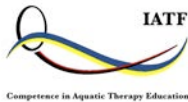




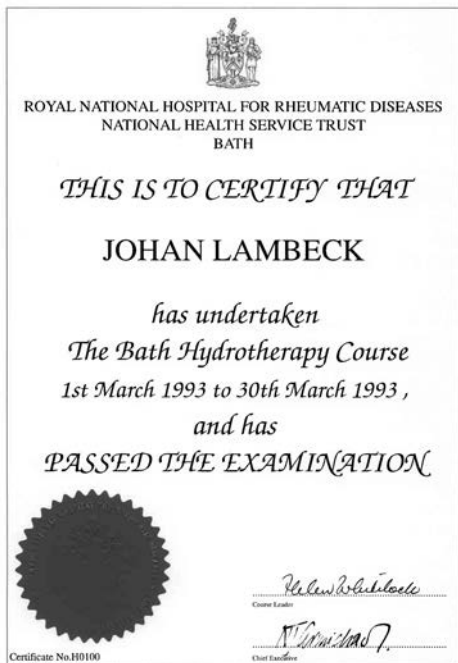
# Aquatic Therapy influences chronic low grade inflammation

Johan Lambeck PT

January 20, 2021



> originally prepared to discuss pre-covid



My Brentry

It is evident that water-based exercise can confer several specific advantages, as compared to land-based exercise. For this reason, **water-based exercise prescription should be a key consideration** for all health care clinicians, providers and commissioners (page 18)

Dr. Moffatt addresses e.g. cardiometabolic health and neurology

## Chapter 1

The individual physical health benefits of swimming: a literature review

Dr Fiona Moffatt, The University of Nottingham

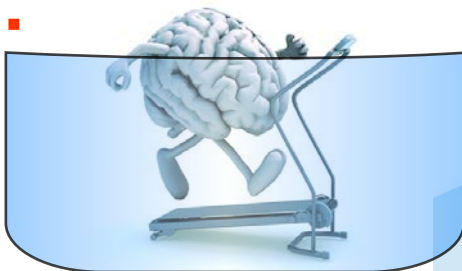
## The health & wellbeing benefits of swimming

individually  
socially  
economically  
nationally

Commissioned by Swim  
England's Swimming and  
Health Commission, chaired  
by Professor Ian Gunning  
Produced June 2017

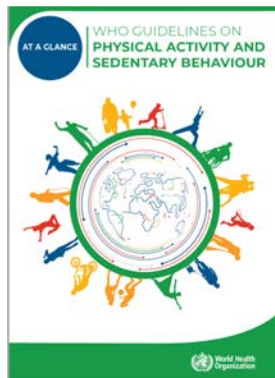
## Discussion objectives

- life-style and low grade inflammation: cytokines
- The immuno-metabolic system
- Vascular endothelial health:
- Aerobic training: what is good for a heart is good for a brain
- Hypothalamus and environmental enrichment
- Aquatic exergaming / motor-cognitive therapy
- Executive functions and fall prevention



## Movement is important, also for the mind

WHO guidelines on physical activity and sedentary behaviour: at a glance. Geneva: World Health Organization; 2020.



A few key messages

Physical activity is good for hearts, bodies and **minds (cognition)**

Any amount of physical activity is better than none, and more is better.

All physical activity / every step counts

Too much sedentary behaviour can be unhealthy

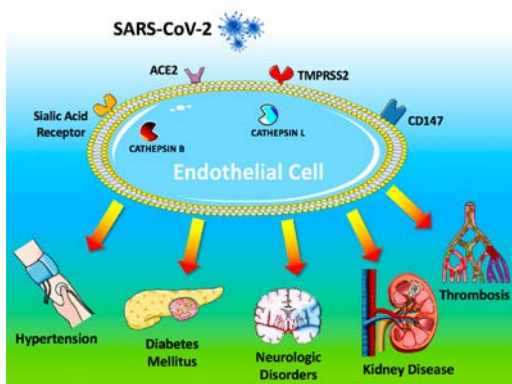


Clin. Med. 2020, 9, 1417;  
doi:10.3390/jcm9051417



### Hypertension, Thrombosis, Kidney Failure, and Diabetes: Is COVID-19 an Endothelial Disease? A Comprehensive Evaluation of Clinical and Basic Evidence

Celestino Sardu <sup>1,2,†</sup>; Jessica Gambardella <sup>3,4,†</sup>; Marco Bruno Morelli <sup>4,5,†</sup>; Xujun Wang <sup>†</sup>; Raffaele Marfella <sup>†</sup>; Gaetano Santulli <sup>3,4,†</sup>



### Co-morbidity in COVID-19 – USA (New York)



Comorbidity	Total No.
Cancer	120 (6)
Cardiovascular disease	3026 (56.4)
Hypertension	595 (11.1)
Coronary artery disease	371 (6.9)
Chronic kidney failure	479 (9)
Chronic respiratory disease	287 (5.4)
Asthma	154 (2.9)
Chronic obstructive pulmonary disease	43 (0.8)
Obstructive sleep apnea	55 (1)
Immunosuppression	308 (5)
HIV	186 (3.5)
History of solid organ transplant	19 (0.4)
Kidney disease	4170 (77.2)
Chronic	1808 (33.8)
End-stage*	19 (0.4)
Liver disease	19 (0.4)
Cirrhosis	8 (0.1)
Chronic	3 (0.1)
Hepatitis B	8 (0.1)
Hepatitis C	3 (0.1)
Metabolic disease	3737 (69.7)
Obesity (BMI ≥30)	4170 (77.2)
No.	792 (14.6)
Metabolic obesity (BMI ≥35)	4170 (77.2)
No.	1808 (33.8)
Diabetes*	

- Hypertension 57%
- Obesity 42%
- Diabetes 34%

n = 5,700  
Admitted to hospital  
Age: 63 years  
Female 39.7%

Richardson et al, JAMA 202

### Elsevier Public Health Emergency Collection

Public Health Emergency COVID-19 Initiative

Diabetes Metab Syndr. 2020 July-August; 14(4): 671–677.

