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Chlorine Stain and the Oral Cavity

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THESIS

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ABSTRACT

Swimming is known worldwide as one of the healthiest, low-impact forms of exercise and for the subsequent promotion of a strong body, heart, and mind. However, many swimmers and non-swimmers do not realize that swimming in a pool can have a negative effect on the oral cavity. Several studies have suggested that pool chlorination is responsible for dental erosion, calculus formation, and stain in competitive and recreational swimmers, and this phenomenon is known as 'swimmer's mouth.' A pilot experimental research study was conducted that evaluated the prevalence of chlorine stain in the oral cavity of twenty-one female swimmers from the University of New Mexico Swimming and Diving Team.

Participants received a consent form, questionnaire, and basic oral screening to evaluate for staining. Utilizing the entire team, data revealed that all twenty-one individuals had staining as a result of 'swimmer's mouth.' The purpose of this pilot study was to assess this condition and determine if daily brushing and professional

cleanings prevent the harmful effects of chlorine on the oral cavity. Interestingly, the presence of stain was not influenced by how often the individual received professional cleanings. Also, the majority of the participants answered that they brushed their teeth two to three times a day. Unfortunately, these factors did not help the removal of stain completely; therefore, additional oral hygiene regimens need to be established to facilitate the complete removal of stain. With the results from this pilot study, further analysis can ultimately take place to solidify data concerning 'swimmer's mouth.'

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Chapter I

Introduction

Swimming is known worldwide as one of the healthiest, low-impact forms of exercise and for the subsequent promotion of a strong body, heart, and mind. However, many swimmers and non-swimmers do not realize that swimming in a pool can have a negative effect on the oral cavity. Several studies have suggested that pool chlorination is responsible for dental erosion, calculus formation, and stain in competitive and recreational swimmers, and this phenomenon is known as 'swimmer's mouth.' This study will focus specifically on the aspect of stain in the oral cavity.

Statement of the Problem

- Does pool chlorination negatively affect the oral cavity by causing dental stain in competitive swimmers and divers?
- Does increased exposure time to properly chlorinated swimming pool water increase the chance of developing stain?

Significance of the Problem

Dental hygienists question swimmers as to whether or not they drink beverages that cause stain and/or use tobacco products due to the presence of black stain on the teeth. Ultimately these individuals presented with 'swimmer's mouth.' The longer the teeth are exposed to chlorinated water, the more likely individuals are to develop 'swimmer's mouth.' Chlorine can deposit residue on the teeth, turning them yellow,

brown, or black after constant exposure.[28] This study is important for the profession of dental hygiene because as increased instances occur involving the "mystery" of a swimmer's mouth, dental providers will become more aware and knowledgeable about providing the appropriate treatment. In addition, competitive swimmers and noncompetitive swimmers alike are unaware about the harmful effects of chlorine on the oral cavity.

Several articles and cases of 'swimmer's mouth' are available on the internet. These articles discuss methods of rinsing the mouth out after swimming and the importance of keeping up with regular teeth cleanings in order to control staining, minimize calculus formation, and avoid erosion. They also provide great tips on how to breathe properly during swim practice. This information is readily available to the public, however most dentists or dental hygienists do not know the signs of 'swimmer's mouth.' There have been previous studies involving 'swimmer's mouth,' however not enough information exists today because it is still not widely recognized. To provide the best possible treatment for patients, dental hygienists need to be knowledgeable on a wide variety of conditions. Studying 'swimmer's mouth' should advance the knowledge and ultimately lead to more effective treatment for all patients.

Research is important to the dental hygiene profession because it expands the knowledge and treatment options for the patients. Without research, dental hygiene would never branch out and discover newer and better methods of treatment. Therefore, researching the elusive effects of pool chlorination on the oral cavity will help expand the knowledge base of the dental hygiene profession, and ultimately provide better treatment

for patients with ‘swimmer’s mouth.’ Helping the swimming community overcome harmful effects on the oral cavity can only lead to happier, healthier individuals.

Operational Definitions

- **Water Chlorination** is the process of adding chlorine (Cl_2) or hypochlorite to water. This method is used to kill certain bacteria and other microbes in tap water, as chlorine is highly toxic. In particular, chlorination is used to prevent the spread of waterborne diseases. $Cl_2 + H_2O \leftrightarrow HOCl + HCl$ represents chlorine gas + water ↔ hypochlorus acid + hydrochloric acid.
- **pH Scale** measures how acidic or basic a substance is. It ranges from 0 to 14. A pH of 7 is neutral. A pH less than 7 is acidic, and a pH greater than 7 is basic.
- **Salivary Flow Rate**: Unstimulated saliva normally flows at a rate of 0.3 ml per minute and a flow rate of less than 0.1 ml per minute is considered dry; stimulated saliva normally flows at a rate of 1–2 ml per minute and a flow rate of less than 0.7 ml per minute is considered reduced.
- **Acid Erosion**, also known as **Dental Erosion**, is a type of tooth wear. It is defined as the irreversible loss of tooth structure due to chemical dissolution by acids not of bacterial origin. Dental erosion is the most common chronic disease of children ages 5–17. There is generally widespread ignorance of the damaging effects of acid erosion; this is particularly the case with erosion due to fruit juices, because they are seen as healthy. Erosion is found initially in the enamel and, if unchecked, may proceed to the underlying dentin.

- **Extrinsic Dental Staining**: Extrinsic stains occur on the outside surfaces of teeth. Tooth structures are porous and can absorb the color from the foods and drinks that the individual consumes. In fact, coffee, soda, wine, blueberries, blackberries, tea, tomato sauce, and balsamic vinaigrette are some of the top tooth-stainers. Additionally, plaque deposits can attach to the enamel and begin to yellow the teeth. Smoke inhalation and the tannins in tobacco can also stain the tooth surfaces. Proper brushing and flossing can help remove and lessen extrinsic stains. For a more dramatic option, bleaching trays can also be used.
- **Barodontalgia**: A phenomenon characterized by dental pain caused by a change in ambient pressure. Also known as 'tooth squeeze' or 'aerodontalgia.'

Chapter II

Review of the Literature

Introduction

For this literature review, personal habits and environmental factors of swimmers and their pools will be discussed. Emphasis will be placed on how or if the swimmers maintain regular recall appointments with their local dentist. For most patients, the American Dental Hygienists' Association recommends a six-month recall in order to keep up with staining, plaque, and calculus debridement.[27] Areas of discussion include how prone each individual swimmer is to plaque and calculus buildup, and how quickly stain and negative effects return to the oral cavity after a prophylaxis.

Components of Tooth Color

An understanding of the elements of tooth color is a very crucial aspect of dentistry. Color can be described using the terms of hue, value and chroma. Hue is the term used to enable one to distinguish between different color groups. Value is the relative lightness or darkness of a color. Chroma is the degree of color saturation and describes the intensity of a color as it changes.

Teeth are characteristically composed of many different color gradients, from the cervical third all the way to the incisal edge of the tooth. Typically, the cervical third has a darker appearance to it because of how close the dentin is to the white enamel. Younger individuals usually have lighter teeth, that appear whiter, especially children with primary teeth. As the body grows older the teeth become darker, often due to

secondary dentine, extrinsic stains, and enamel wear. Gingival recession and tooth wear (such as abrasion, bruxism, and abfractions) can directly and indirectly affect tooth color as well. It is often found that the canine teeth are darker than the central and lateral incisors, and this is because the dentin is thicker on these teeth.

However, the viewing conditions are particularly essential; variables such as the light source, time of day, surrounding conditions, and the angle the tooth is viewed from affect the appearance of tooth color. Light is composed of differing wavelengths and the same tooth viewed under different conditions will exhibit a different color. This occurrence is known as metamerism. Even natural sunlight can vary in its color; at noon the sky appears blue with minimal atmosphere to penetrate, whereas in the early morning and late evening, sunlight has a red-orange tint.[24]

Barodontalgia

Another relative term associated with this study is barodontalgia. This phenomenon is characterized by dental pain. Barodontalgia occurs when the teeth are exposed to a pressure gradient, such as that experienced by underwater divers or air travelers. In this case, we are focusing on the underwater divers. Oftentimes during swim practice the swimmers are required to dive to the bottom of the deep end to perform breathing exercises and pick up weights. This form of dental pain is generally marked by a predisposing oral pathology such as acute or chronic periapical infection, caries, deep or failing restorations, residual dental cysts, sinusitis or a history of recent surgery. There are studies that indicate the severity of barodontalgia and the resulting deterioration of dental health can correlate with the duration of

barometric stress.[23] Restorative materials are also commonly affected by pressure gradients. Ultimately, the key to avoiding barodontalgia is good oral health. Clinicians must pay close attention to areas of dentin exposure, caries, fractured cusps, the integrity of restorations and periapical pathology in those at risk.[23]

Disease Etiology

It takes just one day for bacteria to build up enough to make the mouth susceptible to disease.[1] The severity of this depends on the individual swimmer. Appropriate oral hygiene habits need to be assessed. This includes proper brushing, flossing, and mouthwash techniques. After eating a meal or snack, the bacteria release acids that break down the enamel surfaces of teeth, especially above and below the gingival line and interdentally. Repeated acid attacks increasingly erode the enamel, eventually causing tooth decay and stain. Antimicrobials found in pool water have a much higher pH than our saliva, which causes the proteins to break down and cause discolored deposits to form.

When plaque accumulates beneath the gingival margin, the associated buildup of bacteria and tartar can cause irritation and inflammation of the gingival tissue and can lead to the development of gingivitis and periodontal disease. Irritated and inflamed gingiva typically appears red, or erythematous, and can bleed. Continued plaque accumulation can contribute to structural damage of the teeth and the bone supporting the teeth and gingiva, as well as other health complications.[4]

The Effect of Time in the Pool

How often swimmers practice in a week is also important. Depending on the swim team, practices can range from one to two practices a day, up to five or six days out of the week. The average exposure time gives an idea as to how much chlorinated water is entering the oral cavity. As in most cases, not every mouth is the same; therefore, each swimmer will present with a different case. Exploring the environmental factors would help provide correlations between staining, daily oral habits, and the time spent practicing in the water. With each of the factors graphed, correlations can be drawn to support that each and every one of these factors influences the other.[29] The severity of conditions studied will also vary between each swimmer and their specific habits.

An article from the Academy of General Dentistry states the following regarding this phenomenon: "Athlete swimmers, who often swim laps more than six hours a week, expose their teeth to large amounts of chemically treated water. Pool water contains chemical additives like antimicrobials, which give the water a higher pH than saliva, causing salivary proteins to break down quickly and form organic deposits on swimmer's teeth. The result is swimmer's calculus or stain; hard, brown tartar deposits that appear predominantly on the front teeth."[7]

For further reading on dental erosion and swimming pools, the CDC's Morbidity and Mortality Weekly Report from July 22, 1983 explored the concept of 'swimmer's mouth.' One interesting statistic that they mentioned was that only 15% of frequent, or daily, swimmers displayed enamel erosion while only 3% of infrequent or non-swimmers experienced enamel erosion.[8] For a more current perspective, this is

assuming that within the past 30 years, swimming pools are much more careful about testing the pH of the water to ensure that it is not too acidic. However, it can still occur due to “inadequate maintenance” as the Centers for Disease Control article states.

The figure below explores the salivary flow rates before and after training. The flow rates were taken one hour before and one hour after training. This reveals the difference in composition of the mouth after exposure to chlorine.[9]

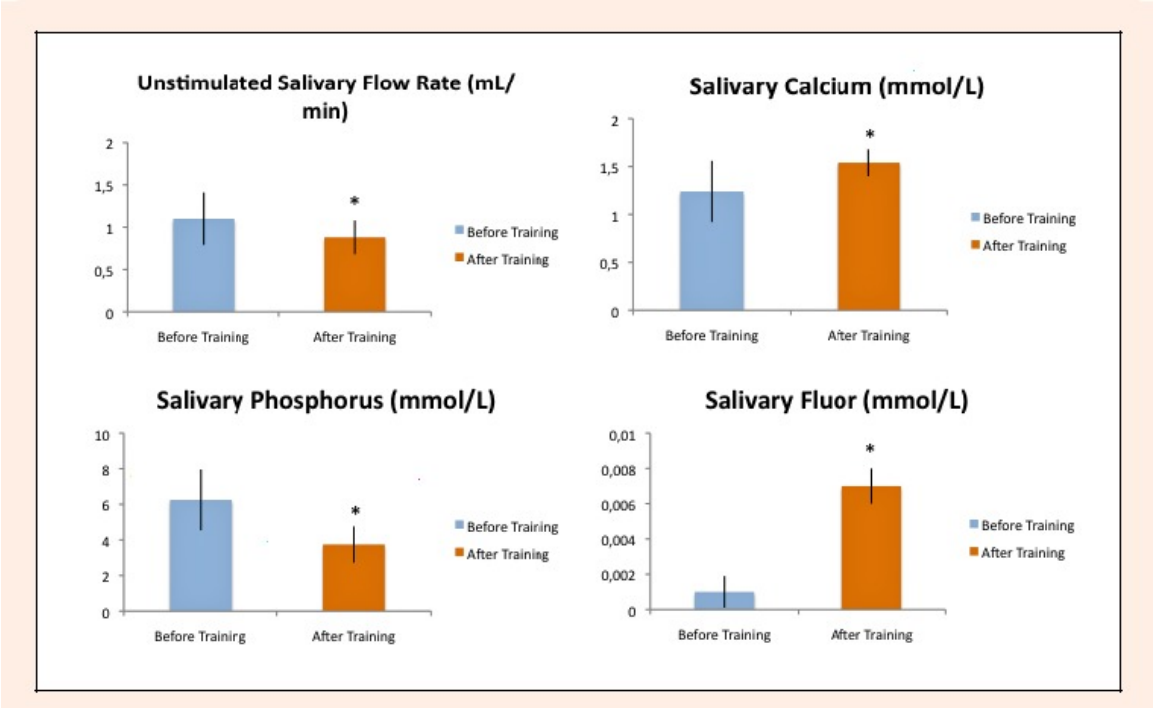


Figure 1: Salivary Flow Rates Before and After Training

Figure 1: Salivary Flow Rates Before and After Training[9]

Breathing During Swimming

Developing a system of changing personal swimming habits to make the individual aware of opening their mouth during swim practice can prove beneficial. This can include providing suggestions for rinsing the oral cavity after each practice,

specifically a solution to neutralize the acidity in the mouth. Furthermore, it would be recommended to fluoridate the teeth of swimmers regularly to prevent dental erosion. Brushing the teeth right after swimming can be harmful because at this time the surface of the teeth is softened by the acidic chlorine and could be more easily brushed away.[2] Therefore simply rinsing with water, baking soda, or ACT mouthwash (which has a high fluoride content) immediately after practice is the solution to help return the mouth to a neutral pH, decreasing the risk of acid erosion. Maintaining regular cleanings will also reduce the presence of stain on the teeth. These solutions are ideal for swimmers who practice daily.

