Human Accomodations to Diving in Cold Water

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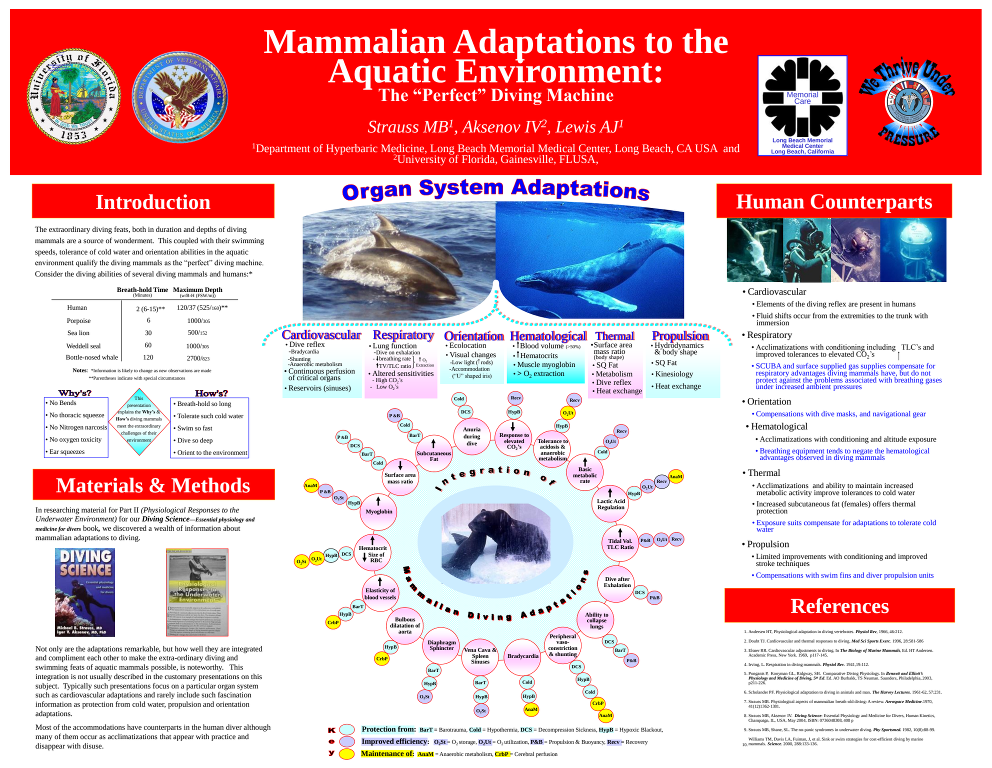
We Thrive Under Pressure
Hyperbaric Medicine

Diving Medicine

Introduction

At the 2006 UHMS meeting we presented the poster copied below. It showed organ systems adaptations in mammalian divers and their human counterparts


Mammalian Adaptations to the Aquatic Environment:
The "Perfect" Diving Machine
Strauss MB, Aksenov IV, Lewis AJ

Introduction

Organ System Adaptations

Human Counterparts

Materials & Methods

References

This presentation describes the accommodations humans make to meet the challenges of diving in cold water and compares & contrasts them with those found in diving mammals

Background

Hypothermia is a major physical challenge of SCUBA diving

The specific heat of water is 1000 times greater than air; and water's heat conductivity is 25 times greater than air.

Naturally occurring factors offer some protection for cold water exposures in humans

Chilling is the first sign of hypothermia and is associated with end of day diving. It has consequences for on- and off-gassing (see our Disordered Decompression poster)

Preservation of core temperature is the crucial consideration in preventing injury and death from hypothermia

As core temperatures decline, predictable responses occur

Effects of Falling Core Temperatures

Temperature F° (Centigrade)	Observations	Comments
98.6 (37)	Normal body temperature	
97.0 (36.1)	Core temperature in resting divers after 6 hour exposures in custom fitted 5/8 inch (core) & 1/4 inch (extremity) neoprene wet suits in near freezing water	Although the core temperature was maintained, the hands & feet were near ambient water temperatures
95.0 (35.0)	Lower limit of "safe" declines in core temperatures observed in trained divers	Recorded in Japanese & Korean diving women (Ama) during winter dives without wet suits
94.0 (34.4)	Memory Deficits, incoordination, confusion; problems with fine motor control	
90.0 (32.2)	Cardiac arrhythmias	May lead to cardiogenic death
86.0 (30.0)	Loss of muscle control, unconsciousness	Possible revivals with rewarming due to "hibernation-like " state
< 86 F°/35 C°	Death	Cessation of cardiac & respiratory activity

