# Aquatic Activity & the Brain

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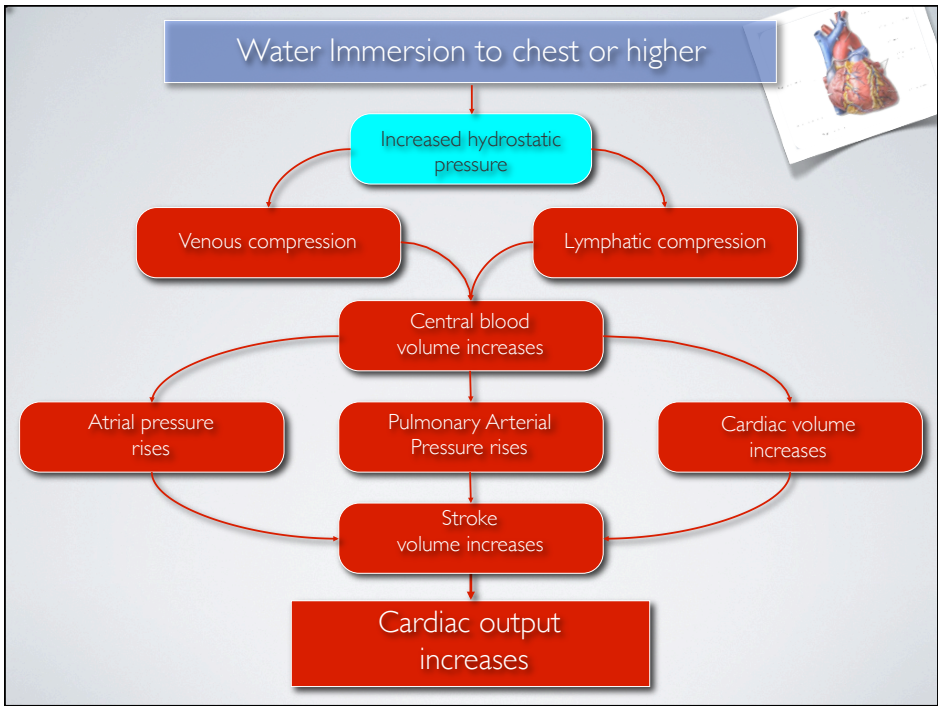
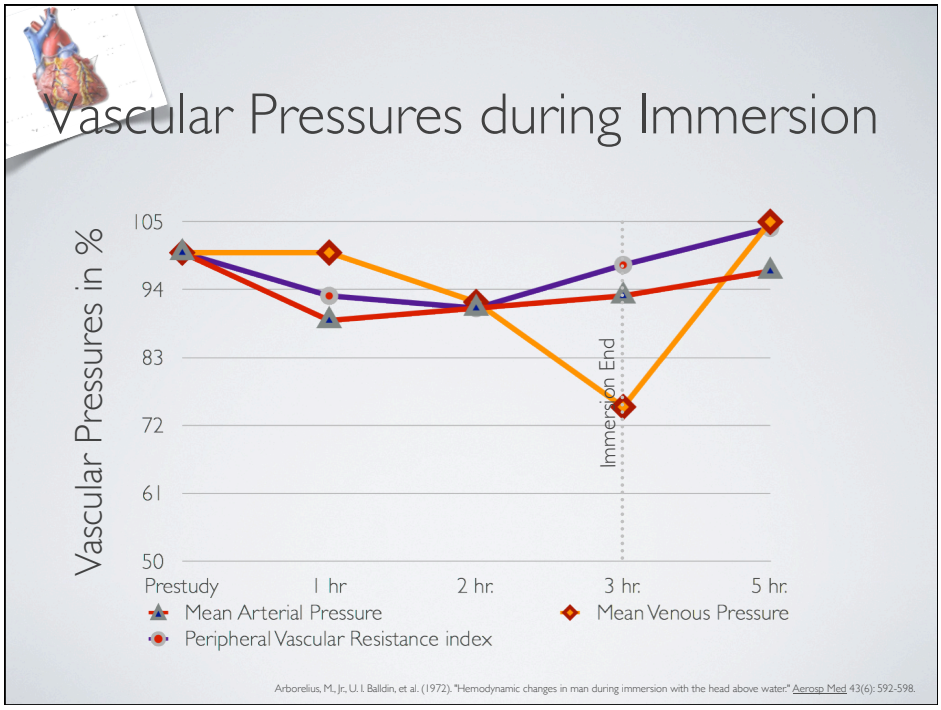
## Aquatic Immersion Creates Important Circulatory Effects