PMCID: PMC7205616

Published online 2020 May 8. doi: 10.1016/j.dsx.2020.05.013

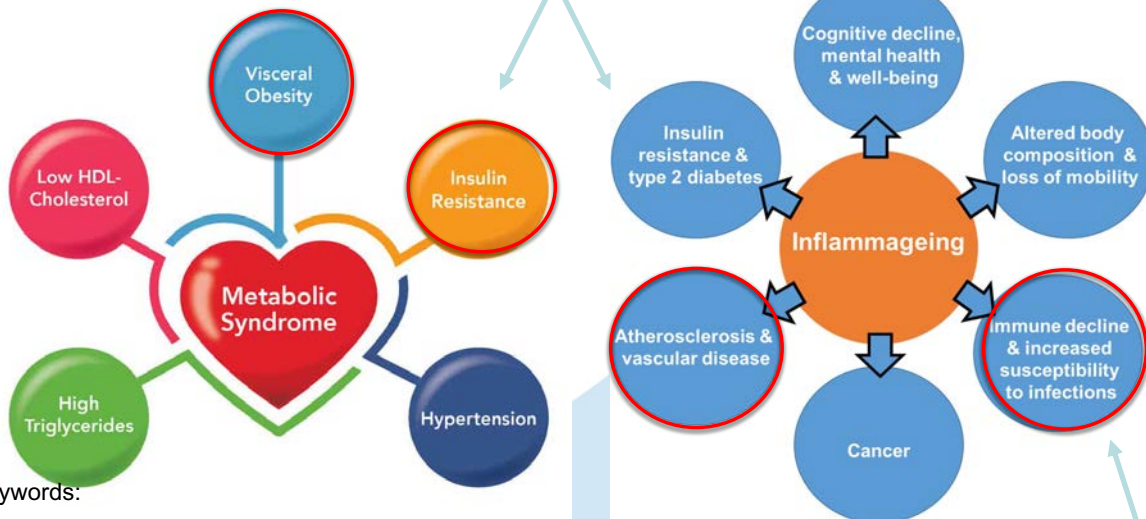
PMID: 32438333

### Diabetes and metabolic syndrome as risk factors for COVID-19

Marko Marhl<sup>a,b,c,\*</sup>, Vladimir Grubelnik<sup>d</sup>, Marša Magdić<sup>a</sup> and Rene Marković<sup>b,d,1</sup>

Various components are related to a sedentary lifestyle

### What is Metabolic Syndrome?



Keywords:

Endothelial dysfunction, insulin resistance, obesity, inflammation + neuroinflammation

## AT in impaired glucose tolerance

Jones ML et al 2009, *J Women's Health*

- Compared 15 women (BMI > 25), either normal (NGT) or impaired glucose tolerance (IGT).
- 12 wk: aquarobics / resistance ex > circuit
  - 3/wk, 60 min, 70-75 % H<sub>r</sub>max, RPE 11-14
- Results:
  - IGT: fasting insulin levels had decreased by 44% and 2-h glucose by 30.4%. Waist circumference decreased by 5.3%.
  - NGT: Waist circumference and waist-to-hip ratio (WHR) decreased (6.0% and 5.5%, respectively)
- Conclusions:
  - **MODERATE intensity, water-based circuit-type exercises appear to be an effective improve glucose and insulin response to a glucose challenge in overweight women with IGT**

We have many MSK patients in our pools, resulting from a life-style disease



Front Med (Lausanne). 2017; 4: 192.  
Published online 2017 Nov 8. doi: [10.3389/fmed.2017.00192](https://doi.org/10.3389/fmed.2017.00192)

PMCID: PMC5682311  
PMID: [29167793](https://pubmed.ncbi.nlm.nih.gov/29167793/)

### Health and Lifestyles Factors Associated With Osteoarthritis among Older Adults in Portugal

Natália Duarte,<sup>1,\*</sup> Ana Maria Rodrigues,<sup>2,3</sup> Jaime Da Cunha Branco,<sup>4</sup> Helena Canhão,<sup>5</sup> Susan L. Hughes,<sup>6</sup> and Constança Paúl<sup>1</sup>



BMC Musculoskelet Disord. 2015; 16: 87.  
Published online 2015 Apr 13. doi: [10.1186/s12891-015-0545-y](https://doi.org/10.1186/s12891-015-0545-y)

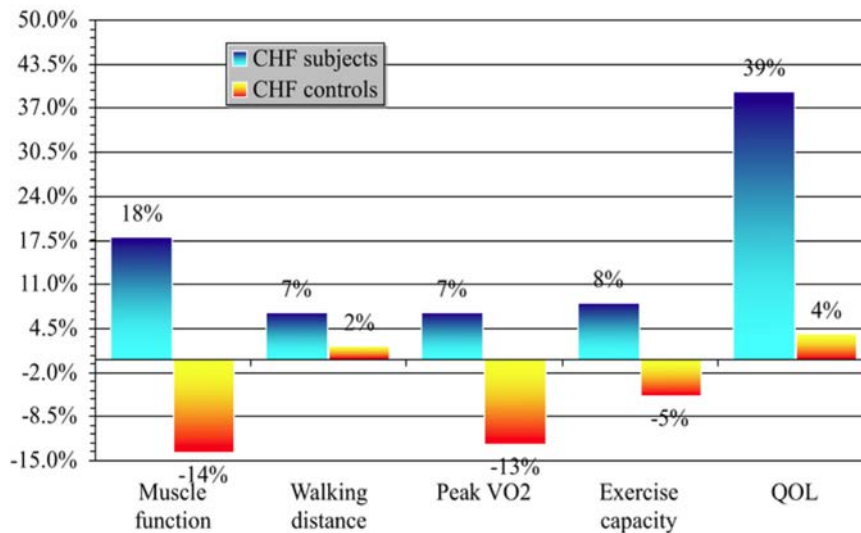
PMCID: PMC4397667  
PMID: [25888381](https://pubmed.ncbi.nlm.nih.gov/25888381/)

### What is the role of lifestyle behaviour change associated with non-communicable disease risk in managing musculoskeletal health conditions with special reference to chronic pain?

