Proprioceptive and muscular training through therapeutic aquatic exercise in MSK rehabilitation

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Partly based on Powerpoints by Urs Gamper and Ben Waller

Aquatic therapy in the rehabilitation of (athletic) injuries

Prins & Cutner: Clinics in Sports Medicine 1999

- The key to effective rehabilitation is the retum to desired functional activity as soon as possible. Aquatic therapy provides a unique environment for promoting normal movement patterns and building strength early in the course of treatment. These changes usually are accomplished in the water, where the risk of further injury is reduced. This frequently is accompanied by a reduction in pain and perceived discomfort. Aquatic therapy in many cases is the only option for rehabilitation when land-based programs have not provided satisfactory results.

Effect of therapeutic aquatic exercise on symptoms and function associated with lower limb osteoarthritis: a systematic review with meta-analysis

B.Waller, A. Ogonowska, M. Vitor, J. Lambeck, D. Daly, U. Kujala, A. Heinonen

Physical Therapy June 2014

- Results: significant TAE effect on pain with a SMD of 0.26 [95% CI 0.11 to 0.41], self-reported function 0.30 [0.18 to 0.43] and physical functioning 0.22 [0.07 to 0.38]. Additionally, a significant effect was seen on stiffness 0.20 [0.03 to 0.36] and quality of life 0.24 [0.04 to 0.45].

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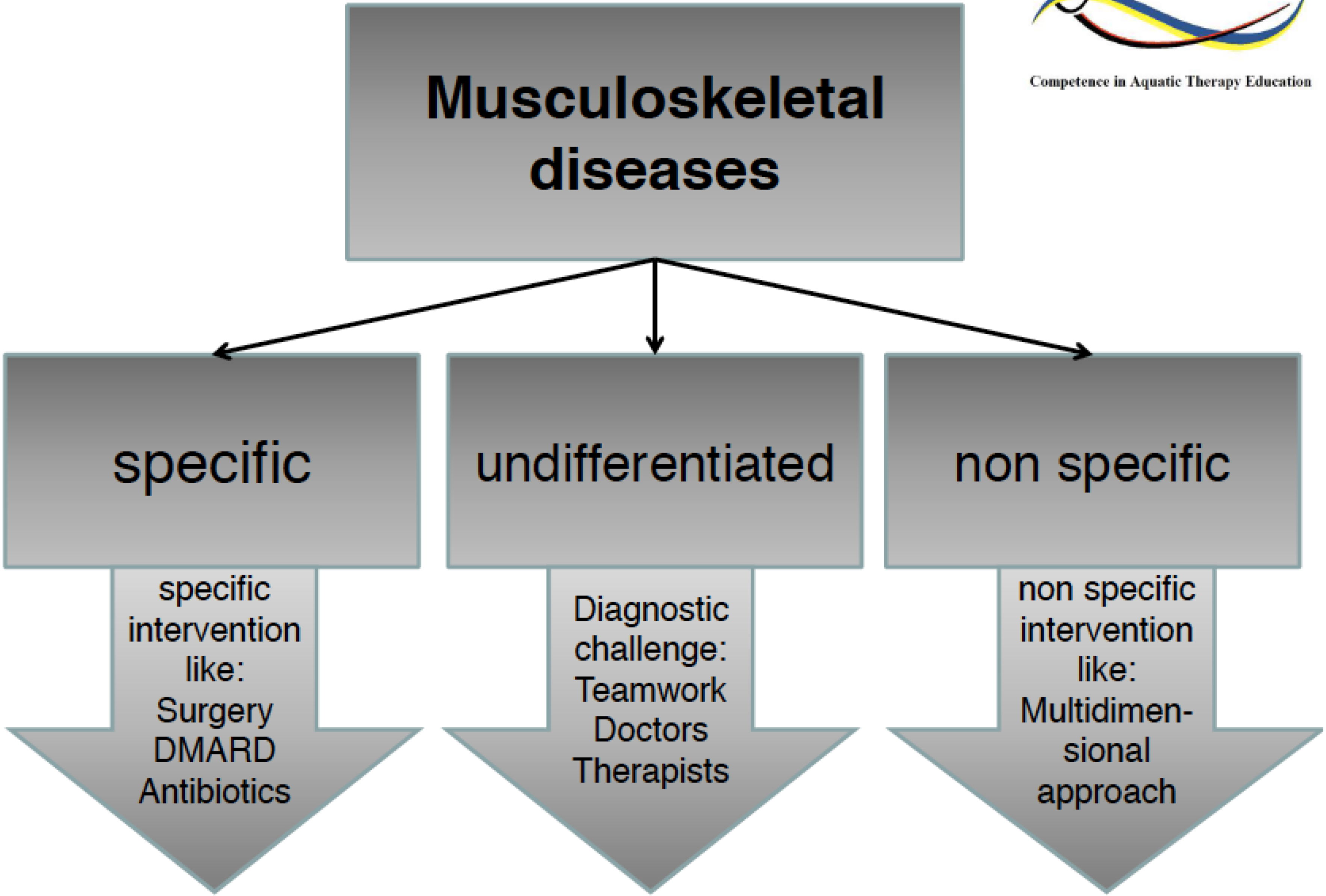
Competence in Aquatic Therapy Education



Chronic musculoskeletal diseases in aquatic therapy

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- Low back pain
- Osteoarthritis
- Osteoporosis
- Rheumatoid Arthritis
- Spondylitis ankylosans
- Fibromyalgia
- Myofascial pain syndrome

Pain and pain related limitations of daily activities and participation

Integrated behavioural on neuromuscular explanation of activity limitations in musculoskeletal diseases

