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Effect of Diver Thermal Status on Nitrogen Uptake and Elimination

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Aim: Enhance N2 Elimination

- Breathing oxygen (or oxygen-enriched gas mixtures)

- Boosting blood perfusion by physiological mechanism acting via increased cardiac output and tissue blood flow

- Circulation effects both uptake and elimination

→ Immersion in water

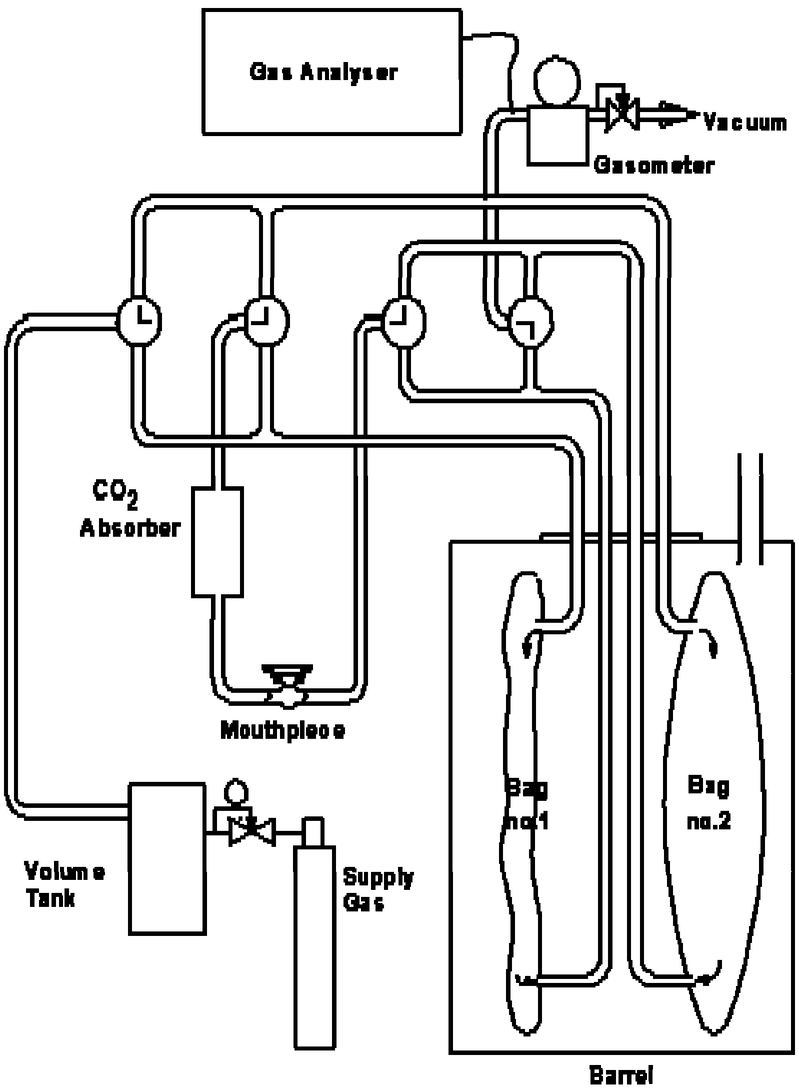
→ Supine or Head-down tilt positions

→ Negative pressure breathing during recumbence

→ Exercise: during decompression does, but pre-dive does not

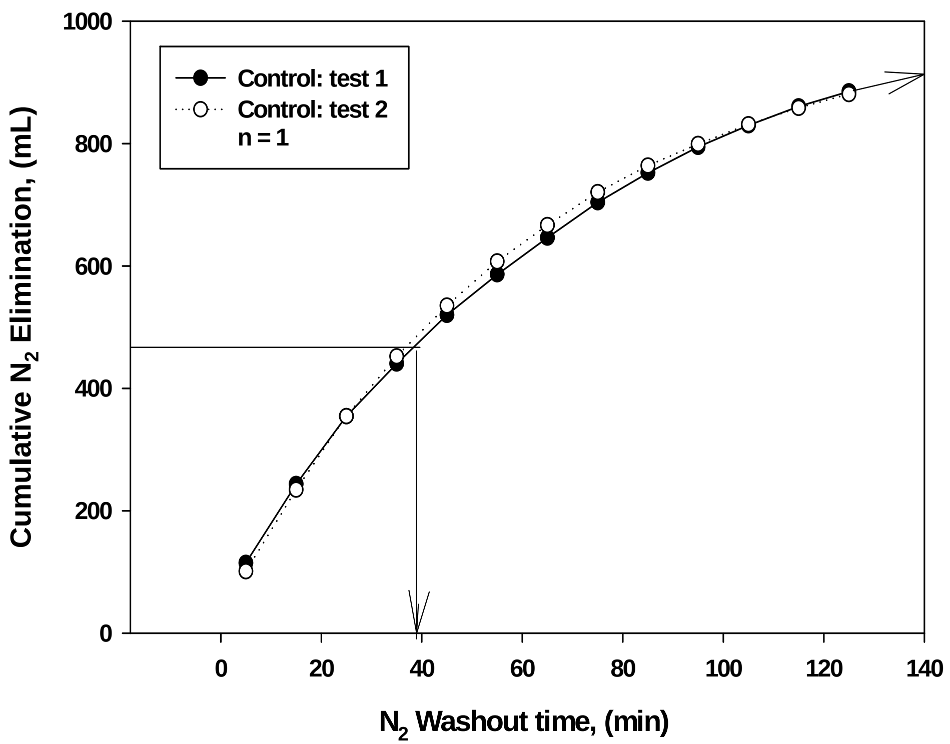
→ Thermal environment

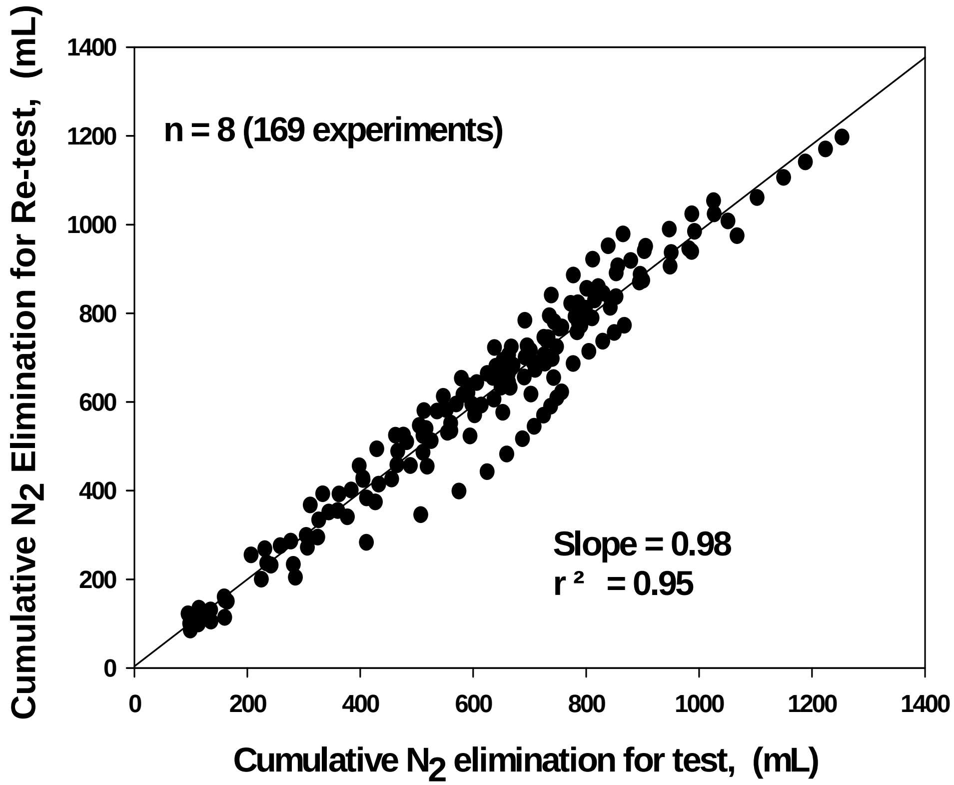
Method: N_2 Washout



- Closed circuit
- Bag-in-Box
- O_2 (21%)/Argon:
  O_2 add system
- CO_2 scrubber
- Subject in tent: Argon to prevent N_2 uptake through skin
- N_2 by Gas Chromatograph
- Vol: wet spirometer
- Collection at 5” and 10” intervals
- First collection is corrected for lung N_2

Validation of N_2 elimination measurements





Calculations: total N_2 elimination and half time calculated from extrapolated total N_2

Inclusion criteria: Exponential rise to asymptote by extrapolation required to agree with total predicted N_2 store based on body mass and composition and solubility coefficients

Method highly reliable based on test-retest data (slope = 0.98)

The present data agree with our previously published data and calculations from estimates of body mass and composition

A novel methodological approach to evaluate fractionated N_2 uptake and elimination

Measurements of whole-body uptake of N_2 have, to our knowledge, not been performed earlier. This is because of the great error inherent in measuring the disappearance (uptake) of a few ml of N_2 per minute from a ventilatory minute volume containing some 6,000-8,000 ml of N_2. The present method circumvents this problem employing the following methodological steps in this study of temperature effects on N_2 exchange:

A novel methodological approach to evaluate fractionated N_2 uptake and elimination

1. Preparatory washout phase: the tissue N_2 is washed out during 2 hrs of oxygen or, in this study, a 21% O2/Ar mixture in thermo-neutral ambient temperature.

2. Loading phase ("field condition": bottom sojourn): directly following (1) fresh air is breathed for 2 hrs in either a thermo-neutral, cool or warm environment.

3. Washout phase ("field condition": decompression or prepa-ration for decom-pression): Immediately following (2) the tissue N_2 is washed out during 2 hrs of breathing oxygen or, in this study, a 21% O2/Ar mixture in a thermo-neutral, cool or warm environment.