Elizabeth Dean<sup>✉</sup> and Anne Söderlund

## AT: CHF can also be a complication

25 pts with CHF randomized , 8 weeks training at 3 times per week / control with usual care



Cider A, Schaufelberger M, Sunnerhagen KS, Andersson B, Eu J  
Heart Failure 5 (2003) 527-535

## Insuline resistance

- The diminished ability of cells to respond to the action of insulin in transporting glucose from the circulation into muscle and other tissues
- The vagal nerve plays a role in the regulation of insulin secretion

ORIGINAL RESEARCH

Physiological Reports ISSN 2051-817X

### Contrasting effects of afferent and efferent vagal nerve stimulation on insulin secretion and blood glucose regulation

Erin E. Meyers<sup>1</sup>, Ana Kronemberger<sup>1</sup>, Vitor Lira<sup>1</sup>, Kamal Rahmouni<sup>2</sup> & Harald M. Stauss<sup>1</sup>

<sup>1</sup> Department of Health and Human Physiology, The University of Iowa, Iowa City, Iowa

2016

SCIENTIFIC  
REPORTS  
nature research

### Vagus Nerve Stimulation Exerts the Neuroprotective Effects in Obese-Insulin Resistant Rats, Leading to the Improvement of Cognitive Function

Titikorn Chunchai, Bencharunan Samniang, [...], and Siriporn C. Chattipakorn

Best effects: combined afferent and efferent stimulation, also leading to improved executive functions

The afferent pathway:

The free gift of immersion

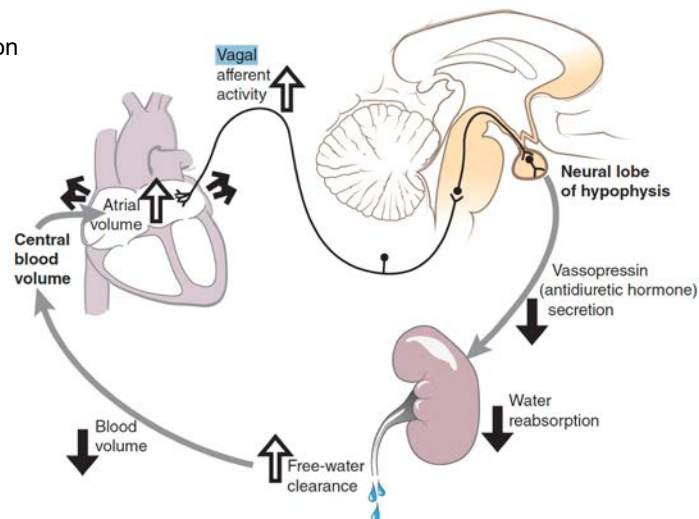
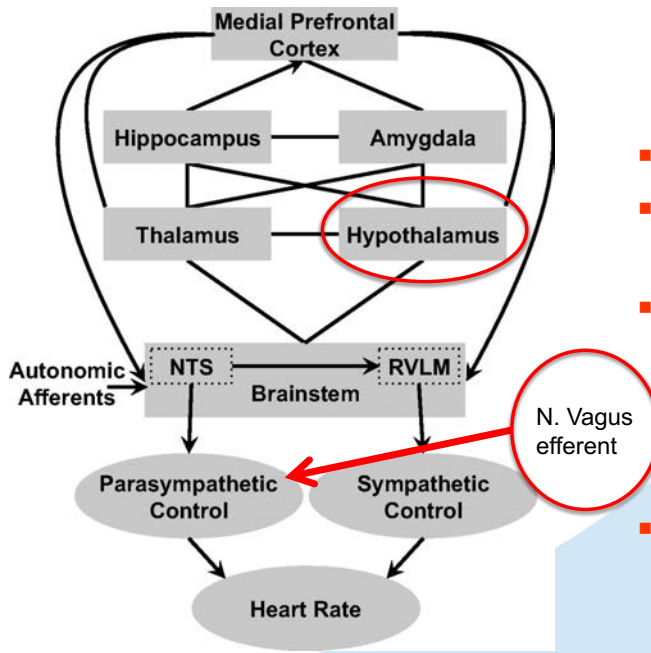


Figure 9 An early version of the Gauer-Henry hypothesis. Arrows indicate an increase or stimulation of the variable, darkened arrows indicate a decrease or inhibition of the variable. Redrawn from Krasney (2011) and reproduced with permission from Elsevier Limited, Oxford, United Kingdom (204).

Pendergast et al, 2015



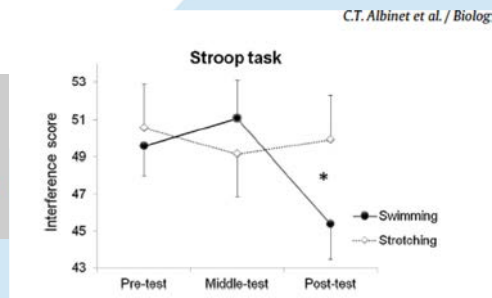
Activity in the prefrontal cortex (+ aerobics) indirectly influences insulin regulation

- C. Albinet et al (2016)
- RCT, n= 36 sedentary elderly 60-75 y
- 21 weeks 2times 1 h/wk
  - Aerobics / swimming at 40-65% HRR (Karvonen)
  - Active stretch and balance exercises
- Goal: role of aerobic fitness and cardiac vagal control (heart rate variability HRV) on executive functions

Thayer & Lane, 2009. doi:10.1016/j.neubiorev.2008.08.004

## Results

- Heart Rate Variability ↑ only in aquarobics
- updating work memory verbal running-span) and inhibition (Stroop) ↑ only in aquarobics
  - > relation HRV and EF



## Endothelial activation and dysfunction in COVID-19: from basic mechanisms to potential therapeutic approaches

Yuefei Jin, Wangquan Ji, Haiyan Yang, Shuaiyin Chen, Weiguo Zhang & Guangcai Duan

Signal Transduction and Targeted Therapy 5, Article number: 293 (2020) | Cite this article

Endothelial cells regulate e.g. vascular tone by releasing nitric oxide (NO). In Covid-19: a decline in NO bio-availability is seen

Patients with e.g. metabolic syndrome show chronic vascular endothelial injury

**Therapy: prevent this injury = increasing NO**

Review > Curr Vasc Pharmacol. 2012 Jan;10(1):94-106. doi: 10.2174/157016112798829788.

### Lifestyle factors and endothelial function

Nikolaos Papageorgiou<sup>1</sup>, Dimitris Tousoulis, Emmanouel Androulakis, Aris Giotakis, Gerasimos Siasos, George Latsios, Christodoulos Stefanadis

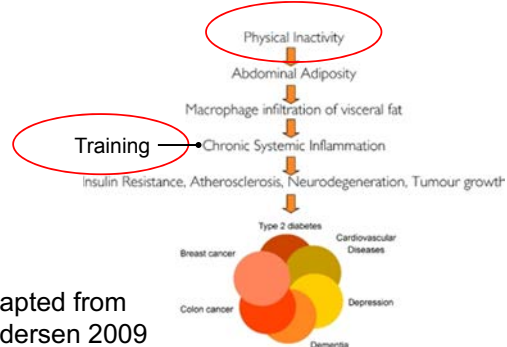
Review Article | Open Access

Volume 2020 | Article ID 1496462 | <https://doi.org/10.1155/2020/1496462>

Show citation

### Impact of Lifestyles (Diet and Exercise) on Vascular Health: Oxidative Stress and Endothelial Function

Andy W. C. Man,<sup>1</sup> Huijie Li,<sup>1</sup> and Ning Xia<sup>1</sup>



Adapted from Pedersen 2009

## NO > BDNF

> Eur J Neurosci. 2016 Sep;44(5):2226-35. doi: 10.1111/ejn.13301. Epub 2016 Jul 14.

