
HL Bio P4
Ms. Soule

IRP: The Effect of Chlorinated Water on Hair Strength

EXPLORATION and PERSONAL ENGAGEMENT

Introduction:

Personal engagement:

Swimmers may experience dry and brittle hair as a result of swimming in chlorinated pools. Even with the use of conditioners and other hair care products there may be obvious damage to hair. As a member of the swim team, I am personally interested in the nature and extent of the damage that chlorine causes to hair.

This led to questions about the effect of exposure to chlorine over time for swimmers and non-swimmers, as well as the rate of damage.

Research question:

What is the relationship between the amount of time in which hair from a swimmer or non-swimmer is soaked in chlorinated water and the strength of hair as measured by the amount of force that can be applied before the hair breaks?

Background Theory:

Chlorine is a popular chemical to add to pool water, as it works as a disinfectant. It has three main purposes: it sanitizes the water by killing bacteria and inactivating viruses, it oxidizes the water as it controls the organic debris from bodily perspiration and oils, and chlorine deters algae (1). Unfortunately, the over-exposure to chlorine has negative side effects as well, as chlorine causes dryness in the skin and the hair.

When chlorine is added to water, hypochlorous acid and hydrochloric acids form:

$$Cl_2 + H_2O \rightarrow HOCl + HCl$$

Hydrochloric acid is a strong acid and dissociates completely. Hypochlorous acid is non-polar so it can enter cells. It is a weak acid, and, depending on pH, it partially dissociates to hypochlorite ions:

$$HCl \rightarrow H^+ + Cl^- \ (aq)$$
$$HOCl + H_2O \leftrightarrow H_3O^+ + OCl^- \ (aq)$$

The result of these chemical reactions is to attack the chemical bonds in microorganisms such as bacteria, making pools less likely to cause infection in humans (3). As a side effect, exposure to chlorine affects both the outer lipid layer of hair and also the core protein structure. The lipid layer is removed by interaction with chlorine causing a dull appearance and allowing greater interaction between chlorine and protein (4). Research done on the keratin fibers in wool suggests that chlorine can then break disulfide bridges found in keratin and also break peptide linkages, meaning that less force is necessary to stretch hair and that the hair has less tensile strength (5).

It was hypothesized that the longer the hair was soaked in the chlorinated water, the weaker the hair would become, as the chlorine and other chemicals would penetrate the lipid layer and have greater time and exposure to disrupt the protein structure of the human hairs. It was also hypothesized that the hair of a non-swimmer would be stronger but also have greater initial damage from exposure to chlorinated water. This is because the swimmer's hair would already have long-term damage but be less likely to have a dramatic change when exposed to the familiar situation of chlorinated water.

Method:

Variables:

The *independent variables* in this experiment were

- the amount of time the hair was exposed to the chlorine
    - The time on classroom clock was noted when the hair samples entered the water and then again when the hair was removed.
- the source of the hair (swimmer and non-swimmer) and
- whether the water was chlorinated (experimental group) or not (control group)
    - Water was taken from the school pool and from the tap

The *dependent variable* in this experiment was

- the maximum force (in Newtons) that the hair strand could withhold before breaking
    - An electronic spring scale force meter was used and the data collected by Logger Pro

Theoretically, the strength of the hair is affected by age of the person, the outside temperature which affects the strength of the bonds, area of the hair on the scalp, and length of the hair strand tested. (3)

Some *controlled variables* in this experiment were

- Genetic factors:
    - The volunteers were teenaged sisters who had similar color hair. As siblings, they share many alleles. Similar hair color suggests alleles relevant to hair may also be shared.
- Environmental factors:
    - The hair was not dyed or permed and used the same hair products.
    - temperature of the room and the water temperature of the experiment were controlled by keeping all samples in the same location
    - the hair was taken from the same place on the scalp, behind the left ear, as hair at the base of the scalp is often weaker than hair on the top.
    - The length and age of the hair sample measured was kept a constant, by cutting from 1 cm from the scalp and trimming to a length of 10 cm thus creating an equal length of hair for each trial.
    - The same sample of pool water with a chlorine level of 2.05 ppm was used in all the trials to minimize the differences in chlorine levels
    - The pool water was filled to the brim and sealed in Tupperware to prevent the evaporation of water or chlorine which could change the concentration over time
    - The same force meter was used to avoid problems with calibration.
    - Dampness of hair, which can affect hair strength, was controlled by removing hairs one at a time for each trial
    - Angle of pull on the hair was controlled by taping the ends of each hair together, creating a loop and pulling directly down

Procedure:

The experiment was explained to the subject and the parents and **approval** was received. Sixty strands of **hair** were cut using **scissors** from the two subjects (one swimmer and one non-swimmer) at 1.0 cm from the scalp on the left side behind the ear. Scissors were used to trim the hair to a length of 10.0 cm.

About 800 mL of 2.05 ppm **chlorinated pool water** was collected from the school pool in a **1 L beaker**.

Four small Tupperware containers were labeled: swimmer (chlorine), swimmer (tap), non-swimmer (chlorine), and non-swimmer (tap). 30 hairs from the swimmer were placed in each swimmer container and 10 hairs from the non-swimmer were placed in each non-swimmer contained. All Tupperwares were then filled to the brim with about 115 mL pool water and sealed.

After two days, all the containers were opened and a **tweezers** was used to remove one hair at a time, for a total of 10 hairs from each volunteer. The hair was placed on a **paper towel** to absorb any extra water and the ends were **taped** together to create a loop. The loop of hair was placed over the hook of the **electronic spring scale force meter** and "collect data" was selected. The taped end of the hair loop was pulled directly downward slowly and steadily until the hair broke. The highest recorded value of force was then recorded.

After the data were collected, the containers were resealed. After four and six days the process was repeated.

Data were analyzed in terms of means and standard deviations. Normality tests and t-tests were used to check for significant differences between samples. Once it was shown that control trials did not change in strength during soaking, percent change in strength of hair was calculated using the mean of all control trials for that volunteer.

Safety and Ethical Concerns:

- Informed consent of volunteers and parents was received
- Scissors were used with care with the points of blades turned away from the scalp
- The glass beaker was handled with care to prevent breaking.
- Chlorine can be a dangerous chemical but at the low concentrations of pool water no special precautions or disposal techniques were required. Hands were washed after working with chlorinated water.
- The force meter was firmly affixed to a ring stand which was clamped to the edge of the table to prevent it from moving or toppling over
- All extra materials were kept out of the way to prevent accidents.
- Used hair, water, and tape were non-hazardous and were disposed of properly with solids in the trash cans and liquids down the sink.