- Hydrostatic pressure forces blood into the central circulation
- That increases the blood volume within the heart
- The heart responds by increasing stroke volume while decreasing heart rate
- Cardiac output increases
- Peripheral blood vessels relax, decreasing blood pressure


Water Immersion to chest or higher
Increased hydrostatic pressure
Venous compression
Lymphatic compression
Central blood volume increases
Atrial pressure rises
Pulmonary Arterial Pressure rises
Cardiac volume increases
Stroke volume increases
Cardiac output increases

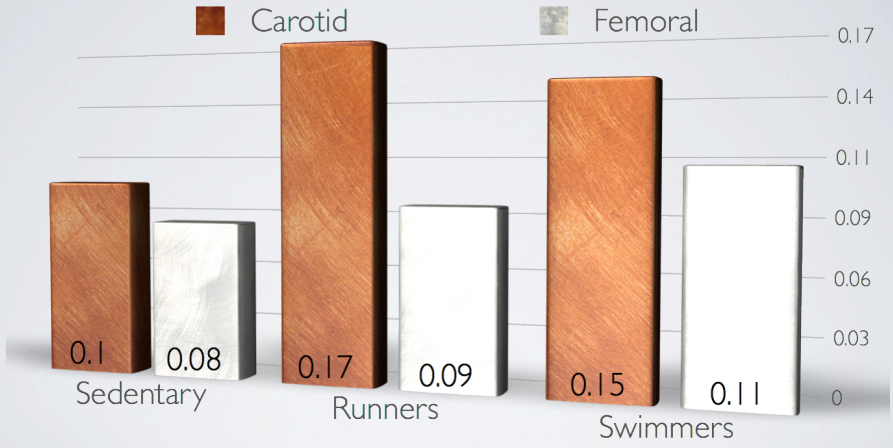

Vascular Pressures during Immersion
Vascular Pressures in %
105
94
83
72
61
50
Immersion End
Prestudy
1 hr
2 hr.
3 hr.
5 hr.
Mean Arterial Pressure
Mean Venous Pressure
Peripheral Vascular Resistance index
Arborelius, M., Jr., U. I. Balldin, et al. (1972). "Hemodynamic changes in man during immersion with the head above water." Aerosp Med 43(6): 592-598.

# Aquatic Exercise and Blood Vessel Compliance

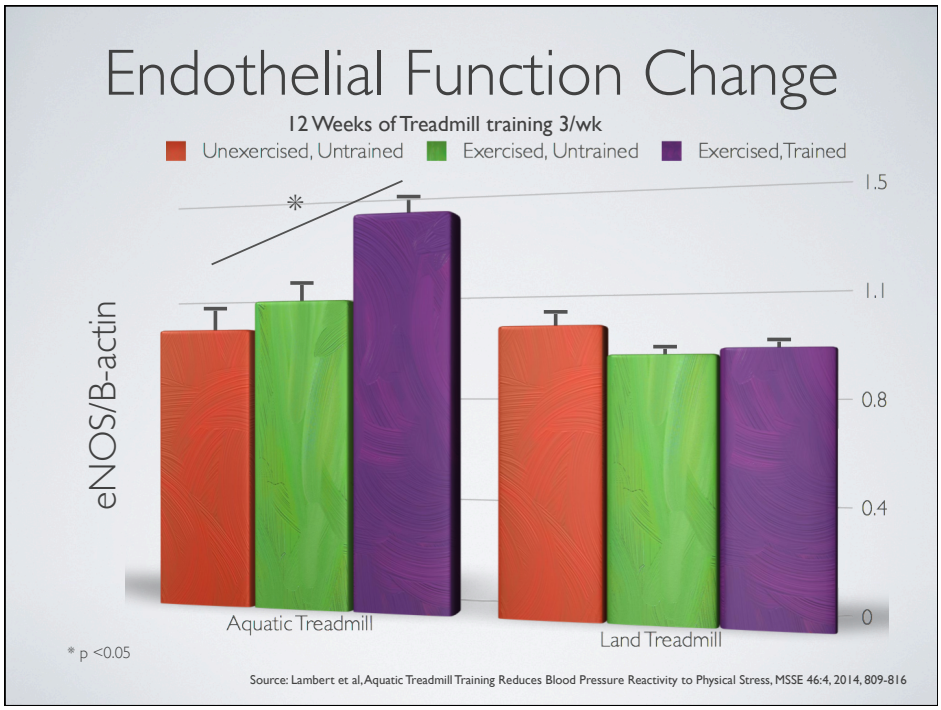
- Aging produces a reduction in arterial vessel elasticity and responsiveness to neural control
- This is a harmful effect, raising blood pressure and reducing circulatory efficiency throughout the body
- Aquatic activity has been shown to increase blood vessel elasticity, increasing circulatory efficiency in both large and small arteries
- Endothelial nitric oxide synthase (eNOS) increases during aquatic exercise, permitting a vasodilatory response from vascular smooth muscle further reducing blood pressure

