

ANALYSIS:

Data Collection:

Quantitative Data:

Table 1 (Controlled Group): the maximum amount of force (in Newtons) that a strand of hair can withstand after being soaked in tap water for 2, 4, and 6 days

	Swimmer Hair			Non-Swimmer Hair		
	2 Days (± 0.001 N)	4 Days (± 0.001 N)	6 Days (± 0.001 N)	2 Days (± 0.001 N)	4 Days (± 0.001 N)	6 Days (± 0.001 N)
Trial 1	0.432	0.427	0.437	0.632	0.697	0.649
Trial 2	0.478	0.431	0.442	0.533	0.787	0.651
Trial 3	0.456	0.484	0.476	0.736	0.732	0.687
Trial 4	0.436	0.502	0.493	0.694	0.745	0.670
Trial 5	0.397	0.447	0.503	0.638	0.683	0.668
Trial 6	0.501	0.483	0.480	0.701	0.694	0.664
Trial 7	0.476	0.437	0.457	0.654	0.682	0.671
Trial 8	0.432	0.449	0.431	0.713	0.714	0.674
Trial 9	0.472	0.475	0.465	0.669	0.709	0.659
Trial 10	0.387	0.456	0.478	0.806	0.688	0.672
Mean	0.447	0.459	0.466	0.678	0.713	0.667
Mean (all)	0.457			0.686		

This table shows the results of the force that individual 10cm strands of hair can withstand. The conditions in this table are swimmer hair and non-swimmer hair being soaked in tap water. The results show that the non-swimmer hair is much stronger than the swimmer hair. The results also show that there little effect on hair strength from soaking in tap water for 2, 4, and 6 days. The average of all tap water trials was used to determine percent change in hair strength.

Table 2 (Manipulated Group): the maximum amount of force (in Newtons) that strand of hair can withstand after being soaked in pool water for 2, 4, and 6 Days

	Swimmer Hair			Non-Swimmer Hair		
	2 Days (± 0.001 N)	4 Days (± 0.001 N)	6 Days (± 0.001 N)	2 Days (± 0.001 N)	4 Days (± 0.001 N)	6 Days (± 0.001 N)
Trial 1	0.337	0.319	0.298	0.531	0.413	0.259
Trial 2	0.345	0.324	0.347	0.572	0.397	0.267
Trial 3	0.356	0.342	0.313	0.546	0.395	0.258
Trial 4	0.331	0.307	0.290	0.551	0.427	0.280
Trial 5	0.381	0.319	0.296	0.593	0.391	0.237
Trial 6	0.365	0.316	0.307	0.496	0.404	0.249
Trial 7	0.364	0.305	0.304	0.485	0.402	0.233
Trial 8	0.342	0.310	0.299	0.557	0.389	0.241
Trial 9	0.355	0.318	0.311	0.548	0.376	0.252
Trial 10	0.359	0.300	0.309	0.596	0.406	0.263
Mean	0.353	0.316	0.307	0.548	0.400	0.254

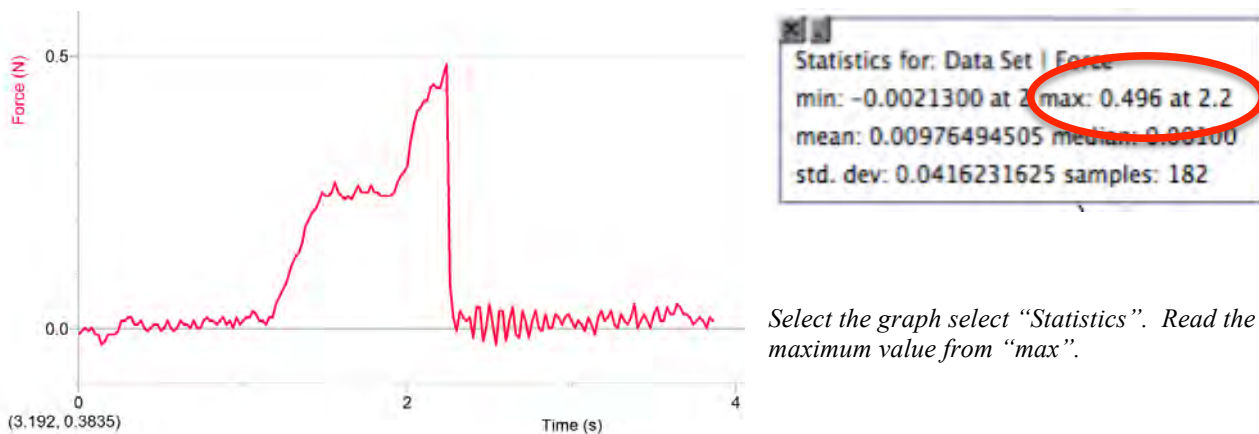
This table shows the results of the force that individual 10cm strands of hair can withhold. The conditions in this table are swimmer hair and non-swimmer hair being soaked in chlorinated pool water with a chlorine concentration of 2.05ppm The results show that the non-swimmer loses strength faster than swimmer hair. Swimmer hair is weaker than non-swimmer hair after 2 and 4 days of soaking in chlorinated water but non-swimmer hair is weaker after 6 days of soaking.