Enamel Erosion

Tooth structure starts to demineralize at a pH below 5. Specifically, caries develop on cementum starting at a pH of 6.0 to 6.5, and on enamel at a pH of 5.5 to 5.0.[30] If a swimming pool is kept at the optimal pH of 7.4, tooth structure will not demineralize. However, if the pH of the swimming pool becomes neglected and therefore acidic, then swimming pools can start dissolving tooth structures. This is usually seen in gas-chlorinated pool systems. When swimming pools are gas-chlorinated, hypochlorous acid is formed. Normally swimming pools counteract this acid with a strong base, such as ash. If the swimming pool does not get enough base to counter the acid from the chlorine, then it can become acidic and start to dissolve the teeth of those who swim regularly.[2]

One case report tells a story of a competitive swimmer who swam in a gas-chlorinated swimming pool and experienced notable dental erosion within 27 days.[2] The high incidence indicates that dental erosion, due to frequent swimming, is of

considerable diagnostic and therapeutic significance.[2] The Eastman Dental Center (EDC) directly mentions that swimming pools can be a cause of tooth erosion, as seen with diet and other factors. The EDC states that, "swimming pools with a low pH due to inadequate maintenance have been implicated in dental erosion."[3]

Chlorination of Pool Water

Education for pool employees to increase awareness of the harmful effects of over-chlorinating the pools is a necessity. Pool employees should monitor the chemistry of the water more carefully to keep everything within the normal ranges. The Health Department recommends keeping the chlorine concentrations between 1.0 and 3.0 ppm. Chlorine kills germs in pools, but it takes time to work. Therefore, it is important to make sure that the chlorine concentrations are always at the appropriate levels. When in a public pool, it is important to take notice of pool linings, railings and ladders. When the water in the pool is too acidic, it will erode these surfaces. If there are areas of erosion and stain on such pool surfaces, the water could ultimately do the same thing to tooth structures.

The pH level of every swimming pool is important to monitor for two 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. At the local University of New Mexico Johnson Pool Center, they report maintaining the pH of the pool between 7.2 and 7.6, and they report checking these statistics every four hours. Keeping 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.[5]

The optimum pH level in a pool is 7.2 to 7.8, which is considered basic. In general, solids dissolve in acid and precipitate in bases. This means that in a basic swimming pool, the calcium and minerals present in the mouth will harden onto the teeth rather than dissolve (as they would if the pH were acidic – this is why teeth dissolve slowly when anything acidic is consumed). The higher the pH of the swimming pool, in combination with the antimicrobial compounds that the pool water contains, causes proteins in the mouth to break down and mesh together with the minerals in the mouth to form a hard, yellowish-brown mineral deposit on the teeth.[3]

Recommendations to Combat 'Swimmer's Mouth'

Fluoridated mouth rinses have repeatedly been used as a caries-preventive intervention in school-based programs, dental offices, and by individuals at home. An update of the Cochrane review of fluoride mouth rinses as a means of preventing dental caries in children and adolescents, first published in 2003, found that regular, supervised use of a fluoride mouth rinse by children and adolescents is associated with a large reduction in caries and stain in permanent teeth. Most of the evidence evaluated the use of fluoride mouth rinse in a supervised school setting, but these findings can be applicable to children in other settings with supervised or unsupervised rinsing. This study stressed that any future research on fluoride mouth rinses should focus on head-to-head comparisons between different fluoride rinse

features or fluoride rinses against other preventive strategies, and should evaluate adverse effects and acceptability.[25]

The use of fluoride on teeth before entering the swimming pool environment could prove beneficial in shielding the teeth from damage. Studies have shown that the use of electric toothbrushes can significantly reduce stain and buildup on teeth. In this study, developed by Stookey and associates at Indiana University Oral Health Research Institute, the in vitro stain removal efficiency of two marketed powered toothbrushes (Crest SpinBrush and Dr. Best Battery), a new prototype (Crest SpinBrush Pro) and two manual toothbrushes (Oral-B Indicator Soft and Oral-B CrossAction) was evaluated using a different brushing technique as a modification of the laboratory testing method. The results of the study show that the new prototype powered toothbrush (Crest SpinBrush Pro) produced statistically significant stain removal efficiency relative to the four other toothbrushes studied. The newly configured brushing machine delivered a robust method for separating statistically significant in vitro differences for the complex cleaning action of powered toothbrushes.[26]

For further research, it is important to note consistent and appropriate recall appointments as well as fluoride treatments at every visit, regardless of age. If 'swimmer's mouth' does not receive recognition from dentists and hygienists from around the world, then it will ultimately cause neglect. Appropriate treatments need to be enforced to ensure that patients are receiving the best care possible.

All in all, if the patient notices that they are getting stained teeth due to swimming, the healthcare provider should recommend more frequent cleanings and

fluoride treatments. If the healthcare provider notices that the patient is losing the enamel on their teeth due to swimming, then a recommendation may be issued to check with the local swimming pool maintenance coordinator to make sure that the pH level of the pool is within normal limits.[4]

Chapter III

Methods and Materials

Research Approaches

For this study, human subjects were utilized. This project used descriptive research and focused on the effects of chlorine stain on the oral cavity, utilizing local swimmers to assess for 'swimmer's mouth.' This study explored stain of female swimmers and divers by promoting surveys at the local University of New Mexico Johnson Pool Facility. Specifically, this research was designed using surveys and analysis of swimmer's mouths. The University of New Mexico Swimming and Diving team consists of twenty-one females, from all around the world, who range from freshman to seniors. The information gathered from the surveys and screening of the swimmers gave insight to how teeth can be stained from swimming in a chlorine environment. With the results from this pilot study, further analysis can ultimately take place to solidify data concerning 'swimmer's mouth.' Studies conducted at 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 effectively prevent it will only come with more research.

Utilizing disposable mouth mirrors and dental loupes with a light, screenings were conducted before practice in the natatorium to determine each swimmer's level of stain, which was based upon the Lobene Stain Index. This index measures the intensity and extent of extrinsic dental stain on the facial surface of the anterior teeth. Each participant signed a consent and then completed a survey before the screenings took place. The surveys included questions such as how frequently the swimmers get their teeth cleaned,

when their last cleaning took place, and if their dental hygienist has ever mentioned staining to them.

The pool area, in general, is a further determining factor as to what the swimmer's and diver's 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 color and the skin will burn or itch. When swimmers notice these issues, then over-chlorinating the pool could be an obvious factor and teeth may become stained even easier. Johnson Pool logs were reviewed to make sure that there are little to no variations in the concentration of chlorine. Pool maintenance plays a huge factor in this research project.

After signing a consent form to perform a limited screening, all members of the swimming and diving team received a survey as well as a basic oral screening utilizing disposable mirrors and dental loupes. A chart with pictures indicating the stages of light to heavy stain provided a universal technique for the screening. This method is called the Lobene Stain Index and it measures the amount of stain by observing the color intensity of the stain and the area that the stain covers the tooth. The screening that was performed did not replace an exam by the dentist and all swimmers were encouraged to maintain regular recalls with their dentist and dental hygienist. Frequency of professional dental cleanings as well as how long each swimmer and diver have been practicing over the years were analyzed by examining the amount of stain on each swimmer. The extraneous variable was then controlled by simply asking how frequently each swimmer, or diver, receives professional dental cleanings. Another extraneous variable could be the gender of all subjects; being only female, another study of the male swimmer population could

yield different results. Therefore, a comparison will be needed to ultimately yield results for a meta-analysis.

After the surveys, consents, and screenings were performed, analysis of the data took place. All factors were included and findings do represent a small part of the Albuquerque district, specifically results linked to the University of New Mexico. With these findings, awareness and treatment options for swimmers will hopefully spread around the nation. The Lobene Stain Index provided a universal mechanism of measuring dental stain. Quantitative variables were summarized by means and standard deviations, and categorical responses were summarized using frequencies and percentages. Graphical summaries were used to display data. Subgroup differences in Lobene Stain Index were assessed using nonparametric Wilcoxon tests. Frequencies of categorical variables were assessed using Fisher exact tests. As this was a pilot study with only a small planned sample size, power analyses was not performed.

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.

Chapter IV

Results

Twenty-one female subjects enrolled in this study. Sixteen participants were swimmers and five participants were divers all from the University of New Mexico Swimming and Diving Team. Descriptive statistics revealed that all twenty-one subjects had stain present. The mean, standard deviation, and median were calculated for all participants (N=21) by using the two measurements: the presence of stain and the thickness of stain. The mean for presence of stain was 1.67 and the mean for thickness of stain was 1.86. The standard deviation of stain was 0.6 and the standard deviation of thickness was 0.8. The median for both was 2, the minimum being 1 and the maximum being 3. A chi-square statistic was performed, and compared the difference between the swimmers and the divers statistics, and those p-values are shown below in Table 1 and Figure 2a and 2b. These numbers reveal that there is no difference between the swimmers and the divers results.

Looking at the results of the questionnaire, it is interesting to note that 100% of the subjects answered questions 2, 4, and 9 uniformly. These questions had to do with frequency of practice, frequency of experiencing dry skin, and smoking habits.

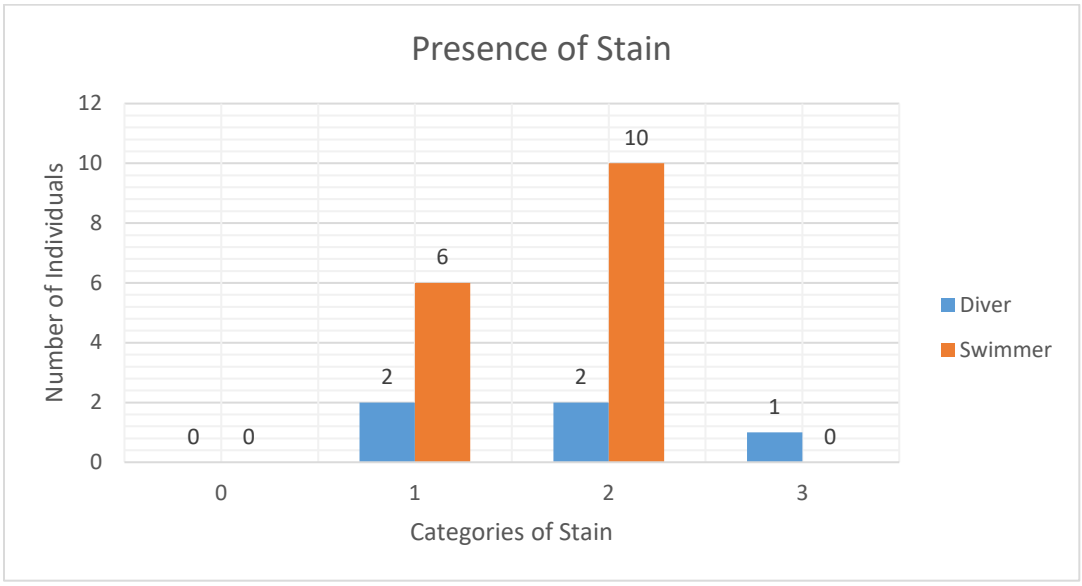
Data are shown in the following tables:

	Stain	Thickness
Mean	1.67	1.86
Standard Deviation	0.6	0.8
Median	2	2
Minimum	1	1
Maximum	3	3
P-Values	0.74	0.41

Table 1: Summary of Data

Table 1: Summary of Data and P-Value Comparison Between Swimmers and Divers

2a.



2b.