### Brain BDNF levels are dependent on cerebrovascular endothelium-derived nitric oxide

Hayat Banoujaafar<sup>1</sup>, Alice Monnier<sup>1,2</sup>, Nicolas Pernet<sup>1</sup>, Aurore Quirié<sup>1</sup>, Philippe Garnier<sup>1,3</sup>, Anne Prigent-Tessier<sup>1</sup>, Christine Marie<sup>1</sup>

Affiliations + expand

### Interplay Between Nitric Oxide and Brain-Derived Neurotrophic Factor in Neuronal Plasticity

September 2015 · CNS & neurological disorders drug targets 14(8) · [Follow journal](#)

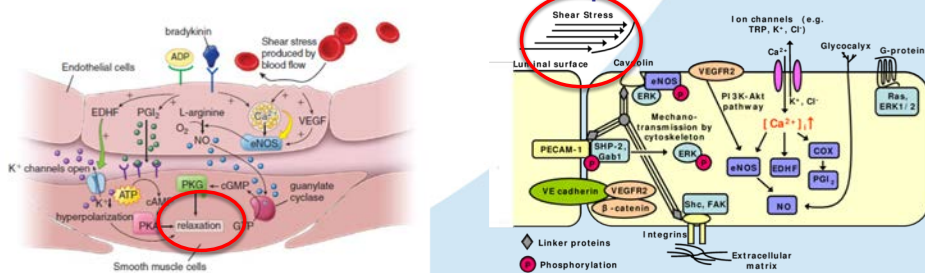
DOI: [10.2174/1871527314666150909113727](https://doi.org/10.2174/1871527314666150909113727)

Caroline Biojone · Plinio Cabrera Casarotto · Sâmia R L Joca · Eero Castrén



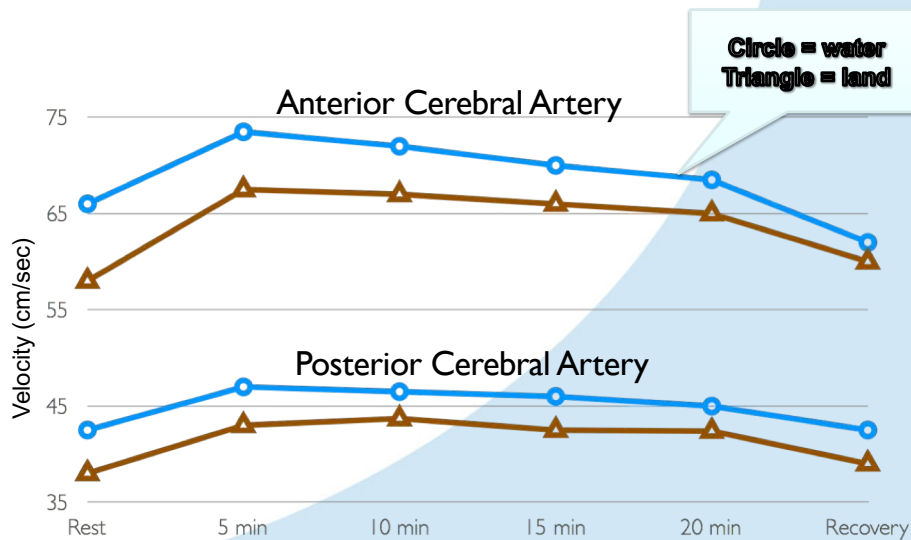
## Increased vascular shear stress

- Nualnim 11, Veiga 14, Bailey 16, Brunt 16, Cruz 16, Karaarslan 17, Acordi da Silva 17, Lambert 14
- Immersion with/without exercise, different temperatures, healthy – hypertensive, sedentary
- > improved endothelial functions + BDNF production



VEGF: vascular endothelial growth factor

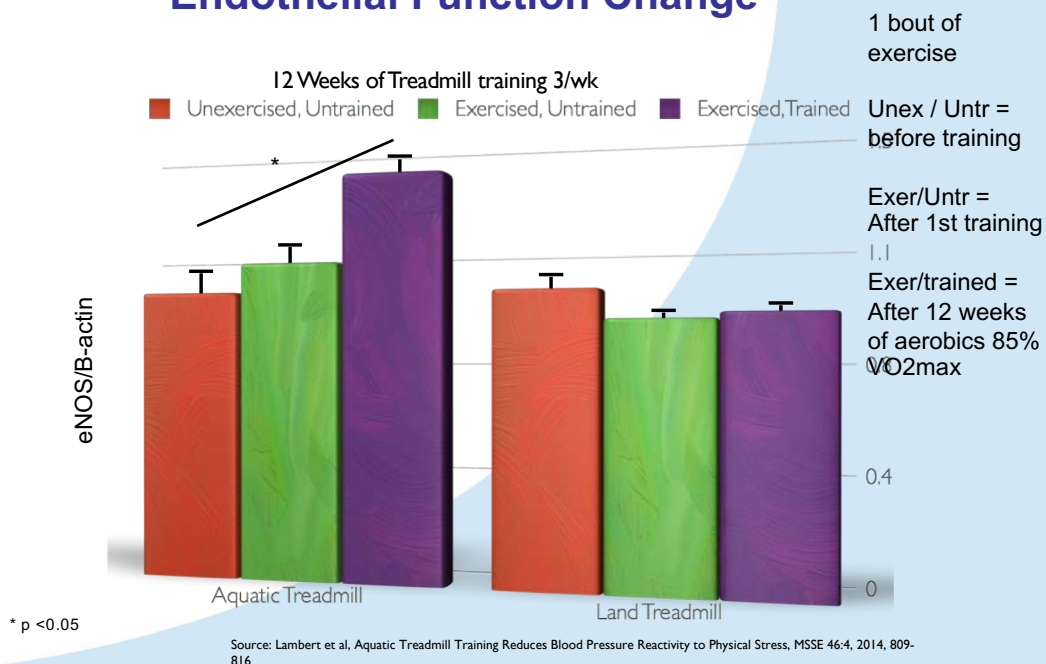
## Cerebral Blood Flow during Aquatic vs. Land Exercise



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.