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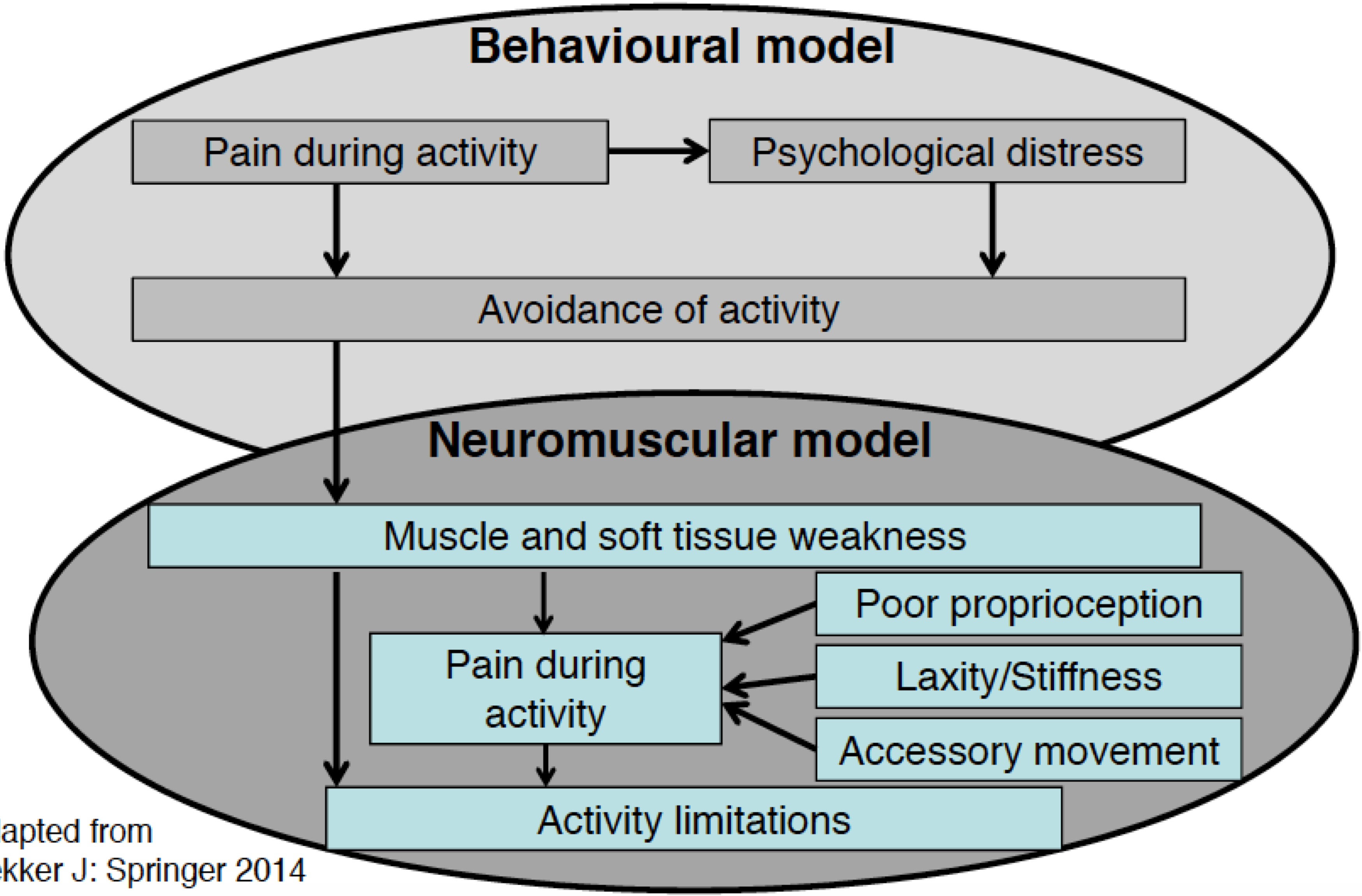

Adapted from
Dekker J: Springer 2014

International classification of functioning, disability and health (ICF) and aims of interventions in muskuloskeletal-diseases

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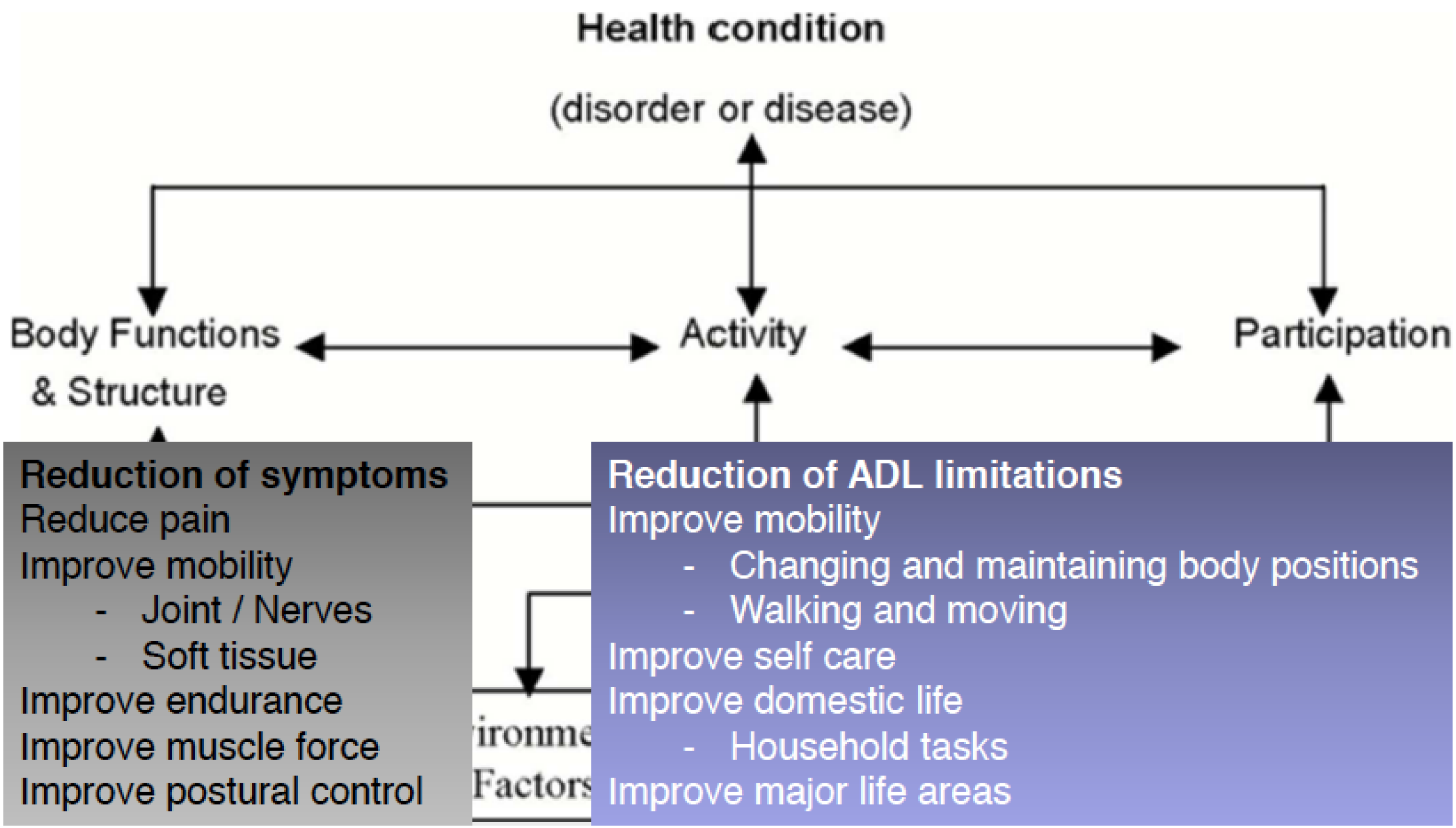