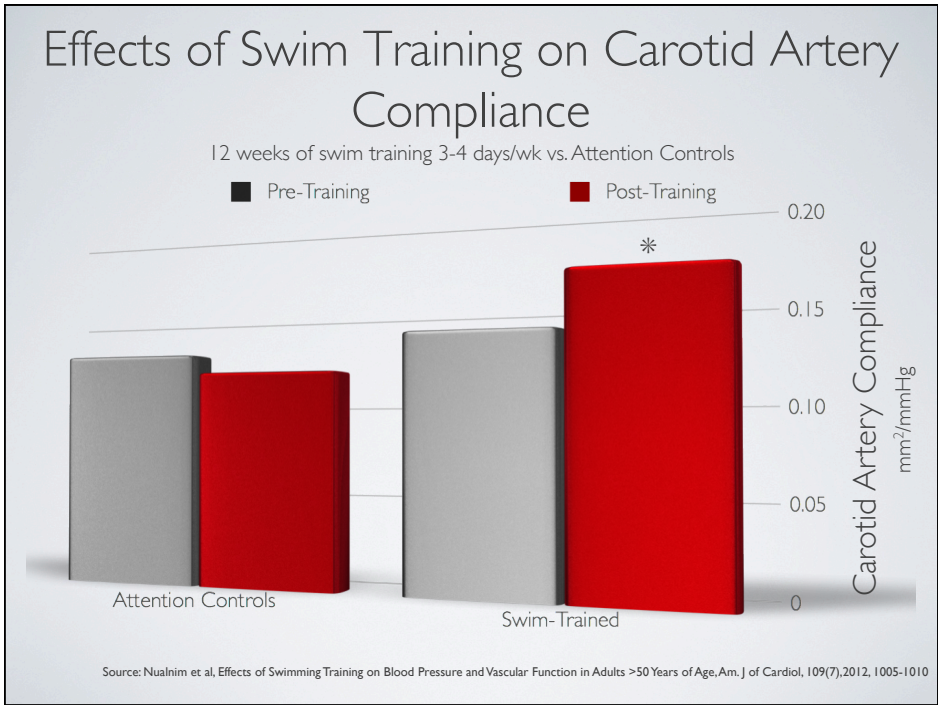
# Arterial Compliance Comparisons

$mm^2/mmHg$




Source: Nualnim N, Barnes JN, Tarumi T, Renzi CP, Tanaka H. Comparison of central artery elasticity in swimmers, runners, and the sedentary. *The American journal of cardiology*. Mar 1 2011;107(5):783-787.


Endothelial Function Change
12 Weeks of Treadmill training 3/wk
Unexercised, Untrained
Exercised, Untrained
Exercised, Trained
eNOS/B-actin
1.5
1.1
0.8
0.4
0
*
Aquatic Treadmill
Land Treadmill
* p <0.05
Source: Lambert et al, Aquatic Treadmill Training Reduces Blood Pressure Reactivity to Physical Stress, MSSE 46:4, 2014, 809-816


Effects of Swim Training on Carotid Artery Compliance
12 weeks of swim training 3-4 days/wk vs. Attention Controls
Pre-Training
Post-Training
Carotid Artery Compliance
mm²/mmHg
0.20
0.15
0.10
0.05
0
*
Attention Controls
Swim-Trained
Source: Nualnim et al, Effects of Swimming Training on Blood Pressure and Vascular Function in Adults >50 Years of Age, Am. J of Cardiol, 109(7), 2012, 1005-1010

