

An assessment of chlorine stain and collegiate swimmers

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ABSTRACT

Background: Swimming is known worldwide as one of the healthiest, low-impact forms of exercise that promotes a strong body, heart, and mind. However, several studies have suggested that swimming pool chlorination is responsible for dental erosion, calculus formation, and stain in competitive and recreational swimmers, a phenomenon known as swimmer's mouth. The purpose of this observational study was to assess chlorine stain on the dentition of competitive female swimmers and divers from a university team and to determine if dental preventive practices affected chlorine stains. **Methods:** Swimmers were recruited from the University of New Mexico Swimming and Diving Team for this IRB-approved study (#17-481). Participants completed a questionnaire regarding individual oral habits and frequency of preventive visits. Following the questionnaire, an oral screening was completed to evaluate for stain. Fisher exact tests, nonparametric Wilcoxon tests, and descriptive statistics were used to analyse the data. Additionally, a cross-sectional analysis was used to compare the chlorine stain between divers and swimmers. **Results:** Twenty-one females, with a mean age of 20.5 years, participated in the study. One hundred percent of these subjects had staining of the teeth, despite the fact that 85% of them reported brushing their teeth 2 to 3 times per day, and 81% reported receiving regular dental prophylaxis. All participants swam 5 or more times every week, with practice length ranging from 1 to 2 hours. There were no differences in stain between collegiate swimmers and divers. **Conclusion:** Within this study sample, extrinsic staining of the teeth was identified on all swimmers and divers and the presence of stain was not prevented by the frequency of tooth brushing or professional stain removal. Additional oral hygiene regimens should be explored to facilitate the prevention or complete removal of swimmer stain.

RÉSUMÉ

Contexte : La natation est reconnue partout dans le monde comme l'une des formes d'exercice physique les plus saines et ayant le moins d'impact, qui renforce le corps, le coeur et l'esprit. Cependant, plusieurs études ont suggéré que la chloration des piscines cause l'érosion dentaire et la formation de tartre et de taches chez les nageurs compétitifs et récréatifs; un phénomène appelé la bouche de nageur. L'objectif de cette étude d'observation était d'évaluer les taches de chlore sur la dentition de nageuses et de plongeuses de compétition d'une équipe universitaire et de déterminer si les habitudes dentaires en matière de prévention influençaient les taches de chlore. **Méthodologie :** Les nageuses ont été recrutées de l'équipe de natation et de plongeon de l'Université du Nouveau-Mexique pour effectuer cette étude approuvée par le comité d'éthique médicale (#17-481). Les participantes ont répondu à un questionnaire à l'égard des habitudes buccodentaires personnelles et de la fréquence de leurs visites dentaires préventives. À la suite du questionnaire, un dépistage buccal a été effectué pour évaluer les taches. Les tests exacts de probabilité de Fisher, les tests non paramétriques de Wilcoxon et les statistiques descriptives ont été employées pour analyser les données. De plus, une analyse en coupe a servi à comparer les taches de chlore chez les plongeuses et les nageuses. **Résultats :** Vingt-et-une femmes âgées en moyenne de 20,5 ans ont participé à l'étude. La totalité des sujets avait des taches sur les dents, malgré le fait que 85 % d'entre elles ont signalé avoir brossé leurs dents 2 à 3 fois par jour et 81 % d'entre elles ont rapporté recevoir régulièrement des prophylaxies dentaires. Toutes les participantes ont nagé 5 fois ou plus par semaine et la durée de leur entraînement variait d'une à deux heures. Les nageuses et les plongeuses universitaires n'ont démontré aucune différence dans leur taux de taches. **Conclusion :** Parmi cet échantillon de l'étude, des taches extrinsèques ont été décelées sur les dents de toutes les nageuses et plongeuses, et la fréquence du brossage de dents ou l'élimination professionnelle des taches n'a pas empêché la présence de taches. Des mesures supplémentaires d'hygiène buccodentaire devraient être explorées afin de faciliter la prévention ou l'élimination complète des taches chez les nageurs.

Keywords: chlorides, chlorine, colouring agents, mouth, staining and labelling, swimming, tooth discolouration
CDHA Research Agenda category: risk assessment and management

WHY THIS ARTICLE IS IMPORTANT TO DENTAL HYGIENISTS

- Dental staining is common among competitive swimmers and divers who practise regularly in chlorinated pools.
- Daily home oral care and professional dental hygiene services can remove stains but do not prevent them in competitive swimmers.
- Dental hygienists must be aware of swimmer's mouth in order to provide appropriate oral health instructions to their swimmer clients for regular home and professional oral care.

