Effect of Water Temperature on Heart Rate in Human Mammalian Dive Response

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Introduction

The Mammalian Dive Response (MDR) is one of the most fascinating reflexes that occur in virtually all mammals, including humans. MDR refers to the ability of mammals to hold their breath underwater for a sustained period, which is reflected by further changes in underlying physiology. Marine mammals such as whales and seals can hold their breath for an hour or more, depending on the species. The most extended mammal breath held was reportedly a Cuvier's beaked whale that held its breath for 2 hours and 17 minutes in 2014 (1). In humans, this response exists in a less developed form, as the average person can hold their breath for only 2 minutes (1). Some cultures, such as the Bajau, who have been free-diving for food for many years, have been found to potentially have genetic and physiological adaptations for more sustained water submersion (up to 12 minutes or so) as part of their lifestyle (2). While it is still incredible compared to regular humans, it is far below that of marine mammals. These animals have increased blood volumes, greater vasoconstriction, more apnea, and a better ability to handle carbon dioxide in their blood, allowing them to handle long-term dives better than humans do (3).

In any case, the underlying physiology is very similar across mammals during MDR and should be considered. When the face becomes wet underwater, sensory receptors in the nasal cavity send signals to the brainstem, which in turn stimulates additional receptors and nervous pathways that trigger a parasympathetic response. This then leads to changes such as apnea (holding the breath), bradycardia (a slower heart rate), vasoconstriction, reorganization of blood supply to prioritize the brain and heart, and a decreased metabolic rate. These efforts collectively preserve the body's oxygen supply while the mammal is underwater (3,4). In general, this response is stronger in colder water than in warmer water, as seen in recent research, and heart rate is often a dominant metric for showing this, although others are tested as well (5,6).

The goal of the present study is to compare and confirm the effects of different water temperatures on the heart rate in different temporal intervals before, during, and after an MDR. It is hypothesized that heart rate will decrease more during cold-water submersion than during room temperature or warm water submersion.

Methods

The heart rate of one participant was measured throughout the duration of the experiment. A finger pulse transducer and a respiratory belt transducer were connected to the participant and configured to PowerLab to display respiratory rate and heart rate in real time in LabChart7. To ensure proper setup and accurate data acquisition before the start of the experiment, a test run was conducted for about a minute, during which the participant's heart rate was monitored at rest and during a breath hold. Once deemed successful, the participant began the submersion process in room temperature water, cold water (6 degrees Celsius), and warm water (30 degrees Celsius). Once data recording began, the participant remained at rest for approximately 30 seconds to obtain a resting heart rate. After 30 seconds, the participant submerged their face in a medium-sized tub of tap water for roughly a minute or until they needed to come up. After another 2-3 minutes of recording the recovery period, the recording stopped, and the trial would be finished. The next recording would begin in approximately 3-5 minutes or when the participant was ready to proceed. This process was repeated for each submersion. Means of heart rate data (only) were calculated using LabChart7 for resting heart rate, 15 seconds after water submersion, 15 seconds before the participant came up, post-breath hold (immediately after coming back up), and during the 2-3 minute recovery period, when data were still being collected. Graphing and data input were done in Microsoft Excel.

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Results

Sample recordings of resting heart rate and respiratory rate were successful, and no major technical issues occurred after test trials(Fig.1). For experimental results, the cold and control (room temperature) water had some similarities and differences in data trajectory, whereas the warm water had the largest gap between the cold and room temperature conditions. The cold water dive had a large initial drop in heart rate, followed by fluctuations (increases followed by decreases) throughout the duration of the trial. The control showed less fluctuation than the cold water and decreased steadily until the participant came up from the water. Both the cold and room temperature heart rates remained below resting heart rate, even during the recovery period (Fig. 2). The warm water dive had a markedly steeper upward trajectory than the cold and control water dives. The heart rate was always higher than the resting heart rate. It fluctuated throughout the dive but started to stabilize somewhat after the dive. (Fig.2)

