Aquatic exercise and therapy in injury prevention and rehabilitation

Ben Waller PT, MSc
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Contents

- What is injury prevention and it’s benefits?
- Examples of aquatic exercises as an alternative training load (Primary injury prevention)
  - Deep water training
  - Shallow water training
  - Skill learning
  - Recovery
- Aquatic rehabilitation (secondary injury prevention)
  - Why aquatic exercises
  - When
  - How
  - Progression from water to land
- Re-injury and aquatic exercises (Tertiary injury prevention)
Who am I?

- Graduated from Brighton University 2001, BSc (Hons) physiotherapy.
- Moved to Finland in 2003.
- Established aquatic therapy service in a sports clinic in Jyväskylä.
- Graduated with Msc (health Sciences) 2010
  - Retrospective Injury profiling in Finnish swimming
- Started PhD in January 2012 – Aquatic exercise and OA
- Worked as a physiotherapist for Swimming Jyväskylä and Finnish Swimming Federation.
- Involved in a number of international aquatic therapy projects.
Types of injury prevention

- **Primary**
  - Before the injury/disease and includes health promotion and injury prevention, e.g. use of ankle brace by entire football team, muscle balance testing.

- **Secondary**
  - Preventing further injury or progression of disease and includes early diagnosis and treatment, e.g. RICE, exercise in diabetes.

- **Tertiary**
  - Occurs after treatment (referred to usually as rehabilitation) and includes methods to prevent re-injury, e.g. balance board exercise and gradual return to sport after MCL injury.
Comprehensive Model for Injury Causation

**Internal Risk Factors**
- Age (maturation, aging)
- Gender
- Body composition (e.g. body weight, BMI¹, fat mass, height)
- Health (e.g. history of previous injury, joint instability)
- Physical fitness (e.g. muscle strength/power, maximal O2 uptake, joint ROM²)
- Anatomy (e.g. alignment, intercondylar notch width)
- Skill level (e.g. sport-specific technique, postural stability)

**Exposure to external risk factors:**
- Human factors (e.g. teammates, opponents, referee)
- Protective equipment (e.g. helmet, shin guards)
- Sports equipment (e.g. skis)
- Environment (e.g. weather, snow and ice conditions, floor and turf type, maintenance)

**Inciting event:**
- Playing situation
- Player/opponent 'behavior'
- Gross biomechanical description
- Detailed biomechanical description

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¹ Body Mass Index
² Range of motion

**Predisposed athlete** ➔ **Susceptible athlete** ➔ **INJURY**

Bahr and Krosshaug, Br J Sports Med, 2005
Internal risk factors

An internal risk factor is within the body

Potentially modifiable
  – Fitness level
  – Skill level
  – Training structure
  – Flexibility
  – Strength
  – Joint Stability

Non-modifiable
  – age,
  – gender,
  – previous injury
External risk factors

An External risk factor is found outside of the body

Potentially modifiable
– Rules
– Playing time
– Playing surface
– Equipment
– Environment

Non-modifiable
– Sport (contact/non-contact)
– Level of participation
– Positioned played
– Weather
– Season structure
Inciting events

- Often referred to at injury mechanism
- Playing situation
  - Change of direction, non-contact
- Player/opponent ‘behavior’
  - Contact, tackle situation
- Biomechanics
  - Each sport and injury type have their own typical patterns, biomechanics and mechanism.