Courtesy B.Becker [www.aquaticdoc.com](http://www.aquaticdoc.com)

## Endothelial Function Change



## Fitness strategies (Lucas 2019)

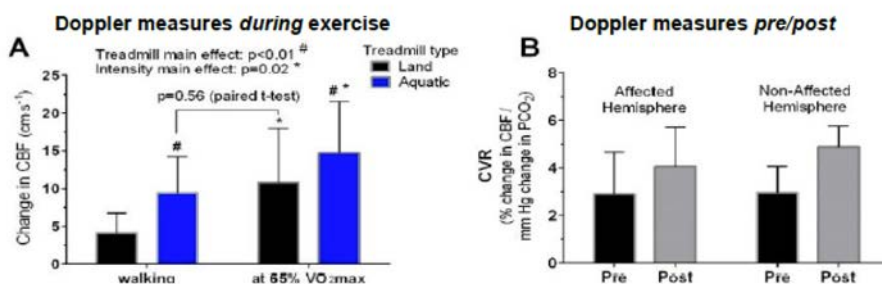
- Controlling vascular risk factors and changing lifestyle such as increased exercise are recommended strategies (WHO, ACSM etc) to prevent vascular diseases.
- Guidelines as mentioned are below threshold to induce adaptations.
- Many “patients” cannot adhere to higher doses when exercising on land. > Water as alternative to elicit the exercise induced physiological strain to induce adaptations

## Cerebral health

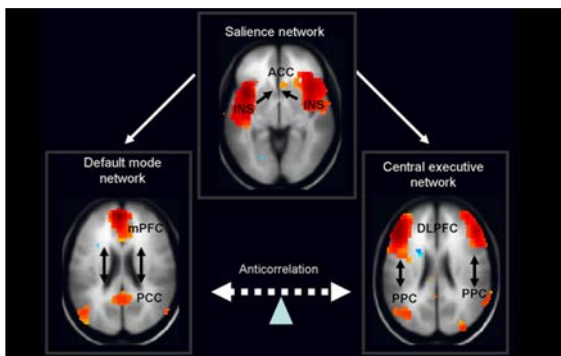
- Cerebral blood flow (CBF) declines by ~half across healthy adulthood, measured as
- Decrease of CO<sub>2</sub> pressure (= reduced cerebrovascular CO<sub>2</sub> reactivity: CVR) > parameter of perfusion
- Reduced CVR is related to cardiovascular mortality
- Higher CVR is achieved with aerobic fitness
- The regulatory capacity of the cerebrovasculature presents as a vital mediator of brain health

A: Cerebral Blood Flow during walking on a treadmill in water equals CBF when running on land at 65% VO<sub>2</sub> max

B: CVR increased markedly more (4 weeks of ex.) than when exercising on land as shown in another study by Ivey in 2005



**Fig 1:** Data from proof-of-concept study in healthy participants showing a direct comparison of increases in CBF for walking and moderate intensity running (65% of aerobic capacity (i.e., VO<sub>2</sub>max)) between land and aquatic treadmills (panel A). Panel B shows the improved CVR measure following 4 weeks aquatic treadmill training in 6 stroke survivors.



### Neuroinflammation and neurologic deficits in diabetes linked to brain accumulation of amylin

Sarah Srodulski, Savita Sharma, Adam B Bachstetter, Jennifer M Brelsfoard, Conrado Pascual, Xinmin Simon Xie, Kathryn E Saatman, Linda J Van Eldik & Florin Despa

*Molecular Neurodegeneration* 9, Article number: 30 (2014) | [Cite this article](#)

Article

### Differential Effects of Tai Chi Chuan (Motor-Cognitive Training) and Walking on Brain Networks: A Resting-State fMRI Study in Chinese Women Aged 60

Yue C, Herold F et al 2020

Low grade inflammation also leads to neuroinflammation e.g prefrontal cortex

exercise is only effective when patients themselves combine kinetic, sensory, cognitive and social challenges in the sense of environmental enrichment (Meijer, 2015)

= figure out what is happening / what to do  
 = executive functioning  
 = attentional / executive network

Default network keywords

- mind-wandering, musing, unwinding
- Enhanced by moderate aerobic activity, rhythm and also imagination

Shane O'Mara

"In praise of walking" (2019)

**walk, ai chi (flow)**

## We need to move: influencing the..

- low grade systemic inflammation + neuroinflammation
- Increase of the NO release
- dysbalance: pro-inflammatory <> anti-inflammatory cytokines
  - TNF- $\alpha$ , C-reactive protein, IL-6, IL-1b <> IL 10, IL-6, IL-4, IL-1ra
- expression of BDNF (brain derived neurotrophic factor)
- hypothalamus

**Osteoblasts produce osteocalcin**  
 regulating metabolism and cognition  
 increasing insulin sensitivity, decreasing low grade inflammation

**Effects of 12-week exercise training on osteocalcin, high-sensitivity C-reactive protein concentrations, and insulin resistance in elderly females with osteoporosis** J Phys Ther Sci 2016

NAYOUNG AHN, PhD<sup>1)</sup>, KIJIN KIM, PhD<sup>1)\*</sup>

Intervention: Resistance training with Teraband  
 Yoga and aerobic dance

Also muscles influence the brain

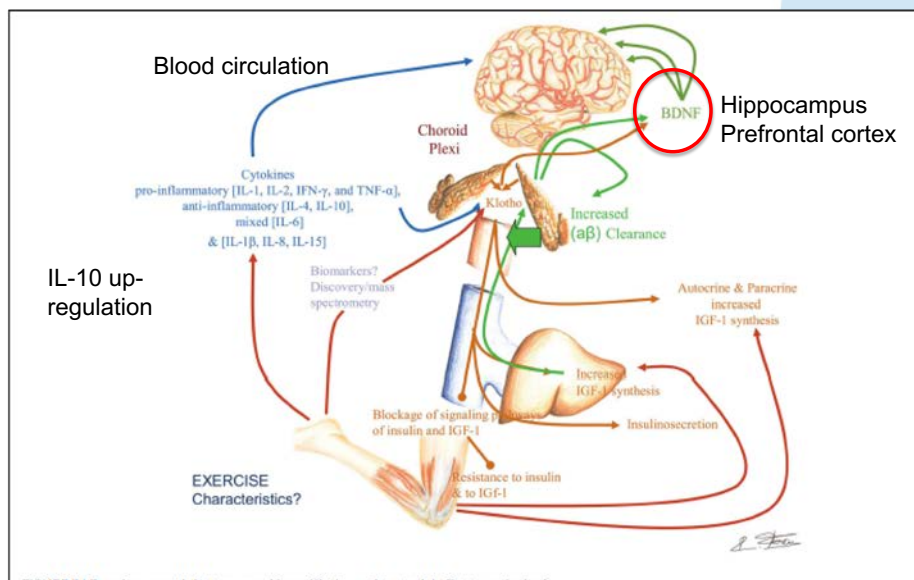


FIGURE 5 | Exercise, growth factors, cytokines, Klotho, and potential effects on the brain.