Effect of thermal environment

- Divers are exposed to cold and warm water which effects both N_2 uptake and elimination
- CO increases in warm environment and decreases in cold, reflecting changes in peripheral vascular resistance
- Skin and muscle blood flows decrease in cold water and skin blood flow increases in warm water
- Vasoconstriction should decrease N_2 uptake
- Vasodilatation should increase N_2 washout
- Thus, cooling during compression and warming during decompression should reduce uptake and facilitate washout

- Hypothesis is supported by:

  a. Theoretical analysis (Olszowka/Pendergast, 1989)

  b. NEDU study showing less DCS and VGB after a cold-warm dive than cold-cold (Gerth/Rutherbusch/Long, 2007)

Thermal status and N_2 Washout

- **Subjects: n = 8 males**
- **N_2 Washout measured as described above**

- **Protocol:**

	Washout	Wash in	Washout
Gas:	O2/argon	Air	O2/argon
Time:	2hrs	2hrs	2hrs
Temp.	TN	TN	TN
	TN	Cold	Cold
	TN	Cold	Warm
	TN	Warm	Cold
	TN	Warm	Warm

- **Measurements: BP & CO (Finnometer), O2 sat (Nonin), Tskin (thermistor), Tcore (CoreTemp)**

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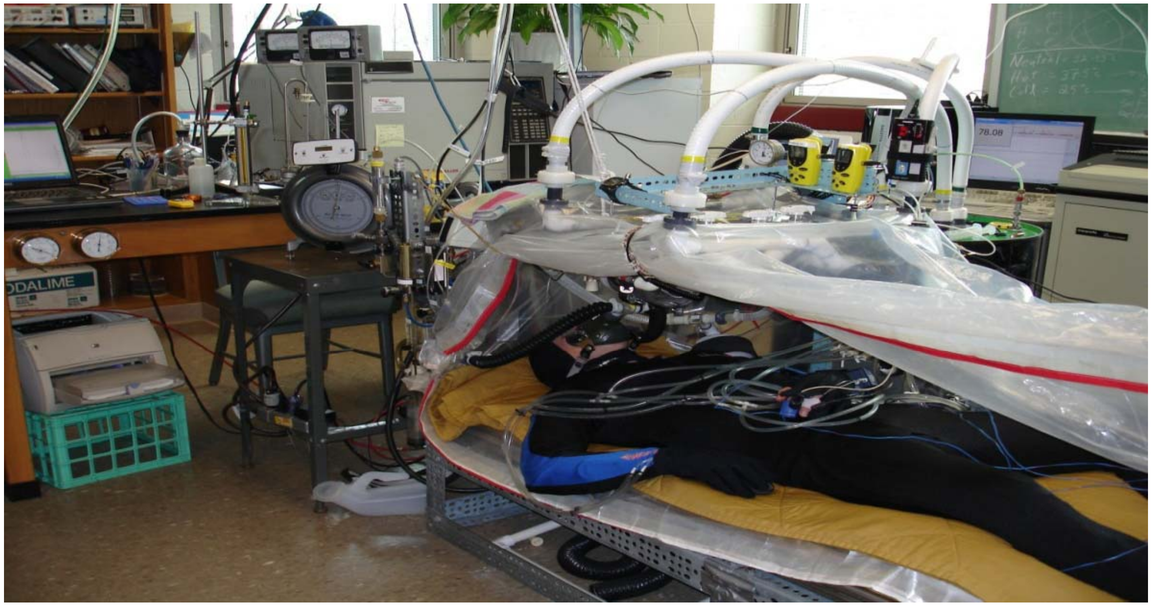
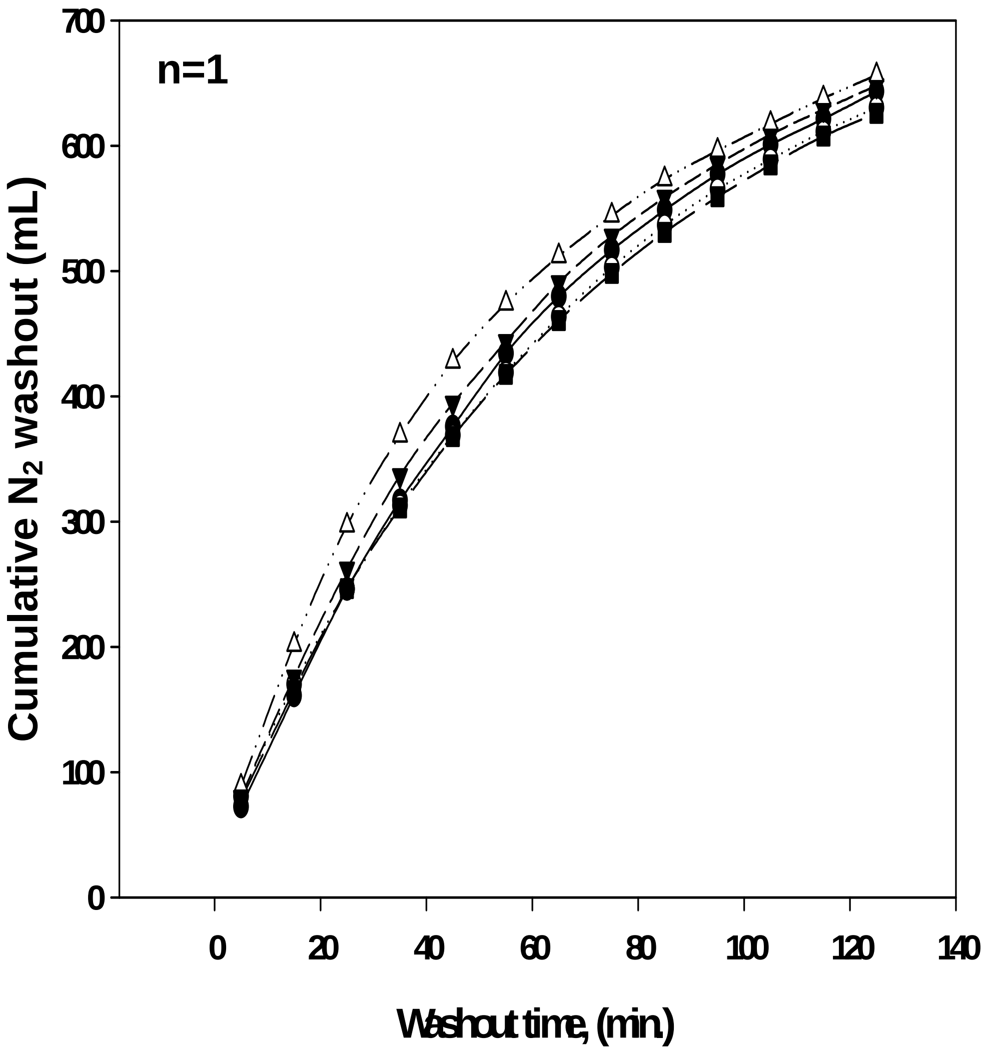
Experimental Setup