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INTRODUCTION

A phenomenon called swimmer's calculus, or stain, is characterized by hard, brown tartar deposits commonly found on the front teeth. To clarify, staining takes place on the acquired enamel pellicle, the layer of proteins and peptides which have a thickness of 1 μm on the enamel surface.¹ This staining is caused when antimicrobials from pool water, which naturally have a higher pH than saliva, contact salivary proteins and quickly break them down, resulting in organic deposits on the swimmer's teeth.²⁻⁴ Athletic swimmers expose their teeth to chemically treated water when they practise, with these exposures usually lasting over 6 hours per week.²

There is little known about swimmer's mouth although one of the first studies to be released on this topic appeared in the Centers for Disease Control and Prevention's *Morbidity and Mortality Weekly Report* more than 30 years ago.⁵ This study analysed data from 740 swimmers, including 452 frequent swimmers. The report suggested that 15% of frequent, or daily, swimmers had enamel erosion while only 3% of infrequent, or non-swimmers, experienced enamel erosion.⁵ A more recent case report described observations of a competitive swimmer who swam in a gas-chlorinated swimming pool and experienced notable dental erosion within 27 days.⁶ Several other studies have been published evaluating changes in salivary composition, dental erosion, calculus, and stain.^{2,3,5-14} One of these studies more specifically investigated staining of the teeth in competitive swimmers. Escartin et al.⁷ concluded the amount of training time required by competitive swimmers to increase their risk for development of dental stains was more than 6 hours. Furthermore, they reported the prevalence of dental stains to be 60.2%, therefore concluding that competitive swimmers have a higher risk of developing extrinsic dental stains.⁷

Improper pool chlorination has been suggested to contribute to the swimmer's phenomenon.^{4,8,13} If a swimming pool is kept at the optimal pH of 7.4, tooth structure should not be at risk for demineralization. However, if the pH of the swimming pool becomes neglected and is allowed to become more acidic, it is possible this could contribute to the dissolving of tooth structures. This phenomenon has been reported to be more prevalent in gas-chlorinated pool systems.³ When swimming pools are gas-chlorinated, hypochlorous acid is formed. Normally this acid can be balanced with the addition of a strong base, such as ash. However, if there is not enough base to counter the acid from the chlorine, the pool water can become acidic.¹⁵ Several governmental regulations have been developed for swimming pool chlorination with the intent to improve the water quality for swimmers. These include regular pool monitoring and, in particular, the management of pH levels.

Evidence suggests swimmer's mouth, including calculus accumulation, tooth staining, and dental erosion, affects competitive swimmers and divers. The purpose of

this study was to gain insight into and add to the limited body of knowledge on dental staining among collegiate swimmers and divers and the effects of preventive dental strategies on these stains.

METHODS

Study population

Participants were eligible for inclusion in the study if they were members of the female swimming and diving team at the University of New Mexico Johnson Pool Facility. The team consists of 21 females from all around the world, who range from freshmen to seniors. All team members were invited to participate, thus comprising a convenience sample. Participants were recruited through an in-person orientation given during a regularly scheduled swim practice.

Approval to conduct this study was granted by the Human Research Protections Office at the University of New Mexico, #17-481. All study participants provided voluntarily written informed consent prior to participation.

Study design

The study used an analytical cross-sectional design to assess swimmer's stain in a university female swimming and diving team. Personal habits and environmental factors of the participants and the pools they swam in were investigated. Data collected included frequency of dental recall visits, their tendency to plaque and calculus buildup, stain accumulation, and return of dental staining or calculus following dental prophylaxis.

Survey

Participants were administered an 11-item survey that included questions such as how frequently the swimmers attended for professional prophylaxis, when their last prophylaxis took place, and if their dental hygienists had ever mentioned staining to them.