Reduction of symptoms

Reduce pain

Improve mobility

- Joint / Nerves
- Soft tissue

Improve endurance

Improve muscle force

Improve postural control

Reduction of ADL limitations

Improve mobility

- Changing and maintaining body positions
- Walking and moving

Improve self care

Improve domestic life

- Household tasks

Improve major life areas

Source: WHO http://apps.who.int/classifications/icfbrowser/

Aquatic Therapy is recommended in several clinical Guidelines

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- EULAR recommendations for the non-pharmacological core management of **hip and knee *osteoarthritis***

  Fernandes L et al. Ann Rheum Dis. 2013;72:1125-1135 doi:10.1136/annrheumdis-2012-202745
- EULAR revised recommendations for the management of ***fibromyalgia***

  Macfarlane GJ et al. Ann Rheum Dis. 2016; doi:10.1136/annrheumdis-2016-209724
- 2010 update of the ASAS/EULAR recommendations for the management of ***ankylosing spondylitis***

  J Braun, et al. Ann Rheum Dis. 2011;70:896-904 doi:10.1136/ard.2011.151027
- An updated overview of clinical guidelines for the management of non-specific ***low back pain*** in primary care

  Koes BW et al. Eur Spine. 2010;19(12):2075–2094 doi:10.1007/s00586-010- 1502-y

Systematic Review

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Aquatic exercise for the treatment of knee and hip osteoarthritis

Bartels EM et al. Cochrane. 2016;3: doi:10.1002/1465858.CD005523.pub3

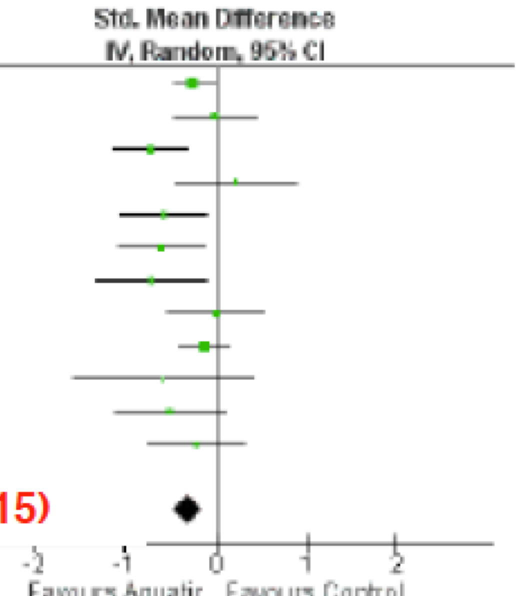
13 RCs 1190 participants, mean duration OA 6.7 y, mean duration aquatic exercise 12 weeks (6-20)

Figure 4. Forest plot of comparison: 1 Aquatic exercise vs control immediately after treatment - knee & hip OA, outcome: 1.1 Pain.

Outcome: Pain

	Aquatic			Control				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Cochrane 2005	8.46	3.74	152	9.35	3.54	158	18.3%	-0.24 [-0.47, -0.02]
Foley 2003	10	2.98	35	10	2.98	35	8.3%	0.00 [-0.47, 0.47]
Fransen 2007	27.3	18.7	55	40	16.2	41	8.7%	-0.71 [-1.13, -0.30]
Hale 2012	7.8	3.88	20	7.1	1.67	15	4.8%	0.23 [-0.44, 0.90]
Hinman 2007	143	79	36	198	108	35	8.1%	-0.58 [-1.05, -0.10]
Kim 2012	6.14	1.9	36	7.26	1.92	35	8.0%	-0.60 [-1.07, -0.12]
Lim 2010	3.27	1.67	24	4.55	1.88	20	5.5%	-0.71 [-1.32, -0.10]
Lund 2008	-60.2	12.47	27	-60.3	12.47	27	6.9%	0.01 [-0.53, 0.54]
Patrick 2001	1.38	0.74	98	1.46	0.62	117	15.8%	-0.12 [-0.39, 0.15]
Stener-Victorin 2004	30	30.37	10	48.5	29.63	7	2.4%	-0.58 [-1.58, 0.41]
Wang 2006	43.5	18.6	21	54.9	25.2	21	5.5%	-0.51 [-1.12, 0.11]
Wang 2011	-72	18	26	-68	18	26	6.6%	-0.22 [-0.76, 0.33]
Total			**538**			**537**		**-0.31 (-0.47, -0.15)**

[illegible]
Test for overall effect: Z = 3.80 (P = 0.0001)



Paracetamol SMD 0.18 (0.11-0.25), NSAR SMD 0.37 (0.26-0.49)

McAlindon TE et al. Osteoarthritis and Cartilage. 2014:22(3):363-88 doi:10.1016/j.joca.2014.01.003.

Contents

- Proprioceptive training and unloading
  - Standing
  - Walking
- Muscular training
  - Jumping: Plyometrics
  - Eccentric exercises in tendinopathy

Aquatic goals in MSK rehab 1

- NEUROMUSCULAR TRAINING: STANCE
  - Static and dynamic balance training are focused on retraining proprioceptive non-intentional postural control in order to allow the athlete to focus on sport specific goals. Frequently using wobble boards and other balance materials.

- NEUROMUSCULAR TRAINING: GAIT
  - Gait parameters show slight differences between water and land in terms of kinetics, kinematics and muscular activation (EMG). There are also clear resemblances however. Both resemblances and differences are important for motor learning
  - Treadmill training and plain pool walking can be applied.

Aquatic goals in MSK rehab 2

- STRENGTH TRAINING
  - This item is well established in literature, in which we can find three possibilities:
    - to create posture and movement with hardly any effort (recruitment of motor units) in terms of fine tuning of e.g. local core stabilizers (Bressell 2011) or to give mechanical information to the reorganizing connective tissue after trauma or surgery.
    - to use the resistance properties of flowing water and use variables as velocity and frontal area increase (with equipment) to activate reversal muscle coordination or even build muscle mass (Pöyhönen 2002, Valtonen 2011, Waller 2014)
    - to use aquatic plyometrics , with evidence that exercise increases sprint time or agility, strength (Robinson 2004, Gulick 2007, Arazi and Asadi, 2011) and vertical jump (Robinson 2004, Gulick 2007) similar to the outcomes in land-based plyometric exercise.