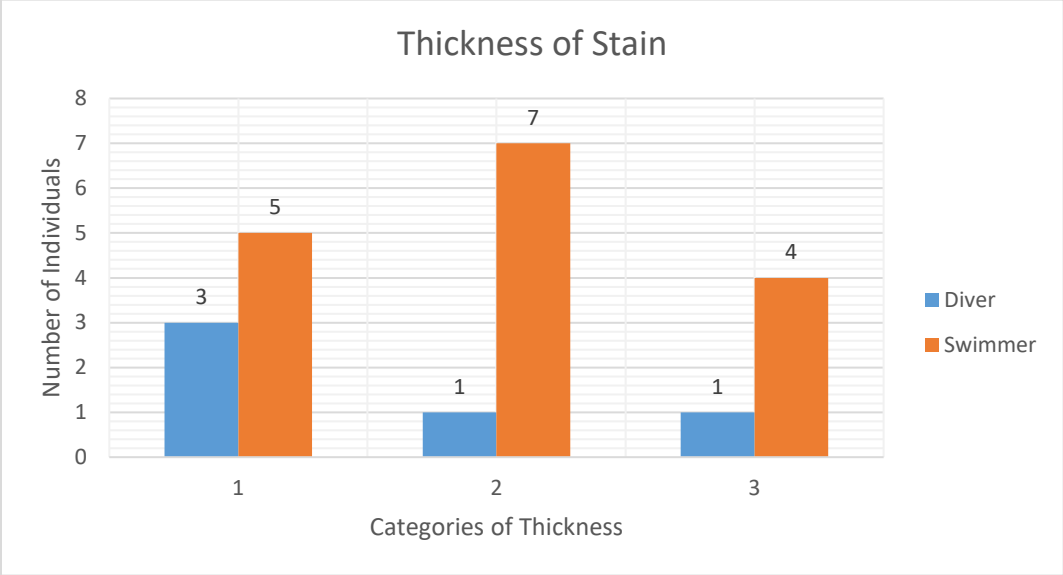


Figure 2a and 2b: Presence of Stain/Thickness of Stain

Figure 2a and 2b: Presence of Stain/Thickness of Stain for Swimmers and Divers

The above figures show the results of the screenings. As per the Lobene Stain Index, thickness is measured in categories of 1, 2, and 3 and presence of stain is measured in categories of 0, 1, 2, and 3. The first category of thickness means that there is a thin line of stain that can be continuous, the second category displays a moderate to thick band of stain, and the third category of the Lobene Stain Index means that there is stain covering the total area. The presence of stain categories in the Lobene Stain Index are measured by 0, meaning no stain present and natural tooth coloration, 1 reveals faint staining, 2 reveals clearly visible stain typically being orange to brown in color, and category 3 reveals dark stain usually deep brown to black in color.

Wilcoxon non-parametric test for stain and thickness:
Null hypothesis is that the median is the same for swimmer = y & n

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Stain Classified by Variable Swimmer					
Swimmer	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
y	16	172.0	176.0	10.555973	10.750
n	5	59.0	55.0	10.555973	11.800
Average scores were used for ties.					

Wilcoxon Two-Sample Test	
Statistic	59.0000
Normal Approximation	
Z	0.3316
One-Sided Pr > Z	0.3701
Two-Sided Pr > |Z|	0.7402
t Approximation	
One-Sided Pr > Z	0.3718
Two-Sided Pr > |Z|	0.7437
Z includes a continuity correction of 0.5.	

Table 2: Wilcoxon Test for Stain

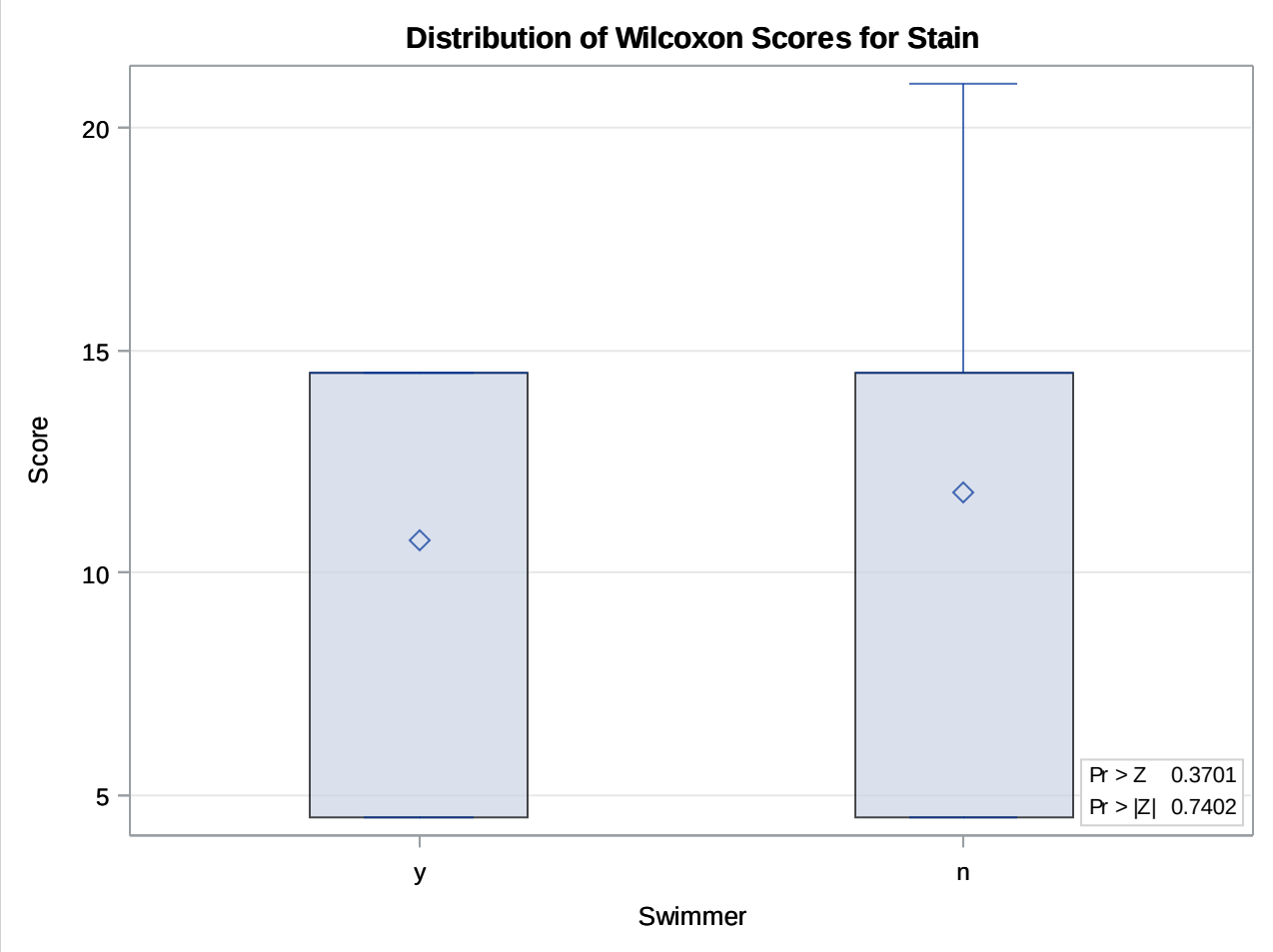


Figure 3: Wilcoxon Stain Scores

Wilcoxon non-parametric tests are equivalent to the dependent t-test. The Wilcoxon signed-rank test is a non-parametric statistical hypothesis test that compares two related samples on a single sample to assess whether their population mean ranks differ. Looking at the above table 2 and figure 3 for presence of stain, P = 0.41 means that medians are not significantly different. P = 0.74 means that there is no difference between the swimmers and divers results.

The tables and graphs below display these results for thickness:

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Thickness Classified by Variable Swimmer					
Swimmer	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
y	16	186.0	176.0	11.347330	11.6250
n	5	45.0	55.0	11.347330	9.0000
Average scores were used for ties.					

Wilcoxon Two-Sample Test	
Statistic	45.0000
Normal Approximation	
Z	-0.8372
One-Sided Pr < Z	0.2012
Two-Sided Pr > |Z|	0.4025
t Approximation	
One-Sided Pr < Z	0.2062
Two-Sided Pr > |Z|	0.4124
Z includes a continuity correction of 0.5.	

Table 3: Wilcoxon Test for Thickness

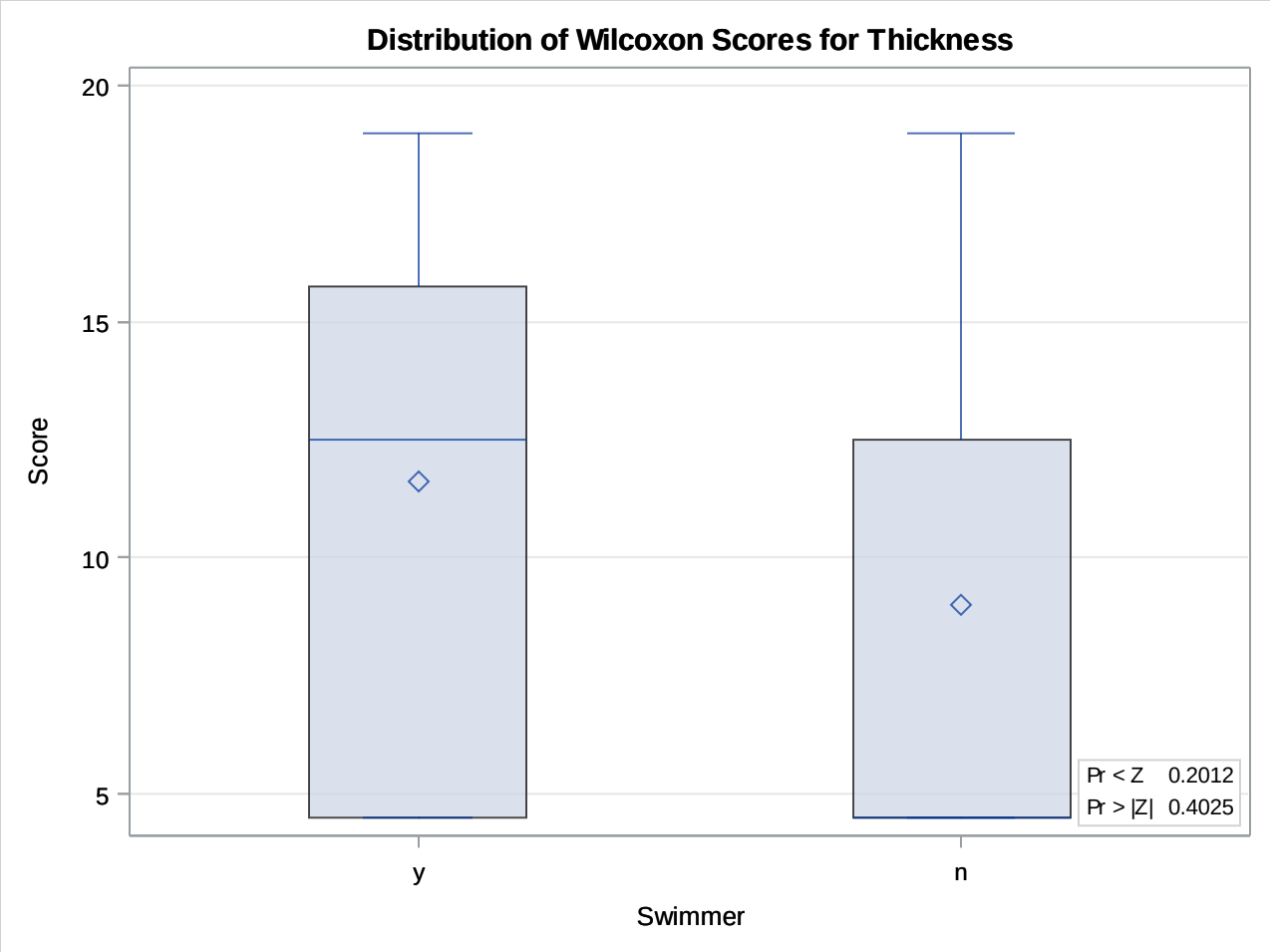


Figure 4: Wilcoxon Thickness Scores

The above data, explained by Wilcoxon tests, reveal that the means are not significantly different. This data is from a small sample, which does affect the results that are shown in these tests.

Below, the questionnaire results are explored:

Questionnaire Results	All		Swimmer			
			n		y	
	N	%	N	%	N	%
1. How long have you been swimming competitively?						
1-5 years	1	4.8	1	20.0	0	0
6-10 years	6	28.6	3	60.0	3	18.8
10+ years	14	66.7	1	20.0	13	81.3
2. How frequently does your swim team practice?						

Questionnaire Results	All		Swimmer			
			n		y	
	N	%	N	%	N	%
5 or more times per week	21	100.0	5	100.0	16	100.0
3. How long does your typical practice last?						
1-2 hours	18	85.7	5	100.0	13	81.3
4 or more hours	3	14.3	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	2	12.5
2-3 months ago	8	38.1	3	60.0	5	31.3
4-5 months ago	3	14.3	1	20.0	2	12.5
6 months or longer	5	23.8	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
Once every 2-3 years	4	19.0	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
No	10	47.6	4	80.0	6	37.5
8. Do you drink colored beverages (tea, coffee)?						
Yes	16	76.2	5	100.0	11	68.8
No	5	23.8	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?						
2-3 times per day	18	85.7	4	80.0	14	87.5
Once a day	2	9.5	1	20.0	1	6.3
Once a week	1	4.8	0	0	1	6.3
11. Are you aware of 'swimmer's mouth?'						
Yes	5	23.8	0	0	5	31.3
No	16	76.2	5	100.0	11	68.8

Table 4: Questionnaire Results

Summary Values for Questions 1-11: Overall and by Swimmer Status

Seen above, table 4 breaks down the answers and related percentages. Answers are further broken down comparing the results of the swimmers' and the divers' responses.