Foster 2011, Wu 2011

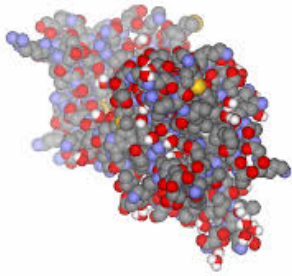
## Exercise: anti-inflammatory properties (in rats)

Teixeira 2011, *Cardiovascular Diabetology*

- Regular **aquatic** exercise:
  - ↓ pro-inflammatory cytokines: IL-6, TNF- $\alpha$ , CRP
  - ↑ anti-inflammatory cytokines: IL-10, IL-4
  - IL-6 comes from exercising muscle and stimulates release of IL-10
  - IL-6 and IL-10 inhibit TNF- $\alpha$  (which increases insulin resistance)
  - IL-6 induces expression of BDNF

## Parkinson: ↓ immune response\* in AT

- Pre-post design with ACSM aerobic levels during games (60% VO<sub>2</sub>max) + balance and proprio exercise (Pochmann 2018)
- PD: astrocytes increase expression of pro-inflammatory cytokines
- AT creates an anti-inflammatory environment
- Anti-inflammatory IL-1ra ↑
- Pro-inflammatory MCP-1 / IL-1b ↓
- \* = the – pathological - defence reaction



BDNF: fertilizer of brain plasticity: synaptogenesis, dendritogenesis, angiogenesis

Through (an)aerobic exercise:

- ↑ BDNF correlates with ↓ pro-inflamm. cytokines
- ↑ Cognition = executive functions / memory

Research | [Open Access](#) | Published: 04 August 2017

## Brain-derived neurotrophic factor reduces inflammation and hippocampal apoptosis in experimental *Streptococcus pneumoniae* meningitis

Danfeng Xu, Di Lian, Jing Wu, Ying Liu, Mingjie Zhu, Jiaming Sun, Dake He & Ling Li [✉](#)

[Journal of Neuroinflammation](#) 14, Article number: 156 (2017) | [Cite this article](#)

ORIGINAL RESEARCH ARTICLE

Front. Physiol., 04 November 2016 | <https://doi.org/10.3389/fphys.2016.00509>



## Inflammatory Cytokines and BDNF Response to High-Intensity Intermittent Exercise: Effect the Exercise Volume

Carolina Cabral-Santos<sup>1</sup>, Carlos I. M. Castrillón<sup>2</sup>, Rodolfo A. T. Miranda<sup>2</sup>, Paula A. Monteiro<sup>1</sup>, Daniela S. Inoue<sup>1</sup>, Eduardo Z. Campos<sup>1,5</sup>, Peter Hofmann<sup>4</sup> and Fábio S. Lira<sup>1\*</sup>

**FINAL**

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Current Alzheimer Research, 2014, 11, 000-000

1

## Physical Exercise in MCI Elderly Promotes Reduction of Pro-Inflammatory Cytokines and Improvements on Cognition and BDNF Peripheral Levels

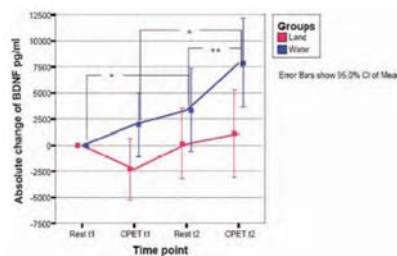
Carla Manuela Crispim Nascimento<sup>1</sup>, Jessica Rodrigues Pereira<sup>1</sup>, Larissa Pires de Andrade<sup>1</sup>, Marcelo Garuffi<sup>1</sup>, Leda Leme Talib<sup>2,3</sup>, Orestes Vicente Forlenza<sup>2,3</sup>, Jose Maria Cancela<sup>4</sup>, Márcia Regina Cominetti<sup>5,6</sup> and Florindo Stella<sup>2,6</sup>

## Bansi 2012: BDNF and aerobic aquatic training



### Enhanced BDNF expression under immersion

Significant BDNF increase by 3387 pg/ml (95% CI -593.4-7367.6;  $p=0.046$ ) within the water group



60%  $VO_{2\max}$

RPE 13

MET 5

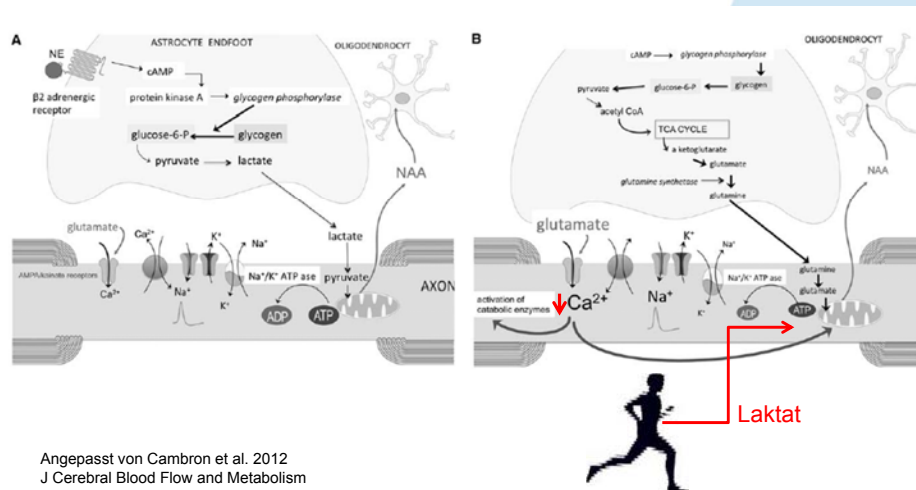
A bit out of breath, but being able to speak

