors include intense itching, excessive sweating, topical corticosteroid use, recent antibiotics, or exposure to communal water facilities. Folliculitis is classified based on its location and etiology, with water exposure being a notable risk factor [9].

Hot tub folliculitis is attributed to Pseudomonas aeruginosa and typically arises following exposure to contaminated water in environments such as swimming pools, hot tubs, and baths. It can also manifest in areas covered by diving suits and in women who shave their legs. [2]. It is characterized by the appearance of dark spots and papules on body areas submerged in water, typically emerging 8 - 48 hours after using a water facility. Hot tub folliculitis is estimated in 80% of all folliculitis cases associated with the water. Almost 20% of these are related to swimming facilities [10]. Swimming pools with very hot water are an important predisposing factor for infection. Patients may also report symptoms including fever, fatigue, nausea, diarrhea, ear pain, sore throat, and lymphadenopathy. Fortunately, infection is generally treated without resulting in scars [2]. Research indicates that 93% of swimmers and 88% of winter athletes experienced fulliculitis after using a swimming pool. The largest recorded outbreak of folliculitis occurred at a water park in Utah, USA, where 590 swimmers became ill after utilizing a water slide [10].

Impetigo is a highly contagious infection that affects the upper layers of the skin, primarily caused by Gram-positive bacteria. It spreads through direct contact with infected individuals or contaminated surfaces, and self-inoculation can also occur. There are two main types of impetigo: bullous and non-bullous [11]. The non-bullous variant is predominantly caused by Staphylococcus aureus in 80% of cases, while Streptococcus pyogenes is responsible for 10%, with both bacteria present in the remaining 10%. Staphylococcus aureus typically colonizes areas such as the nose, perineum, axillae and between the fingers, with infections often arising from skin injuries like insect bites, cuts, burns, herpes simplex lesions, or atopic dermatitis. Impetigo is prevalent among children, affecting both sexes and all ethnicities, with a higher occurrence in warm, humid climates, particularly during the summer and fall months. [12].

The infection is commonly seen in athletes participating in contact sports or those who share equipment [10]. Additionally, exposure to seawater may elevate the risk of developing impetigo, especially in children and individuals engaged in water sports like swimming, diving, and surfing [13].

Pitted keratolysis is a prevalent bacterial infection affecting the soles of the feet, primarily caused by various Gram-positive bacteria such as Micrococcus and Corynebacterium. This condition is typically localized to the soles. It is more common among bare footed workers, farmers, marine workers, soldiers wearing occluded shoes for prolonged periods such as among athletes who sweat profusely while wearing socks, as well as those who walk barefoot [14,15]. Clinically, it is characterized by pitted desquamation and erosions of the stratum corneum. Small pinpoint erosions, measuring 1–3 mm in diameter, develop in areas of the soles that experience pressure [10,16]. A strong, unpleasant odor is often associated with this infection. Pitted keratolysis can occur in individuals of all ages, although it is frequently seen in adolescents and young adults. There is a higher prevalence among males, likely due to their greater use of occlusive footwear [16]. Dermatological treatment typically results in improvement, and effective management of the condition focuses on minimizing excess moisture on the feet.

There is lack of literature references regarding cutaneous bacterial infections in swimmers. Studies, usually consist of case studies or reviews of children, general population and sports' athletes [16,17]. Examining the existence of these infections in competitive swimmers is essential for preventing and protecting against the transmission of these bacterials, as well as for reducing the possible effects on training schedules and competition procedures.

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## 2. Materials and Methods

This cross-sectional study aimed to assess the prevalence of skin infections among competitive swimmers in Greece, considering the impact of the COVID-19 pandemic on data collection. Ethical approvals were secured from the University of West Attica (52645-20 July 2020) and the Hellenic Swimming Federation (787 15 March 2019). Due to pandemic-related restrictions, an online survey was conducted from June to December 2021. The study employed a self-selected sampling method, which was the only feasible approach given the challenges in reaching the entire population of competitive swimmers in Greece.

Participants were drawn from swimming clubs across the country. Out of 182 clubs, swimmers from 80 clubs participated. Recruitment involved sending invitations to adult swimmers and the minors' parents via email and social media, with assistance from coaches and club managers to facilitate communication. Participation was voluntary and anonymous. A total of 1047 competitive swimmers took part, representing junior categories (ages 9–12), age group categories (ages 13–18), and both Men - Women categories. The sample size of 9.23% was deemed statistically adequate and representative of the overall swimmer population.