	N	Mean	Std	Median	Min	Max
Stain	21	1.7	0.6	2.0	1.0	3.0
Thickness	21	1.9	0.8	2.0	1.0	3.0

	Swimmer											
	n						y					
	N	Mean	Std	Median	Min	Max	N	Mean	Std	Median	Min	Max
Stain	5	1.8	0.8	2.0	1.0	3.0	16	1.6	0.5	2.0	1.0	2.0
Thickness	5	1.6	0.9	1.0	1.0	3.0	16	1.9	0.8	2.0	1.0	3.0

Table 5: Summary Values for Stain and Thickness

Summary Values for Stain and Thickness: Overall and by Swimmer Status

The above data explore the mean, median, minimum, maximum, and standard deviation of the staining results. Specifically, looking at each question, the following can be deduced:

For question 1, 66.7% of swimmers have been swimming for 10 or more years, 28.5% have been swimming for 6-10 years, and 4.7% have been swimming for 1-5 years. It is important to note that 80% of the swimmers answered that they have been swimming for 10 or more years while only 20% of the divers noted this answer. Using a Fisher's Exact Test, the following is shown:

Fisher's Exact Test	
Table Probability (P)	0.0138
Pr <= P	0.0251

Table 6: Question 1 P-Values

For question 2, 100% of the swimmers and divers practice 5 or more times a week. Moving forward, for question 3 it is shown that 85.7% of swimmers practice for

1-2 hours and 14.3% practice for 4 or more hours, as shown below:

Fisher's Exact Test	
Cell (1,1) Frequency (F)	5
Left-sided Pr <= F	1.0000
Right-sided Pr >= F	0.4211
Table Probability (P)	0.4211
Two-sided Pr <= P	0.5489
Not significant	

Table 7: Question 3 P-Values

Question 4 revealed that 100% of swimmers and divers experience dry skin from the chlorine. For question 5, 38.1% of swimmers had their teeth cleaned 2-3 months ago, 23.8% had their teeth cleaned 6 months ago or longer, 14.3% had their teeth cleaned 4-5 months ago or over 1 year ago, and 9.5% of swimmers had their teeth cleaned within the past month. This is displayed below:

Fisher's Exact Test	
Table Probability (P)	0.0248
Pr <= P	0.5371
Not significant	

Table 8: Question 5 P-Values

Question 6 revealed that 57.1% of swimmers get their teeth cleaned every 6 months, 23.8% get their teeth cleaned once a year, and 19.0% of swimmers get their teeth cleaned once every 2-3 years:

Fisher's Exact Test	
Table Probability (P)	0.1216
Pr <= P	0.6540
Not significant	

Table 9: Question 6 P-Values

Question 7 disclosed that 52.4% of swimmers notice, or have been told, that their teeth are stained, while 47.6% of swimmers do not notice that they have stained teeth:

Fisher's Exact Test	
Cell (1,1) Frequency (F)	1
Left-sided Pr <= F	0.1259
Right-sided Pr >= F	0.9876
Table Probability (P)	0.1135
Two-sided Pr <= P	0.1486
Not significant	

Table 10: Question 7 P-Values

Question 8 displayed that 76.2% of swimmers drink colored beverages while 23.8% of swimmers do not:

Fisher's Exact Test	
Cell (1,1) Frequency (F)	5
Left-sided Pr <= F	1.0000
Right-sided Pr >= F	0.2147
Table Probability (P)	0.2147
Two-sided Pr <= P	0.2776
Not significant	

Table 11: Question 8 P-Values

Question 9 revealed that 100% of swimmers do not have any smoking habits. Question 10 discovered that 85.7% of swimmers brush their teeth 2-3 times a day, 9.5% brush once a day, and 4.8% brush only once a week:

Fisher's Exact Test	
Table Probability (P)	0.3008
Pr <= P	0.5789
Not significant	

Table 12: Question 10 P-Values

Last, but not least, question 11 revealed that 76.2% of swimmers are not aware of 'swimmer's mouth' and 23.8% of swimmers are aware:

Fisher's Exact Test	
Cell (1,1) Frequency (F)	0
Left-sided Pr <= F	0.2147

Fisher's Exact Test	
Right-sided Pr >= F	1.0000
Table Probability (P)	0.2147
Two-sided Pr <= P	0.2776
Not significant	

Table 13: Question 11 P-Values

The above tables show that P < 0.05 means that the distribution of categories are not the same for swimmers and divers. If the p-value is less than 0.05 then the null hypothesis is rejected in favor of the experimental hypothesis, which means that there is less than a 5% chance that the results were obtained by random chance or error.

Next, the exposure time for swimmers and divers is explored:

	Q1											
	<10yr						10+yr					
	N	Mean	Std	Median	Min	Max	N	Mean	Std	Median	Min	Max
Stain	7	1.7	0.5	2.0	1.0	2.0	14	1.6	0.6	2.0	1.0	3.0
Thickness	7	1.6	0.5	2.0	1.0	2.0	14	2.0	0.9	2.0	1.0	3.0

Table 14: Stain and Thickness Values by Years of Pool Exposure

Summary Values for Stain and Thickness by Years of Pool Exposure

Table 15 below shows the Wilcoxon non-parametric test for stain and thickness. The null hypothesis is that the median is the same for levels of pool exposure.

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Stain Classified by Variable Q1					
Q1	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
10+yr	14	149.50	154.0	11.683321	10.678571
<10yr	7	81.50	77.0	11.683321	11.642857
Average scores were used for ties.					

Wilcoxon Two-Sample Test	
Statistic	81.5000
Normal Approximation	
Z	0.3424
One-Sided Pr > Z	0.3660
Two-Sided Pr > |Z|	0.7321
t Approximation	
One-Sided Pr > Z	0.3678
Two-Sided Pr > |Z|	0.7356
Z includes a continuity correction of 0.5.	

Kruskal-Wallis Test	
Chi-Square	0.1484
DF	1
Pr > Chi-Square	0.7001

Table 15: Wilcoxon Stain Values by Years of Exposure

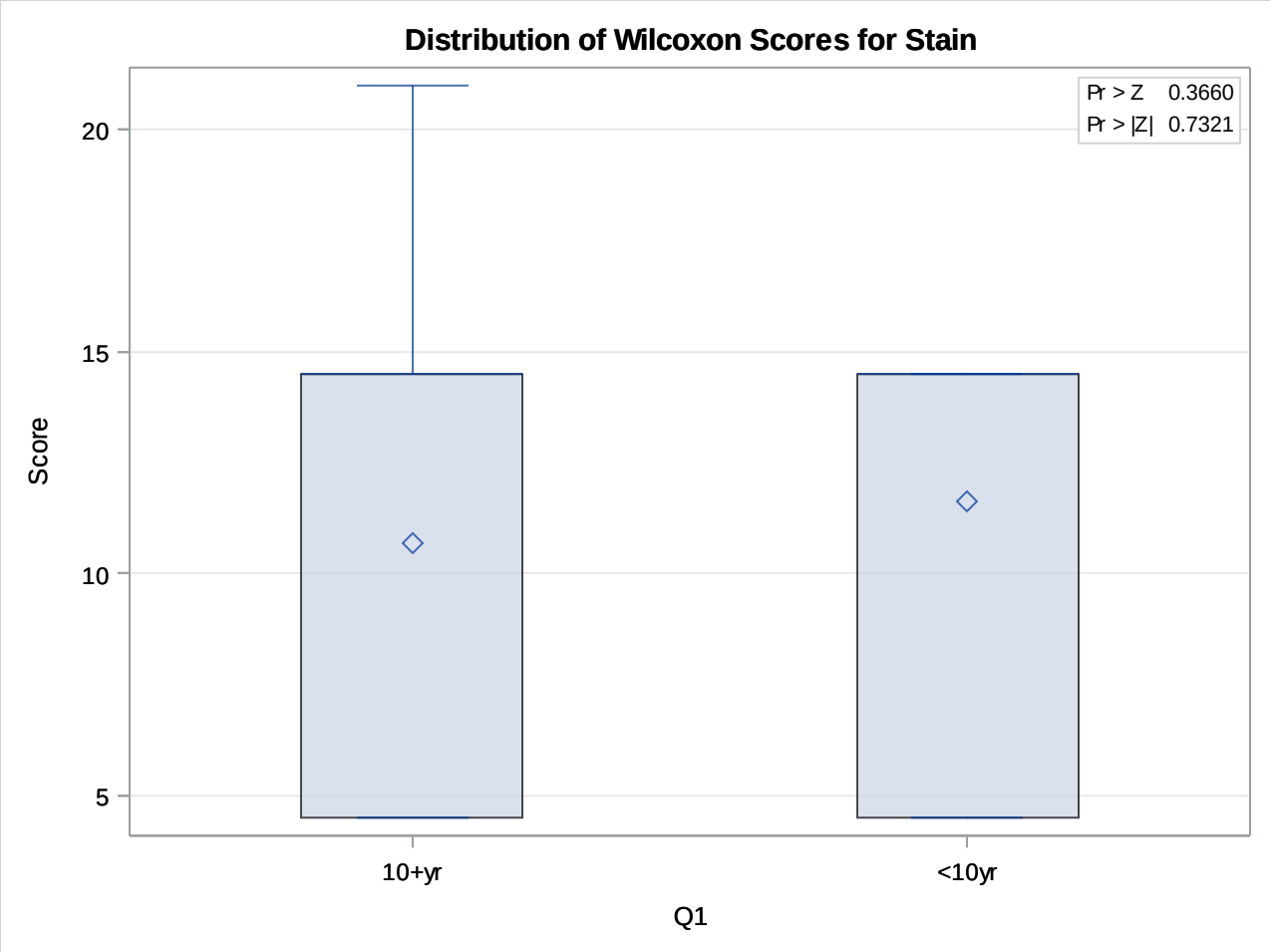


Figure 5: Wilcoxon Stain Scores by Years of Exposure

The above graphs and tables explore the stain as related to years of pool exposure.

Below, thickness results are explored as related to years of pool exposure:

The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable Thickness Classified by Variable Q1					
Q1	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
10+yr	14	167.50	154.0	12.559193	11.964286
<10yr	7	63.50	77.0	12.559193	9.071429
Average scores were used for ties.					

Wilcoxon Two-Sample Test	
Statistic	63.5000
Normal Approximation	
Z	-1.0351
One-Sided Pr < Z	0.1503
Two-Sided Pr > |Z|	0.3006
t Approximation	
One-Sided Pr < Z	0.1565
Two-Sided Pr > |Z|	0.3130
Z includes a continuity correction of 0.5.	

Kruskal-Wallis Test	
Chi-Square	1.1554
DF	1
Pr > Chi-Square	0.2824

Table 16: Wilcoxon Thickness Values by Years of Exposure

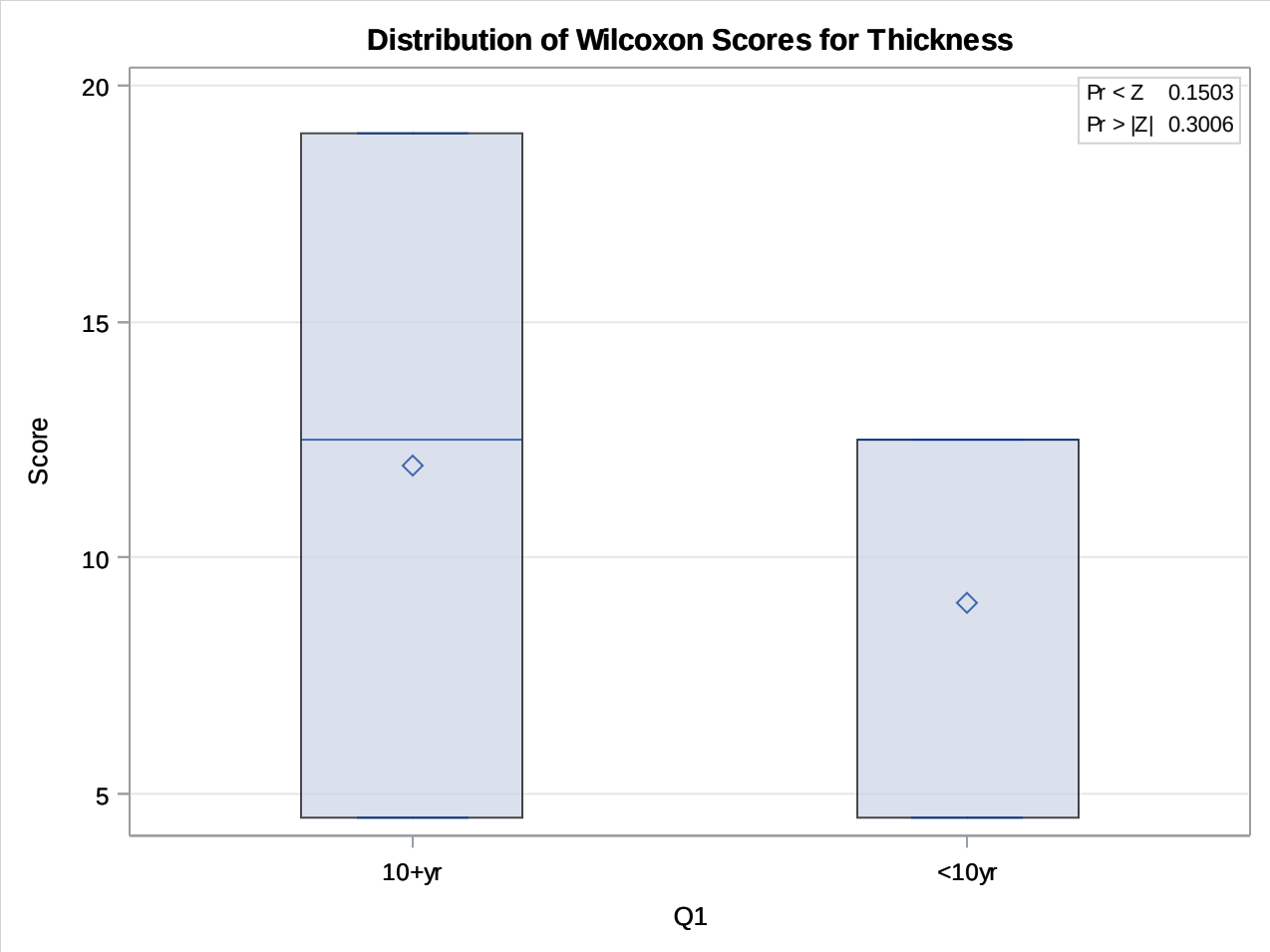


Figure 6: Wilcoxon Scores for Thickness by Years of Exposure

The above comparison of stain and thickness, as related to years of exposure to a chlorine environment, show that there is no difference between the results of the swimmers and divers who swam more than ten years and those who have been swimming for less than ten years.