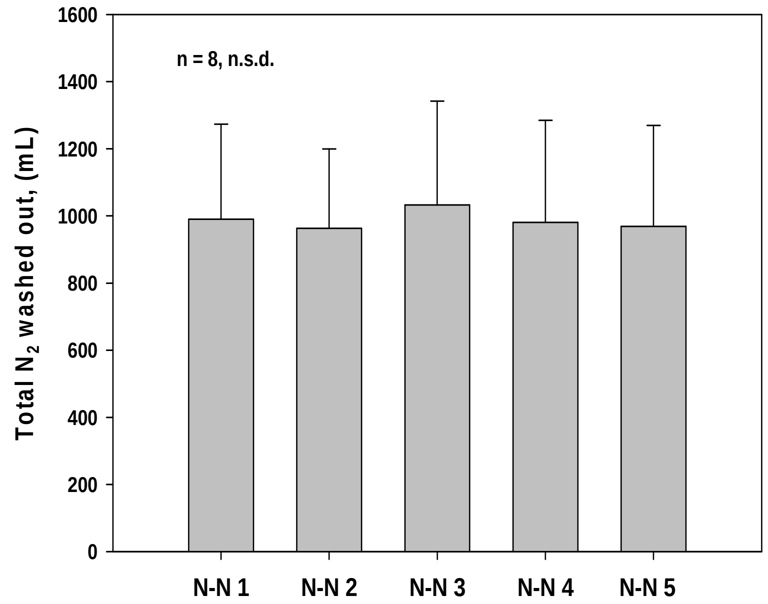
NAVSEA
NAVAL SEA SYSTEMS COMMAND

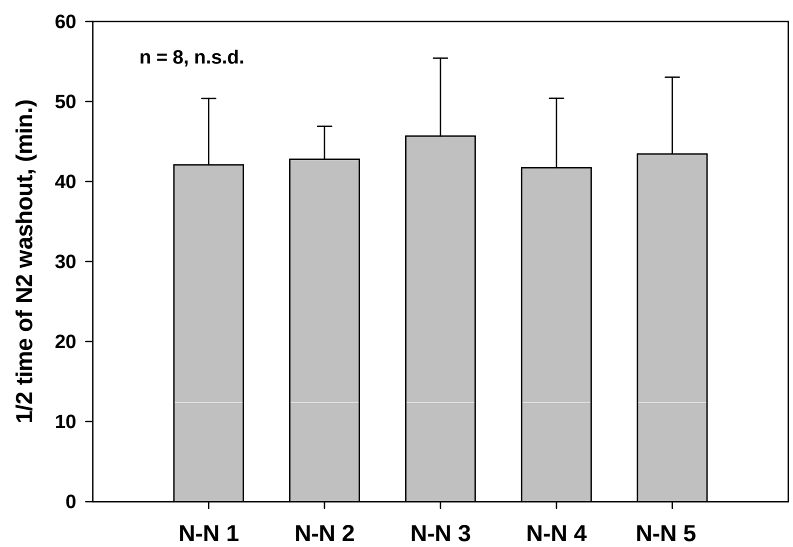


- 6 Heater/chiller units (Julabo) or DTPS with variable set-points perfusing the tube suit
- tube suit with 6 individually perfused zones (head, torso, arms, hands, legs, feet)
- Insulation: thin dive shell