The questionnaire was developed and validated by the researchers through a pilot study utilizing the test-retest method. It was distributed via Google Forms and consisted of two primary sections. The first section gathered general information, including demographics, training habits, pool behavior, and overall skin health. The second section delved into specific details regarding various skin infections. For this study, data were extracted from specific sections of the questionnaires, concentrating on demographic details, training practices, infection timings, and the seasons when athletes might be more vulnerable to infections. Information regarding the type of swimming facility, years of training, daily training hours, swimming-related behaviors and history of virus infections and allergies was also documented. Participants with recurrent infections were asked to share details about their most recent episode, as recalling recent events is generally more accurate for respondents.

*Statistical Analysis*

Categorical variables were reported as absolute numbers (n) and related frequencies (%). The chi-square test was employed to assess the relationship between two categorical variables. To explore the connections between a categorical variable and an ordinal variable, the chi-square trend test was utilized. Bivariate correlations were analyzed between bacterial infections and factors such as "gender," "type of facility," "years of training," "weekly training" and "daily training hours". Correlations were examined between the cutaneous bacterial infections and swimmer behaviors, including "walking barefoot on the pool deck" and "sharing equipment." The correlation between a history of virus infections and allergic manifestations and the incidence of cutaneous bacterial infections was also, investigated.

Multivariate logistic regression analyses were performed to identify possible associations between hygiene practices (e.g., sharing equipment and behaviors), allergic history, history of viral infections and the bacterial infections under investigation. This analysis involved calculating the odds ratio (OR) along with a 95% confidence interval (CI). The threshold for statistical significance (p) was established at 0.05 for all tests (two-sided). Data analysis was conducted using IBM SPSS 26.0 software (Statistical Package for Social Sciences).

## 3. Results

*3.1. Demographic Characteristics*

A total of one thousand and forty-seven swimmers (n=1047) were participated in this study, resulting in a response rate of 9.23%. Among the participants, 577 were female (55.1%) and 470 were male (44.9%). 637 (60.8%) of the swimmers were training at outdoor facilities, while 470 (39.2%) were

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using indoor facilities. The largest group of participants was in the junior category, aged 9 to 12 years (n = 359, 34.3%), followed by those aged 13 to 14 years (n = 231, 22%), 15 to 16 years (n = 195, 18.6%), 17 to 18 years (n = 111, 10.6%), and over 18 years (n = 151, 14.4%). Most participants reported training for "7–9 years" (n = 265, 25.3%) and "4–6 years" (n = 262, 25%). Based on parents' and swimmers' responses, half of the swimmers (n=541) follow a daily training schedule that lasts two hours.

### *3.2. General Characteristics of Cutaneous Bacterial Infections and Their Association with Triaining Routines*

#### 3.2.1. Folliculitis

A total of 28 swimmers (2.7%) experienced folliculitis during their swimming careers. Two third of the infected swimmers developed folliculitis once. "Lower limbs" (42.8%) and "torso" (28.6%) were the sites with the most occurrences. Half of the folliculitis infections occurred during "spring". Infections were significantly less common in "winter" (21%), "summer" (21%) and "autumn" (7.2%). Twenty (71.4%) swimmers continued their training while receiving treatment whereas training was interrupted for 8 swimmers, though the duration of absence varied (Table 1). Half of the infections were diagnosed and treated by dermatologists.

Folliculitis occurred in 3.1% of female and 2.1% of male swimmers. A statistically significant difference was observed with adult swimmers demonstrating the highest prevalence. Additionally, long-term swimmers experienced the highest incidence of folliculitis at 7.4% ($p<0.001$) (Table 2). Type of swimming pool, times of weekly training and hours of daily training did not seem to affect the occurrence of folliculitis.

**Table 1.** Bacterial infections.

| | **Folliculitis n (%)** | **Impetigo n (%)** | **Pitted Keratolysis n (%)** |
|---|---|---|---|
| Yes | 28 (2.7) | 114 (10.9) | 33 (3.2) |
| No | 1019 (97.3) | 933 (89.1) | 1014 (96.8) |
| **Number of infectious events reported** | | | |
| One | 21 (75) | 78 (68.4) | 20 (60.6) |
| Two | 0 | 22 (19.3) | 5 (15.2) |
| Three | 2 (7.1) | 11 (9.6) | 5 (15.2) |
| Four | 3 (10.7) | 0 | 0 |
| Five | 0 | 1 (0.9) | 1 (3) |
| ≥Six | 2 (7.1) | 2 (1.8) | 2 (6.1) |
| **Sites of infections** | | | |
| Face | 4 (14.3) | 25 (30.1) | 0 |
| Torso | 8 (28.6) | 19 (22.9) | 0 |
| Upper limbs | 4 (14.3) | 18 (21.7) | 0 |
| Lower limbs | 12 (42.8) | 21 (25.3) | 33 (100) |
| **Season of infection** | | | |
| Winter | 6 (21.4) | 20 (24.7) | 12 (33.3) |
| Spring | 14 (50) | 14 (17.3) | 12 (33.3) |
| Summer | 6 (21.4) | 37 (45.7) | 8 (22.2) |
| Autumn | 2 (7.2) | 10 (12.3) | 4 (11.1) |
| **Training interruption** | | | |
| <1 week | 6 (21.4) | 16 (28.6) | 4 (12.1) |