For overuse injuries, the inciting event is usually distant from the outcome
What the model does not include:
Season structure and training demands

- Change of season e.g. indoor to outdoor, change of surface.
- Transition periods, e.g. from a period of low to high volume and intensity, vice versa.
- Training camps and tournaments (intensive periods without adequate recovery)
- Start of competitive season, increase demand often combined with environmental factors such as education demands
- Competitive season
- Transition from amateur to professional or professional to amateur
- Transition between training groups
What is water???
Deep water training options
Deep water training

Mainly:
- Aerobic
- Aerobic power
- Co-ordination

Training options
- Deep water running
- Swimming
Increased hydrostatic pressure

Venous compression

Lymphatic compression

Central venous blood increases (700ml)

Atrial pressure rises

Pulmonary artery pressure increases

Cardiac volume increases

Stroke volume increases

Cardiac output increases

Water immersion to chest or higher

Cole and Becker 2003
Head-out water immersion

↓ Central blood volume

↑ Pulmonary vessel fill

↓ Diffusion capacity

↓ Efficiency

SI ↓ PO2

↑ Work Of breathing 60%

↑ Chest wall pressure

↓ Chest circumference

↑ Airway resistance

↓ Expiratory flow rate

↓ Pulmonary compliance

↑ Abdominal compression

↑ Diaphragm height

↓ Lung volume and VC

Cole and Becker 2003
Measuring training intensity

Options

– Perceived rate of exertion (Borg 6-20 or similar)
– Average and maximum heart rates
– VO2 consumption
– Blood lactates
– Accelerometers
– EMG

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Biophysical response to Aquatic training compared to land (Denning et al 2012)

- **VO2 consumption**
  - 10-27% lower in DW running
  - 10-16% lower in SW exercise
  - Conflicting data for water calisthenics, difficult to control
  - Conflicting also for underwater treadmill, dependent of depth, speed and water jet strength, easiest to control

- **Heart Rate**
  - 15% lower in DW running than land based running
  - SW produces higher HR compared to DW
  - Conflicting data for water calisthenics, difficult to control
  - When set at similar levels of V02 consumption HR during underwater treadmill running HR is comparable to land.

- **Rating of Perceived exertion**
  - At maximal effort RPE is similar during DW than land,
  - At set levels of HR RPE was higher during DW
  - Limited data for water calisthenics
  - RPE higher at set levels of V02 max during underwater treadmill running although dependent on depth.

- **Blood lactates**
  - Lower or similar when comparing maximal VO2 effort to DW running (Brennan & Wilder 2011)
  - Blood Lactates similar post maximal effort on underwater treadmill (Silvers et al 2007)
Dee Water Running

- Cardiovascular fitness is maintained in runners using deep water running over 3-6 weeks

- There is limited evidence to suggest DWR can increase fitness in trained individuals

- Structure should be identical to land training i.e. HIIT or long interval depending on goals
## Brennan Scale of Perceived exertion and Cadence values for Aqua Jogging

<table>
<thead>
<tr>
<th>Level</th>
<th>RPE</th>
<th>CPM*</th>
<th>Land Equivalent</th>
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<td></td>
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<tr>
<td>Very light</td>
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<tr>
<td>1</td>
<td>1.0</td>
<td>&lt;55</td>
<td>recovery jog</td>
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<td></td>
<td>1.5</td>
<td>55-59</td>
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<tr>
<td>2</td>
<td>Light</td>
<td></td>
<td>Easy run</td>
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<td></td>
<td>2.0</td>
<td>60-64</td>
<td></td>
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<tr>
<td></td>
<td>2.0</td>
<td>65-69</td>
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<td>3</td>
<td>Somewhat hard</td>
<td></td>
<td>Brisk run</td>
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<td>3.0</td>
<td>70-74</td>
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<td>3.5</td>
<td>75-79</td>
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<td>4</td>
<td>Hard</td>
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<td>4.0</td>
<td>80-84</td>
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<td>Very Hard</td>
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<td>Short track intervals</td>
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<td>5.0</td>
<td>&gt;90</td>
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</table>

* Cycles Per Minute
Shallow water training options
Shallow water training

Training options

- Shallow water running/walking
- Aquatic treadmill walking
- Aquatic Bikes
- Strength exercises
- Plyometrics
- Balance/proprioception
Usein Bolt Pre 2012 olympics (2011)

https://www.youtube.com/watch?v=gX2YjmMN7mg
Main points about shallow water running (SWR)

