Human Adaptations:

Free divers

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Abstract:

Freediving has been around for thousands of years and was only way to dive until the invention of oxygen tanks in the 19th century. Around the world, people dove for goods such as pearls, and today people freedive for sport. Divers stretch the limit of their body and mind's capabilities through psychological adaptations from thermal, respiratory, and cardiovascular responses. Findings conclude that thermal adaptations are a similar process to cold adaptive response. With the implementation of wetsuits, this adaptation has disappeared. Other adaptations include respiratory tolerance of the build up of carbon dioxide, different flows of gas exchange, and increased lung volume capacity. Cardiovascular changes in freedivers are attributed to the diving response, or the innate animalistic ability to survive when in water. These innate responses include: a decreased heartbeat, increased blood pressure, and decreased blood flow to the limbs. This response is more pronounced after only two weeks of breath-hold training. Freediving, although adaptive, is dangerous and causes issues ranging from dizziness to death. There are many environmental adaptations, but little research and conclusive evidence of genetic adaptations involved.

Introduction

Freediving is the act of holding a single breath during a deep-sea dive with out any external supply of oxygen (Nitsch, 2010). In the past, freediving was the only way to dive, and used around the world dating back to 4,500 B.C for the sake of obtaining economical profit for sponge harvesting, seafood collecting, and treasure from ships (Lin and Hong, 2011). Other areas freedivers were used for economical reasons such as for shells at the Torres Strait near Australia, pearls in the Archipelago, and sponges in the Aegean Sea (Lin and Hong, 2011). In Japan and South Korea, pearl diving has been an essential practice since the 3rd century BC and still used to this day (Ferretti and Costa, 2003). In Japan, as much as 13,000 freedivers were still active in the early 1990's (Ferretti and Costa, 2003). In South Korea and Japan, women are divers and are given a special title called the Ama or Hae-Nyo, meaning "sea women" (Ferretti and Costa, 2003).

Studying human adaptations of freediving began in the 1920's with observations and measurements diving patterns, seasons, and equipment among the Ama people (Ferretti and Costa, 2003). Researchers began to understand what physiological changes and adaptations were in these divers to allow them to exceed standard limits of what scientists thought possible. Today freediving is categorized as an extreme sport where people compete internationally to beat world records in breathe holds and deeper dives (Engelbrecht, 2009). The record for breath hold duration (with use of a part motorized sled) is currently held by Herbert Nitsch at 214 meters with an ability to hold his breath 10:12 minutes (Nitsch, 2010). He also holds the world record by traditional methods (*Skandalopetra* diving) of using only a rope and weights, at 107 meters. (Lindholm and Lundgren, 2008). Freedivers are drawn to the ability of having the control of their breath, being more accepted by underwater wildlife, and the inexplicable drive to find their body's limits (Nitsch, 2010). This essay will provide evidence of three main physiological adaptations and risks of the human body when in a freedive, and add to the knowledge of how humans continuously adapt to their environment.

Thermal adaptations

When freedivers submerge themselves in cold ranges of water temperature and do not have protective gear such as a wetsuits, they adapt similarly to people in cold air environments. In an experiment, Ferretti and Costa (2003) used non-diving controls (Americans) and the Ama to understand underwater adaptations. The control group had a mean subcutaneous fat thickness of 4 mm and could only stay in water at a temperature of 30°C for 3 hours before they reach a threshold of shivering. This is a process of finding their critical water temperature (CWT) (Ferretti and Costa, 2003). The Ama—who dive in water that can get below the normal CWT of 30°C—had no visible shivering (Ferretti and Costa, 2003). Researchers first believed that the Ama adapted to the cold water in a similar way marine mammals do, by building up a higher percentage of subcutaneous fat (Ferretti and Costa, 2003). This was proved not the case when the Ama had none of these adaptations, and instead had less subcutaneous fat of 2.2 mm (Ferretti and Costa, 2003). The decreased CWT limit provided evidence that the Ama adapted to the cold separately from diving adaptations (Ferretti and Costa, 2003). The increased shivering threshold implied better heat exchange and blood flow (Ferretti and Costa, 2003). However, after the introduction of neoprene wetsuits to the Ama in the 1980s, they lost their cold adaptation and CWT tolerance in two years (Ferretti and Costa, 2003). A similar case was found for sponge divers in the Aegean Sea when they began wearing wetsuits and saw after 10 years they had no difference in their shivering threshold than non-diving controls (Ferretti and Costa, 2003). The lack of protection against cold-water temperature provided freedivers with an environmental thermal adaptation, but with the introduction of wetsuits, this adaptation diminished.