## Anaerobic exercise and BDNF

- BDNF does not increase after 10 min moderate aerobic exercise on land, only after incremental High Intensity Interval Training to exhaustion (= anaerobic)
  - Rojas Vega 2006
- Also cortisol and lactate ( $> 10$  mmol/L) increase during HIIT.
- Correlations between lactate and BDNF: yes
  - $>$  in water BDNF increase during aerobic exercise (Bansi)



## Alternative energy source for axonal protection: Lactate > dysfunctional astrocytes



### Effect of Exercise-Induced Lactate Elevation on Brain Lactate Levels During Hypoglycemia in Patients With Type 1 Diabetes and Impaired Awareness of Hypoglycemia

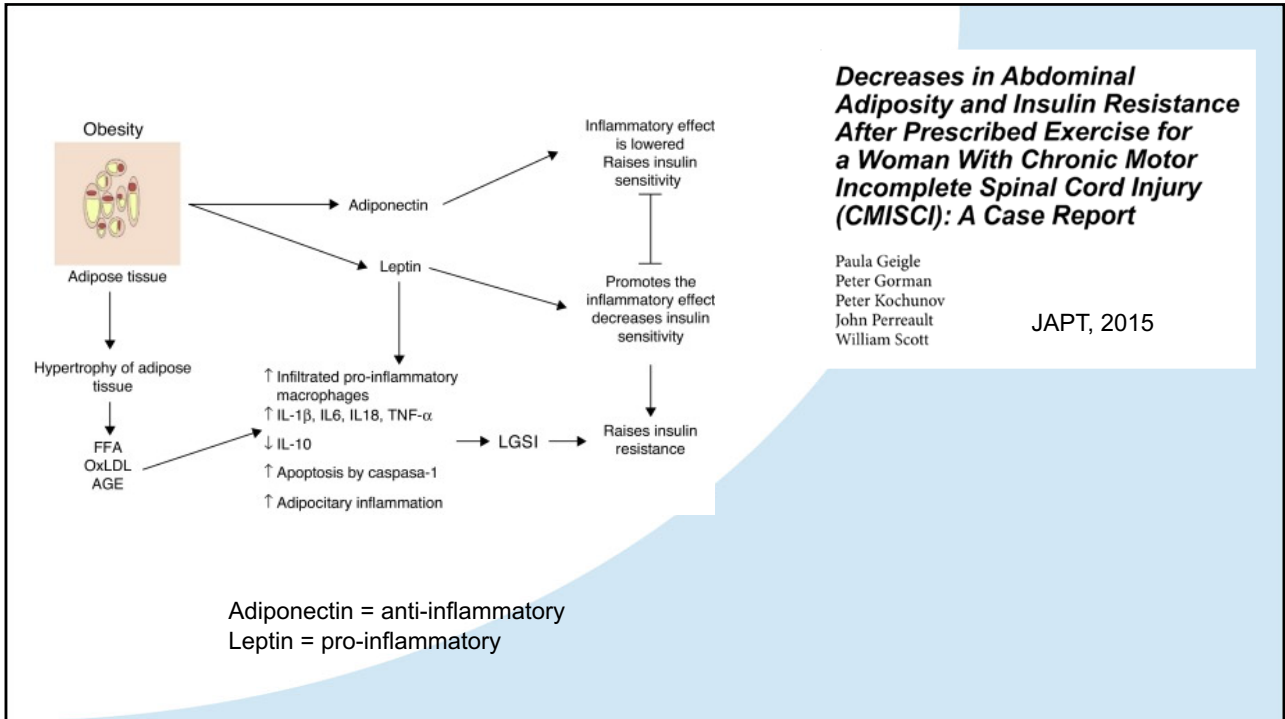
Evita C. Wiegers<sup>1</sup>, Hanne M. Rooijackers<sup>2</sup>†, Cees J. Tack<sup>2</sup>, Hans J.M.M. Groenewoud<sup>3</sup>, Arend Heerschap<sup>1</sup>, Bastiaan E. de Galan<sup>2</sup> and Marinette van der Graaf<sup>1,4</sup>

*Diabetes*, 2017

H.I.I.T. gave increased brain lactate levels, both in DM1 and healthy persons

Cook et al 2013 *IJARE*

Compared blood lactates sprint water – land  
9 m, 100% effort, 30 sec rest, 10 times  
RPE: land 11, water 15  
Sprint time water 15 sec, land 2 sec  
Lactate water 8±2 and land 4±2 mmol



**REVIEW ARTICLE**  
Front. Endocrinol., 04 April 2017 | <https://doi.org/10.3389/fendo.2017.00060>

## Lipid Processing in the Brain: A Key Regulator of Systemic Metabolism

Kimberley D. Bruce<sup>1\*</sup>, Andrea Zsombok<sup>2</sup> and Robert H. Eckel<sup>1</sup>

Review > Neuroendocrinology. 2011;94(1):1-11. doi: 10.1159/000328122. Epub 2011 May 17.

### Hypothalamic Control of Lipid Metabolism: Focus on Leptin, Ghrelin and Melanocortins

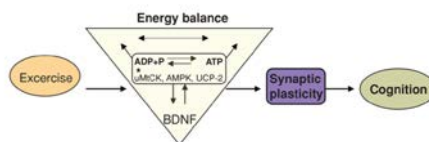
Carlos Diéguez<sup>1</sup>, María J Vazquez, Amparo Romero, Miguel López, Ruben Nogueiras

- Hypothalamus coordinates intestins, white fat, glucose
- And is very sensitive for environmental enrichment
  - Then BDNF expression increases
  - And also more adiponectin and less leptin
- (an)aerobics works, but less when it's only exercise
  - To be included:
    - Acive inclusion of patients by giving challenges, incl (an)aerobic ex
      - Sensory, kinetic, cognitive and social
      - **Effort in a relaxed way**

• Cao 2010, Mainardi 2013, Sale 2014, Foglesong 2016, Kentner 2019, Meijer 2015

## First aerobics and then (motor) learning? Could be First (motor) learning and then aerobics? no

- aerobic PA **prior** to a cognitive task facilitates cognitive flexibility as well as other executive functions (i.e., inhibitory control and working memory). Bae, 2019



exercise exerts its effects on cognition by affecting molecular events related to the management of energy metabolism and synaptic plasticity

Gomez-Pinilla F & Hillman H 2013, *Compr Physiol*

**They belong together: what is good for your heart is good for your brain**

## Environmental Enrichment

- Related to executive functions in motor control >
- Problem solving, memorizing, concentration
  - Exergaming

