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
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

Vascular Pressures during Immersion

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

12 Weeks of Treadmill training 3/wk
- Unexercised, Untrained
- Exercised, Untrained
- Exercised, Trained

* 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

* 0.20

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

<table>
<thead>
<tr>
<th></th>
<th>Pre-Training</th>
<th>Post-Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swim Systolic</td>
<td>128</td>
<td>98</td>
</tr>
<tr>
<td>Control Systolic</td>
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<td>95</td>
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<tr>
<td>Swim Diastolic</td>
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<td>95</td>
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<tr>
<td>Control Diastolic</td>
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</tbody>
</table>

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

Aquatic Treadmill Exercise and Exercising Blood Pressure


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) and Carotid Artery Dia. (mm)

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Hip</th>
<th>0-1 min</th>
<th>3-5 min</th>
<th>8-10 min</th>
<th>Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac output</td>
<td>4.8</td>
<td>5.1</td>
<td>5.1</td>
<td>5.0</td>
<td>4.9</td>
<td>4.9</td>
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<tr>
<td>Carotid Artery Dia.</td>
<td>5.7</td>
<td>6.0</td>
<td>6.1</td>
<td>6.1</td>
<td>5.9</td>
<td>5.9</td>
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</table>

P<0.05

Cerebral Artery Velocities during Immersion

Middle Cerebral Artery Velocity

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Hip</th>
<th>0-1 min</th>
<th>3-5 min</th>
<th>8-10 min</th>
<th>Rest</th>
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<tbody>
<tr>
<td>Velocity</td>
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<td>63</td>
<td>67</td>
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</table>

Posterior Cerebral Artery Velocity

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<th>Baseline</th>
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<th>3-5 min</th>
<th>8-10 min</th>
<th>Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity</td>
<td>41</td>
<td>43</td>
<td>45</td>
<td>44.3</td>
<td>44.3</td>
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</table>

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Cerebral Blood Flow during Aquatic vs. Land Exercise

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

Catecholamine Changes During Immersion

<table>
<thead>
<tr>
<th>Catecholamine</th>
<th>Percentage Changes from Baseline</th>
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</thead>
<tbody>
<tr>
<td>Norepinephrine</td>
<td>30%</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>60%</td>
</tr>
<tr>
<td>Dopamine</td>
<td>90%</td>
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<tr>
<td></td>
<td>120%</td>
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<tr>
<td></td>
<td>150%</td>
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</tbody>
</table>

Percentage Changes from Baseline
Sympathetic Nervous System Change by Age Group

- Cool: 31.1°C
- Neutral: 36.7°C
- Warm: 38.9°C

Sympathovagal Balance

Average of both young and older subjects over the study interval
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
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.