Respiratory Adaptations

Respiratory adaptations develop after a freediver has practiced techniques and control over their breath (Lin and Hong, 2011). To introduce these adaptations it is important to understand the main phases of a breath hold that happens throughout a dive (Lin and Hong, 2011). When one inhales and voluntarily refrains from respiration, their glottis (space in between vocal chords) closes and begins to feel a slight pressure on lungs (Lin and Hong, 2011). Then the intensification of lung pressure increases as the glottis continues to stay closed (Lin and Hong, 2011). Finally, the absolute threshold is reached and involuntary activity such as diaphragm contractions signals the need and desire to breath due to the toxic build up carbon dioxide in the blood (Lin and Hong, 2011). Once a practiced freediver is immersed into water and begins a build up of CO2 in their blood and their body fights to breath, the diver has an increased ability to ignore these warning signs. Their threshold CO2 tolerance increases above normal by their willpower of continuously ignoring the stimulation of chemoreceptor's informing the body the need to breath (Ferretti and Costa, 2003). Practice, squeezing a rubber ball, swallowing during the contractions, a calm psychological state, and hyperventilation are all ways to increase ones breath hold (Lin and Hong, 2011). During the breath holding process freedivers have an increased lung capacity to sustain a longer dive.

Freedivers have different adaptive responses to increase their breath hold. The Ama have the ability to go beyond the maximal inspiratory pressure (the negative pressure from air intake) through force as well as the ability to decrease the residual volume left in the lungs after exhaling (Ferretti and Costa, 2003). Their lung capacity is 15% larger than non-divers in the area (Ferretti and Costa, 2003). In competitions, freedivers go through a respiratory process before, during, and after the dive to maximize length of breath hold and lessen the life threatening consequences. Before the dive, they "pack" their lungs through short and rapid inhales called "lung packing" (Ferretti and Costa, 2003). For equalizing ear and lung pressure, they "unpack" the air into a bottle during the first part of their dive (Ferretti and Costa, 2003). After touching down to the desired depth and ascending they need to wait for their lungs to unfold due to the pressure and nitrogen by stopping for another minute (Nitsch, 2010). With training and utilizing all techniques properly, one has the ability to adapt and increase their breath hold and lung volume, but individual limit varies substantially even among divers (Nitsch, 2010).

Unique patterns in gas exchange are another respiratory adaptation found in freedivers. In a case study among three female divers, findings showed they all had a lower partial pressure of carbon dioxide (PCO2) by 11 torr (unit) and higher PO2 by 20 torr than normal (Lin and Hong, 2011). In other examples, when a diver is descending CO2 diffusion has been found and their alveolar gas increases substantially by 40% (Lin and Hong, 2011). These gas exchange adaptations are thought to be a back up signal during the breaking point in the lung capability to contain a breath when there is a maximum built up of nitrogen (N2) (Lin and Hong, 2011). This is important due to the voluntary suppression of other stimulus such as diaphragm contractions and signals to the diver they absolutely need air (Lin and Hong, 2011). The techniques and respiratory adaptations freedivers successfully use can provide groundwork for understanding how the human body adapts.

Cardiovascular Adaptations

Diving response is an involuntary cardiovascular adaptive response in all air-breathing mammals when they are in water (Gooden, 1994). Reflexes the body uses to conserve as much oxygen as possible are: slowing the heart rate, decreasing blood flow in organs and muscle, and increasing blood pressure (Gooden, 1994). When the forehead and eyes are in water, the stimulation elicits this response faster (Foster and Sheel, 2005). The most prominent diving responses are in colder water, and in those who are healthy and younger (Lindholm and Lundgren, 2008). Supporting evidence shows how three experienced freedivers reached 55m in water at 25°C and at 35°C (Lindholm and Lundgren, 2008). In colder water their heartbeat measurements showed higher and premature rhythmic irregularities and their heart rates fell below 30 beats/min (Lindholm and Lundgren, 2008). This provides evidence that the diving response is a unique evolutionary cardiovascular adaptation most prevalent in cold water dives.