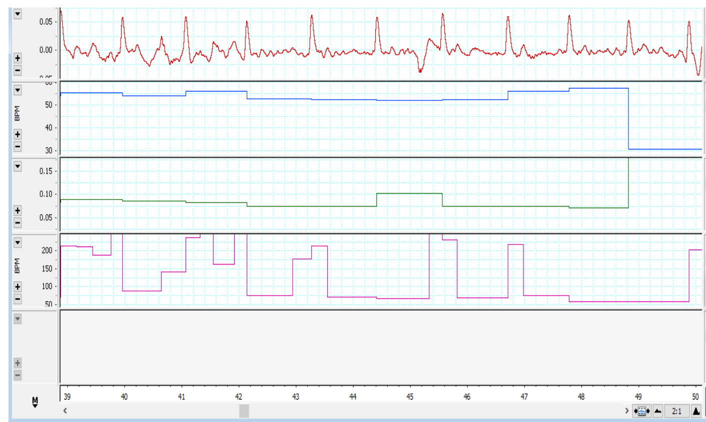

Figure 1. Sample 11-second recording screenshot of heart and respiratory rate at rest using a finger pulse transducer and a respiratory belt transducer.

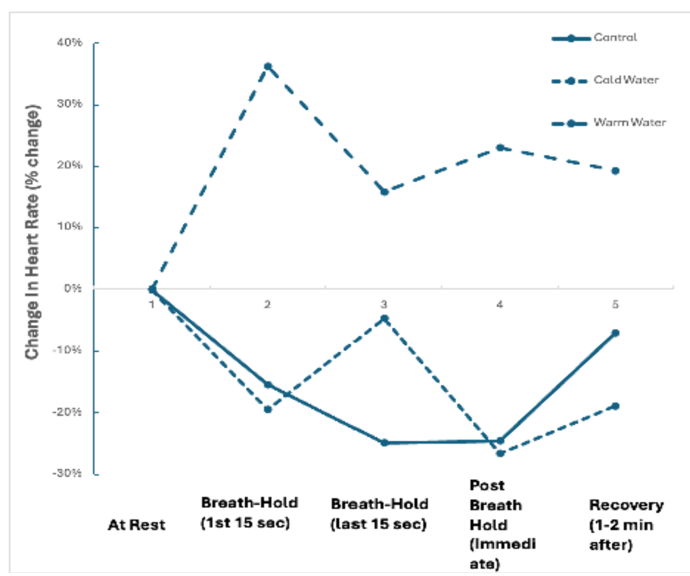

Figure 2. Percent change (%) in heart rate from one volunteer in different temporal intervals before, during, and after placing the face in a tub filled with room temperature, cold, and warm water. Heart rate was monitored with a finger pulse transducer.

Discussion

Our initial hypothesis for this experiment was that cold water would cause larger drops in heart rate than room temperature or warm water. This hypothesis was partially supported in the comparison between cold and warm conditions. The warm water heart rate did not decrease as much as the cold water, and this signified differences that have been observed in previous research (5,6). However, when comparing the cold water to the control, these results were more similar than expected, and the control water decreased more than the cold water during the dive. This would likely contradict research where cold water has been seen to have the most pronounced decreases in heart rate

In this data, however, there were a few factors and limitations to consider that minimize the conclusiveness of the results. The main limitation is a very small sample size of just one participant. This would need to be increased in future experiments that examine this phenomenon to obtain more robust data. Another factor was some anxiety during trials due to holding breath. This may help explain fluctuations in heart rate during the experiment, and it is important to consider future studies. The last factor to consider is the inclusion of more diverse physiological measures beyond heart rate. Respiratory rate was measured but not analyzed in this experiment. As there are several physiological changes besides heart rate, further additions would be beneficial for understanding what happens during MDR and its other important changes. Even so, this data has still provided insights into heart rate changes during water submersion in humans

In addition to improving the experiment, there are intriguing studies that could further explore MDR. Since the participant was also an athlete, comparing MDR between athletes (those who play sports) and non-athletes would be of interest to determine whether MDR is heightened or suppressed in athletes. Also, age and gender differences would be another possible direction. MDR is a fascinating phenomenon, and expanding research in humans can further advance understanding of how it works and its developmental stages.

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