Aquatic goals in MSK rehab 3

- REHABILITATION OF ACUTE CASES
  - Evidence shows that aquatic rehabilitation significantly improves
    - function, pain, strength and swelling following e.g. anterior cruciate ligament reconstruction (Tovin 1994, Zamarioli 2008). Land-based exercise leads to similar changes without additional benefits with aquatic exercise and more rapid improvements in some outcomes in early in rehabilitation.
    - walking, balance and pain in acute knee and ankle ligament injuries (Kim 2010)
  - Connective tissue should be addressed carefully, supported by recent evidence that growth factors and inflammatory markers (cytokines) “behave” differently in water (Léauté 2001, Schenking 2009)
  - Eccentric contractions form one of the major components of aquatic therapy in acute cases, just as on land

Aquatic goals in MSK rehab 4

- MAINTAINING AEROBIC FITNESS
  - Training in water, and avoiding strain on the site of trauma or surgery, is a possibility to maintain fitness parameters. Aquatic treadmills, aquabikes, aquajogging or swimming are modes of exercise that can be offered and should follow the rules of aerobic training.
  - Aquatic treadmill running may be used as an alternative to running when high level weight-bearing function is limited by pain or injury. Cardiovascular fitness is maintained in persons using aquatic aerobic training over 3-6 weeks (Gatti 1979; McLuckie and McKenzie 1991; Eyestone 1993; Wilber 1996; Bushman 1999).

Why do patients choose hydrotherapy?

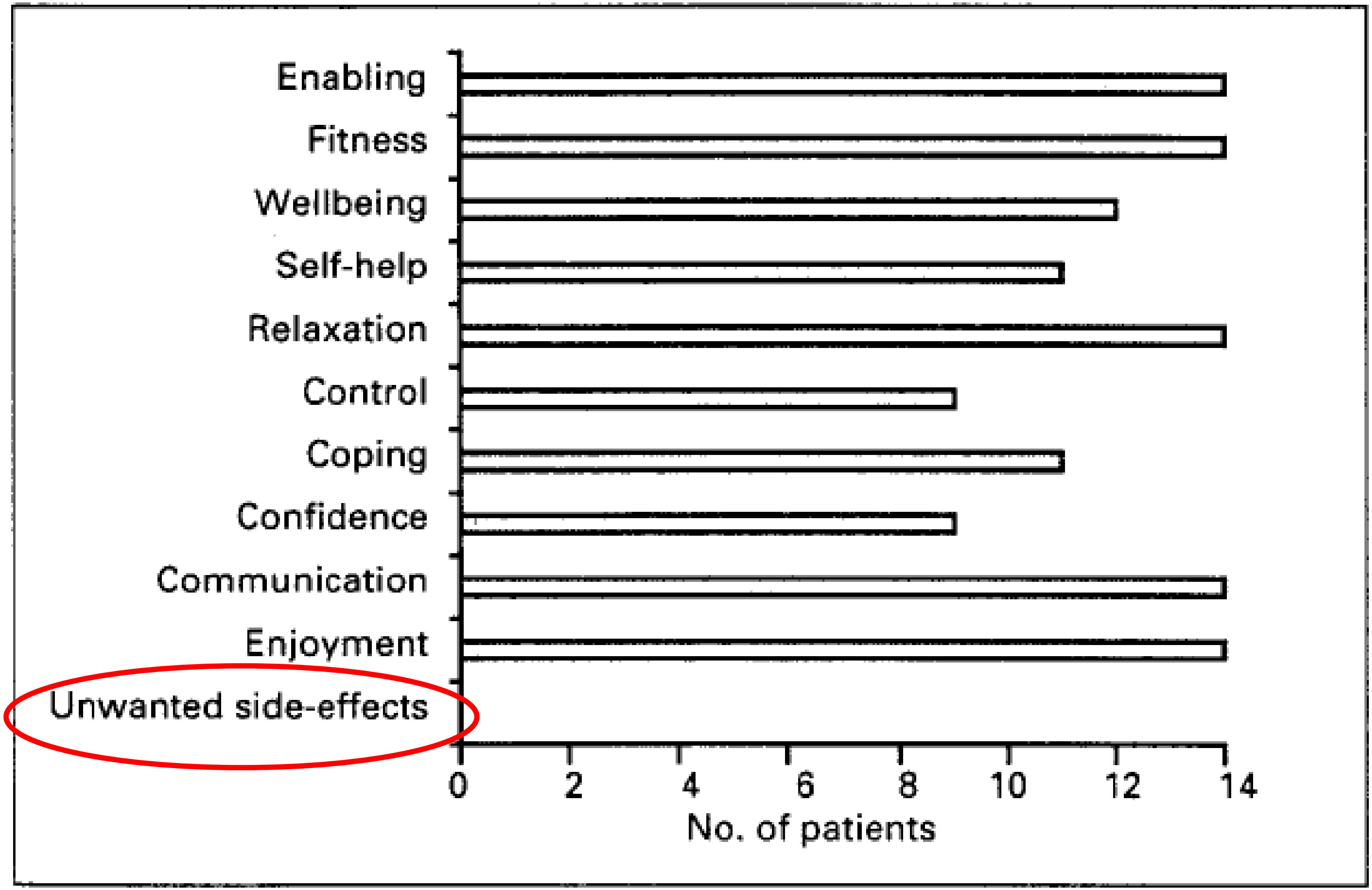


Figure 5. The number of patients who reported that they experienced each effect of hydrotherapy in the validity study (n=14).

Jackson 1996

Hydro and T'ai Chi in knee OA

RCT by M. Fransen, Arthritis & Rheumatism 2007

- T'ai Chi: = 56, Hydro: n = 55, waiting list controls: n = 41
- Mean age = 70, minimum = 63 y
- 12 wk, 2/wk and 12 wk follow up
- > congruence hydro better than T'ai Chi
- > hydro larger improvements in objective measures of physical performance than TC
- > improvements sustained in follow-up

Effect sizes at 12 wk

	Hydro vs control	TC vs control
WOMAC pain	0.43**	ns*
WOMAC function	0.62***	0.63
SF12 physical	0.34	0.25
TUG	0.76	0.32
16m walking time	0.49	0.36

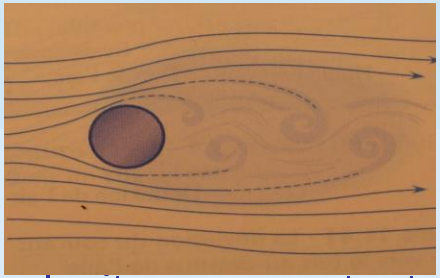
*: knee pain on land because of T'ai Chi position: semi squat

**: recent meta-analysis about graded exercise in knee OA: ES = same range for pain

***: same study: ES physical function (0.23 – 0.39) much lower than here

Walking

Land vs water



- Kinetics are quite different
  - Buoyancy forces: Archimedes law
  - Drag forces: Fd= .5 * d * Ap * v2 * c
    - Fd = drag force, d = density, Ap = frontal plane, v = velocity, c = constant factor
    - The average kinematic viscosity differs 14 times (0-42) in walking

- Kinematics are robust: dynamic similarity
  - At different speeds and in different environments we try to preserve energy as best as possible. For this, biomechanically, we need to walk with similar Froude numbers
    - Froude number: ratio of inertia forces over gravity forces
      - Ref: Exploring biomechanics, animals in locomotion. R. McNeill Alexander (1992). Scientific American Library, New York. ISBN 0 7167 5035 X