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| | | | |
|---|---|---|---|
| <1 month | 2 (7.2) | 22 (39.3) | 2 (6.1) |
| >1 month | 0 | 10 (17.8) | 2 (6.1) |
| Non-training interruption | 20 (71.4) | 8 (14.3) | 25 (75.7) |

3.2.2. Impetigo

An impetigo infection was reported by 10.9% of the individuals surveyed. Among them, 68.4% had it "once," and 19.3% "two" times. Face (30.1%) and lower limbs (25.3%) were the sites with the most occurrences. Nearly half of the reported infections occurred in "summer" (45.7%). Of those affected, 39.3% interrupt their training for "less than a month" and only 8 swimmers "did not interrupt their training" (Table 1). Almost all the infected swimmers visit a dermatologist and receiving treatment.

The incidence of impetigo did not differ significantly between male and female participants. The highest prevalence rates of impetigo infection were observed among younger age groups, with infections predominantly occurring up to the age of 14. Among those training in indoor facilities, 13.2% had developed impetigo, with the difference approaching but not reaching statistical significance (p=0.057). A significant association was identified regarding the number of weekly training sessions, with the highest infection rate found among swimmers training up to three times per week (20.8%, p<0.001). This finding aligns with the younger age profile of the athletes affected by the condition (Table 2).

3.2.3. Pitted Keratolysis

Pitted keratolysis was reported by 33 (3.2%) of the swimmers. "Winter" and "Spring" reported as the seasons with the highest incidence of pitted keratolysis. 60% of infected swimmers developed folliculitis once. Most of the participants (75.7%) did not interrupt their training schedule because of the infection (Table 1) and half of them were diagnosed and treated by dermatologists.

**Table 2.** Bivariate analysis using Folliculitis, Impetigo and Pitted Keratolysis as dependent variables.

| | **Folliculitis n(%)** | | | **Impetigo n(%)** | | | **Pitted Keratolysis n(%)** | | |
|---|---|---|---|---|---|---|---|---|---|
| Characteristic | **Yes** | **No** | **p value** | **Yes** | **No** | **p value** | **Yes** | **No** | **p value** |
| **Gender** | | | 0.322[a] | | | 0.450[a] | | | 0.087[a] |
| Male | 10(2.1) | 460 (97.9) | | 47(10) | 423(90) | | 10 (2.1) | 460 (97.9) | |
| Female | 18 (3.1) | 559 (96.9) | | 67 (11.6) | 510 (88.4) | | 23 (4) | 554 (96) | |
| **Age** | | | <0.001[b] | | | 0.024[b] | | | 0.003[b] |
| 9 – 12 years old | 3 (0.8) | 356 (99.2) | | 46 (12.8) | 313 (87.2) | | 1 (0.3) | 358 (99.7) | |
| 13 – 14 years old | 5 (2.2) | 226 (97.8) | | 28 (12.1) | 203 (87.9) | | 7 (3) | 224 (97) | |
| 15 – 16 years old | 2 (1.1) | 192 (98.9) | | 21 (10.8) | 173 (89.2) | | 9 (4.7) | 185 (95.3) | |
| 17 – 18 years old | 2 (1.8) | 110 (98.2) | | 6 (6.4) | 106 (94.6) | | 6 (6.4) | 106 (94.6) | |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| >18 years old | 16 (10.6) | 135 (89.4) | | 13 (8.6) | 138 (91.4) | | 10 (6.6) | 141 (93.4) | |
| **Type of swimming pool** | | | 0.234[a] | | | 0.057[a] | | | 0.978[a] |
| Outdoor facility | 14 (2.2) | 623 (97.8) | | 60 (9.4) | 577 (90.6) | | 20 (3.1) | 617 (96.9) | |
| Indoor facility | 14 (3.4) | 396 (96.6) | | 54 (13.2) | 356 (86.8) | | 13 (3.2) | 397 (96.8) | |
| **Training years** | | | <0.001[b] | | | 0.391[b] | | | <0.001[b] |
| ≤ 3 years | 1 (1) | 99 (99) | | 14 (14) | 86 (86) | | 1 (1) | 99 (99) | |
| 4-6 years | 6 (2.3) | 256 (97.7) | | 28 (10.7) | 234 (89.3) | | 2 (0.8) | 260 (99.2) | |
| 7-9 years | 1 (0.4) | 264 (99.6) | | 31 (11.7) | 234 (88.3) | | 5 (1.9) | 260 (99.1)) | |
| 10-12 years | 5 (2.3) | 211 (97.7) | | 26 (12) | 190 (88) | | 9 (4.2) | 207 (95.8) | |
| > 12 years | 15 (7.4) | 189 (92.6) | | 15 (7.4) | 189 (92.6) | | 16 (7.8) | 188 (92.2) | |
| **Weekly training** | | | 0.630[b] | | | <0.001[b] | | | 0.088[b] |
| ≤ 3 times | 4 (2.7) | 145 (97.3) | | 31 (20.8) | 118 (79.2) | | 6 (4) | 143 (96) | |
| 4 – 5 times | 6 (2) | 301 (98) | | 19 (6.2) | 288 (93.8) | | 4 (1.3) | 303 (98.7) | |
| ≥ 6 times | 18 (3) | 573 (97) | | 64 (10.8) | 527 (89.2) | | 23 (3.9) | 568 (96.1) | |
| **Daily training hours** | | | 0.801[b] | | | 0.289[b] | | | 0.114[b] |
| ≤ 1.5 hour/day | 8 (2.6) | 302 (97.3) | | 41 (13.2) | 269 (86.8) | | 6 (1.9) | 304 (98.1) | |
| 2 hour/day | 16 (2.9) | 527 (97.1) | | 54 (9.9) | 489 (90.1) | | 23 (4.2) | 520 (95.8) | |
| > 2 hour/day | 4 (2.1) | 190 (97.9) | | 19 (9.8) | 175 (90.2) | | 4 (2.1) | 190 (97.9) | |