Oral screenings

Screenings were then performed by one examiner, using disposable mouth mirrors and dental loupes with a light, before practice in the natatorium to determine each swimmer's level of stain, based upon the Lobene Stain Index.¹⁶ This index measures the intensity and extent of extrinsic dental stain on the facial surface of the anterior teeth. A chart with pictures indicating the stages of light to heavy stain provided a universal technique for the screening. As per the Lobene Stain Index, stain thickness was measured in 4 categories: 0–none, 1–thin line of stain that can be continuous, 2–moderate to thick band of stain, and 3–stain covering the total area. Presence of stain was measured in 4 categories: 0–no stain present with natural tooth colouration, 1–faint staining, 2–clearly visible stain typically orange to brown in colour, and 3–dark stain usually deep brown to black in colour.¹⁷

Statistical analysis

Quantitative variables were summarized by means and standard deviations, and categorical responses were summarized using frequencies and percentages. Subgroup differences in Lobene Stain Index intensity and thickness categories were assessed using Fisher exact tests. Secondary analysis of ordinal stain intensity and thickness scores were conducted using nonparametric Wilcoxon tests. The *p* value for this study was set at $p < 0.05$. As this study was conducted with a small planned sample size, a power analysis was not performed.

RESULTS

Twenty-one female subjects enrolled in this study. Sixteen participants were swimmers and five participants were divers, all from the university swimming and diving team (Table 1). All 21 subjects had stain present. Frequency distributions were similar for swimmers and divers for stain intensity and stain thickness (Table 2, $p = 0.32$ and $p = 0.81$, respectively). A comparison of stain intensity and thickness by duration of exposure was also undertaken (Table 3, $p = 0.76$ and $p = 0.19$, respectively). When analysed as ordinal variables, stain intensity was not different for swimmers (1.6 ± 0.5) compared to divers (1.8 ± 0.8 , $p = 0.74$), and stain thickness also was not different for swimmers (1.9 ± 0.8) and divers (1.6 ± 0.9 , $p = 0.41$). Frequency of practice, frequency of experiencing dry skin, and smoking habits were all uniformly reported between the participants.

Sixty-six percent of swimmers reported swimming for 10 or more years, 28.5% reported swimming for 6 to 10 years, and 4.7% 1 to 5 years. All of the swimmers and divers attended practice 5 or more times per week. Practice times varied; 85.7% of swimmers practise for 1 to 2 hours daily and 14.3% practise for 4 or more hours per day. All of the participants reported experiencing dry skin from the chlorine. Thirty-eight percent of the respondents reported getting their teeth cleaned within the last 2 to 3 months, 23.8% reported a cleaning within 6 or more months, 14.3% had their teeth cleaned 4 to 5 months ago or over 1 year ago, and 9.5% of swimmers had their teeth cleaned within the past month. Fifty-two percent of swimmers noticed or have been told that their teeth are stained. Of extrinsic stain retentive factors, 76% reported drinking coloured beverages, 4.8% brush only once a week, and none of the respondents reported any smoking habits. Lastly, 76% of the participants were not aware of the swimmer's mouth phenomenon (Table 1).

DISCUSSION

The purpose of this study was to assess dental stain on collegiate swimmers and divers and the effects of preventive dental strategies on these stains. Results showed that all 16 female swimmers and 5 divers from the University of New Mexico swimming and diving team had staining mirroring what has been reported

as the swimmer's mouth phenomenon.²⁻¹⁴ Interestingly, the presence of stain was not influenced by how often the swimmer received professional prophylaxis; most swimmers answered that they had their teeth cleaned just 2 to 3 months prior to the study. In addition, the majority of the swimmers answered that they brushed their teeth 2 to 3 times a day. Unfortunately, these factors did not help the swimmers remove or prevent the staining completely; therefore, different oral hygiene or other regimens may need to be established to facilitate the complete removal, and preferably, prevention of stain. This finding is similar to those of previous studies done on swimmer's mouth.²⁻¹⁴ In addition to stain, other studies found negative effects such as erosion and calculus formation.^{3,5-7,9-11,13,14} Different colours of stain are indicative of absorption of various chemical structures, making staining an initial indicator of, or precursor to, the possibility of diseases such as this phenomenon.¹⁸

The pool area, in general, is a further determining factor as to what the swimmers' and divers' mouths reveal. Specifically, if any of the railings or lane lines are corroded then tooth structure could be subject to the same outcome. In general, if the chlorine content is too high, then hair will begin to change colour and the skin will burn or itch. When swimmers notice these issues, then overchlorinating the pool could be an obvious factor and teeth may become stained more easily. Pool maintenance is a possible confounding factor to consider when researching this condition.

