Aquatic Immersion Effects on the Human Body

Central Nervous System
- Increases autonomic balance
- May increase brain blood flow
- Produces relaxation

Respiratory
- Increases work of breathing
- Allowing strengthening of respiratory musculature

Cardiovascular
- Increases stroke volume and cardiac output
- Reduces circulatory resistance
- Reduces blood pressure

Musculoskeletal
- Increases muscle blood flow
- Offloads bones and joints
- Reduces pain

Renal
- Increases renal blood flow
- Improves renal function
- Facilitates sodium excretion
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
EXERCISE EFFECTS ON THE NERVOUS SYSTEM

- Increases nerve fiber diameter, and cell volume
- Maintains nerve conduction speed
- Boosts dendritic linkage number
- Delays onset of motoneuron aging
- Prevents brain atrophy, especially frontal brain and hippocampus, the areas involved with complex thinking and memory
Why is Exercise So Powerful?

- Exercise promotes production of many biologic factors that are critical to restore and repair the effects of aging and injury.

  - **BDNF** promotes nerve regeneration, brain healing, protection against brain atrophy, and seems to lead to improved cognitive and memory function.

  - **PGC-1α** prevents muscle wasting and protects many cellular repair processes.

  - **IGF-1** protects nerve and muscle cells following injury, like stroke and head injury.

  - **NT3, NT4** stimulate growth and differentiation of many types of neurons and synapses

- We continue to find more and more of these bioprotective factors that are stimulated by exercise.
EXERCISE BIOLOGY

• Each of these factors has a specific role in repairing damage from injury.

• Each also plays a critical role in retarding, or even reversing the effects of aging!

• **Without these biologic factors, Mother Nature allows the body to deteriorate, opening the way for disease and dysfunction, and an ungraceful exit left from the stage of life.**
AQUATIC EXERCISE
UNIQUE BENEFITS OF AQUATIC EXERCISE

• Slows heart rate and improves cardiac efficiency, reducing the work the heart must do to increase circulation

• Decreases blood pressure

• Improves respiratory efficiency facilitating increased oxygen delivery to the tissues

• Increases blood flow to the brain and kidneys

• Reduces blood glucose by increasing muscle blood flow and glucose uptake

• Alters the brain and central nervous system to create a feeling of well-being and relaxation
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 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
**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

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
ARTERIAL COMPLIANCE COMPARISONS

mm²/mmHg

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,

<table>
<thead>
<tr>
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<th>Cardiac output (L/min)</th>
<th>Carotid Artery Dia. (mm)</th>
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<tr>
<td>Baseline</td>
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<tr>
<td>Hip</td>
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<td>5.1</td>
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<tr>
<td>0-1 min</td>
<td>5.1</td>
<td>6.0</td>
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<tr>
<td>3-5 min</td>
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<td>6.1</td>
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<tr>
<td>Rest</td>
<td>4.9</td>
<td>5.9</td>
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* = P<0.05

Cerebral Artery Velocities During Immersion

Middle Cerebral Artery Velocity

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<th>Time</th>
<th>Value</th>
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<tbody>
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<td>Baseline</td>
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<tr>
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Posterior Cerebral Artery Velocity

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<td>44.3</td>
</tr>
<tr>
<td>Rest</td>
<td>41</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

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
What comprises Cognitive Function?

• Executive Functions

  • Cognitive Flexibility (shifting between multiple tasks)

  • Behavioral inhibition (suppression of automatic responses)

  • Updating of working memory (substitution of old with new information)
    • Spatial information
    • Verbal information

• Processing speed
EXERCISE EFFECTS ON COGNITIVE PROCESSING

Colcombe, S. and Kramer AF, Fitness Effects on the Cognitive Function of Older Adults, Psych. Sci, 14:2, Mar 2003, 125-130
EXERCISE EFFECTS ON COGNITIVE PROCESSING

Colcombe, S. and Kramer AF, Fitness Effects on the Cognitive Function of Older Adults, Psych. Sci, 14:2, Mar 2003, 125-130
AQUATIC EXERCISE EFFECT ON CARDIOVASCULAR FITNESS

Non-randomized cohorts, 33 controls vs 27 active, Moderate intensity (60-70% HR$_{max}$) aquaerobic exercise, 6 sequential days, tested 1 week prior to and post intervention. Aquatic group were 15% less active (self-rated) at baseline, with 15% lower 2min step test and 15% higher BMI (30.12 vs 25.81)