# Aquatic Exercise and Blood Pressure

- Because the peripheral blood vessels relax during immersion, blood pressure drops
- Repeated exposure to immersion and exercise has shown a positive effect upon blood pressure in hypertensive individuals
- This effect has been seen with both swimming exercise as with aquatic treadmill exercise
- The elevation in blood pressure during exercise is also lower with aquatic activities

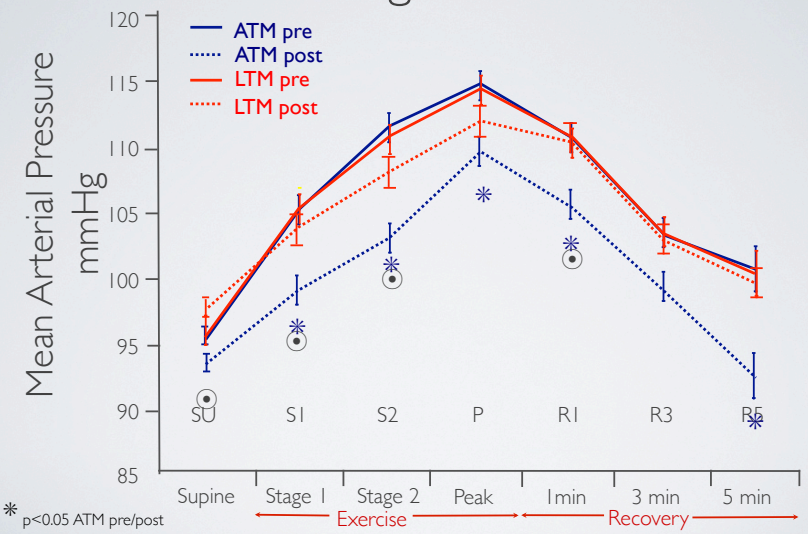
# Effects of Swim Training on Blood Pressure

(mmHg)

12 weeks of swim training 3-4 days/wk vs. Attention Controls


Source: Nualnim et al, Effects of Swimming Training on Blood Pressure and Vascular Function in Adults >50 Years of Age, Am. J of Cardiol, 109(7),2012, 1005-1010