Values are expressed as n (%), unless stated otherwise. [a] $X^2$ test, [b] $X^2$ test for trend.

Pitted keratolysis was reported by 4% of female and 2.1% of male swimmers. The analysis revealed a statistically significant difference related to both the athletes' ages (p=0.003) and their years of swimming experience (p<0.001), with adults and individuals older than 12 years exhibiting the highest rates (Table 2).

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*3.3. Correlation Between Swimmers' Behavior and Habits, Allergy History, History of Viral Infections and the Development of Cutaneous Bacterial Infections*

3.3.1. Correlation of Cutaneous Bacterial Infections and Swimmers' Behavior and Habits

The statistical analysis conducted to explore the connection between cutaneous bacterial infections, behavioral factors in the pool area, and allergic history of swimmers.

Folliculitis, appears to be associated with the sharing of swimming equipment such as fins (p=0.001) and puddles (p=0.006). Additional statistical analysis, considering the significance noted in the previously mentioned associations, indicated that sharing fins (OR 2.611 CI 95% 1.141 – 5.973 p=0.023) is in an increased risk of developing folliculitis (Table 3).

Regarding impetigo infections, 89 (11.7%) swimmer do not wear any footwear in the pool area and 90 (13.1%, p=0.001) placing their personal clothing on the pool benches. Sharing equipment such as fins (p=0.012), kick boards (p=0.006) and flip flops (p=0.026) was also, associated with the incidence of impetigo (Table 3). Further statistical investigation revealed that the likelihood of developing impetigo is twice as greater for those who have placed personal clothing on pool benches (OR 2.097 CI 95% 1.301 – 3.379 p=0.002), share kick boards (OR 1.894 CI 95% 1.173 – 3.059 p=0.009) and flip-flops (OR 2.109 CI 95% 1.306 – 3.406 p=0.002).