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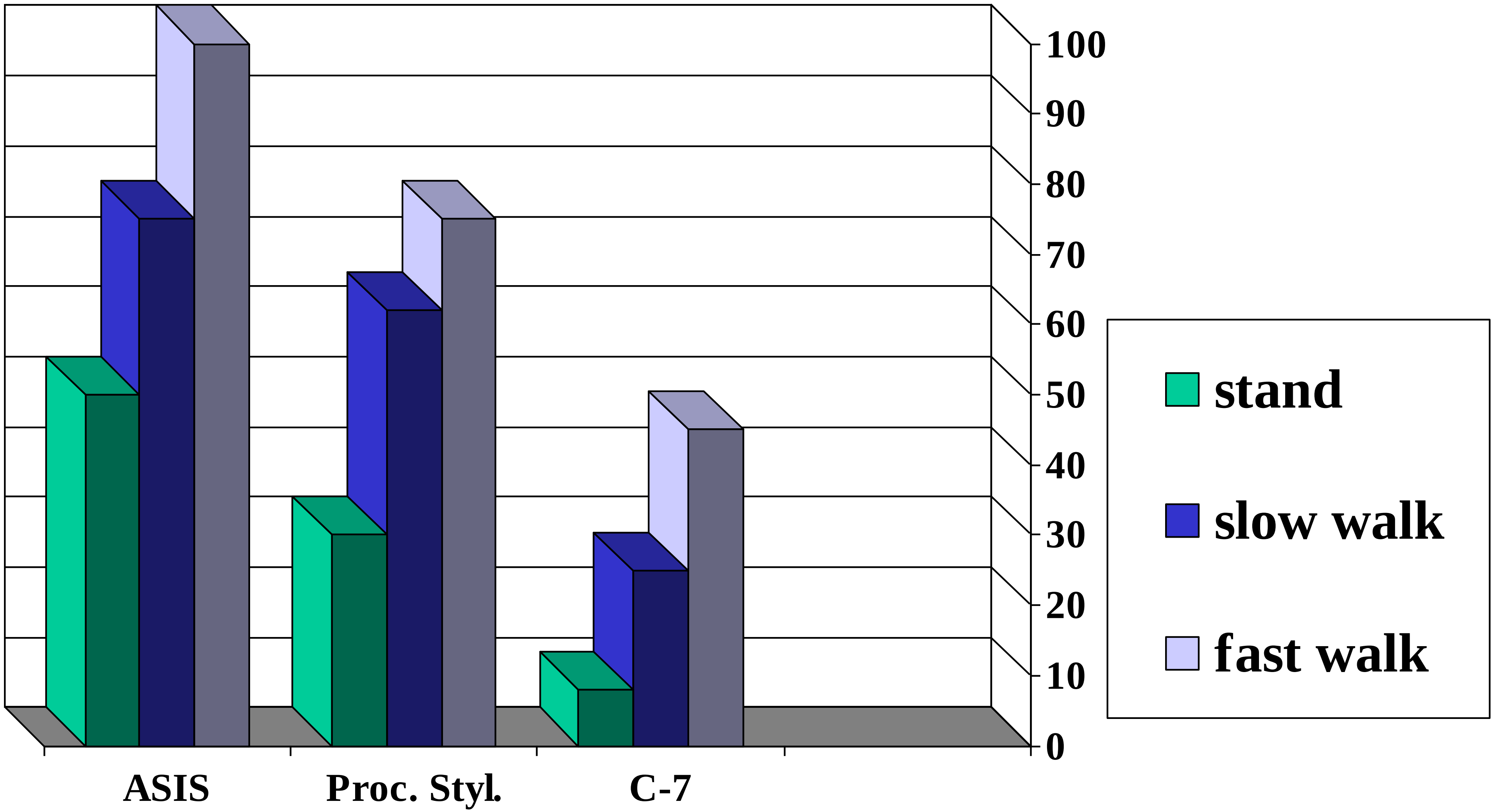
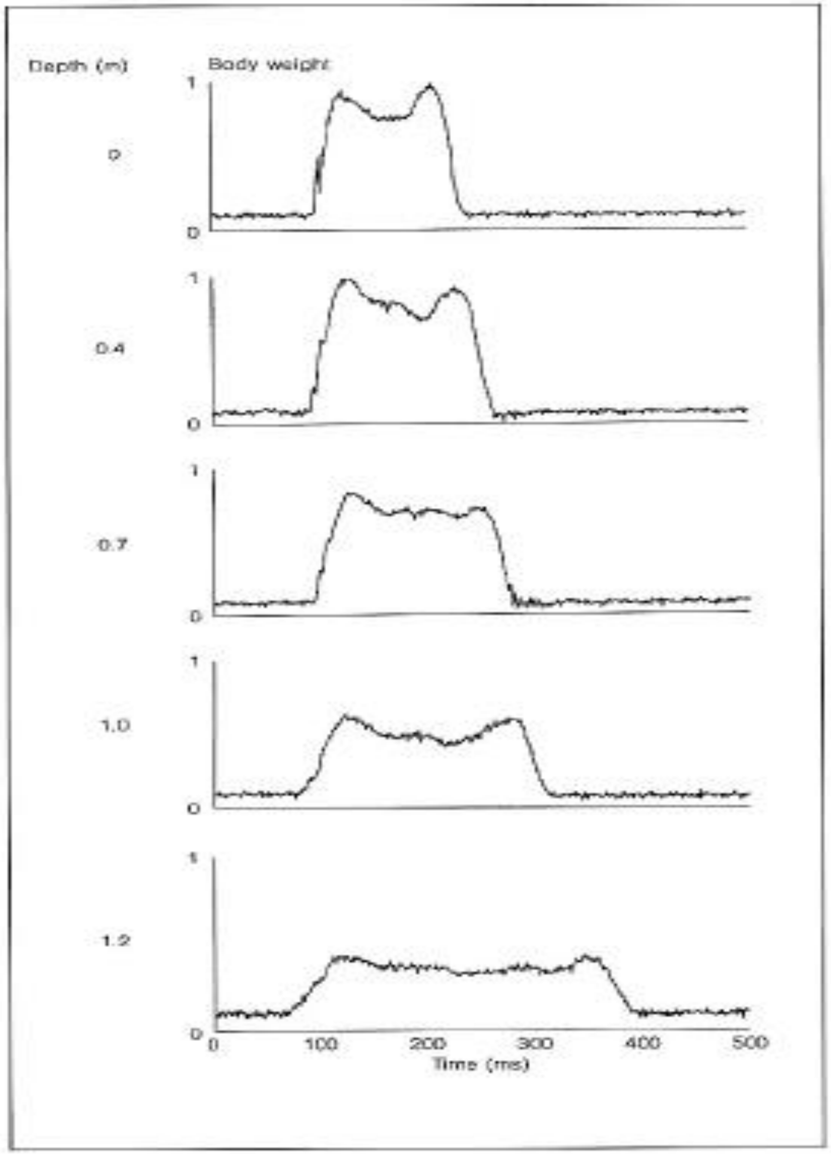
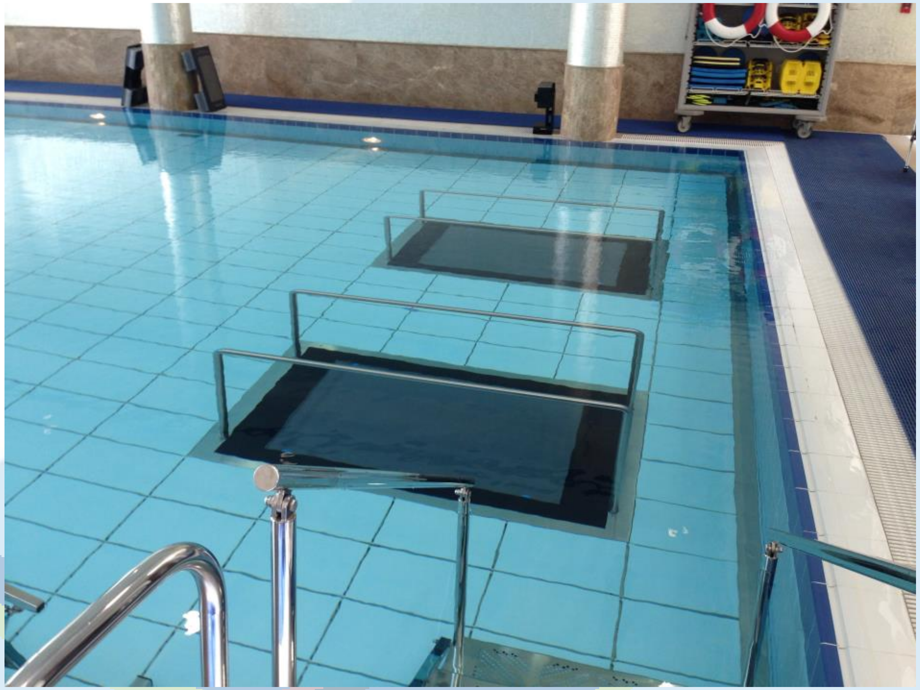
Unloading and resistance