Qualitative Data:

- When placed in the water, the hair strands were straight and long. However, when the hair strands were removed from the chlorinated water after being soaked for a few days, the hair had become more brittle, and was slightly curled.
- After being soaked in the pool water, the hair strands had lightened significantly, turning from a brown to a light brown or dark blonde in color.
- The hair soaked in water changed minimally – there was little to no difference in color or shape.
- When the hair strands were pulled on the electronic spring scale, the hair seemed slightly more “elastic”, stretching to become longer before breaking.
- Upon being removed from the water with tweezers, the hair strands stuck to each other, making it difficult to separate them.

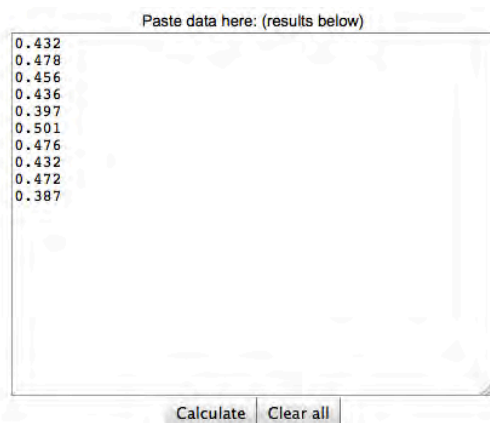
Sample Calculations:

Figure 1: Example Graph of Logger Pro to find the Trial Value and Statistics Box (Non-Swimmer, 2 Days, Trial 6)



Select the graph select “Statistics”. Read the maximum value from “max”.

Figure 2: Test for normal distribution of data.



Results:

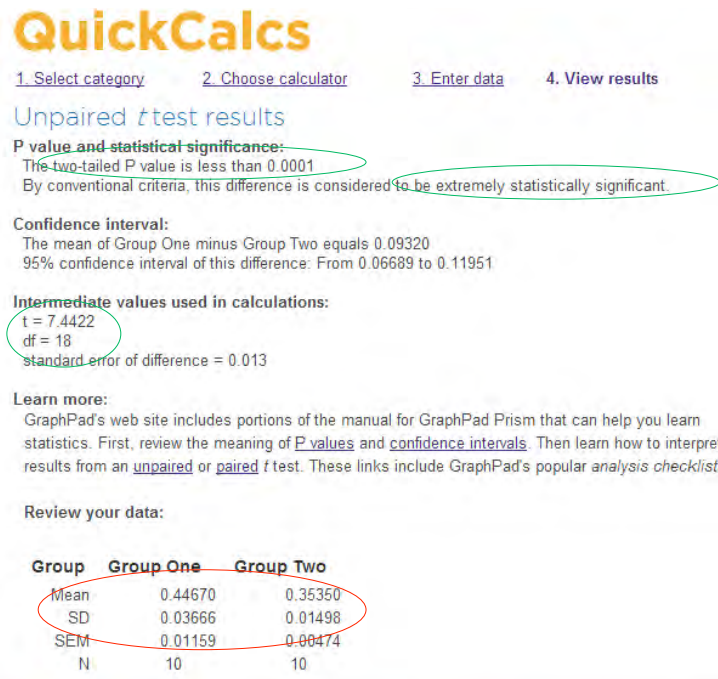
n = 10
Mean = 0.4467
SD = 0.036657726182742
W = 0.9501330182709183

Threshold (p=0.01) = 0.781000018119812 --> H0 accepted
Threshold (p=0.05) = 0.8420000076293945 --> H0 accepted
Threshold (p=0.10) = 0.8690000176429749 --> H0 accepted

--> Your data seems normal

To show that a t-test can be used, the data must show normal distribution. The Shapiro test for normality provided at <http://sdittami.altervista.org/shapirotest/ShapiroTest.html> was applied to each set of 10 values. They all showed normal distribution.