Other cardiovascular adaptations are presented through observing one's oxygen, carbon dioxide, and blood pressure. In a control group the diving response can decrease ones arterial blood pressure of oxygen (PaO2) down to 60 mmHg (which measured blood pressure in millimeters of mercury), and carbon dioxide pressure (PaCO2) high as 45 mmHg (Foster and Sheel, 2005). When divers with only two weeks of training are measured, their PaO2 decreases to 35mmHg and PaCO2 increases up to 50 mmHg (Foster and Sheel, 2005). This emphasizes a quick adaptive response, however, it is unclear how an adapted freediver would measure up to these results. What is known is that freedivers who are able to dive at lower and longer depths (70 m at 111-138 s) are shown to have an extreme increase in arterial blood pressure (unknown if it was oxygen or carbon dioxide), in one case a diver obtained 280/200 mmHg during their decent (Ferretti and Costa, 2003). The increased diving response freedivers experience are believed to be due to their lowered drive to breath, which might increase the level of these cardiovascular diving mechanisms (Ferretti and Costa, 2003). With a two-week training, a person's body shows quick cardiovascular adaptations to their underwater environment.

Risks

Even though humans are able to adapt and use their innate diving response, there have always been deadly risks during and after a breath-hold dive. In other cultures specific words elicit different issues divers face such as Taravana, which means to literally "to fall crazily" where a diver has dizziness or visual troubles (Ferretti and Costa, 2003). These consequences are relatively mild. Some other mild consequences include general hypoxia (the deprivation of oxygen from the body), over packing before descent (loss of consciousness), alternobaric vertigo (middle ears pressure), bruised or ruptured ear-drums, hyperventilation, and ascent blackout (Lin and Hong, 2011). More commonly heard of in SCUBA divers, decompression sickness or the bends may occur when there is too much gas pressure when ascending (Hooker et. al., 2011).

As divers go to greater depths, extreme risks are more prevalent (Lindholm and Lundgren, 2008). For example, the more pressure and build of nitrogen may cause nitrogen narcosis (getting a euphoric high from having too much nitrogen in the body) and cause the forgetting of a simple life saving movement, for example, pushing a lever to ascend (Lindholm and Lundgren, 2008). More severely, when there is too much pressure on the chest and lungs during a dive there can be three devastating consequences: a collapse of the lungs, fluids entering the lungs and alveolar space, and/or a ruptured alveolocapillary membrane that causes bleeding (Lindholm and Lundgren, 2008). Even for those who are more adapted, dangers are still prevalent. The world record holder diver Nitsch stops during the ascent at 10 m to allow the nitrogen build up and blood pressure build up in the lungs to decrease as well as to allow his lungs to unfold (Nitsch, 2010). If a freediver is not careful, severe cases can include paralyses of extremities, unconsciousness, and death (Lindholm and Lundgren, 2008). It is still unclear the genetic or environmental adaptations to allow some divers the ability to dive with out any ill effects at a greater depth than 100 m while others suffer death from 20-30 m (Lindholm and Lundgren, 2008). Although humans have the ability to survive longer in an underwater environment, there is a limit to these physiological adaptations.

Conclusion

The human body's ability to adapt continues to surpass and surprise us; who knows our future potential (Nitsch, 2010). Freedivers have environmentally adapted to one of the greatest inhospitable environment for the collection of goods and food for over 4,000 years (Lin and Hong, 2011). This research sought to highlight the three physiological adaptations freedivers undergo in their thermal, respiratory, and cardiovascular body systems. They adapt to cold water similarly to the cold, are able to maximize their lung capacity and suppress their body's urge to breath through training and practice, and are able to utilize the diving response to the fullest. There are still many questions left in regard to post dive dangers and long term cognitive effects freedivers face. This evidence of a physiological adaptation for surviving longer underwater should be groundwork for further research on how these adaptations affect the freediver community. Future research should seek to understand at greater detail adaptive responses freedivers use as they keep pushing for longer breath holds, and greater depths.

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Ms. Troy Z. Tournat will be graduating from the University of California, Merced this year with a Bachelors of Arts in Anthropology and Psychology. Last year she studied abroad through the UCEAP program, and upon returning was asked to become a contact for other potential students. This past year she worked in the Bright Success Center as a Success Mentor for incoming freshman. She has also received the Chancellor's honors award for her academic performance. This semester her involvements include a research assistant position in a psychology laboratory, a Reader for one of her past art courses, and a proud member of the woman's fraternity Kappa Kappa Gamma. Her academic endeavors will continue as she works towards candidacy for a Masters degree.