- Biomechanics closer to land than DWR
- Aquatic treadmill running closer to land than SWR
- Variable resistance
  - ↓ depth = ↑ resistance
  - ↓ depth = ↑ impact
- Stride length ↓ as stride frequency ↑ (opposite to land)
Aquatic plyometric training

Donoghue et al (2011) Compared 5 different jumps Significant reductions were observed in:
- peak impact forces (33%-54%)
- impulse (19%-54%)
- rate of force development (33%-62%) in water compared with land
- However great individual variability in all parameters

- Peak concentric force and rate of force development was higher in aquatic group
- Significantly less impact force in aquatic group

Arazi and Asadi 2011
Donoghue et al, Sports health 2011
Aquatic plyometric training (Level 2)

- Plyometric exercise increases:
  - Sprint time, agility, strength (Robinson et al., 2004, Gulick et al., 2007, Arazi and Asadi, 2011)
  - Vertical jump (Robinson et al., 2004, Gulick et al., 2007, Stemm and Jacobson 2007)
  - Less muscle soreness compared to land plyometrics (Robinson et al., 2004)

- Similar outcomes to land-based plyometric exercises
- Aquatic plyometric training is useful when wanting to improve power and muscle torque while minimizing muscle soreness.
- Improvement are seen in athletes and non-athletes
Differences between land, aquatic and aquatic with resistance

Ground reaction force during land and aquatic counter movement jumps.

Donoghue et al, Sports health 2011

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### Example of plyometric exercises in water

<table>
<thead>
<tr>
<th>week</th>
<th>volume</th>
<th>Training</th>
<th>sets</th>
<th>intensity</th>
<th>whole week volume</th>
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<td>2 x 15</td>
<td>low</td>
<td>180</td>
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<tr>
<td></td>
<td></td>
<td>standing jump and reach</td>
<td>2 x 15</td>
<td>low</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>front cone hops</td>
<td>6 x 5</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>120</td>
<td>side-to-side ankle hops</td>
<td>2 x 15</td>
<td>low</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td></td>
<td>standing long jump</td>
<td>2 x 15</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>lateral jump over barrier</td>
<td>6 x 5</td>
<td>medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>double leg hops</td>
<td>10 x 3</td>
<td>medium</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>120</td>
<td>side-to-side ankle hops</td>
<td>2 x 12</td>
<td>low</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td></td>
<td>standing long jump</td>
<td>2 x 12</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>lateral jump over barrier</td>
<td>6 x 4</td>
<td>medium</td>
<td></td>
</tr>
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<td></td>
<td>double leg hops</td>
<td>8 x 3</td>
<td>medium</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td>lateral cone hops</td>
<td>2 x 12</td>
<td>medium</td>
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</tr>
<tr>
<td>4</td>
<td>140</td>
<td>single leg bounding</td>
<td>2 x 12</td>
<td>high</td>
<td>280</td>
</tr>
<tr>
<td></td>
<td></td>
<td>standing long jump</td>
<td>3 x 10</td>
<td>low</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>lateral jump over barrier</td>
<td>8 x 4</td>
<td>medium</td>
<td></td>
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<tr>
<td></td>
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<td>lateral cone hops</td>
<td>3 x 10</td>
<td>medium</td>
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<tr>
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<td></td>
<td>Tuck jump with knees up</td>
<td>4 x 6</td>
<td>medium</td>
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<tr>
<td>5</td>
<td>140</td>
<td>single leg bounding</td>
<td>2 x 10</td>
<td>high</td>
<td>280</td>
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<tr>
<td></td>
<td></td>
<td>jump to box</td>
<td>2 x 10</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>double leg hops</td>
<td>6 x 3</td>
<td>medium</td>
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<td>lateral cone hops</td>
<td>2 x 12</td>
<td>medium</td>
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<tr>
<td></td>
<td></td>
<td>Tuck jump with knees up</td>
<td>6 x 5</td>
<td>high</td>
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<td></td>
<td></td>
<td>lateral jump over barrier</td>
<td>3 x 10</td>
<td>high</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>120</td>
<td>jump to box</td>
<td>2 x 10</td>
<td>low</td>
<td>240</td>
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<tr>
<td></td>
<td></td>
<td>depth jump to prescribed height</td>
<td>4 x 5</td>
<td>medium</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>double leg hops</td>
<td>6 x 3</td>
<td>medium</td>
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<td></td>
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<td>lateral cone hops</td>
<td>2 x 10</td>
<td>medium</td>
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<tr>
<td></td>
<td></td>
<td>Tuck jump with knees up</td>
<td>4 x 5</td>
<td>high</td>
<td></td>
</tr>
</tbody>
</table>