Figure 3: Standard Deviation Calculation and T-Test Calculation:



When finding the t-value, the results of the QuickCalcs also calculate the means and standard deviations of the two sets of inputted data, as shown to the left circled in red.

The results of the t-test (the t-value, degrees of freedom, and the two-tailed p-value, as well as the degree of significance) is shown in the results, which are circled in green.

Percent change in strength of hair:

$((\text{Mean of manipulated sample} - \text{mean of control sample}) / \text{mean of control sample}) \times 100$

Swimmer Pool 2 Days v. All Swimmer Tap Water

$((0.353 - 0.457) / 0.457) \times 100 = -22.8\%$

Results:

Table 3: The Mean Values and the Standard Deviation for the trials of Swimmer and Non-Swimmer Hair found in Table 1 and Table 2.

	Swimmer					
	2 Days		4 Days		6 Days	
	Tap	Pool	Tap	Pool	Tap	Pool
Mean Value	0.447	0.353	0.459	0.316	0.466	0.307
Standard Deviation	0.037	0.015	0.026	0.012	0.024	0.016
	Non-Swimmer					
	2 Days		4 Days		6 Days	
	Tap	Pool	Tap	Pool	Tap	Pool
Mean Value	0.678	0.548	0.713	0.400	0.667	0.254
Standard Deviation	0.072	0.036	0.033	0.014	0.011	0.015

The results above compare the mean value of each trial set to the standard deviation. These values are used in the graph below – the mean value is the height of each bar, while the standard deviation constitutes as the error bars.

Table 4: The Percent Change in Strength of Hair By Length of Time Soaked in Pool Water as Compared to Average of All Control Trials.

	Swimmer Hair			Non-Swimmer Hair		
	Day 2	Day 4	Day 6	Day 2	Day 4	Day 6
Change in Hair Strength (%)	-22.8	-30.9	-32.8	-20.1	-41.7	-63.0

The loss of strength of the swimmer's hair is about the same after two days of soaking but thereafter the non-swimmer hair loses strength in a greater degree. There is little difference between day 4 and 6 for the swimmer unlike the non-swimmer.

Table 5: Below are the t-values, p-values, and degrees of significance to compare the effects of length of chlorination for swimmers versus non-swimmers, effects of tap water and chlorinated pool water.

	Swimmer Hair in Tap Water			Non-Swimmer Hair in Tap Water		
	Day 2 to Day 4	Day 4 to Day 6	Day 2 to Day 6	Day 2 to Day 4	Day 4 to Day 6	Day 2 to Day 6
T- Value	0.8782	0.6390	1.4042	1.4090	4.1902	0.4791
P-Value	0.3914	0.5309	0.1773	0.1759	0.0006	0.6376
Degree of Significance	Not significant	Not Significant	Not Significant	Not Significant	Extremely Significant	Not Significant

The t-test above calculated differences based on length of time submerged in tap water. All the results showed that the tap water did not make a significant difference to the strength of the hair, with the exception of the anomalous result between Day 4 and Day 6 for the non-swimmer.