# Aquatic Treadmill Exercise and Exercising Blood Pressure



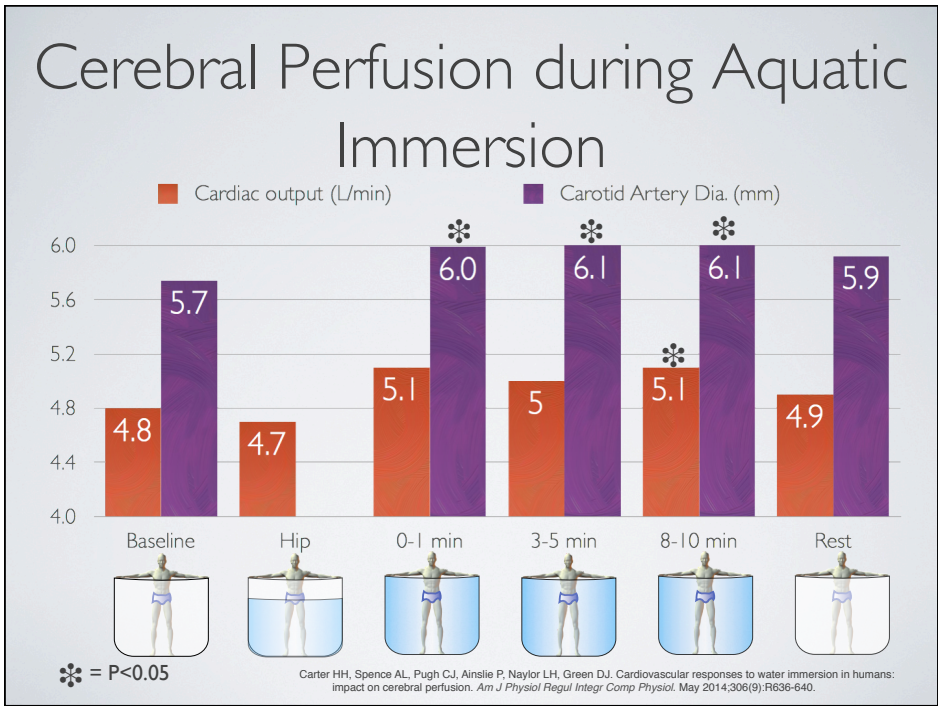

* p<0.05 ATM pre/post

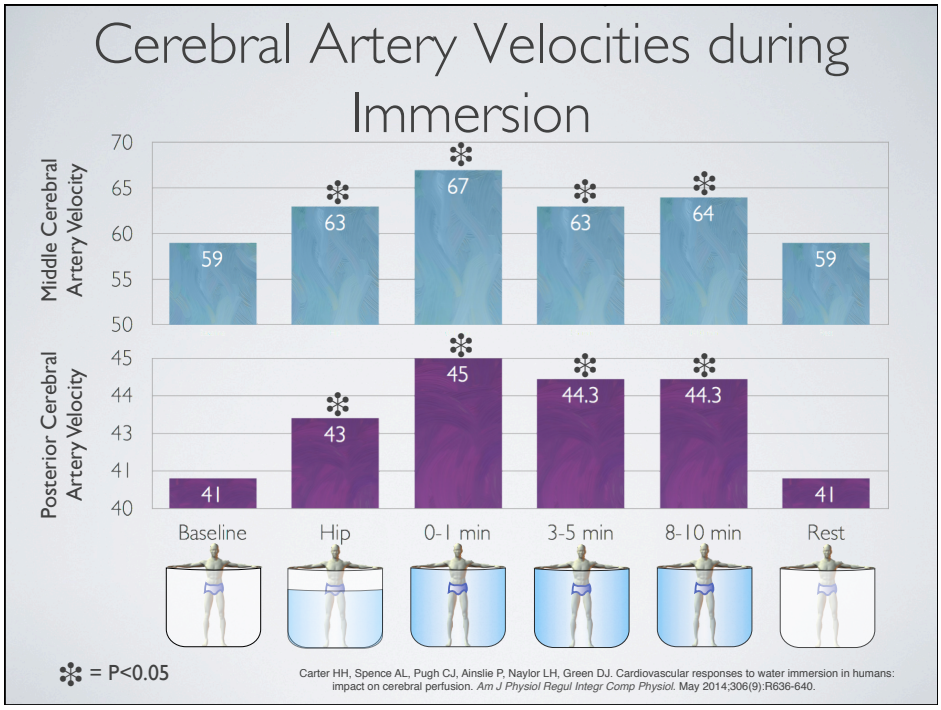
⊙ p<0.05 LTM to ATM

Lambert BS, Greene NP, Carradine AT, et al. Aquatic treadmill training reduces blood pressure reactivity to physical stress. *Med Sci Sports Exerc.* Apr 2014;46(4):809-816.

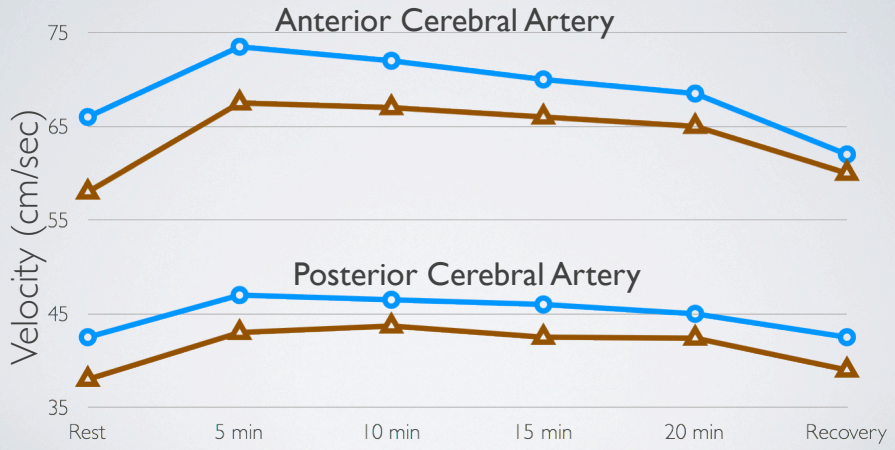
# Aquatic Immersion Impact on Brain Blood Flow

- Aquatic immersion has been shown to positively impact brain blood flow
- Both carotid arterial diameter and blood flow velocity increase during immersion
- Simultaneously, blood flow through both the anterior and posterior cerebral arteries increases significantly, providing a substantially greater blood flow to the brain
- This increase in brain blood flow (averaging +7%) persists during aquatic exercise