Discussion of Results

Principle Findings

The purpose of this study was to determine if pool chlorination negatively affects the oral cavity by causing dental stain in competitive swimmers and divers, as well as to evaluate if increased exposure time to properly chlorinated swimming pool water increases the individuals chance of developing stain. Utilizing all sixteen female swimmers and five divers from the University of New Mexico Swimming and Diving Team, it was shown that all twenty-one individuals had staining as a result of 'swimmer's mouth.' Interestingly, the presence of stain was not influenced by how often the swimmer received professional cleanings; most swimmers answered that they had their teeth cleaned just two to three months ago. Also, the majority of the swimmers answered that they brushed their teeth two to three times a day. Unfortunately these factors did not help the swimmers remove the staining completely; therefore, different oral hygiene regimens need to be established to facilitate in the complete prevention of stain.

Every single swimmer answered that they have felt dry skin as a result of chlorine exposure. Also relevant is that one swimmer commented that she puts Vaseline on her eyebrows before every practice to protect her hair from falling out. This individual also commented that the majority of the team had lost almost all of their arm hair, as well as eyebrows, as a result of chlorine exposure.

Pool maintenance logs were reviewed during this study, and the lifeguards reported that the pH of the Olympic Pool is checked every four hours. The staff follows the State Standards of Pool Maintenance as follows: Olympic Pool temperature is kept between 79-81 degrees Fahrenheit, the pH is maintained between 7.2-7.8, the free

available chlorine stays between 1-10 ppm, the combined chlorine remains < 0.4 ppm, and the alkalinity is kept between 60-180 ppm.

	State Standard	Thomas' Standard
Olympic Pool Flow	> 1844 gpm	> 20000 gpm
Olympic Pool Temp	79-81 °F	80 °F
Olympic Pool pH	7.2-7.8	7.4-7.6
Olympic Pool ORR/HRR	n/a	770-780
Olympic Pool Free Available Cl	1-10 ppm	3-5 ppm
Olympic Pool Combine Cl	< 0.4 ppm	< 0.2 ppm
Olympic Pool Alkalinity	60-180 ppm	90-110 ppm
Olympic Pool Calcium	< 1000 ppm	270-350 ppm
Olympic Pool Filter Differential	< 15	< 15

Table 17: Olympic Pool Standards

Table 17: Olympic Pool Standards

Despite the strict maintenance of the Olympic Pool, all swimmers felt the repercussions of extended chlorine exposure. While hair and skin are the most noticeably impacted, awareness of the harm that it can produce on the oral cavity is what this study is trying to assess. Awareness of 'swimmer's mouth' will help the local population, and eventually, the rest of the world understand what harm chlorine can produce not only on the body, but on the oral cavity as well.

Limitations

The limitations present in this study included extraneous variables associated with individual oral hygiene. Attempts were made to control this by asking how frequently each swimmer receives professional dental cleanings. Other limitations include the single gender of all subjects. Assessment of the male swimmer and diver population

could possibly yield different results. The sample size of this population was small, therefore yielding not enough 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; every state has a standard protocol that is followed, so results could vary from state to state.

Recommendations for Future Studies

When conducting future studies, it will be important to study a larger population of swimmers, both male and female, to support results found in this pilot study. Educational seminars could prove beneficial for both swimmers and pool maintenance employees. Discussion of the harmful effects of 'swimmer's mouth' will provide awareness of this condition and therefore prevention strategies.

Analyzing what stain is a function of, time vs. exposure, to discover correlational strategies between how quickly stain develops after regular swimming will also be beneficial in furthering this research. The National Center for Biotechnology Information did a study on 'swimmer's mouth' and found that notable dental erosion was seen in a competitive swimmer who swam in a gas-chlorinated swimming pool within only twenty-seven days. This ultimately shows that this is a relevant subject that requires more research to thoroughly understand the signs and symptoms of 'swimmer's mouth.'

Conclusion

This study yielded significant results of the effects of chlorine on the oral cavity. Staining was found on all subjects, despite the efficient maintenance of the Olympic

Pool. All subjects represent a small part of the Albuquerque district, specifically linked to the University of New Mexico. With these findings, awareness and treatment options for swimmers and divers will hopefully spread nationally. 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 healthy individuals in communities around the world.

Chapter V

Article for Submission

Title Page

CHLORINE STAIN AND THE ORAL CAVITY

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Abstract

Swimming is known worldwide as one of the healthiest, low-impact forms of exercise and for the subsequent promotion of a strong body, heart, and mind. However, many swimmers and non-swimmers do not realize that swimming in a pool can have a negative effect on the oral cavity. Several studies have suggested that pool chlorination is responsible for dental erosion, calculus formation, and stain in competitive and recreational swimmers, and this phenomenon is known as 'swimmer's mouth.' A pilot experimental research study was conducted that evaluated the prevalence of chlorine stain in the oral cavity of twenty-one female swimmers from the University of New Mexico Swimming and Diving Team.

Participants received a consent form, questionnaire, and basic oral screening to evaluate for staining. Utilizing the entire team, data revealed that all twenty-one individuals had staining as a result of 'swimmer's mouth.' The purpose of this pilot study was to assess this condition and determine if daily brushing and professional cleanings prevent the harmful effects of chlorine on the oral cavity. Interestingly, the presence of stain was not influenced by how often the individual received professional cleanings. Also, the majority of the participants answered that they brushed their teeth two to three times a day. Unfortunately, these factors did not help the removal of stain completely; therefore, additional oral hygiene regimens need to be established to facilitate the complete removal of stain. With the results from this pilot study, further analysis can ultimately take place to solidify data concerning 'swimmer's mouth.'

Clinical Relevance

Scientific Rationale For The Study

Researching the elusive effects of pool chlorination on the oral cavity will help expand the knowledge base of the dental hygiene profession, and ultimately provide better treatment for patients with ‘swimmer’s mouth.’

Principal Findings

Utilizing all sixteen swimmers and five divers from the University of New Mexico Swimming and Diving Team, it was revealed that all twenty-one females had staining as a result of ‘swimmer’s mouth.’

Practical Implications

This study is important for the profession of dental hygiene because as increased instances occur involving the “mystery” of a swimmer’s mouth, dental providers will become more aware and knowledgeable about providing the appropriate treatment.

Introduction

The purpose of this study was to determine if pool chlorination negatively affects the oral cavity by causing dental stain in competitive swimmers and divers, as well as to evaluate if increased exposure time to properly chlorinated swimming pool water increases the individuals chance of developing stain. For this study, personal habits and environmental factors of swimmers and their pools will be discussed. Specifically, how or if the swimmers maintain regular recall appointments with their local dentist. Areas of discussion include how prone each individual swimmer is to plaque and calculus buildup, and how quickly stain and negative effects return to the oral cavity after a prophylaxis.

Antimicrobials found in pool water have a much higher pH than our saliva, which causes the proteins to break down and cause discolored deposits to form. An article from the Academy of General Dentistry states the following regarding this phenomenon: "Athlete swimmers, who often swim laps more than six hours a week, expose their teeth to large amounts of chemically treated water. Pool water contains chemical additives like antimicrobials, which give the water a higher pH than saliva, causing salivary proteins to break down quickly and form organic deposits on swimmer's teeth. The result is swimmer's calculus or stain; hard, brown tartar deposits that appear predominantly on the front teeth."[7]

The use of fluoride on teeth before entering the swimming pool environment could prove beneficial in shielding the teeth from damage. For further research, it is important to note consistent and appropriate recall appointments as well as fluoride treatments at every visit, regardless of age. If 'swimmer's mouth' does not receive recognition from dentists and hygienists from around the world, then it will ultimately cause neglect.

Appropriate treatments need to be enforced to ensure that patients are receiving the best care possible.

Study Population and Methodology

For this study, human subjects were utilized. This project used descriptive research and focused on the effects of chlorine stain on the oral cavity, utilizing local swimmers to assess for 'swimmer's mouth.' This study explored stain of female swimmers and divers by promoting surveys at the local University of New Mexico Johnson Pool Facility. Specifically, this research was designed using surveys and analysis of swimmer's mouths. The University of New Mexico Swimming and Diving team consists of twenty-one females, from all around the world, who range from freshman to seniors. The information gathered from the surveys and screening of the swimmers gave insight to how teeth can be stained from swimming in a chlorine environment. With the results from this pilot study, further analysis can ultimately take place to solidify data concerning 'swimmer's mouth.' Studies conducted at 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 effectively prevent it will only come with more research.

Utilizing disposable mouth mirrors and dental loupes with a light, screenings were conducted before practice in the natatorium to determine each swimmer's level of stain, which was based upon the Lobene Stain Index. This index measures the intensity and extent of extrinsic dental stain on the facial surface of the anterior teeth. Each participant signed a consent and then completed a survey before the screenings took place. The surveys included questions such as how frequently the swimmers get their teeth cleaned, when their last cleaning took place, and if their dental hygienist has ever mentioned staining to them.

The pool area, in general, is a further determining factor as to what the swimmer's and diver's 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 color and the skin will burn or itch. When swimmers notice these issues, then over-chlorinating the pool could be an obvious factor and teeth may become stained even easier. Johnson Pool logs were reviewed to make sure that there are little to no variations in the concentration of chlorine. Pool maintenance plays a huge factor in this research project.

After signing a consent form to perform a limited screening, all members of the swimming and diving team received a survey as well as a basic oral screening utilizing disposable mirrors and dental loupes. A chart with pictures indicating the stages of light to heavy stain provided a universal technique for the screening. This method is called the Lobene Stain Index and it measures the amount of stain by observing the color intensity of the stain and the area that the stain covers the tooth. The screening that was performed did not replace an exam by the dentist and all swimmers were encouraged to maintain regular recalls with their dentist and dental hygienist. Frequency of professional dental cleanings as well as how long each swimmer and diver have been practicing over the years were analyzed by examining the amount of stain on each swimmer. The extraneous variable was then controlled by simply asking how frequently each swimmer, or diver, receives professional dental cleanings. Another extraneous variable could be the gender of all subjects; being only female, another study of the male swimmer population could yield different results. Therefore, a comparison will be needed to ultimately yield results for a meta-analysis.

After the surveys, consents, and screenings were performed, analysis of the data took place. All factors were included and findings do represent a small part of the Albuquerque district, specifically results linked to the University of New Mexico. With these findings, awareness and treatment options for swimmers will hopefully spread around the nation. The Lobene Stain Index provided a universal mechanism of measuring dental stain. Quantitative variables were summarized by means and standard deviations, and categorical responses were summarized using frequencies and percentages. Graphical summaries were used to display data. Subgroup differences in Lobene Stain Index were assessed using nonparametric Wilcoxon tests. Frequencies of categorical variables were assessed using Fisher exact tests. As this was a pilot study with only a small planned sample size, power analyses was not performed.

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.