(Ploeg et al 2010)  
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Strength/power Training

Methods for progressing aquatic strength training
- Buoyancy assisted/resisted
- Increase in speed of motion
- Change in direction of motion (curvilinear)
- Increase surface area

Hydrodynamic properties of viscosity, drag and turbulence combine to provide a unique gymnasium for the progressive strengthening of both individual muscles and functional movements
"Drag show"

Drag force, \( F_d = \frac{1}{2} \rho A v^2 Cd \)

P = density of fluid
A = surface area
V = Angular velocity
Cd = Coefficient of drag

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Significance of additional resistance

(Pöyhönen et al 2001)
Aquatic Exercises

- 16 weeks
  - 3 x 1 hours training sessions per week
  - 30 minutes of high intensive interval training per session

30-45 seconds per leg plus 30-45 seconds rest

**AS HARD AND FAST AS POSSIBLE**

1. Hip adduction/abduction
2. Seated knee flexion/extension
3. Standing knee flexion/extension
4. Hip flexion/extension with knee remaining in full extension
5. Kickback (reverse lunge)
Balance and Proprioception

- Postural muscle activation in water and dry land occurred similarly in standing and sitting but not in floating. There needs to have some element of gravity in the balance exercises (Dietz and Colombo 1996).

- Balance reactions can be effectively performed in water as well as land. There were similar improvements between land and aquatic exercises however in water reaction size were smaller (EMG) and slower (Roth et al 2006).
Balance and Proprioception

- Athlete can safely fall

- Can be in deep water but has significant decrease in sensory input

- Hydrostatic pressure and buoyancy help to maintain postures previously difficult to achieve due to the effects of gravity.

- Increase in activity of sensory receptors, particularly baroreceptors in skin

- Posture control is more difficult in deeper water. Reduction in afferent feedback from muscle spindles, golgi tendon organs and joint pressure proprioceptors.
Bouyancy: Metacentric effect

Stable: centre of gravity and buoyancy on top of each other

Stable: centre gravity and buoyancy closer together assisting horizontal stability

Centre of gravity and buoyancy further apart together, producing torque (rotation) in both sagittal and coronal planes.
Example progression: Position and changes are infinite!

TRC – Short lever (wrist flexion)

TRC – Long lever (shoulder flexion)

CRC – Shoulder flexion followed by horizontal Abduction

Physiotools
(http://www.physiotools.com/products/aquatic-therapy)
Skill acquisition and functional training

These can be initiated much earlier in the aquatic environment preventing de-training effect

Serves as psychological preparation for the physical demands of a return to sport. Reproducing movements in water before attempting on dry land will increase confidence.

All movement in the aquatic environment require core stability and balance skills

Due to viscosity water resists movements in all plane making aquatic strength training more functional than traditional training
Recovery
Recovery

- **Cold water immersion (level 1)**
  - reduces delayed onset muscular soreness
  - increases muscle power

- **Contrast therapy (Level 2)**
  - Conflicting results for improving physiological
  - Some functional beneficial effects.

- Practical recommendations for improving physical performance include whole body immersion of 14-15 min of either cold water immersion (10-15 °C) or contrast therapy, with hot water at 38-40°C (Halson 2011).