**Table 3.** Correlation between cutaneous bacterial infections and swimmers' behavior and habits.

| | **Folliculitis n (%)** | | **Impetigo n (%)** | | **Pitted Keratolysis n (%)** | |
|---|---|---|---|---|---|---|
| | **Yes** | **No** | **Yes** | **No** | **Yes** | **No** |
| **Walking barefoot in the swimming pool deck** | | | | | | |
| | p=0.465 | | p=0.158 | | p=0.670 | |
| Yes | 22 (2.9) | 737 (97.1) | 89 (11.7) | 670 (88.3) | 25 (3.3) | 734 (96.7) |
| No | 6 (2.1) | 282 (97.9) | 25 (8.7) | 263 (91.3) | 8 (2.8) | 280 (97.2) |
| **Placing bathrobes or clothes on the pool's bench** | | | | | | |
| | p=0.098 | | p=0.001 | | p=0.036 | |
| Yes | 12 (2) | 596 (98) | 90 (13.1) | 596 (86.9) | 25 (4.1) | 583 (95.9) |
| No | 16 (3.6) | 423 (96.4) | 24 (6.6) | 337 (93.4) | 8 (1.8) | 431 (98.2) |
| **Sharing swimming equipments** | | | | | | |
| **Fins** | p=0.001 | | p=0.012 | | p=0.007 | |
| Yes | 19 (4.7) | 382 (95.3) | 56 (14) | 345 (86) | 20 (5) | 381 (95) |
| No | 9 (1.4) | 637 (98.6) | 58 (9) | 588 (91) | 13 (2) | 633 (98) |
| **Puddles** | p=.006 | | p=0.057 | | p=0.003 | |
| Yes | 18 (4.4) | 392 (95.6) | 54 (13.2) | 356 (86.8) | 21 (5.1) | 389 (94.9) |
| No | 10 (1.6) | 627 (98.4) | 60 (9.4) | 577 (90.6) | 12 (1.9) | 625 (98.1) |
| **Kick board** | p=0.206 | | p=0.006 | | p=0.075 | |
| Yes | 22 (3.1) | 685 (96.9) | 90 (12.7) | 617 (87.3) | 27 (3.8) | 680 (96.2) |
| No | 6 (1.8) | 334 (98.2) | 24 (7.1) | 316 (92.9) | 6 (1.8) | 334 (98.2) |
| **Flip flops** | p=0.260 | | p=0.026 | | p=0.300 | |
| Yes | 8 (3.8) | 203 (96.2) | 32 (15.2) | 179 (84.8) | 9 (4.3) | 202 (95.7) |
| No | 20 (2.4) | 816 (97.6) | 82 (9.8) | 754 (90.2) | 24 (2.9) | 812 (97.1) |

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For pitted keratolysis infections, twenty-five of the infected swimmers used to walk barefoot on the swimming pool deck. Furthermore, placing personal clothing on benches was identified as a significant factor (p=0.036), as well as sharing fins (p=0.007) and puddles (p=0.003) (Table 3).

3.3.2. History of Allergies

Research into the swimmers' allergy history revealed that a significant number exhibit some type of allergy. Additionally, many of these individuals also showed signs of cutaneous bacterial infections. Specifically, the data indicated that:

- 17.3% of those with skin allergy reported impetigo infections and 6.2% pitted keratolysis.
- 6.4% of individuals with seasonal allergy noted folliculitis, 16.5% with impetigo, and 7.5% pitted keratolysis.
- 7.8% of individuals with respiratory allergy manifested folliculitis, 25.6% impetigo, and 7.8% pitted keratolysis (Table 4).

Further statistical analysis revealed that:

- Swimmers with a history of seasonal allergy were found to be almost five times more likely to experience folliculitis (OR 4.754 CI 95% 2.197 – 10.285 p=0.001) and almost four times to experience pitted keratolysis (OR 3.710 CI 95% 1.769 – 7.782 p=0.001).
- Swimmers with skin allergy had an increased risk of heaving impetigo (OR 2.108 CI 95% 1.405 – 3.164 p<0.001) and pitted keratolysis (OR 2.57 CI 95% 1.225 – 5.394 p=0.013).
- Swimmers with respiratory allergy had an increased risk of heaving impetigo (OR 2.457 CI 95% 1.428 – 4.227 p<0.001) (Table 4).

3.3.3. History of Common Viral Infections

Research into the history of viral infections in swimmers revealed that a considerable percentage carried signs of viral pathogens. Additionally, many of these individuals also showed clinical symptoms of skin bacterial infections. Specifically, the data indicated that:

- 5.9% of those with warts reported folliculitis infection, 17.3% impetigo and 5.9% pitted keratolysis.
- 13.3% of individuals with molluscum contagiosum noted folliculitis, 37.8% with impetigo, and 15.6% pitted keratolysis (Table 4).

Further statistical analysis revealed that:

- Swimmers with warts history were found to be in a high risk of occurrence folliculitis (OR 7.039 CI 95% 2.828 – 17.521 p<0.001), pitted keratolysis (OR 3.811 CI 95%1.827–7.950 p<0.001) and impetigo (OR 2.610 CI 95%1.759 – 3.872 p<0.001).
- Swimmers with a history of molluscum contagiosum had an extremely increased risk of heaving folliculitis (OR 9.048 CI 95%4.134 – 19.803 p<0.001), pitted keratolysis (OR 9.094 CI 95%4.388 – 18.849 p<0.001) and impetigo (OR 6.656 CI 95% 4.103 – 10.796 p<0.001) (Table 4).