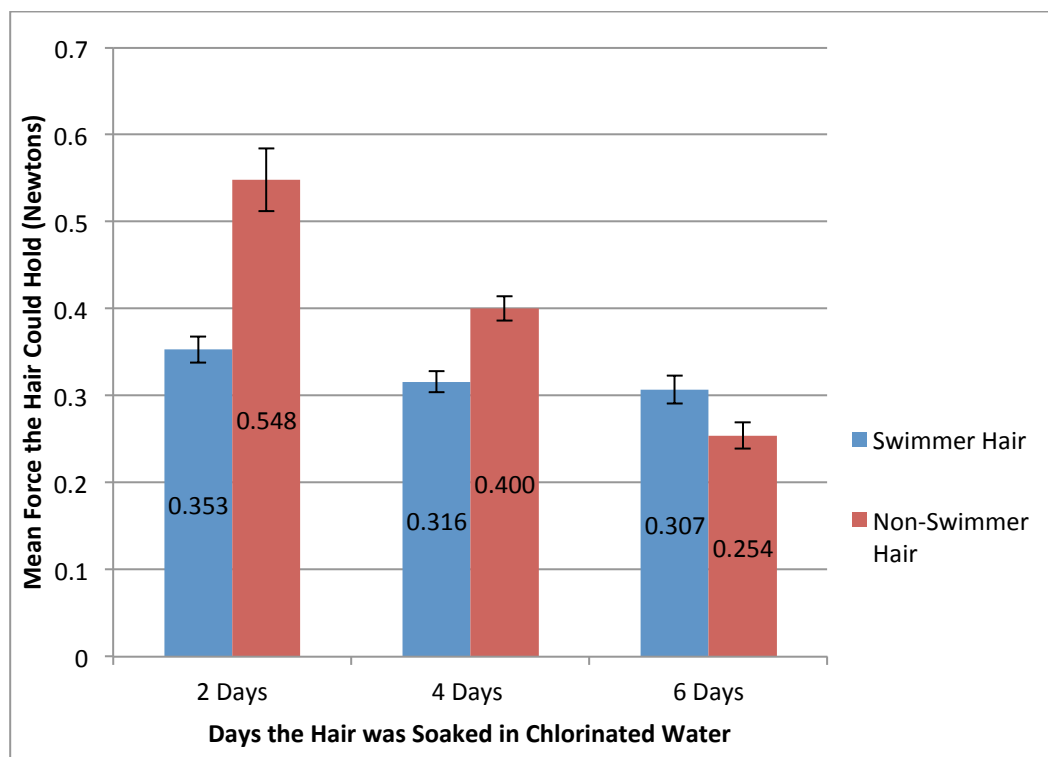
	Swimmer Hair in Pool Water			Non-Swimmer Hair in Pool Water		
	Day 2 to Day 4	Day 4 to Day 6	Day 2 to Day 6	Day 2 to Day 4	Day 4 to Day 6	Day 2 to Day 6
T- Value	6.2521	1.3841	6.7137	11.9972	22.9075	23.7604
P-Value	<0.0001	0.1832	<0.0001	<0.0001	<0.0001	<0.0001
Degree of Significance	Extremely significant	Not Significant	Extremely Significant	Extremely Significant	Extremely Significant	Extremely Significant

The t-test above calculated differences based on length of time submerged in tap water. All the results showed that length of time submerged in pool water caused a significant difference in the strength of the hair, with the exception of the anomalous results of Day 4 and Day 6 for the non-swimmer.

	2 Days		4 Days		6 Days	
	Swimmer: Tap Water and Pool Water	Non-Swimmer: Tap Water and Pool Water	Swimmer: Tap Water and Pool Water	Non-Swimmer: Tap Water and Pool Water	Swimmer: Tap Water and Pool Water	Non-Swimmer: Tap Water and Pool Water
T- Value	7.4422	5.0769	16.1035	27.4054	17.4189	70.9297
P-Value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Degree of Significance	Extremely significant	Extremely Significant	Extremely Significant	Extremely Significant	Extremely Significant	Extremely Significant