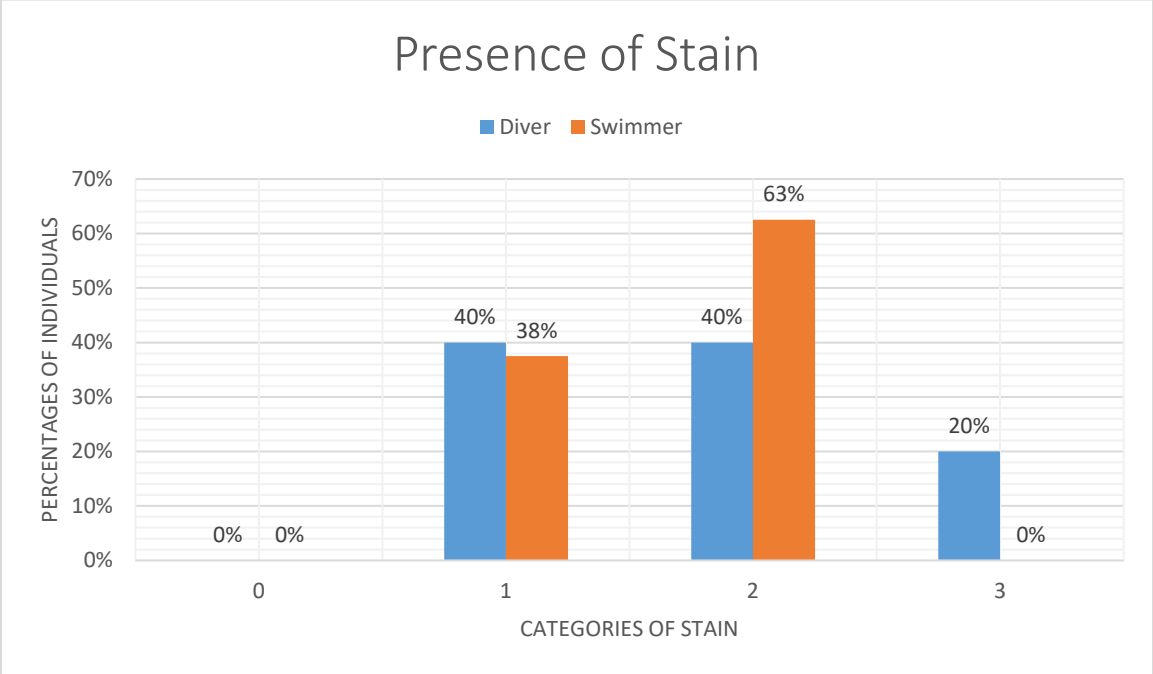
Results

Twenty-one female subjects enrolled in this study. Sixteen participants were swimmers and five participants were divers all from the University of New Mexico Swimming and Diving Team. Descriptive statistics revealed that all twenty-one subjects had stain present. The mean, standard deviation, and median was calculated for all participants (N=21) by using the two measurements: the presence of stain and the thickness of stain. The mean for presence of stain was 1.67 and the mean for thickness of stain was 1.86. The standard deviation of stain was 0.6 and the standard deviation of thickness was 0.8. The median for both was 2, the minimum being 1 and the maximum being 3. A chi-square statistic was performed, and compared the difference between the swimmers and the divers statistics, and those p-values come out to 0.74 for stain and 0.41 for thickness. These numbers mean that there is no difference between the swimmers and the divers results.

Looking at the results of the questionnaire, it is interesting to note that 100% of the subjects answered questions 2, 4, and 9 uniformly. These questions had to do with frequency of practice, frequency of experiencing dry skin, and smoking habits.

Data are shown in the following figures and tables:

1a.



1b.

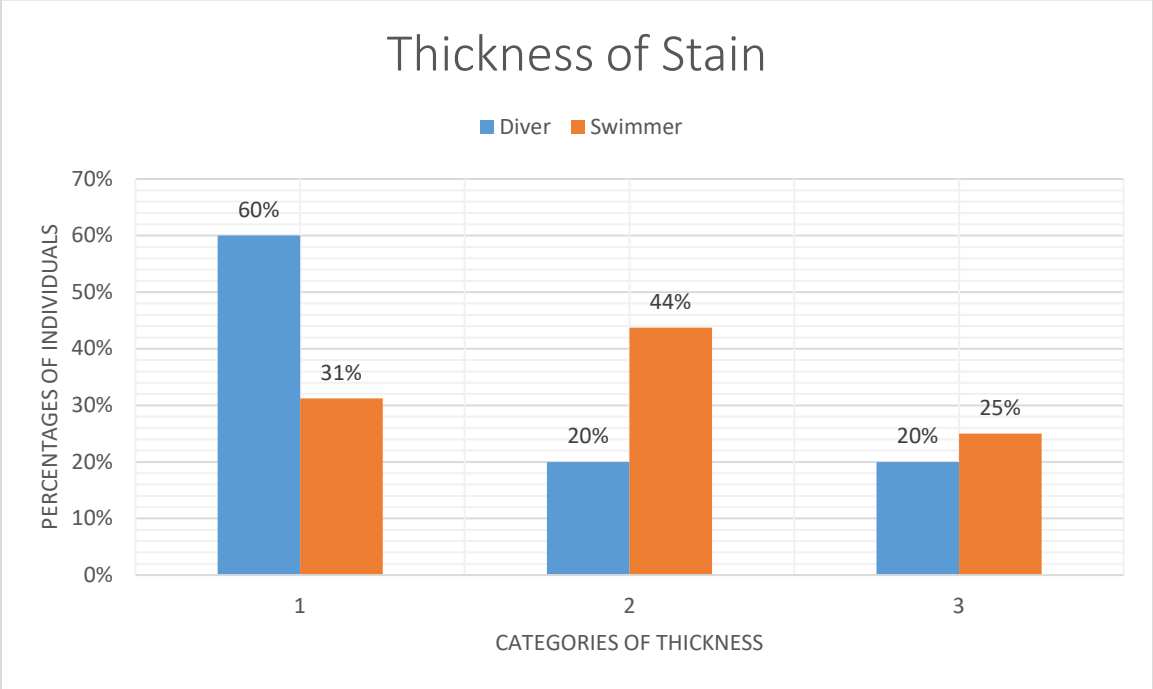


Figure 7a and 1b: Presence of Stain and Thickness of Stain for Swimmers and Divers

The above figures show the results of the screenings. As per the Lobene Stain

Index, thickness is measured in categories of 1, 2, and 3 and presence of stain is measured in categories of 0, 1, 2, and 3. The first category of thickness means that there is a thin line of stain that can be continuous, the second category displays a moderate to thick band of stain, and the third category of the Lobene Stain Index means that there is stain covering the total area. The presence of stain categories in the Lobene Stain Index are measured by 0, meaning no stain present and natural tooth coloration, 1 reveals faint staining, 2 reveals clearly visible stain typically being orange to brown in color, and category 3 reveals dark stain usually deep brown to black in color.

Wilcoxon non-parametric tests are equivalent to the dependent t-test. The Wilcoxon signed-rank test is a non-parametric statistical hypothesis test that compares two related samples on a single sample to assess whether their population mean ranks differ. Looking at the below figure for presence of stain, $P > 0.05$ means that medians are not significantly different. $P = 0.74$ means that there is no difference between the swimmers and divers results.

The graphs below display these results for stain and thickness from the Lobene Stain Index:

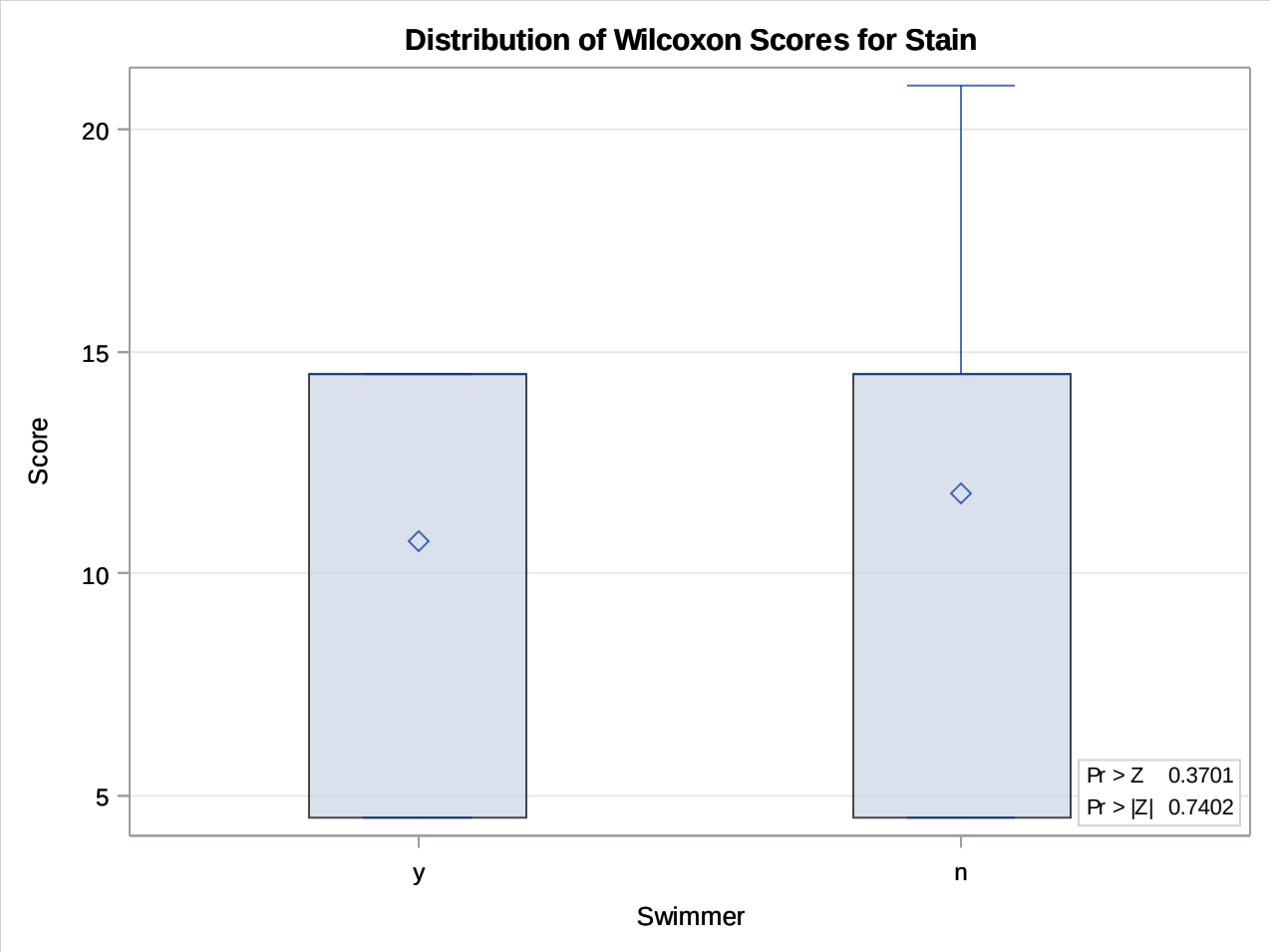


Figure 8: Wilcoxon Stain Scores

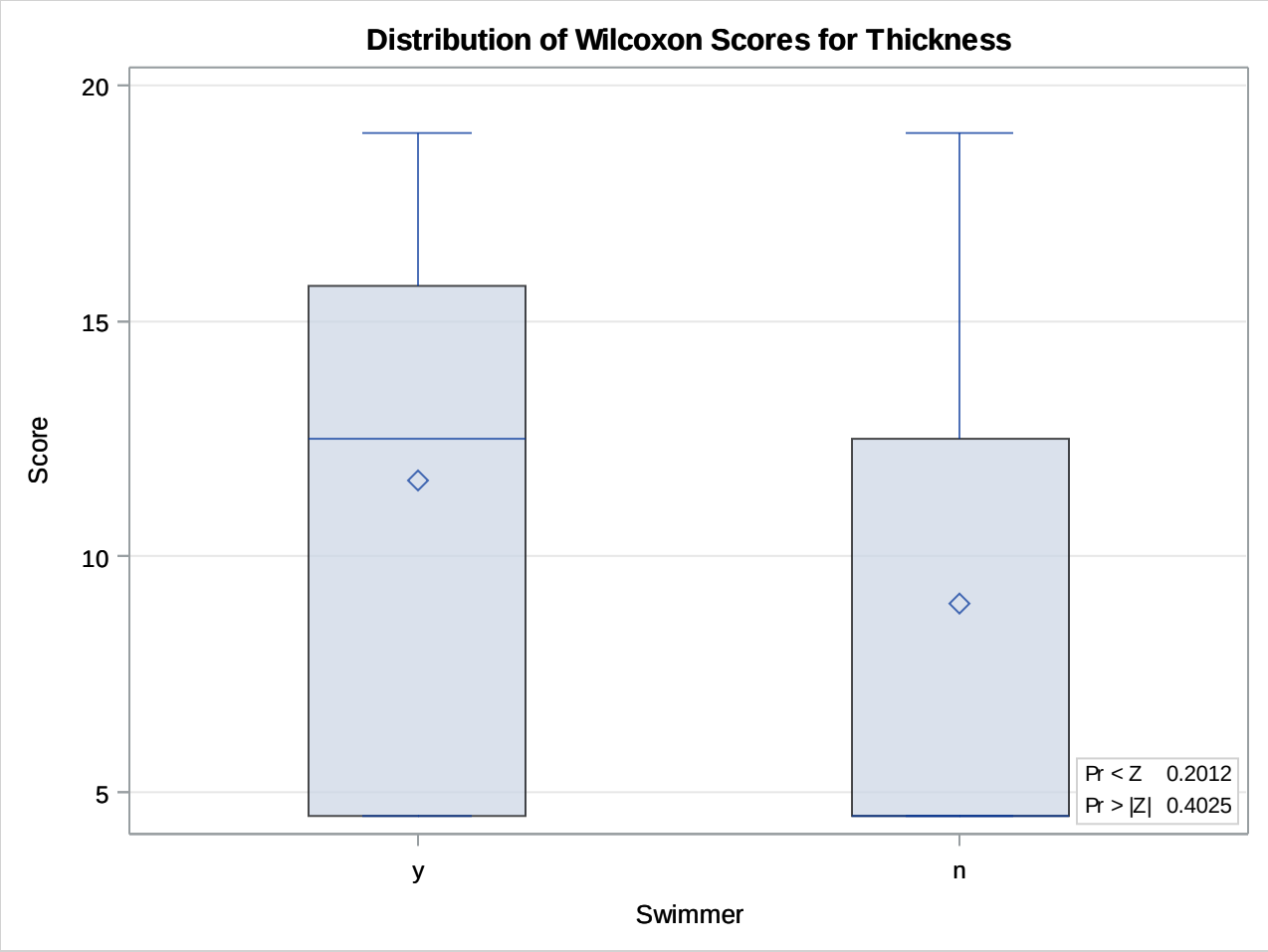


Figure 9: Wilcoxon Thickness Scores

The above data, explained by Wilcoxon tests, reveal that the means are not significantly different; when comparing the swimmers and the divers results, there is no difference. This data is from a small sample, which does affect the results that are shown in these tests.