The LD_{50} for survival in near freezing water is about 5 minutes

Mechanisms & Methods for Accomodations to Cold Water Immersion

Mechanisms / Methods	Body Form	Peripheral Vasoconstriction	Subcutaneous Fat	Monitoring Respiration	Counter-current Heat Exchange
Physiological / Physical Effects	Reduced surface (extremities) to mass (core) ratios lessens conductive heat losses	Preserves core temperature; limits conductive heat loss from extremities	Improved insulation effect	20 % of insensible heat loss is from breathing; It is increased in SCUBA diving due to increasing densities of the breathing gas with descending	With slowing of blood flow (vasoconstriction), heat in warm core blood is exchanged with cold extremity blood to preserve core temperature
Diving Mammal Adaptations	Tear drop form; minimal core to appendages skin surface area ratios	With apneic dives,, peripheral vasoconstriction stops blood flow to the appendages; stops "radiator-effect" heat losses	Natural occurrence; Enhances propulsion by minimizing swim resistance by conforming to water turbulence patterns ;	Apneic Diving;	Another natural occurrence complimented by the vasoconstriction component of the diving reflex
Human Observations	Propensity for cold water divers to have Sheldon's endomorphic body types	A "natural" reflex in humans, but extremity movement negates effect; conditioning to cold enhances effect	Women have increased subcutaneous fat and this enhances ability to tolerate cold water	Monitoring breathing pattern not only preserves gas supply, but also reduces respiratory heat losses	Not aware of studies of this in humans; but with minimized extremity movements is believed to occur
Human Survival Enhancement	Posture in knee-chest position; huddle with fellow immersion victims	With cold water challenges avoid / minimize extremity movement	Pharmacological gender alterations—not recommended!!!	Avoid "panic" breathing with cold water immersion	Same as for vasoconstriction, slowing blood flow improves heat exchange
Equipment, etc. Modifiers	Increased thermal protection (wet suit thickness) for core vs. extremities	Thermal protection devices; dive planning to minimize extremity movement e.g. diver propulsion units	Neoprene wet suits as a substitute for subcutaneous fat	Rewarming devices for SCUBA regulators; Rebreather equipment, but CO_2 absorption is impaired in cold environments	Same as for vasoconstriction
Comments	"Bulking-up" diets to increase body fat of questionable value; make exposure suit fitting more difficult	For extreme hypothermia extremity tourniquets with serial releases advised to prevent "flooding" warm core blood with cold extremity blood	Food gathering working divers in Japan & Korea (Amas) were females until the advent of neoprene wet suits	"Skip breathing" is not acceptable to conserve gas supply since it may be associated with blackout	Heat exchange is a principle of thermodynamics

The beluga whale with tear-drop body contour, an oily subcutaneous fat layer and large body mass to flipper and fluke exemplifies what the spectators are trying to achieve with their wet suits

Body hair is a good insulator and explains why washing one's hair in cold water is so well tolerated. The polar bear epitomizes the effectiveness of hair as an insulator

Perhaps thin semi-dry suits should be used as the first layer to maintain body heat; then layering insulation (as in cold weather survival) of neoprene

The Japanese & Korean diving women (Ama) have a selective advantage for diving in cold water because of increased naturally occurring subcutaneous fat

Conclusions

Thermal challenges are secondary only to gas supplies for limiting SCUBA diving

Diving mammals have adaptations that compliment the diving reflex and propulsion mechanisms to ensure survival in cold water

Human divers have limited counterparts of the diving mammal adaptations, but most of measures to meet the challenge of cold water are through use of thermal exposure suits and breathing equipment modifications

For survival in accidental cold water immersions, survival techniques are based on the same principles as diving mammals use to mitigate hypothermia