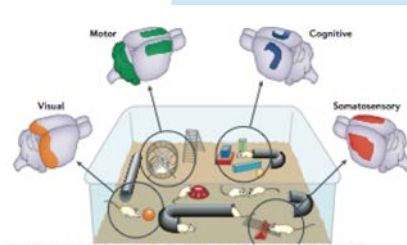
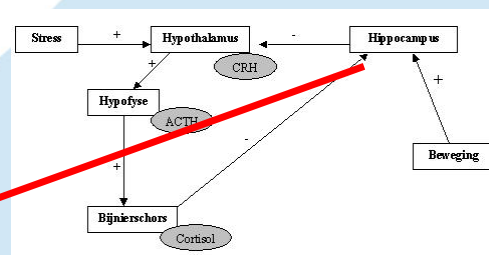


Figure 1 | Environmental enrichment and the effects of enhanced sensory, cognitive and motor stimulation on different brain areas. Enrichment can promote



- Hippocampus > visuo-spatial attention / work memory



## EE in (aquatic) physical therapy

- Therapy should be
  - Challenging with success experiences : motivating and leading to confidence and self-efficacy
  - Repetitive, yet variable to learn open skills
  - Attention taking when solving problems (error making)
  - Positive arousal stimulating: fun and enjoyment
  - At a certain level of exertion
  - With social elements (e.g. group work)
- Forced practice in enriched environments, constraint induced in a behaviorally relevant task (Taub & Wolf, 1997)
- Or **PLAY / EXERGAME**

- Memory and immersion
- Healthy elderly made 111-192% more mistakes during an auditive task when standing staggered on land in comparison to water
  - Mean age was 72
- E.Bressel et al 2018. Water immersion affects episodic memory and postural control in healthy older adults

## AE and cognitive functions

- Sato et al 2014 (Aging Clinical and Experimental Research)
- *Differential effects of water-based exercise on the cognitive function in independent elderly adults.*
  - Concl: water-based exercise, including watercognitive tasks, has shown to improve several cognitive functions, such as attention and memory of inactive older adults
- Kang et al (2015) (Exercise Science)
- *Combined aquatic exercise program to improve fitness and cognitive function for elderly with mild dementia.*
  - Aquatic exercise included multiple tasking (CAEG) at RPE 10-13
  - CAEG had better effects on EF than simple exercises (NAEG)

## Water-cognitive exercise: walking + ...

Rock-paper-scissors by both hands  
Juggling balls  
Copy / mirror the movement of someone else  
Catching ball with other participants  
Counting numbers  
Walking in a group setting  
Clapping at the set timing during walking

Sato 2014, Kang 2015

## Dual task AT Kim et al 2016 RCT

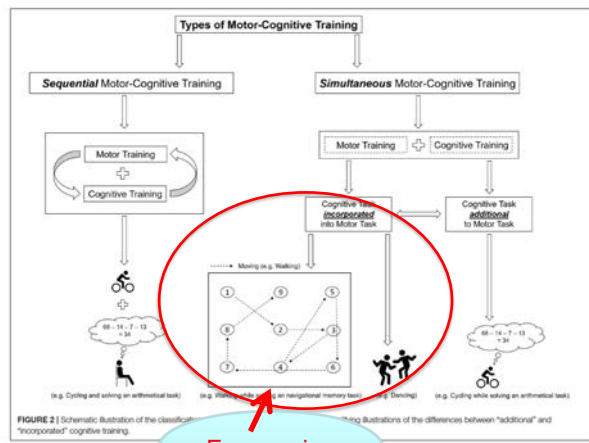
Controls: NDT land  
Exp: NDT land + Dual task AT

CG 6 wk / 5days/week / 30 min NDT  
EG same + 6 wk / 5days/wk / 30 min aquatic  
double task > mostly manipulation during standing  
and walking

Effect Size	BBS	FTST	FR	10MWT	TUG
intergroup	2.65	1.4	1.79	1.49	0.02



Carrying objects: multi-tasking, also in a group



Moving while thinking instead of the regular dual task

## Health exergaming: also early after stroke

- Impairment recovery: focus on movement quality, *rather than task accomplishment*, with elements of EE and **high-dose playful movements**
  - Krakauer (2008), non-task oriented approach based on high-dose playful movement exploration for the upper limb early after stroke



MindPod Dolphin



Fig. 3. Exoskeletal robotic arm used to control a dolphin simulation. Setup currently used in the SMARTS 2 trial (NCT02292251). The goal in this trial is to allow movement exploration in an immersive and engaging video game in order to boost motor recovery of the upper limb. Adapted from Krakauer and Carmichael (2017).

## Cognition: executive functions (EF)

- To figure out what to do
- cognitive control processes, governing goal-directed action and behavioral adaptation to complex, novel or ambiguous situations (Hughes et al 2005)
  - Response inhibition
  - Cognitive flexibility / shifting / problem solving
  - Working memory
    - » >>>> **visuospatial attention/navigation important in ADL**
- EF allow us to initiate and organize tasks, necessary to recognize unexpected situations and to make alternative plans quickly + inhibit (inappropriate) motor behavior.
- No routines! Although much ADL is based on routines



Visuospatial memory and navigation in e.g. posture and gait-variability



## Executive Functions + gross motor physical activity

- Strong correlation between EF and:
  - reaction speed and agility (Hilton 2014)
  - motor agility (Fama 2002)
  - environmental enrichment with physical exercise (Halperin 2011)
  - walking + dual tasking or obstacle course (Yogev 2008)

## Executive functions

- Memory tests with movement
  - In pairs: 1a any movement 2 times, 2a any movement 2 times + add 1a, #1b any movement 2 times + add 1a and 2a
    - Mother buys X things at the market...summing up
- Problem solving
  - how many combinations to make with e.g. SRC – TRC – LRC
  - Moving Stroop (Simon says)
- Concentration on tasks:
  - walk slowly and make every step different or every step the same

## Fall prevention topics

- Agility      but also:
- Teaching stumble strategies
- Gait variability
- Distraction
- Unexpected perturbations
- Obstacle negotiation
- Lateral safety
- Challenge balance: no hand support, narrow base, shift COG
- Limits of reaching



Asking Urs Gamper to walk in 5 different ways, do something else and ask to repeat the 5 original ways again



## In conclusion

- Patients should be tired at first, or
- Combine aerobic activity with balance + coordination
- Play through exergame-like activities: motor-cognitive therapy
- Move while thinking
- Focus on visuospatial memory, inhibition, problem solving
- Let patients explore
- Put into the context of fall prevention
- Therapy is fun: play

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TBI patient:

Fast leg movements  
Plantair flexion: power  
to propell  
Gait variability