Cerebral Perfusion during Aquatic Immersion
Cardiac output (L/min)
Carotid Artery Dia. (mm)
6.0
5.6
5.2
4.8
4.4
4.0
4.8
5.7
4.7
5.1
6.0
5
6.1
5.1
6.1
4.9
5.9
Baseline
Hip
0-1 min
3-5 min
8-10 min
Rest
= P<0.05
Carter HH, Spence AL, Pugh CJ, Ainslie P, Naylor LH, Green DJ. Cardiovascular responses to water immersion in humans: impact on cerebral perfusion. Am J Physiol Regul Integr Comp Physiol. May 2014;306(9):R636-640.


Cerebral Artery Velocities during Immersion
Middle Cerebral Artery Velocity
70
65
60
55
50
59
63
67
63
64
59
Posterior Cerebral Artery Velocity
45
44
43
41
40
41
43
45
44.3
44.3
41
Baseline
Hip
0-1 min
3-5 min
8-10 min
Rest
= P<0.05
Carter HH, Spence AL, Pugh CJ, Ainslie P, Naylor LH, Green DJ. Cardiovascular responses to water immersion in humans: impact on cerebral perfusion. Am J Physiol Regul Integr Comp Physiol. May 2014;306(9):R636-640.

# Cerebral Blood Flow during Aquatic vs. Land Exercise




Pugh CJ, Sprung VS, Ono K, et al. The Effect of Water Immersion during Exercise on Cerebral Blood Flow. *Med Sci Sports Exerc.* Feb 2015;47(2):299-306.

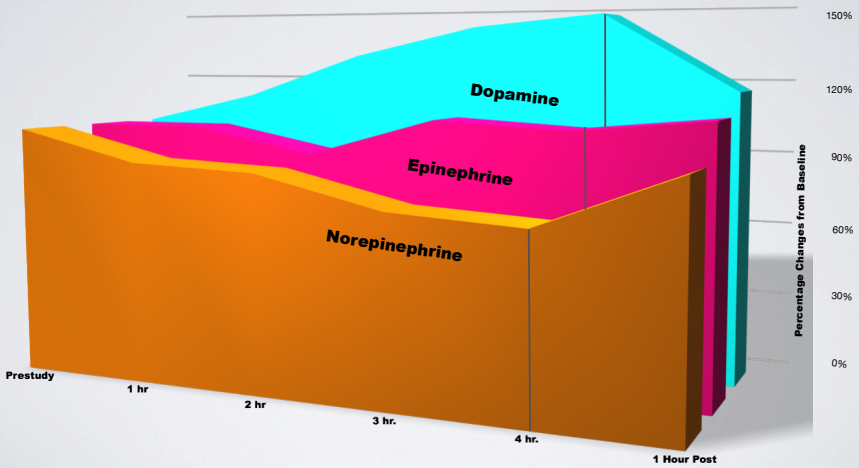
# The Autonomic System

- Is the master control panel for bioregulation and governs all responses to biologic threats
- Regulates essentially all major body functions
  - Cardiac and vascular systems
  - Respiratory
  - Digestive
  - Endocrine
- Functions mainly subconsciously

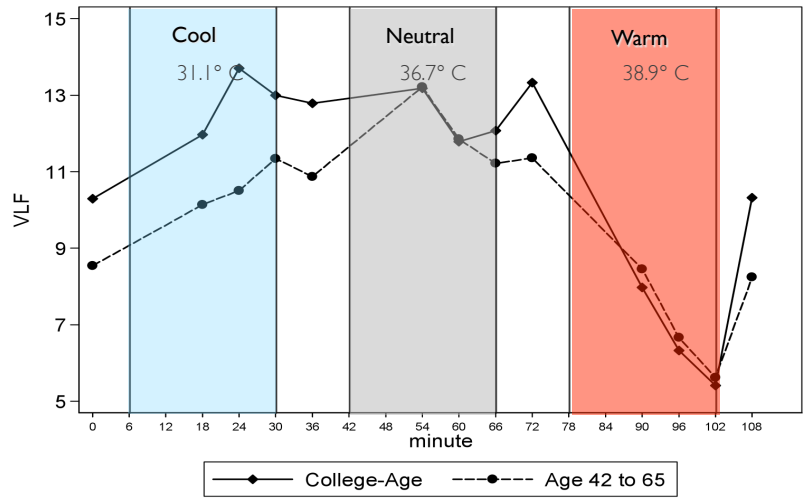
# Autonomic Function & Health

- Autonomic imbalance has been suggested to be the final common pathway in many diseases
- Highly correlated with cardiovascular health
- Associated with diabetes, inflammatory processes, and immune dysfunction
- An increase in parasympathetic tone decreases release of inflammatory cytokines, & increased sympathetic tone increases them