**Table 4.** History of allergies, viral cutaneous infections and bacterial manifestations.

| | Yes n (%) | No n (%) | OR | CI 95% | p value |
|---|---|---|---|---|---|
| | | **Folliculitis** | | | |
| **Seasonal allergy** | | | 4.754 | 2.197 – 10.285 | 0.001 |
| Yes | 17 (6.4) | 250 (93.6) | | | |
| No | 11 (1.4) | 769 (98.6) | | | |
| **Respiratory allergy** | | | 1.553 | 0.558 – 4.322 | 0.399 |
| Yes | 7 (7.8) | 83 (92.2) | | | |
| No | 21 (2.2) | 936 (97.8) | | | |

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| | | | | | |
|---|---|---|---|---|---|
| **Warts** | | | 7.039 | 2.828 – 17.521 | <0.001 |
| Yes | 22 (5.9) | 349 (94.1) | | | |
| No | 6 (0.9) | 670 (99.1) | | | |
| **Molluscum contagiosum** | | | 9.048 | 4.134 – 19.803 | <0.001 |
| Yes | 12 (13.3) | 78 (86.7) | | | |
| No | 16 (1.7) | 941 (98.3) | | | |
| **Impetigo** | | | | | |
| **Skin allergy** | | | 2.108 | 1.405 – 3.164 | <0.001 |
| Yes | 56 (17.3) | 267 (82.7) | | | |
| No | 58 (8) | 666 (92) | | | |
| **Seasonal allergy** | | | 1.233 | 0,768 – 1.979 | <0.001 |
| Yes | 44 (16.5) | 223 (83.5) | | | |
| No | 70 (9) | 710 (91) | | | |
| **Respiratory allergy** | | | 2.457 | 1.428 – 4.227 | <0.001 |
| Yes | 23 (25.6) | 67 (74.4) | | | |
| No | 91 (9.5) | 866 (90.5) | | | |
| **Warts** | | | 2.610 | 1.759 – 3.872 | <0.001 |
| Yes | 64 (17.3) | 307 (82.7) | | | |
| No | 50 (7.4) | 626 (92.6) | | | |
| **Molluscum contagiosum** | | | 6.656 | 4.103 – 10.796 | <0.001 |
| Yes | 34 (37.8) | 56 (62.2) | | | |
| No | 80 (8.4) | 877 (91.6) | | | |
| **Pitted keratolysis** | | | | | |
| **Skin allergy** | | | 2.570 | 1.225 – 5.394 | 0.013 |
| Yes | 20 (6.2) | 303 (93.8) | | | |
| No | 13 (1.8) | 711 (98.2) | | | |
| **Seasonal allergy** | | | 3.710 | 1.769 – 7.782 | 0.001 |
| Yes | 20 (7.5) | 247 (92.5) | | | |
| No | 13 (1.7) | 767 (98.3) | | | |
| **Respiratory allergy** | | | 1.227 | 0.477 – 3.156 | 0.672 |
| Yes | 7 (7.8) | 83 (92.2) | | | |
| No | 26 (2.7) | 931 (97.3) | | | |
| **Warts** | | | 3.811 | 1.827 – 7.950 | <0.001 |
| Yes | 22 (5.9) | 349 (94.1) | | | |
| No | 11 (1.6) | 665 (98.4) | | | |
| **Molluscum contagiosum** | | | 9.094 | 4.388 – 18.849 | <0.001 |
| Yes | 14 (15.6) | 76 (84.4.) | | | |
| No | 19 (2) | 938 (98) | | | |

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## 4. Discussion

The increasing number of athletes has led to a rise in bacterial cutaneous infections [1]. Consequently, this study focuses on bacterial infections that can affect competitive swimmers. Some of the infections are linked to the swimming pool environment, the behaviors and habits of the swimmers, while others are primarily influenced by external factors. Research on swimmers is limited in the existing literature, which complicates the comparison of infection rates across different studies. Other research has identified fungal, bacterial, contact dermatitis, and common viral infections as the most frequently reported sports-related infections [10,18,19]. To our knowledge, this is the first study to present the epidemiology of cutaneous bacterial infections among a large number of competitive swimmers. The previous literature on swimmers' bacterial infections has been limited to case reports and literature reviews.