Repeated N_2 washouts in thermally neutral conditions

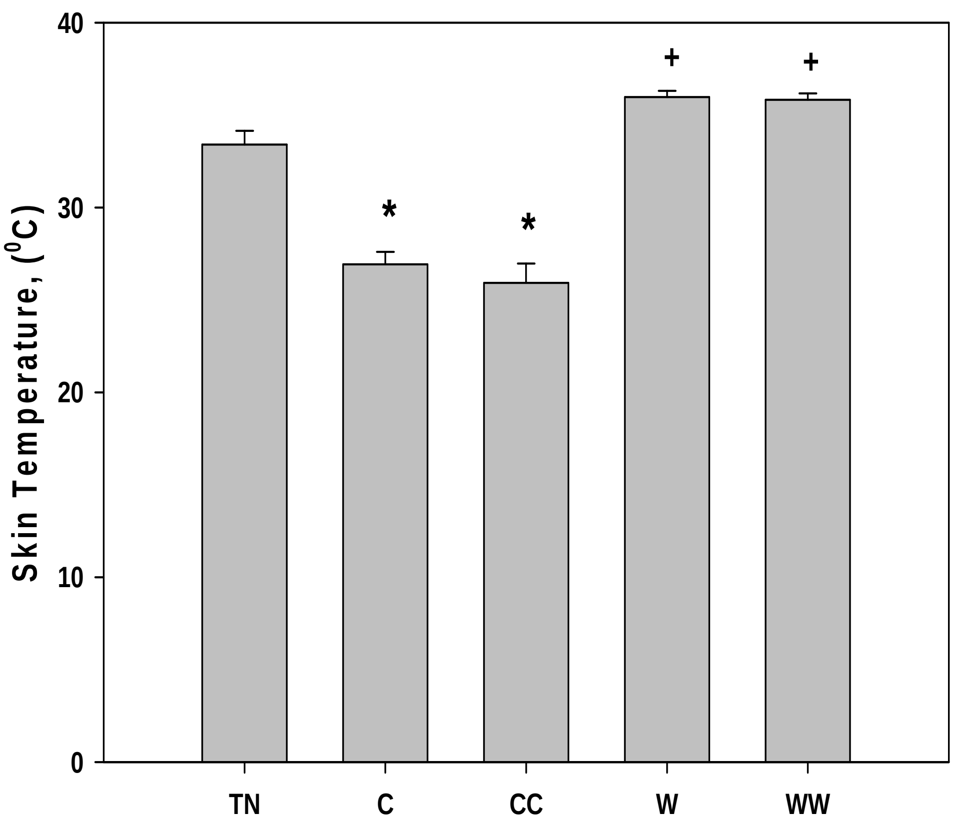




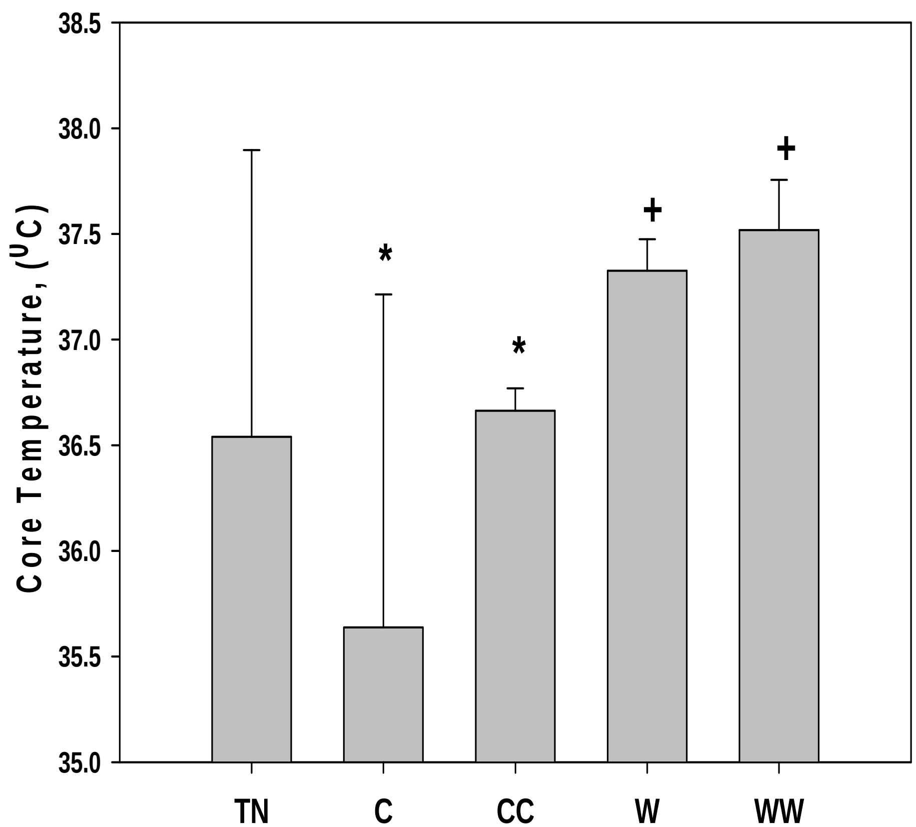


Thermal Conditions

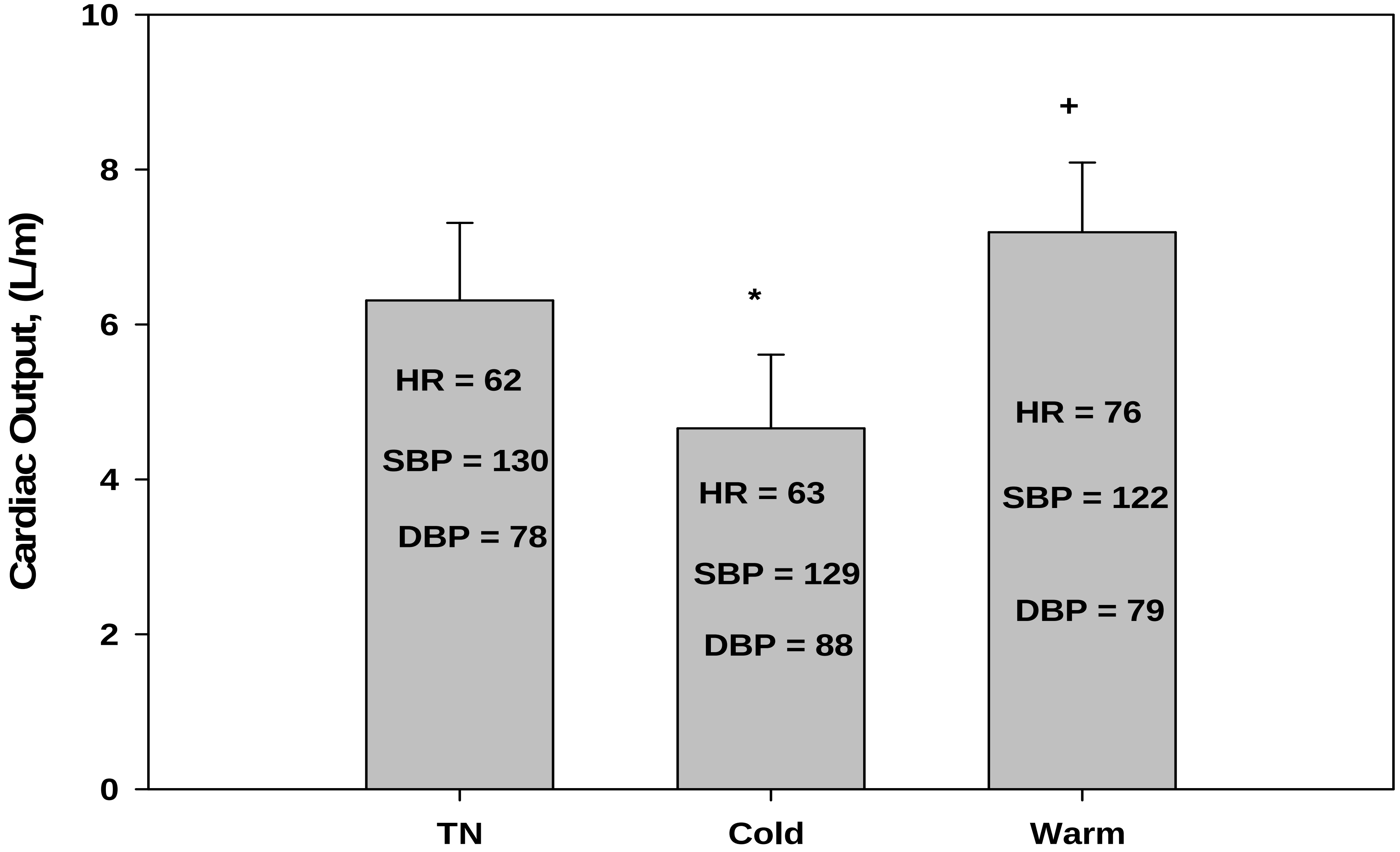
Skin Temperature



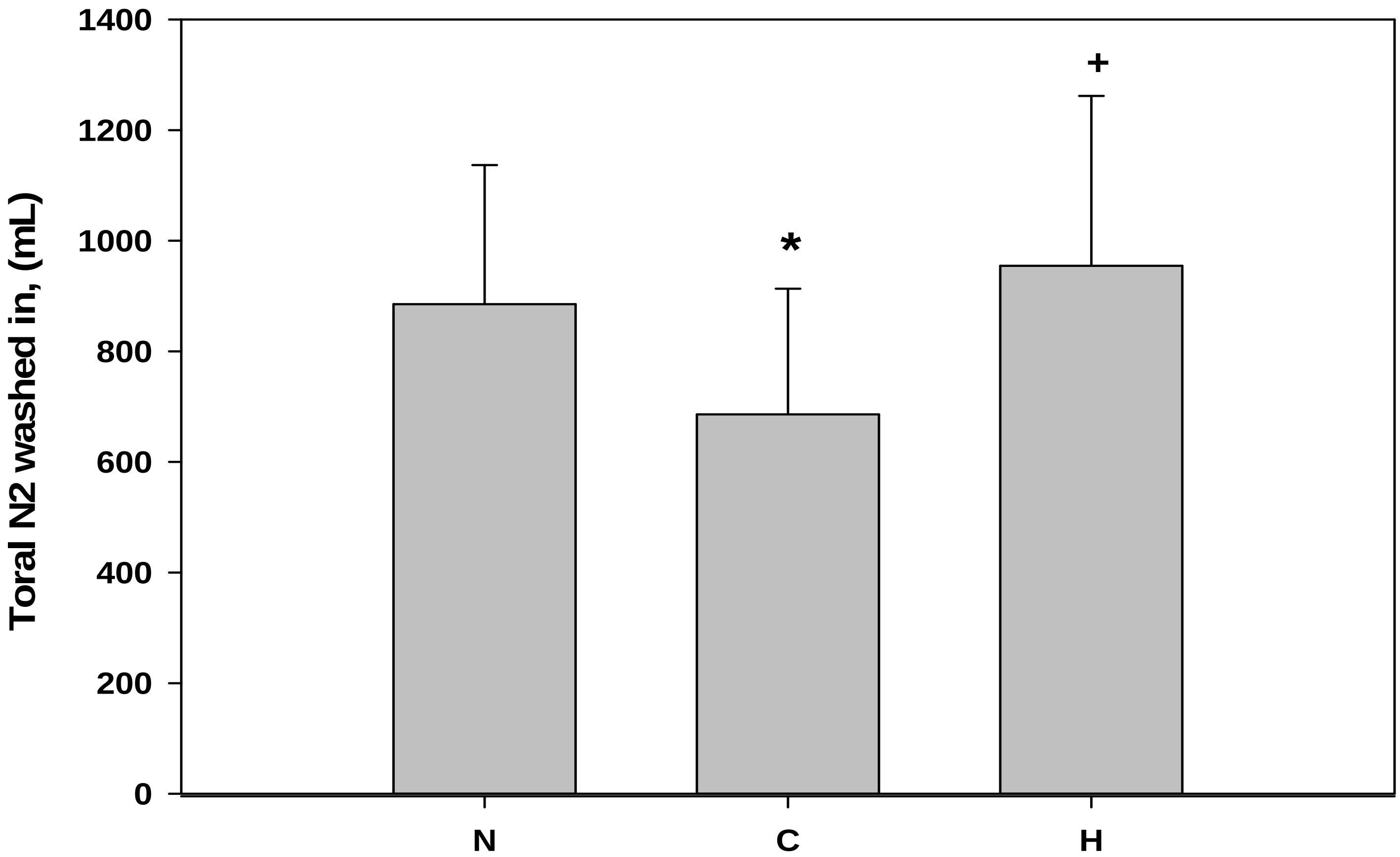
