Cardiac output increases

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

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


ENDOTHELIAL FUNCTION CHANGE

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

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.

**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 arterial flow velocity (averaging +7%) persists during aquatic exercise.

**Cerebral Perfusion During Aquatic Immersion**

9 male subjects 24 ± 2 yrs age, BMI 25 ± 1.7, water temp 30°C.

Cardiac output (L/min)  
Cardiovascular responses to water immersion in humans.

<table>
<thead>
<tr>
<th>Time</th>
<th>Cardiac Output (L/min)</th>
<th>Carotid Artery Dia. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>4.8</td>
<td>5.1</td>
</tr>
<tr>
<td>0-1 min</td>
<td>4.7</td>
<td>5.1</td>
</tr>
<tr>
<td>3-5 min</td>
<td>5.1</td>
<td>5.1</td>
</tr>
<tr>
<td>8-10 min</td>
<td>4.9</td>
<td>4.9</td>
</tr>
<tr>
<td>Rest</td>
<td>5.9</td>
<td>5.9</td>
</tr>
</tbody>
</table>

*p = P<0.05*
Cerebral Artery Velocities During Immersion

<table>
<thead>
<tr>
<th>Time</th>
<th>Anterior Cerebral Artery</th>
<th>Middle Cerebral Artery</th>
<th>Posterior Cerebral Artery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>59</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>0-1 min</td>
<td>64</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>3-5 min</td>
<td>64</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>8-10 min</td>
<td>63</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>Rest</td>
<td>59</td>
<td>59</td>
<td>59</td>
</tr>
</tbody>
</table>

*P<0.05

Cerebral Blood Flow During Aquatic vs. Land Exercise

Water temp 30°C, 20 min land vs. immersed repetitive stepping exercise @ 100 bpm

Anterior Cerebral Artery

- 45
- 46
- 45
- 44
- 43

Posterior Cerebral Artery

- 45
- 44
- 45
- 43

Immersion Effects on CBF

- Immersion and immersed exercise produces a statistically significant effect upon mean arterial pressure, stroke volume and cardiac output
- These in combination with decreased peripheral resistance act to increase common carotid diameter and carotid flow velocity
- The end result is an increase in blood flow velocity in anterior, middle and posterior cerebral arteries
- Blood flow increases and increased velocity driven shear stress in cerebral arteries act to produce positive endothelial adaptation
- These adaptations may alter eNOS production in endothelium producing increases in vascular compliance, potentially resulting in improved brain health
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

SYMPATHETIC NERVOUS SYSTEM CHANGES BY AGE GROUP

- Chart showing changes in sympathetic nervous system activity across different age groups and body temperatures.
**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.

**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

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**GRAPH:**

- **SYMPATHOVAGAL BALANCE**
  - Average of both young and older subjects over the study interval
  - Immersion Minutes
  - Sympathovagal Balance PSD
  - Cool 31.1°C  N  36.7°C  W  38.9°C
  - Neutral
  - Warm

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**Reference:**

Aquatic Therapy & Dementia: A Case Report

**THE BRAIN & AQUATIC THERAPY**

- Aquatic immersion increases both the rate and volume of blood flow to the brain, increasing oxygen delivery, enhancing cellular repair and regeneration.
- Immersion and aquatic exercise stimulate eNOS production, enhancing vascular compliance and blood flow.
- 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, spatial perceptual function, language skills 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.

**Happy Brains ARE All Wet**