The current study indicates that 2.7% of competitive swimmers have experienced folliculitis. There is no specific prevalence rate for folliculitis in the general population documented in the literature [20]. A study indicated that approximately 1.3% of schoolchildren were affected [21]. A separate study revealed that 27% of organ transplant recipients who were immunosuppressed experienced ongoing folliculitis [22]. In a clinical study, in the UK it was reported that the incidence of folliculitis manifestations doubled within a decade [23]. Lin et.al [24] reported that the studies they reviewed included more male than female participants. In our study although the percentage of cases was slightly higher among females, possibly due to more frequent hair removal in certain areas, gender did not appear to be linked to the prevalence of folliculitis. This issue was more prevalent in adult swimmers for similar reasons. However, among athletes, the use of hot tubs is associated with over 80% of all folliculitis cases, while swimming pools account for approximately 20% of occurrences [10]. Our study found that spring had the highest occurrences of folliculitis, contrasting with other research that highlights winter and autumn [25,26]. This increase in cases during spring coincides with the start of competitive swimming season, leading to more frequent shaving of body hair among both male and female swimmers

Bacterial folliculitis typically affects children or adults who have certain predisposing factors that contribute to an increase in the bacterial population on the skin's surface. [7,27]. History of viral infections such as warts and molluscum contagiosum can affect the presence and cause of folliculitis [9,28]. Folliculitis infections commonly affect the face, buttocks, and axillae in infants and children, while in adolescent girls, typically occur on the legs, and in adolescent boys, often found in the flexural sites [7]. Our participants' locating points—their faces and lower limbs—align with the references found in the literature. Mycobacterium marinum or pseudomonas aeruginosa are most likely the cause of infections data that arise through laboratory analysis. Staphylococcus aureus is the most frequent causative agent, and types of streptococcus, proteus, and coliform bacteria have also been implicated in the folliculitis. Pseudomonas folliculitis involves the exposed aspects of the trunk and follows an exposure to contaminated water [29,30]. This type of bacteria is commonly found in most swimming pools and in areas of the body where the skin barrier is compromised, such as after shaving, affecting both swimmers and non-swimmers [31]. Seasonal allergy seems to be linked to the occurrence of folliculitis, a finding that requires more investigation.

Folliculitis infection, occurred once, for the majority of participants (75%). This data probably related to the existence of the bacterium in the pool at the time of infection. A visit to the dermatologist may have significantly contributed to the folliculitis times of recurrence. The growth of these bacteria is usually encouraged by higher water temperatures. The consistently warm and humid enironment present on surfaces such as decks, benches, floors and equipment in pool facilities provides optimal conditions for the proliferation of pseudomonas, which are capable of sustaining growth at temperatures up to 41°C [32]. Our not significant results concerning swimmers' hygiene practices, such as placing personal clothing on benches, are not supported by the available literature. Only equipment sharing appears to be a documented risk factor for the development of folliculitis. However, in swimming pools, where the water temperature is generally moderate (approximately

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26°C), bacterial proliferation is more often affected by conditions like overcrowding and water turbulence, which can result in lower chlorine levels [33].

The occurrence of impetigo among our swimmers is noted to be 10.9%, which is three times higher than the rate found in the general child population (1.9% - 3.7%) [34]. Nevertheless, studies addressing the global incidence of impetigo have determined that prevalence rates can soar to 49%, affected by geographical location and the living conditions of the individuals involved [35,36]. The occurrence of this infectious skin disease in swimmers' concerns, mainly, the age category 9-12 years (12.8%), a fact that agrees with previous research in children [34]. An interesting finding in our study was the high rate of impetigo in adolescence, with a declining trend as age increased. Children experience the greatest disease burden, with incidence decreasing with increasing age [37]. A potential reason for this phenomenon could be the significant utilization of swimming equipment among this age groups along with the strong association of its sharing, with the impetigo manifestation. Most swimmers infected once, fact that probably related to the treatment provided by the dermatologist and the guidelines given to manage the infection and avoid spreading.

The location points mainly focused on the face (25.3%), the lower limbs (25.3%) and the torso (22.9%), findings that agree with Steele et al [38]. This data is justified by the frequent contact of hands with the face which subsequently come into contact with equipment such as kick board and flip-flops, as indicated by the respondents' statements. The "torso" and "lower limbs" in adolescents "13-16 years old" are probably related to the use of equipment, as mentioned above, data that contradict literature, where the detections are mainly in the face [10,34,39]. The incidence of impetigo was greater in the summer compared to winter, aligning with existing literature, with the exception of a Canadian study that reported a peak in cases during the winter months [40,41]. An interesting finding, which agrees with Walker et al. [42] is that, the occurrence of allergies and viral skin infections is associated with the impetigo development. The atopic manifestations history in children with the correlation of impetigo occurrence has been also confirmed [43]. In contrast, Amin et al. [34] referred to the coexistence of impetigo with fungal infections. In our study, atopic manifestations of our athletes, such as respiratory and skin allergy, were strongly associated with impetigo disease, a result that requires further investigation.