## Catacholamine Changes During Immersion



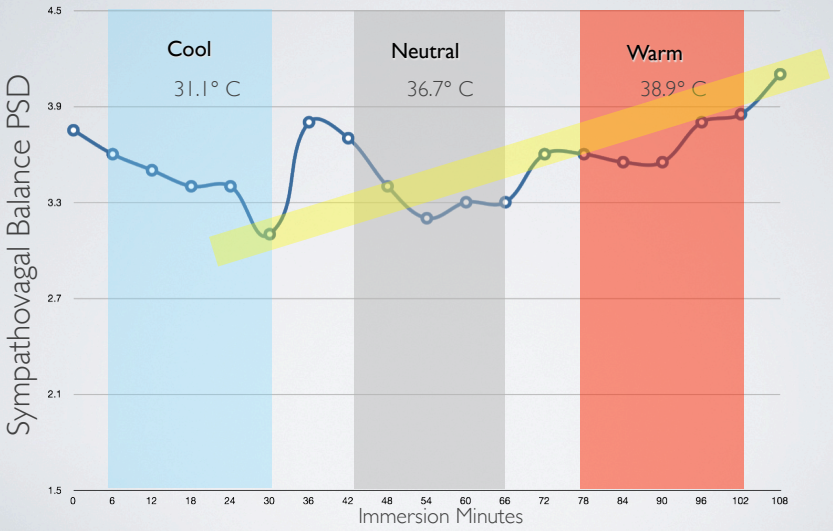
# Sympathetic Nervous System Change by Age Group




Becker BE, Hildenbrand K, Whitcomb RK, Sanders JP. Biophysiologic Effects of Warm Water Immersion. International Journal of Aquatic Research & Education. 2009;3(1):24-37

# Sympathovagal Balance

Average of both young and older subjects over the study interval




Becker BE, Hildenbrand K, Whitcomb RK, Sanders JP. Biophysiologic Effects of Warm Water Immersion. International Journal of Aquatic Research & Education. 2009;3(1):24-37

# Autonomic Nervous System Study Conclusions

- There seems to be a very significant effect of warm water immersion upon the autonomic nervous system
- That effect seems to enhance the balance between parasympathetic and sympathetic components, and is likely one of the major changes that creating the sensation of relaxation in warm water.
- The increase in autonomic balance did not happen in cooler water temperatures
- Sympathetic activation occurred in both cool and neutral temperatures, but not in warm
- The changes noted were quite consistent across all of the subjects tested

Becker BE, Hildenbrand K, Whitcomb RK, Sanders JP. Biophysiologic Effects of Warm Water Immersion. International Journal of Aquatic Research & Education. 2009;3(1):24-37

# Autonomic Nervous System Associations

- **Warm water immersion produces a balancing of the sympathetic and parasympathetic systems**
- This autonomic effect has been associated with
  - Reduction in cardiac irritability
  - Reduction in blood pressure, both systolic & diastolic
  - A decrease in inflammatory processes
  - Anxiety reduction & mental relaxation
  - Improvement in mood state & reduction in mood state disorders
  - Improvement in working memory
  - Increase in cognitive task-performance, creative problem-solving & cognitive flexibility

Aquatic Therapy & Dementia: A Case Report

# The Brain & Aquatic Therapy

- Aquatic immersion increases both the rate and volume of blood flow to the brain
- Aquatic immersion in warm water reduces sympathetic nervous system activity and increases sympathovagal balance
- The combination of these effects may improve brain function, with an increase in working memory, spatioperceptual function and processing speed
- Case reports of improved cognitive function in Alzheimer's disease, and studies in traumatic brain injury, autism and ADHD have shown significant benefits from aquatic immersion with exercise
- More research is badly needed as these effects have profound clinical utility for our field.