The pH level of swimming pools is important to monitor for 2 reasons. First, the germ-killing power of chlorine varies with the pH level of the pool. As pH goes up, the ability of chlorine to kill germs goes down. Second, a swimmer's body has a pH between 7.2 and 7.8, so if the pool water is not kept in this range then swimmers will start to feel irritation in their eyes and on their skin. The pH of the saliva can vary over the range of about 5.8 to 7.6, depending on the flow rate. Whole saliva at a very low flow rate may have a pH as low as 5.8, while stimulated saliva may have a pH as high as 7.6 or slightly higher.¹² At this university, pool maintenance employees report keeping the pH of the pool between 7.2 and 7.6, and they report checking these statistics every 4 hours. Maintaining the pH in this range will balance chlorine's germ-killing power while minimizing skin and eye irritation. A pH of below 7.0 and above 8.0 can harm the swimmers and their bodies. Therefore, careful specificity is very important in pool maintenance.¹⁰

Pool maintenance logs were reviewed during this study, and the lifeguards reported that the pH of the Olympic Pool is checked every 4 hours. The staff follows the State Standards of Pool Maintenance, which require that the Olympic Pool temperature be kept between 79 degrees and 81 degrees Fahrenheit, that the pH be maintained between 7.2 and 7.8, that the free available chlorine stay between 1 ppm and 10

Table 1. Summary values for questionnaire by swimmer status, with p value associations

Questionnaire results	All (N = 21)		Diver (n = 5)		Swimmer (n = 16)		Fisher's exact test (p value)
	n	%	n	%	n	%	
1. How long have you been swimming competitively?							
1 to 5 years	1	4.8	1	20.0	0	0.0	
6 to 10 years	6	28.6	3	60.0	3	18.8	0.03
10+ years	14	66.7	1	20.0	13	81.3	
2. How frequently does your swim team practise?							
5 or more times per week	21	100.0	5	100.0	16	100.0	-
3. How long does your typical practice last?							
1 to 2 hours	18	85.7	5	100.0	13	81.3	0.55
4 or more hours	3	14.3	0	0.0	3	18.8	
4. What is the frequency that you have experienced dry skin from the chlorine?							
Frequently (weekly)	21	100.0	5	100.0	16	100.0	-
5. When was the last time you had your teeth cleaned?							
Within 1 month	2	9.5	0	0.0	2	12.5	
2 to 3 months ago	8	38.1	3	60.0	5	31.3	
4 to 5 months ago	3	14.3	1	20.0	2	12.5	0.54
6 months or longer	5	23.8	0	0.0	5	31.3	
Over 1 year ago	3	14.3	1	20.0	2	12.5	
6. How frequently do you get your teeth professionally cleaned by a dental hygienist?							
Every 6 months	12	57.1	4	80.0	8	50.0	
Once a year	5	23.8	1	20.0	4	25.0	0.65
Once every 2 to 3 years	4	19.0	0	0.0	4	25.0	
7. Has your dental hygienist (or you) ever noticed that your teeth are stained?							
Yes	11	52.4	1	20.0	10	62.5	0.15
No	10	47.6	4	80.0	6	37.5	
8. Do you drink coloured beverages (tea, coffee)?							
Yes	16	76.2	5	100.0	11	68.8	0.28
No	5	23.8	0	0.0	5	31.3	
9. Do you smoke daily?							
No	21	100.0	5	100.0	16	100.0	-
10. How often do you brush your teeth?							
2 to 3 times per day	18	85.7	4	80.0	14	87.5	
Once a day	2	9.5	1	20.0	1	6.3	0.58
Once a week	1	4.8	0	0.0	1	6.3	
11. Are you aware of swimmer's mouth?							
Yes	5	23.8	0	0.0	5	31.3	0.28
No	16	76.2	5	100.0	11	68.8	

Table 2. Comparison of stain and thickness of stain among swimmers and divers

	All (N = 21)		Diver (n = 5)		Swimmer (n = 16)		p value
	n	%	n	%	n	%	
Lobene Stain Index intensity							0.32
0 (none)	0	0.0	0	0.0	0	0.0	
1 (faint)	8	38.1	2	40.0	6	37.5	
2 (clearly visible orange to brown colouration)	12	57.1	2	40.0	10	62.5	
3 (dark and usually deep brown to black)	1	4.8	1	20.0	0	0.0	
Lobene Stain Index thickness							0.81
0 (none)	0	0.0	0	0.0	0	0.0	
1 (thin)	8	38.1	3	60.0	5	31.2	
2 (moderate to thick)	8	38.1	1	20.0	7	43.8	
3 (entire area)	5	23.8	1	20.0	4	25.0	

ppm, that the combined chlorine remain <0.4 ppm, and the alkalinity be kept between 60 ppm and 180 ppm.