- Further research is needed
The role of Aquatic Therapy in the Management of Sports Injuries
What do these athletes have in common??
Goal of rehabilitation in sports medicine

- **Primary Goals:**
  - Return athlete to prior level of function
  - Return athlete to sport safely and quickly
  - Protection of healing structures

- **Aquatic therapy can help meet this challenge:**
  - Allows early mobilization, strengthening, performance of functional activities, and maintenance of cardio-respiratory fitness.
  - Gradual progression from very light loading to very high loading is possible
  - It is essential that the “dry-land” and aquatic rehabilitation programs compliment each other

- Use aquatic therapy at the right time to achieve maximal results
Stages of soft tissue response to injury

- **Inflammation stage**: 0 days
- **Repair phase**: 3 days
- **Remodelling phase**: 6 weeks
- **Final phase**: 12 months

**TIME**
Collagen after wound healing

Normal ligament

Ligament 2 weeks after wound healing
Effect of a too early return to Sport on tissue healing

**Inflammatory phase 1 week**
- Injury e.g. MCL
- Type I collagen damaged
- Pain
- Guarding of loading

**Initial healing phase 1-2 weeks**
- Pain decreases
- Maturing of collagen begins
- Inflammation decreases

**Too early return to activity**
- Tissue unable to withstand forces in direction of the injury
- Undeveloped collagen fires are re-damaged
- Inflammatory process starts again
- Incomplete healing occurs

**Early phase of healing 3 -12 weeks**
- No Pain
- Primarily type III collagen fibres!!!
- Injured tissues’ tensile strength remains weak
Mechanotransduction and Mechanotherapy

Mechanotransduction:

“the processes whereby cells convert physiological mechanical stimuli into biochemical responses”

Mechanotherapy:

“The employment of mechanotransduction for the stimulation of tissue repair and remodeling”
Early phase aquatic therapy

- Acute knee and ankle ligament injuries (Kim et al 2010)
  - Walking
  - Balance (single leg balance)
  - Pain
    - AT group experienced less pain in aquatic therapy group.
    - More rapid change in AT group

  - Function
    - ROM increased in both AT and land groups
  - Pain
    - AT group had greater changes but not statistically different
  - Strength
  - Swelling

Similar to land based but possible additional benefits and more rapid improvements in some early phases (pain, ROM and muscle strength).

- Knees respond better with early mobilization (day 4 than hips)
- No increased infection risk if appropriate measures taken
Components of a complete rehabilitation program

Return to sport

Skill acquisition

Proprioception  Strength  Flexibility

Motor re-education and muscle activity
EMG activity decreases in water: 
(allows for graded mechanotherapy for muscles)

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Medium</th>
<th>30°/s</th>
<th>SPEED</th>
<th>60°/s</th>
<th>90°/s</th>
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<tr>
<td>Supraspinatus</td>
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<td>17</td>
<td>17</td>
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<td></td>
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<td>2</td>
<td>3</td>
<td>21</td>
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How speed of ambulation affects weight bearing.

Ground Reaction Forces (GRF) kävelyssä 1.2m syvässä vedessä (Cole – Becker 2003)
Flexibility

- Elasticity of collagen increases
- Muscle guarding decreases (reduction in pain)
- Decreased activation of muscle spindles and golgi apparatus

Aquatic stretching:
- Increase range of motion
  - Buoyancy assisted stretches
  - Active assisted movements
- Easier to perform typical static and dynamic stretches
- Ai Chi
- Using buoyancy
  - Passive stretching using buoyancy
  - Hold contract relax. Contract muscle against buoyancy for 5 seconds then relax and allow to stretch.
Conclusion

- Water facilitates an endless supply of training possibilities for athletes.
- Full understanding of the hydrostatic properties of water maximizes this potential.
- Water can be used at all levels of injury prevention and treatment.
- Try it!
Thank you

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