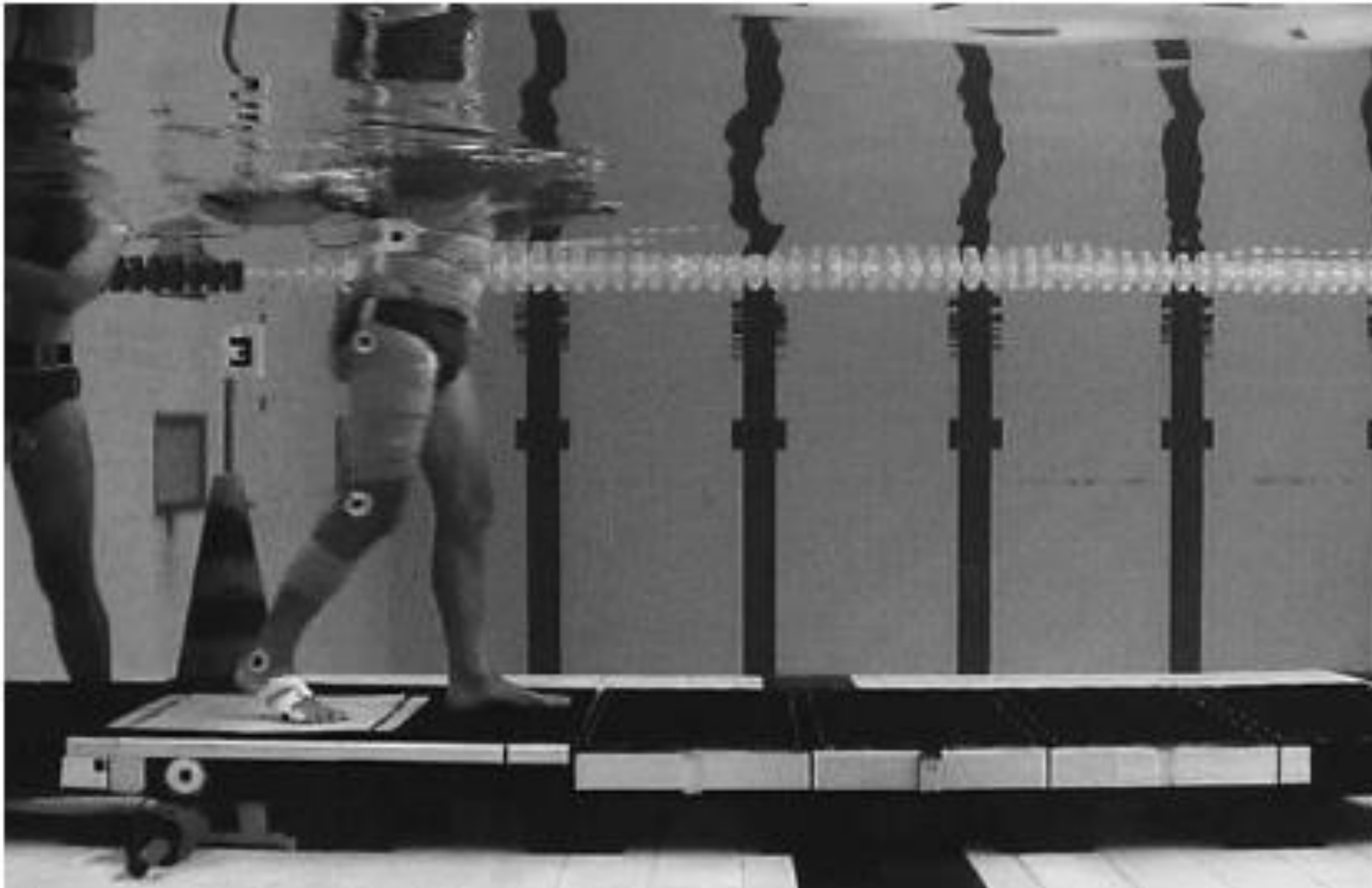
Harrison R, J of Physiotherapy 1987



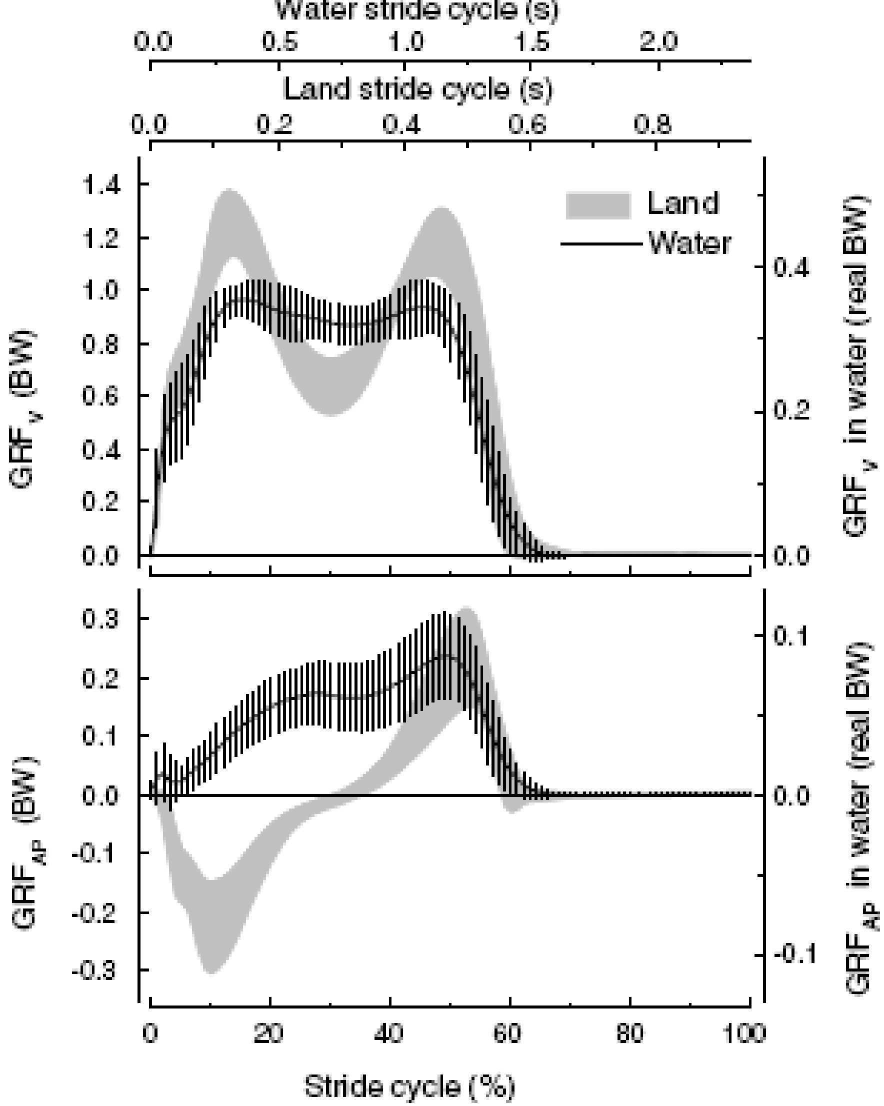


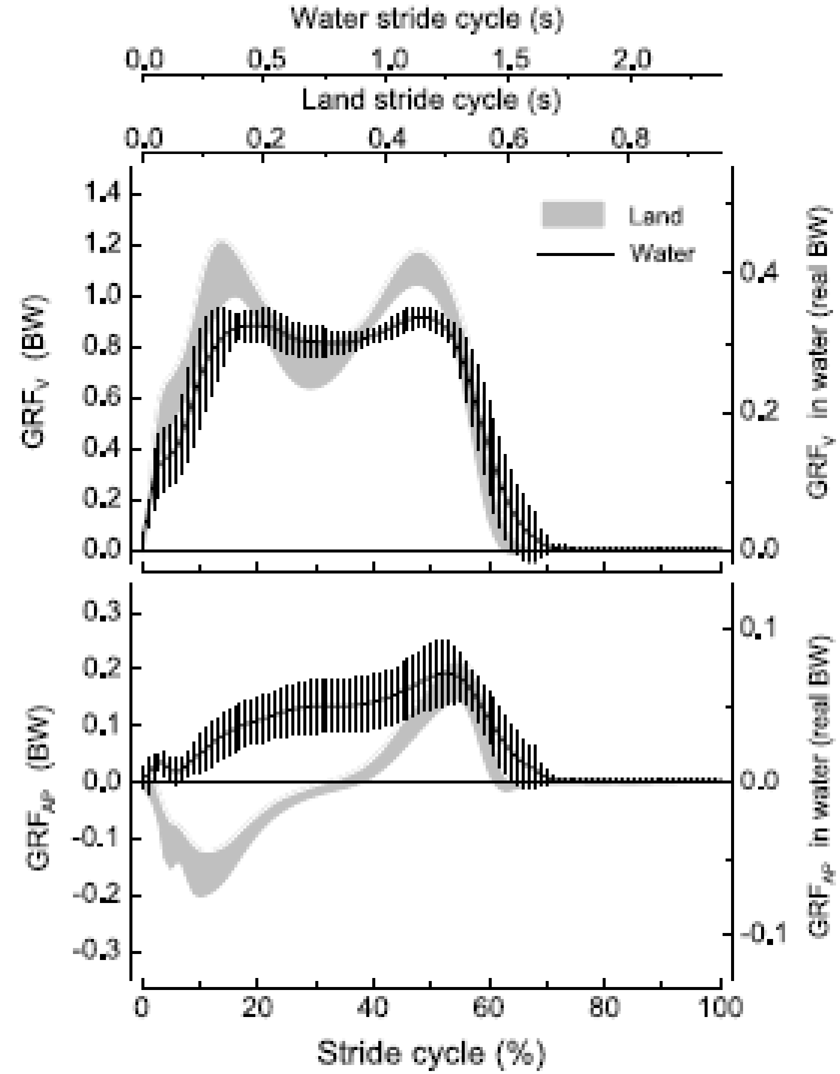
Some differences exist between walking through the pool and on a treadmill: a treadmill is most comparable to land walking, also depending on depth