Below, the questionnaire results are explored:

Questionnaire Results	All		Diver		Swimmer		Fischer's Exact Test
	N	%	N	%	N	%	
1. How long have you been swimming competitively?							0.0251*
1-5 years	1	4.8	1	20.0	0	0.0	
6-10 years	6	28.6	3	60.0	3	18.8	

Questionnaire Results	All		Diver		Swimmer		Fischer's Exact Test
	N	%	N	%	N	%	
10+ years	14	66.7	1	20.0	13	81.3	
2. How frequently does your swim team practice?							-
5 or more times per week	21	100.0	5	100.0	16	100.0	
3. How long does your typical practice last?							0.5489
1-2 hours	18	85.7	5	100.0	13	81.3	
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?							0.5371
Within 1 month	2	9.5	0	0.0	2	12.5	
2-3 months ago	8	38.1	3	60.0	5	31.3	
4-5 months ago	3	14.3	1	20.0	2	12.5	
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?							0.6540
Every 6 months	12	57.1	4	80.0	8	50.0	
Once a year	5	23.8	1	20.0	4	25.0	
Once every 2-3 years	4	19.0	0	0.0	4	25.0	
7. Has your dental hygienist (or you) ever noticed that your teeth are stained?							0.1486
Yes	11	52.4	1	20.0	10	62.5	
No	10	47.6	4	80.0	6	37.5	
8. Do you drink colored beverages (tea, coffee)?							0.2776
Yes	16	76.2	5	100.0	11	68.8	
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?							0.5789
2-3 times per day	18	85.7	4	80.0	14	87.5	
Once a day	2	9.5	1	20.0	1	6.3	
Once a week	1	4.8	0	0.0	1	6.3	
11. Are you aware of 'swimmer's mouth?'							0.2776
Yes	5	23.8	0	0.0	5	31.3	
No	16	76.2	5	100.0	11	68.8	

Questionnaire Results	All		Diver		Swimmer		Fischer's Exact Test
	N	%	N	%	N	%	
*QUESTION 1: NULL HYPOTHESIS IS REJECTED							

Table 18: Summary Values for Questionnaire by Swimmer Status with P-Value Associations

Seen above, table 1 breaks down the answers and related percentages. Answers are further broken down, in table 2, comparing the results of the swimmers' and the divers' responses.

	N	Mean	Std	Median	Min	Max
Stain	21	1.7	0.6	2.0	1.0	3.0
Thickness	21	1.9	0.8	2.0	1.0	3.0

	Swimmer											
	n						y					
	N	Mean	Std	Median	Min	Max	N	Mean	Std	Median	Min	Max
Stain	5	1.8	0.8	2.0	1.0	3.0	16	1.6	0.5	2.0	1.0	2.0
Thickness	5	1.6	0.9	1.0	1.0	3.0	16	1.9	0.8	2.0	1.0	3.0

Table 19: Summary Values for Stain and Thickness: Overall and by Swimmer Status

The above data explore the mean, median, minimum, maximum, and standard deviation of the staining results. Specifically, looking at each question, the following can be deduced:

For question 1, 66.7% of swimmers have been swimming for 10+ years, 28.5% have been swimming for 6-10 years, and 4.7% have been swimming for 1-5 years. It is important to note that 81% of the swimmers answered that they have been swimming for 10+ years while only 20% of the divers noted this answer. For question 2, 100% of the swimmers and divers practice 5 or more times a week. Moving forward, for question 3 it is shown that 85.7% of swimmers practice for 1-2 hours and 14.3% practice for 4 or more hours. Question 4 revealed that 100% of swimmers and divers experience dry skin from

the chlorine. For question 5, 38.1% of swimmers had their teeth cleaned 2-3 months ago, 23.8% had their teeth cleaned 6 months ago or longer, 14.3% had their teeth cleaned 4-5 months ago or over 1 year ago, and 9.5% of swimmers had their teeth cleaned within the past month. Question 6 revealed that 57.1% of swimmers get their teeth cleaned every 6 months, 23.8% get their teeth cleaned once a year, and 19.0% of swimmers get their teeth cleaned once every 2-3 years. Question 7 disclosed that 52.4% of swimmers notice or have been told, that their teeth are stained, while 47.6% of swimmers do not notice that they have stained teeth. Question 8 displayed that 76.2% of swimmers drink colored beverages while 23.8% of swimmers do not. Question 9 revealed that 100% of swimmers do not have any smoking habits. Question 10 discovered that 85.7% of swimmers brush their teeth 2-3 times a day, 9.5% brush once a day, and 4.8% brush only once a week. Last, but not least, question 11 revealed that 76.2% of swimmers are not aware of 'swimmer's mouth' and 23.8% of swimmers are aware.

As shown in Table 1, question 1 reveals that $P < 0.05$, which means that the distribution of categories are not the same for swimmers and divers. If the p-value is less than 0.05 then the null hypothesis is rejected in favor of the experimental hypothesis, which means that there's less than a 5% chance that the results were obtained by random chance or error. Technically speaking, the null hypothesis is not rejected, there is simply not enough evidence to see a difference between the swimmers and the divers. However, for the rest of the questions, $P > 0.05$ therefore the null hypothesis is accepted. The null hypothesis states that there is no difference between the swimmer's and diver's results.

Next, the exposure time for swimmers and divers is explored:

	Q1											
	<10yr						10+yr					
	N	Mean	Std	Median	Min	Max	N	Mean	Std	Median	Min	Max
Stain	7	1.7	0.5	2.0	1.0	2.0	14	1.6	0.6	2.0	1.0	3.0
Thickness	7	1.6	0.5	2.0	1.0	2.0	14	2.0	0.9	2.0	1.0	3.0

Table 20: Summary Values for Stain and Thickness by Years of Pool Exposure

Figure 4 below shows the Wilcoxon non-parametric test for stain and thickness. The null hypothesis is that the median is the same for levels of pool exposure.

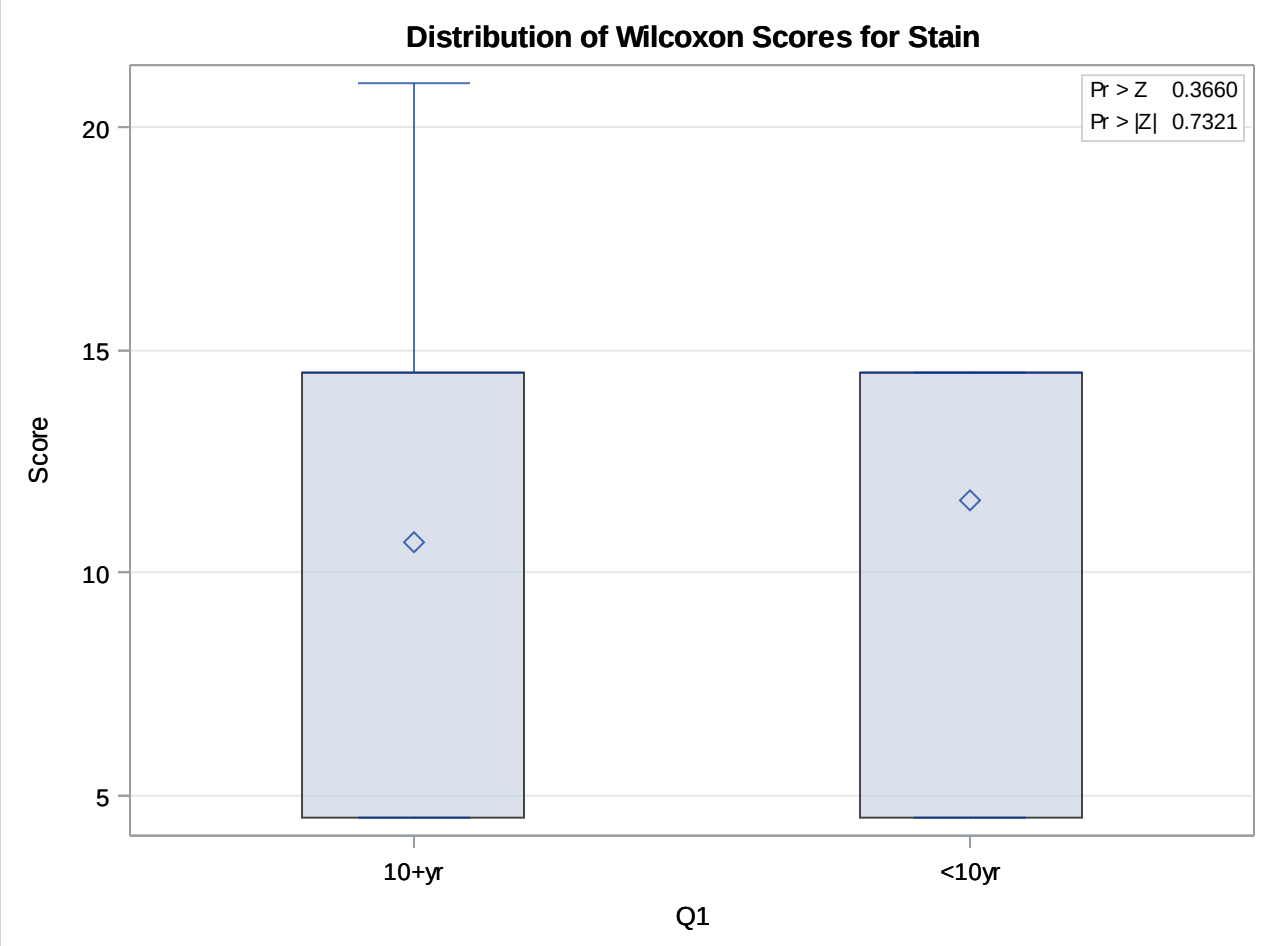


Figure 10: Wilcoxon Stain Scores by Years of Pool Exposure

The above graph explores the stain as related to years of pool exposure. Below, thickness results are explored as related to years of pool exposure:

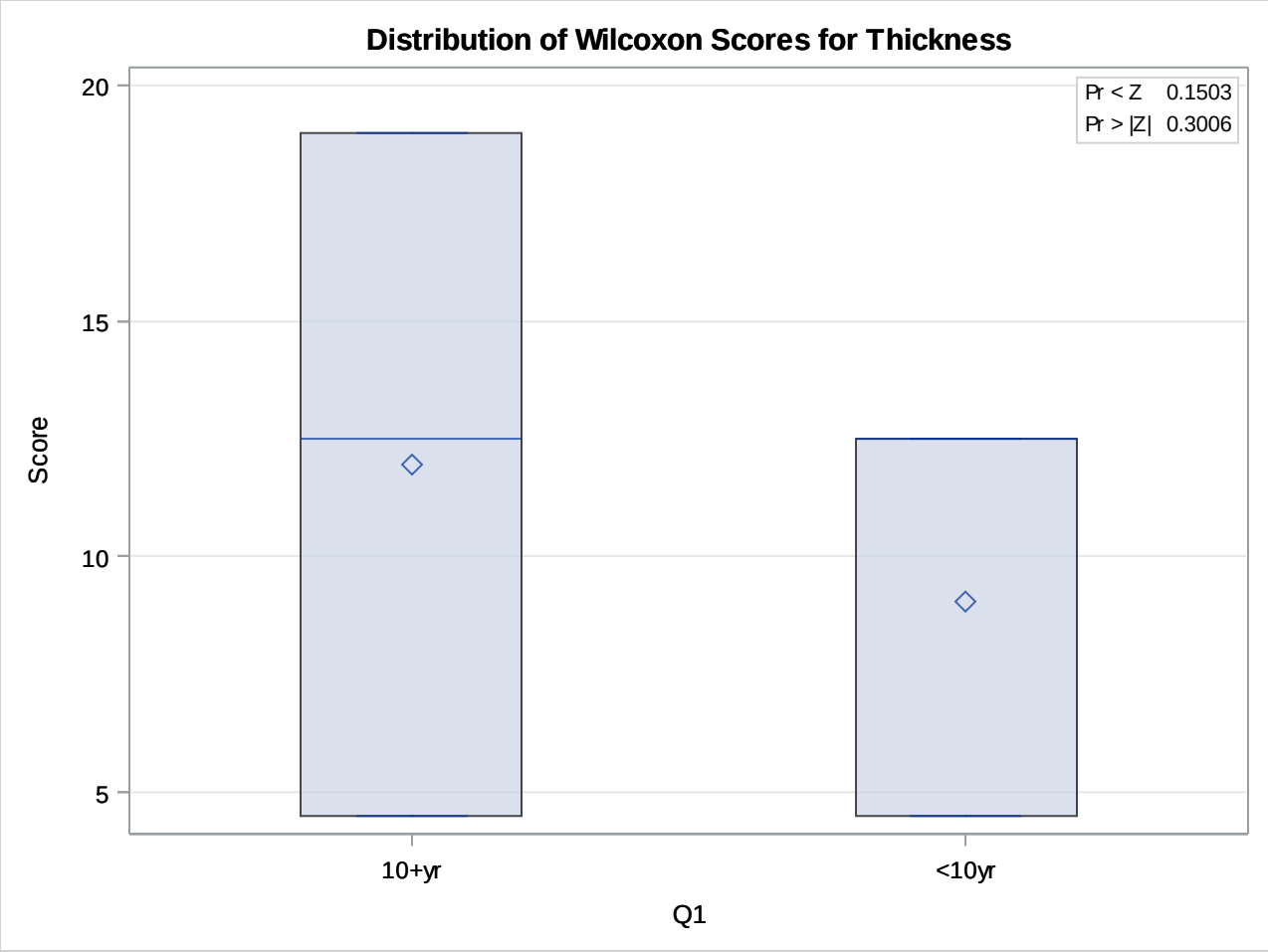


Figure 11: Wilcoxon Thickness Scores by Years of Pool Exposure

The above comparison of stain and thickness as related to years of exposure to a chlorine environment show that there is no difference between the results of the swimmers and divers who swam more than ten years and those who have been swimming for less than ten years.