Despite the strict maintenance of the Olympic Pool, all swimmers reported the repercussions of extended chlorine exposure. While hair and skin are the most noticeably affected, awareness of the harm that chlorine exposure can produce on the oral cavity was the aim of this study. Awareness of swimmer's mouth will help the local population, and eventually, increase global awareness of the harm chlorine can have not only on the body, but also on the oral cavity.

This study adds to the body of knowledge by bringing awareness to one particular facet of swimmer's mouth: staining. Staining, in and of itself, is a precursor to the swimmer's mouth phenomenon. Because minimal research has focused on this phenomenon, there is a need for further studies to facilitate understanding of and possible interventions to alleviate this condition.

The field of dental hygiene is at a pivotal point in history; research drives the profession to new levels. Studies, such as this one, help eliminate avoidable occurrences such as swimmer's mouth as well as promote oral health. Swimming pools are not only used for competitive swimming, but also for recreation and exercise. All members of society will need to be aware of the harmful effects that chlorine can have upon the oral cavity. Awareness will lead to better treatment options and, hopefully, swimmer's stain may become a condition of the past.

Limitations

The limitations of this study include extraneous variables associated with individual oral hygiene. Frequency of professional dental cleanings as well as how long each swimmer and diver have been practising over the years were analysed by examining the amount of stain on each swimmer. The extraneous variable was then controlled

Table 3. Comparison of stain and thickness of stain by duration of exposure

	All (N = 21)		<10 years (n = 7)		≥10 years (n = 14)		p value
	n	%	n	%	n	%	
Lobene Stain Index intensity							0.76
0 (none)	0	0.0	0	0.0	0	0.0	
1 (faint)	8	38.1	2	28.6	6	42.9	
2 (clearly visible orange to brown colouration)	12	57.1	5	71.4	7	58.3	
3 (dark and usually deep brown to black)	1	4.8	0	0.0	1	7.1	
Lobene Stain Index thickness							0.19
0 (none)	0	0.0	0	0.0	0	0.0	
1 (thin)	8	38.1	3	42.9	5	35.7	
2 (moderate to thick)	8	38.1	4	57.1	4	28.6	
3 (entire area)	5	23.8	0	0.0	5	35.7	

by simply asking how frequently each swimmer, or diver, receives professional dental cleanings. Ideally, a control group of non-swimmers should have been established to further analyse staining factors. If this route is explored in future studies, then assessors should also be blinded to the swimming status of the subjects. Another confounding factor could be the inclusion of only female participants; future research should include both genders as the male swimmer and diver population could possibly yield different results. The sample size of this population was small, therefore yielding insufficient evidence to determine a statistical correlation to the population as a whole. This study has shown inference rather than significance. Different pools could also yield different results as all pools and jurisdictions follow different standard protocols.

When conducting future studies, it will be important to obtain a larger representative sample of swimmers, both male and female. It would be worthwhile to investigate the potential value of educational seminars for both swimmers and pool maintenance employees. Discussion of the harmful effects of swimmer's mouth at these seminars would raise awareness of this condition and ultimately establish prevention strategies. Studies conducted on a larger scale, taking into account different genders and swimming frequencies could help supply correlational data. Fully understanding the causes of swimmer's mouth and how to prevent it effectively will

only come with more research.

The use of fluoride on teeth before entering the swimming pool environment could prove beneficial in shielding the teeth from damage.¹³ For further research, it is important to note consistent and appropriate recall appointments as well as fluoride treatments at every visit, regardless of age. Analysing whether stain is a function of time or exposure would also be beneficial, as it may allow for the discovery of correlations between how quickly stain develops after regular swimming. If swimmer's mouth is not recognized by dentists and dental hygienists, then it will ultimately result in neglect.¹⁹ Appropriate treatments need to be enforced to ensure that clients are receiving the best care possible.

CONCLUSION

The information gathered from the surveys and screening of the swimmers and divers suggests that dental stain can result from competitive swimming and diving and that traditional preventive dental strategies such as regular dental prophylaxis and recall appointments do not prevent staining in competitive swimmers.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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