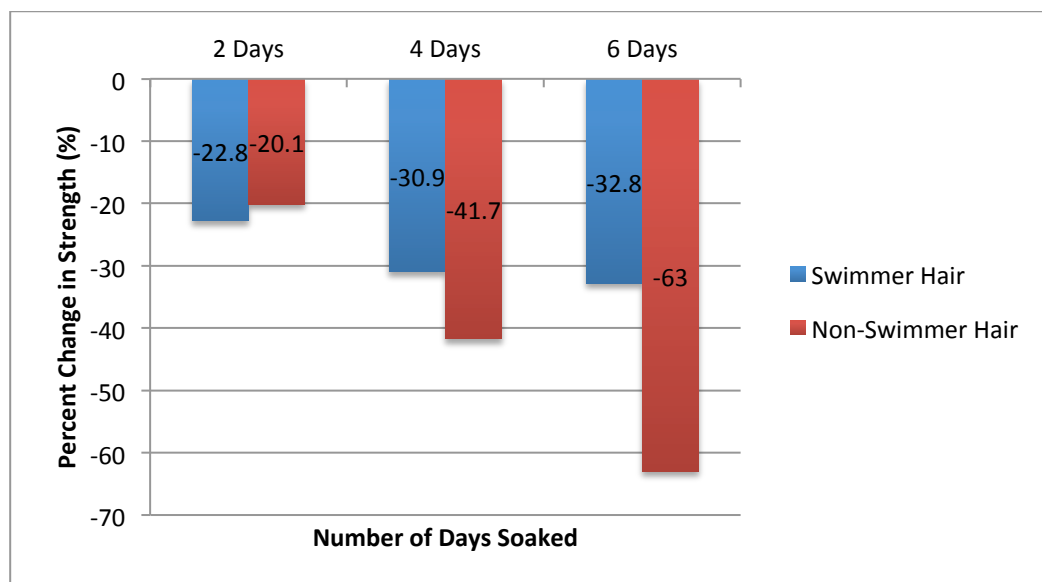
The t-test above calculated the difference between the control groups of hair submerged in tap water and the manipulated groups with the hair submerged in pool water. All the results showed that the tap water and the chlorinated pool water have significant differences, showing that the strength of the hair was affected solely by the chlorine not the water itself. Therefore, it is now possible to compare the results of only the chlorinated water in the graph that follows.

Figure 4: The Mean Values of the Force (in Newtons) that a Strand of Hair from Swimmers and Non-Swimmers Could Hold after being soaked in Chlorinated Water for Two, Four, and Six Days.



The graph shows the mean breaking force of hairs with error bars showing \pm one standard deviation. Hairs of both swimmers and non-swimmers showed a negative correlation between time spent in chlorinated water and mean breaking force. The non-swimmer's hair was much stronger in the beginning but lost strength much more rapidly than the swimmer's. By the end of six days, the non-swimmers hair had a lower mean breaking force than the swimmers.

Figure 5: The Change in Strength of a Hair Soaked in Chlorinated Pool Water As a Percent of Control.



The graph shows the loss of strength in hairs soaked in chlorinated pool water. Both swimmers and non swimmers show a correlation between time soaked an loss of hair strength. Although both swimmer and non-swimmer start with similar percent change in hair strength, the non-swimmer loses more pronounced and continued loss of strength in days 4 and 6.

Interpretation:

Using the tap water as a control group, it was established that for the most part, length of soaking did not significantly change the strength of the hair. There were no significant differences in the control samples for swimmers. The mean tensile strength of swimmer hair soaked in tap water was 0.457 ± 0.029 N. Non-swimmer hair had an average strength of 0.686 ± 0.049 N, however there was a significant difference between the strength in days 4 and 6 (0.713 N and 0.667 N respectively). By using these values as a control group, it is possible to compare not just the strength, but the change in strength, of the hair in the manipulated trials.

The hair strands added to chlorinated water always showed significantly less strength than the control trials. By using a t-test for each section gave a p-value of less than 0.0001, showing that the difference between the sets of data were all extremely statistically significant. This suggests that the changes in the strength of the hair was likely due to the pool water, presumably the chlorine, and not the water itself.

For the swimmer hair, the mean force that the hair strand could hold after being soaked in chlorinated water was 0.353 after two days, 0.316 after four days, and 0.307 after six days. The strength decreased rapidly between the second and fourth day, decreasing by 0.037 N, but by the sixth day, it decreased only 0.009 N. Compared to the control, this represented a 22.8% loss of strength of day 2, a 30.9% loss of strength of day 4, and a 32.8% loss of strength on day 6.

For the non-swimmer hair, the mean force that the hair strand could hold after being soaked in chlorinated water was 0.548 after two days, 0.400 after four days, and 0.254 after six days. The strength decreased rapidly and consistently between the second and fourth day (-0.148 N) and between the fourth and sixth day (-0.416 N). Compared to the control, this represented a 20.1% loss of strength of day 2, a 41.7% loss of strength of day 4, and a 63.0% loss of strength on day 6.

For two and four days of soaking swimmer hair was weaker than non-swimmer hair, with swimmer hair having being able to withstand only 64% as much force as the non-swimmer hair. However after six day, the swimmer hair could withstand 121% of the force that non-swimmer hair could hold.