Discussion

The purpose of this study was to determine if pool chlorination negatively affects the oral cavity by causing dental stain in competitive swimmers and divers, as well as to evaluate if increased exposure time to properly chlorinated swimming pool water increases the individuals chance of developing stain. Utilizing all sixteen female swimmers and five divers from the University of New Mexico Swimming and Diving Team, it was shown that all individuals had staining as a result of 'swimmer's mouth.' Interestingly, the presence of stain was not influenced by how often the swimmer received professional cleanings; most swimmers answered that they had their teeth cleaned just two to three months ago. Also, the majority of the swimmers answered that they brushed their teeth two to three times a day. Unfortunately these factors did not help the swimmers remove the staining completely; therefore, different oral hygiene regimens need to be established to facilitate in the complete prevention of stain.

Every single swimmer answered that they have felt dry skin as a result of chlorine exposure. Also relevant is that one swimmer commented that she puts Vaseline on her eyebrows before every practice to protect her hair from falling out. This individual also commented that the majority of the team had lost almost all of their arm hair, as well as eyebrows, as a result of chlorine exposure.

Pool maintenance logs were reviewed during this study, and the lifeguards reported that the pH of the Olympic Pool is checked every four hours. The staff follows the State Standards of Pool Maintenance as follows: Olympic Pool temperature is kept between 79-81 degrees Fahrenheit, the pH is maintained between 7.2-7.8, the free available chlorine stays between 1-10 ppm, the combined chlorine remains < 0.4 ppm,

and the alkalinity is kept between 60-180 ppm.

Despite the strict maintenance of the Olympic Pool, all swimmers felt the repercussions of extended chlorine exposure. While hair and skin are the most noticeably impacted, awareness of the harm that it can produce on the oral cavity is what this study is trying to assess. Awareness of 'swimmer's mouth' will help the local population, and eventually, the rest of the world understand what harm chlorine can produce not only on the body, but on the oral cavity as well.

Limitations

The limitations present in this study included extraneous variables associated with individual oral hygiene. Attempts were made to control this by asking how frequently each swimmer receives professional dental cleanings. Other limitations include the single gender of all subjects. Assessment of the male swimmer and diver population could possibly yield different results. The sample size of this population was small, therefore yielding not enough 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; every state has a standard protocol that is followed, so results could vary from state to state.

Recommendations for Future Studies

When conducting future studies, it will be important to obtain a larger representative sample of swimmers, both male and female, to be able to make inference to these populations. Educational seminars could prove beneficial for both swimmers and pool maintenance employees. Discussion of the harmful effects of 'swimmer's mouth' will provide awareness of this condition and therefore prevention strategies.

Analyzing what stain is a function of, time vs. exposure, to discover correlational strategies between how quickly stain develops after regular swimming will also be beneficial in furthering this research. The National Center for Biotechnology Information did a study on 'swimmer's mouth' and found that notable dental erosion was seen in a competitive swimmer who swam in a gas-chlorinated swimming pool within only twenty-seven days. This ultimately shows that this is a relevant subject that requires more research to thoroughly understand the signs and symptoms of 'swimmer's mouth.'

Conclusion

This study found that dental staining was evident for all subjects, despite the efficient maintenance of the Olympic Pool. All subjects represent a small part of the Albuquerque district, specifically linked to the University of New Mexico. With these findings, awareness and treatment options for swimmers and divers will hopefully spread nationally. 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 healthy individuals in communities around the world.

Acknowledgements

I wish to express my sincere appreciation to everyone who has supported me throughout this educational journey. First and foremost, I would like to recognize my thesis committee, Christine Nathe, RDH, MS, Christina Calleros, RDH, MS, Diana Aboytes, RDH, MS, and Orrin Myers, PhD. With their extensive knowledge and motivation I was able to accomplish everything that I set my mind to.

It is impossible to express the amount of love and gratitude that I have for my family and friends and all of the support that they have given me. I wish to especially thank my mother, whose aspiring guidance and unconditional encouragement has helped me to achieve my fullest potential.

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Appendices

Appendix A.

Consent:

THE UNIVERSITY OF NEW MEXICO HEALTH SCIENCES CENTER
CONSENT TO PARTICIPATE IN RESEARCH

CHLORINE STAIN AND THE ORAL CAVITY

12/18/2017

Introduction

You are being asked to participate in a research study that is being done by Christine Nathe who is the Principal Investigator, and Alexandra Moore who is the Co-Investigator. Both individuals are from the Department of UNM Novitski Dental Hygiene Master's Program. This research is studying dental staining.

Swimming is known worldwide as one of the healthiest, low-impact forms of exercise and for the subsequent promotion of a strong body, heart, and mind. However, many swimmers and non-swimmers alike do not realize that swimming in a pool can have a negative effect on the oral cavity. Several studies have suggested that improper pool chlorination is responsible for dental erosion, calculus formation, and stain in competitive and recreational swimmers. This is known as 'swimmer's mouth.' This study will focus specifically on the aspect of stain in the oral cavity.

By signing this form, you are consenting to receive a basic oral health assessment, or dental screening. This screening is only a basic evaluation and does not take the place of a thorough dental examination. In order to receive a complete dental examination necessary to establish and maintain oral health, the services of a dentist must be secured. Receiving this dental screening does not establish any new, ongoing, or continuing doctor-patient relationship.

You are being asked to participate in this study because you are a swimmer and you support the foundation of this study. 21 people will take part in this study at the University of New Mexico.

This form will explain the research study, and will also explain the possible risks as well as the possible benefits to you. We encourage you to talk with your family and friends before you decide to take part in this research study. If you have any questions, please ask one of the study investigators.

What will happen if I decide to participate?

If you agree to participate, the following things will happen:

This information gathered from the surveys and screening of the swimmers will give insight to how teeth can be stained from swimming in a chlorine environment. With the results from this pilot study, further analysis can ultimately take place to solidify data concerning 'swimmer's mouth.'

How long will I be in this study?

Participation in this study will take a total of 10 minutes.

What are the risks or side effects of being in this study?

No known risks are associated with this study. The participant will only have to give up 10 minutes of their time.

There are risks of stress, emotional distress, inconvenience and possible loss of privacy and confidentiality associated with participating in a research study.

For more information about risks and side effects, ask the investigator.

What are the benefits to being in this study?

Swimming pools are not only used for competitive swimming, but also for playing and working out. 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 eventually, swimmer's stain will become a condition of the past.

What other choices do I have if I do not want to be in this study?

If the participant does not wish to be a part of this study, then their information will not be collected.

How will my information be kept confidential?

We will take measures to protect the security of all your personal information, but we cannot guarantee confidentiality of all study data.

Information contained in your study records is used by study staff and, in some cases it will be shared with the sponsor of the study. The University of New Mexico Health Sciences Center Human Research Review Committee (HRRC) that oversees human subject research, and the Food and Drug Administration and/or other entities may be permitted to access your records. There may be times when we are required by law to share your information. However, your name will not be used in any published reports about this study. A copy of this consent form will be kept in your medical record.

No personal information will be used in this study. Each participant will simply fill out a questionnaire and will then receive a number.

What are the costs of taking part in this study?

No costs are associated with this study.

What will happen if I am injured or become sick because I took part in this study?

If you are injured or become sick as a result of this study, UNMHSC will provide you with emergency treatment, at your cost.

No commitment is made by the University of New Mexico Health Sciences Center (UNMHSC) to provide free medical care or money for injuries to participants in this study.

In the event that you have an injury or illness that is caused by your participation in this study, reimbursement for all related costs of care will be sought from your insurer, managed care plan, or other benefits program. If you do not have insurance, you may be responsible for these costs. You will also be responsible for any associated co-payments or deductibles required by your insurance.

It is important for you to tell the investigator immediately if you have been injured or become sick because of taking part in this study. If you have any questions about these issues, or believe that you have been treated carelessly in the study, please contact the Human Research Review Committee (HRRC) at the University of New Mexico Health Sciences Center, Albuquerque, New Mexico 87131, (505) 272-1129 for more information.

Will I be paid for taking part in this study?

Each participant will receive a "goodie-bag" containing a toothbrush, toothpaste, and floss.

How will I know if you learn something new that may change my mind about participating?

You will be informed of any significant new findings that become available during the course of the study, such as changes in the risks or benefits resulting from participating in the research or new alternatives to participation that might change your mind about participating.

Can I stop being in the study once I begin?

Your participation in this study is completely voluntary. You have the right to choose not to participate or to withdraw your participation at any point in this study without affecting your future health care or other services to which you are entitled.

Whom can I call with questions or complaints about this study?

If you have any questions, concerns or complaints at any time about the research study, Alexandra Moore, or her associates will be glad to answer them at 575-640-6107.

If you would like to speak with someone other than the research team, you may call the UNMHSC HRRC at (505) 272-1129.

Whom can I call with questions about my rights as a research participant?

If you have questions regarding your rights as a research participant, you may call the UNMHSC HRRC at (505) 272-1129. The HRRC is a group of people from UNM and the community who provide independent oversight of safety and ethical issues related to research involving human participants. For more information, you may also access the HRRC website at http://hsc.unm.edu/som/research/hrrc/.

CONSENT

You are making a decision whether to participate (or to have your child participate) in this study. Your signature below indicates that you/your child read the information provided (or the information was read to you/your child). By signing this consent form, you are not waiving any of your (your child's) legal rights as a research participant.

I have had an opportunity to ask questions and all questions have been answered to my satisfaction. By signing this consent form, I agree to participate (or let my child participate) in this study. A copy of this consent form will be provided to you.

_____	_____	_____
		Date
Name of Adult Subject (print)	Signature of Adult Subject	
or for Child enrollment, Name of Parent/Child's Legal Guardian	or for Child enrollment, Signature of Parent/Child's Legal Guardian	

_____ _____

Legally Authorized Representative Date

INVESTIGATOR SIGNATURE

I have explained the research to the participant and answered all of his/her questions. I believe that he/she understands the information described in this consent form and freely consents to participate.

_____

Name of Investigator/ Research Team Member (type or print)

_____ _____

(Signature of Investigator/ Research Team Member) Date

Appendix B.

Questionnaire:

QUESTIONNAIRE FOR SWIMMERS

1. How long have you been swimming competitively?
    a. Less than 1 year
    b. 1-5 years
    c. 6-10 years
    d. 10+ years
2. How frequently does your swim team practice?
    a. 1-2 times per week
    b. 3-4 times per week
    c. 5 or more times per week
3. How long does your typical practice last?
    a. 1 to 2 hours
    b. 3 hours
    c. 4 or more hours
4. What is the frequency that you have experienced dry skin from the chlorine?
    a. Never
    b. Rarely (1-3 times in the past year)
    c. Frequently (weekly)
5. When was the last time you had your teeth cleaned?
    a. Within 1 month
    b. 2-3 months ago
    c. 4-5 months ago
    d. 6 months or longer
    e. Over a year ago
6. How frequently do you get your teeth professionally cleaned by a dental hygienist?

a. 3-4 times a year
b. Every 6 months
c. Once a year
d. Once every 2-3 years
e. Rarely/never

7. Has your dental hygienist ever mentioned to you that you have stained teeth? Or have you ever noticed that your teeth are stained?
   a. Yes
   b. No
8. Do you drink colored beverages (tea, coffee)?
   a. Yes
   b. No
9. Do you smoke daily?
   a. Yes
   b. No
10. How often do you brush your teeth?
    a. 2-3 times a day
    b. Once a day
    c. 3 or 4 times a week
    d. Once a week
    e. Rarely/Never
11. Are you aware of 'swimmer's mouth?'
    a. Yes
    b. No

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