AQUATIC EXERCISE EFFECT ON COGNITIVE FUNCTION

Non-randomized cohorts, 33 controls vs 27 active, Moderate intensity (60-70% HR_{max}) aquaerobic exercise, 6 sequential days, tested 1 week prior to and post intervention. Controls were statistically more active at baseline, with 15% higher 2min step test.


\[ * = p < 0.001 \]
Structured Aquatic Exercise Effect on Cognitive Function in Older Adults

Single-blind randomized study of 21 older adults (>69 yrs) following a 10 week 1x/wk exercise, 10 min land warmup followed by 50 minutes of aquatic exercise @ RPE 10-11 on a 6-20 scale

Change in Cognitive Function

- Std. Aquatic Group
- Aquatic Cognitive Group

<table>
<thead>
<tr>
<th></th>
<th>Std. Aquatic Group</th>
<th>Aquatic Cognitive Group</th>
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</thead>
<tbody>
<tr>
<td>Attention</td>
<td>115.7%</td>
<td>110.7%</td>
</tr>
<tr>
<td>Memory</td>
<td>115.4%</td>
<td>121%</td>
</tr>
<tr>
<td>5-Cog Score</td>
<td>104.6%</td>
<td>110%</td>
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**SWIMMING EFFECTS ON COGNITIVE EXECUTIVE FUNCTION MEASURES**

36 seniors (60-75) randomly assigned to a twice weekly 21 wk swimming or stretching program.

- **Stroop Interference Score**
  - Pre-test
  - Mid-study
  - Post-test

* = p<0.05 between cohorts

**Swimming Effects on Cognitive Executive Function Measures**

36 seniors (60-75) randomly assigned to a twice weekly 21 wk swimming or stretching program

- **Pre-test**
- **Mid-study**
- **Post-test**

Verbal Running Span

- 31
- 33
- 35
- 36
- 38

* = p<0.05 between cohorts

AQUATIC EXERCISE EFFECTS IN TBI

Randomized comparative effects of a 10 week 3x/wk 60 min. aquatic exercise program (60-70% HR_{max}) on fitness in moderate chronic TBI (Rancho >6)

* = p<0.05

LAND VS. AQUATIC CYCLING EFFECTS ON BDNF & FUNCTION IN MULTIPLE SCLEROSIS

Randomized comparative effects of a 3 week 5x/wk 30 min. aquatic exercise program (60-70% HR_{max}) on fitness in 60 multiple sclerosis patients

Land Cyclers

Aquatic Cyclers


*B = p<0.05
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 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, and increased sympathetic tone increases them.
SYMPATHETIC SYSTEM

FUNCTIONS

• Up-regulates the body for action
• Increases heart rate and forcefulness
• Constricts blood vessels in gut, but not in muscle, brain and heart
• Increases blood pressure
• Dilates pulmonary bronchioles
• Slows gastric activity
THE PARASYMPATHETIC SYSTEM

- Sometimes called the “rest & digest” or “feed and breed” component
- Slow response system functioning in opposition to the sympathetic system
- Nerve fibers flow from the sacral and cranial nerves (craniosacral outflow)
- Controls salivation, lacrimation, urination, defecation and sexual arousal, but also some brain functions
SYMPATHETIC NERVOUS SYSTEM
CHANGE BY AGE GROUP

SYMPATHOVAGAL BALANCE

Average of both young and older subjects over the study interval

![Chart showing the Sympathovagal Balance with different temperatures: Cool 31.1° C, Neutral 36.7° C, Warm 38.9° C.](chart)

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.
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
SWIMMING EFFECTS ON THE AUTONOMIC NERVOUS SYSTEM

36 seniors (60-75) randomly assigned to a twice weekly 21 wk swimming or stretching program


Heart Rate Variability

* = p<0.05 between cohorts

RMSSD
Sympathetic Power
Vagal Power
Cardiac Vagal Control

Percent Change pre/post

Swimmers
Stretchers

AQUATIC EXERCISE EFFECTS ON PERSONS WITH DEMENTIA

24 residents of memory care facilities assigned to a twice weekly 12 wk aquatic exercise program

PW-BCIP = Psychological Well-Being in Cognitively Impaired Persons
RMBPC BPSD frequency = Revised Memory and Behavior Checklist behavioral and psychological symptoms of dementia
RMBPC (staff reaction to BPSD) = Staff reaction to behavioral and psychological symptoms of dementia

*N* = *p*<0.05

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, spatioperceptual 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