The prevalence of pitted keratolysis among the swimmers in our study was 3.2%, representing the only report involving a large cohort of competitive-level swimmers. Literature references concerning this infection mainly pertain to isolated case reports or outbreaks linked to the use of specific swimming facilities [44–46]. The prevalence of pitted keratolysis, as reported in different studies, ranges from 1.5% in industrial worker to 2.25% in New Zealand [47,48]. In field workers, pitted keratolysis was reported to be the most common infective skin disease in a prevalence of 6.3% [48]. This may be attributed to walking barefoot and being exposed to a moist environment [49]. Pitted keratolysis manifestations in our participants, were more frequent in both winter and spring, contrary to the literature concerning the general population, which reports an exacerbation of events in hot and rainy seasons [50,51]. Generally, is a condition that occurs worldwide and can be seen in both temperate and tropical environments [47].

The current research indicates that most swimmers with pitted keratolysis were older than 14 years old, which contradicts previous studies that suggest a higher prevalence of this skin condition in younger children [52]. Since pitted keratolysis is related to microtraumas on the soles of the feet, its incidence seems to be affected by behaviors observed in the pool setting. Specifically, 25 out of 33 swimmers affected, reported walking barefoot in the pool area, frequently on abrasive surfaces intended to reduce slipping. This, along with possibly inadequate disinfection of the water and surrounding areas, may contribute to the development of the infection. Our research revealed a higher incidence rate among female swimmers, which contradicts previous studies. This difference may be due to women's increased health-seeking behavior, characterized by a greater awareness of their physical appearance and a stronger tendency to seek medical advice when any health issues arise [53].

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The strong association that emerged between the infection and the predisposition to skin and seasonal allergies is probably linked to an additional factor, which has been reported by Cohen [140] and concerns the allergic reaction to the color and lime of cement which can cause irritation and lead to infection of the feet. Except atopic manifestations, previous virus skin infections appear to tended to develop pitted keratolysis [48]. These correlations require additional research.

Based on the previous discussion, it is essential to implement strategies to prevent this infection. This can be achieved through the use of suitable disinfectants to eliminate pathogenic microorganisms and smoothing the surfaces around the swimming pool and in the shallow areas.

This study represents the first global assessment of the incidence of folliculitis, impetigo, and pitted keratolysis among competitive swimmers. However, it is important to note certain limitations. Due to the restrictions imposed by the COVID-19 pandemic, data collection was carried out via an online questionnaire without clinical examinations. All information was self-reported, requiring participants to recall their past medical conditions, which may lead to recall bias. We opted for this method as it allowed for a quicker and more convenient experience for participants, giving them sufficient time to consider their answers without external pressure. The questionnaire covered a wide range of skin infections, which were not specifically analyzed in this study. Therefore, we cannot definitively ascertain whether the participants' responses were based on actual experiences with the bacterial infections being studied. Additionally, our research did not include assessments of water quality and hygiene practices. It is in our future plan to link our findings with water quality metrics to evaluate the risk of infectious disease transmission.

This research on cutaneous bacterial infections among competitive swimmers offers a novel perspective within the existing literature. Based on data provided by our participants, a correlation exists between folliculitis, impetigo, pitted keratolysis and the swimming pool environment. While swimming equipment and pool areas are suspected carriers of these bacteria, the precise source of infections remains unclear. Implementing best practices can help reduce the adverse health effects on swimmers. Factors such as poor water quality, overcrowding, and inadequate maintenance of pool equipment must be addressed to ensure the safe operation of swimming facilities and to prevent cutaneous bacterial infections [54]. It is noteworthy that infected swimmers often continued their training sessions during treatment, potentially increasing the risk of bacterial transmission to teammates. Education on transmission modes, clinical progression, hygiene practices, and return to training guidelines is essential for swimmers. Mandatory measures include showering before swimming, handwashing, avoiding training during infections, and using personal swimming equipment to prevent infection spread [55,56]. Swimmers should also be advised to consult a dermatologist annually, wear flip-flops, and avoid walking barefoot in public areas [57]. Competent authorities, facility operators, and swimming club managers play a crucial role in disseminating information about facility rules and the importance of adherence to these guidelines [54]. Additional research is needed to assess the prevalence and factors influencing the occurrence of these bacterial infections in sports overall.

## 5. Conclusions

This study, while exploring bacterial infections with various characteristics and manifestations, presents findings that are notable for competitive swimmers. The prevalence of these three skin infections among swimmers is noteworthy compared to the general population. It is crucial for every swimmer to receive an early diagnosis of all skin infections through a dermatological assessment. This proactive approach will help prevent potential transmission to other swimmers or individuals. Additionally, educating swimmers about modes of transmission, clinical progression, hygiene practices, and guidelines for returning to training is vital. Pool operators and club managers must provide information regarding facility rules and emphasize the importance of following these guidelines. Further research is necessary to assess the frequency of these viral infections and the factors that contribute to their manifestation in sports.

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