Core Temperature



Physiological Responses

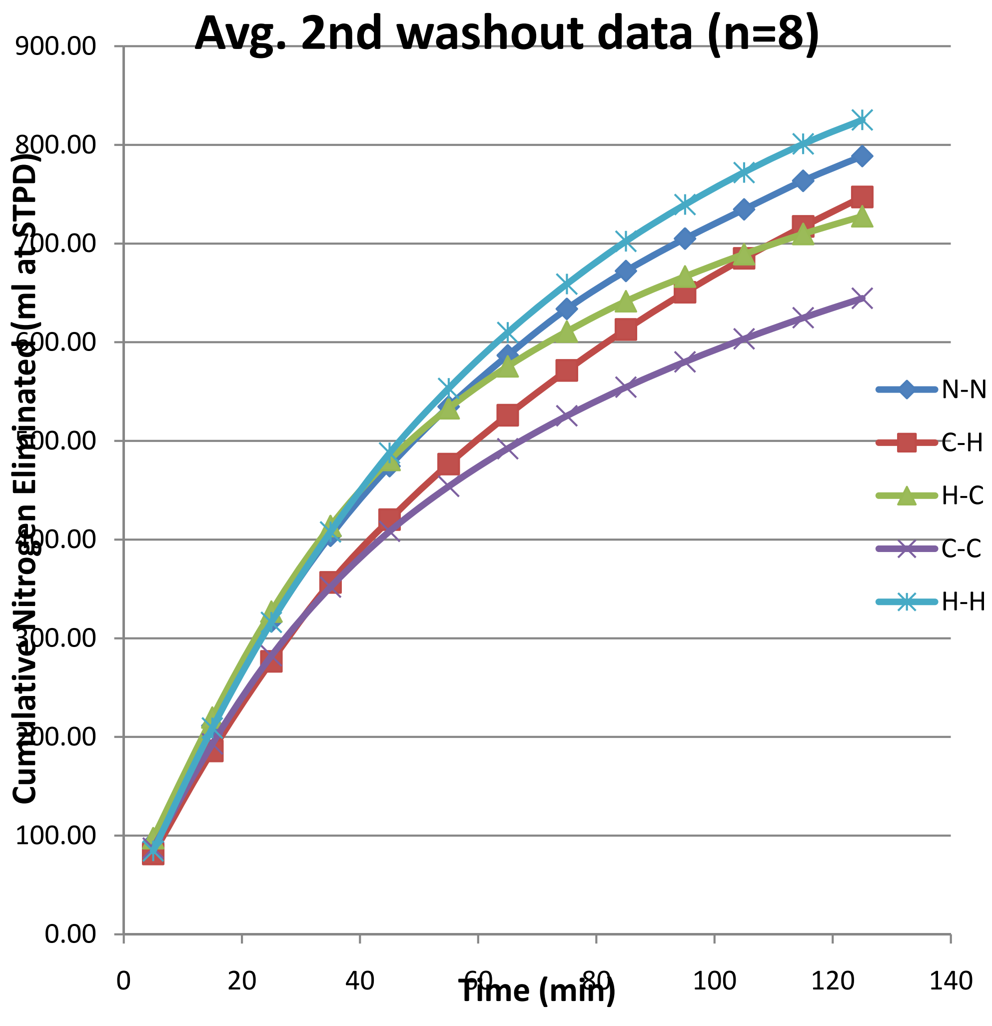


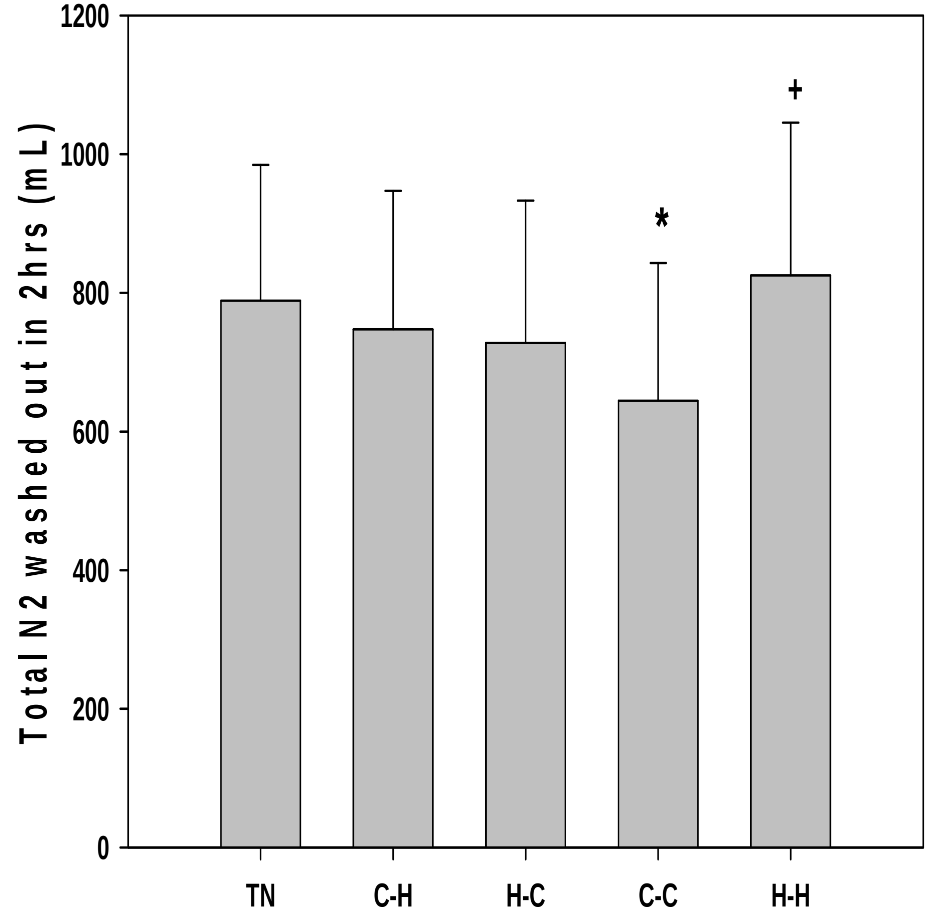
Total N_2 washed in



- 23% less N_2 washed in during cold than when thermally neutral
- 8% more washed in during warm than when thermally neutral

Temperature effect on N_2 elimination





N_2 wash out slower in CC and faster in H-H

Summary

The data from this project demonstrated that:

- Thermal environment effects N_2 uptake/washout: As expected, uptake is less in cool environment and washout is faster in warm, confirming previous theory and NEDU experiments demonstrating less VGB and DCS under similar conditions

- Technology (DTPS) currently exists to keep divers cool at the bottom and warm during in-water decompression