Barela 2006





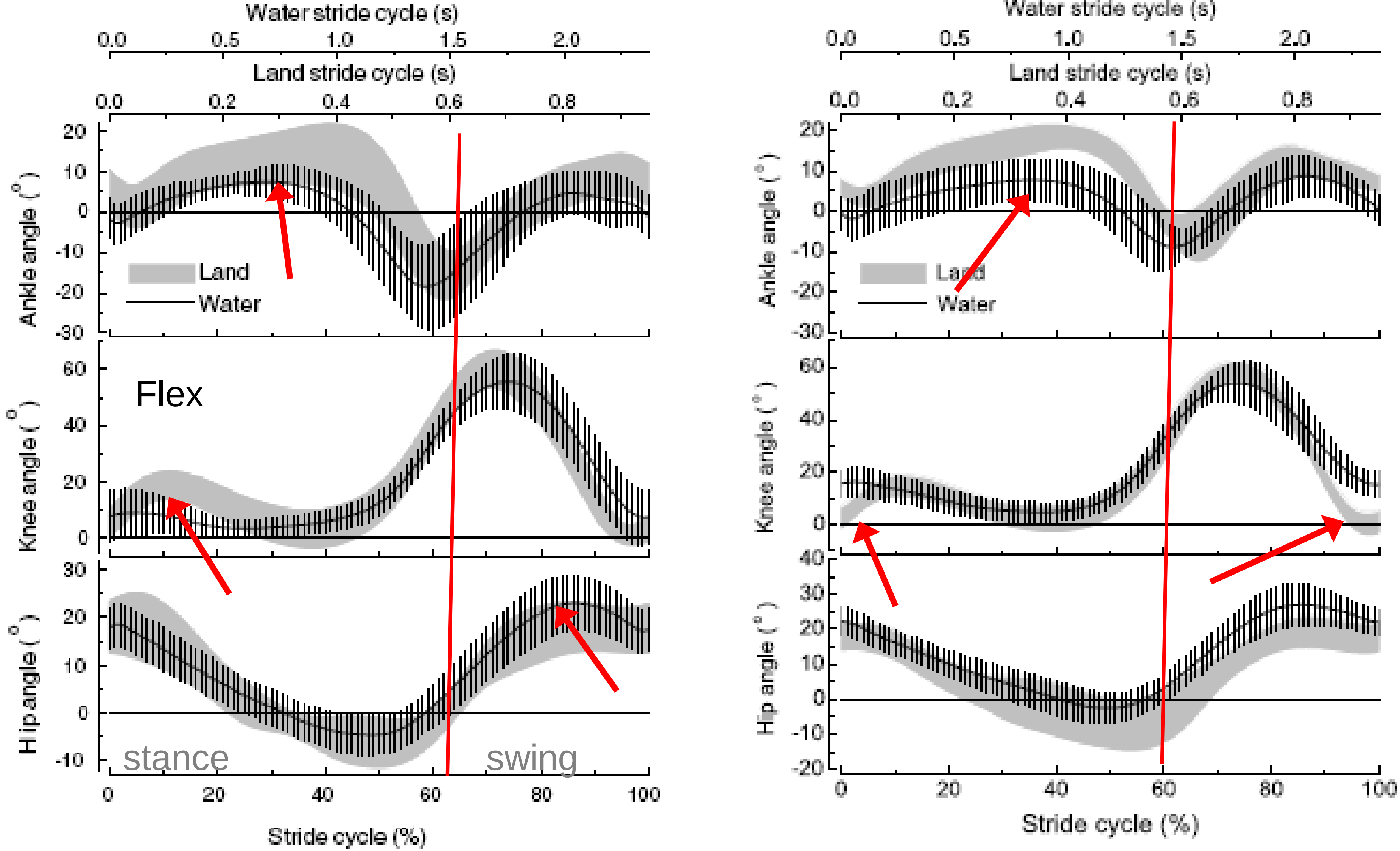
Barela et al 2006a: young adults

Barela & Duarte 2006b: elderly

Always a positive av GRF in water: always propulsion needed against impedance.

Temporal and spatial gait parameters

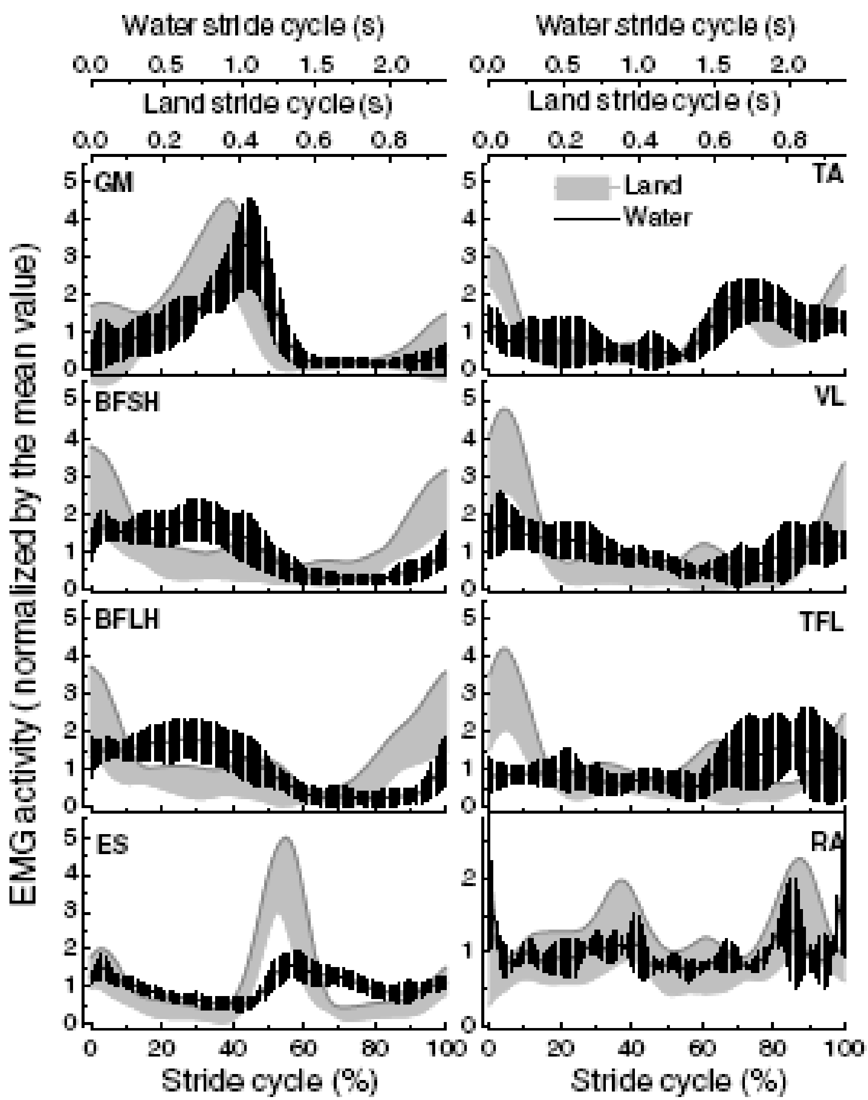
Stride cycle water vs land		Duration (s)	Length (m)	Speed (m/s)	Stance time	Support phase %
Barela a	adults	150% Longer	Same	60% Slower		same
Barela b	elderly	100% Longer*	same	60% Slower*		same
Nakaza-wa	adults				Longer ↑ depth	
Shono treadmill	Adults			Slower		Lower
Chevutsc hi	Adults		25% less	60% slower		
Fowler-Horne	Adults		reduce d	slower		



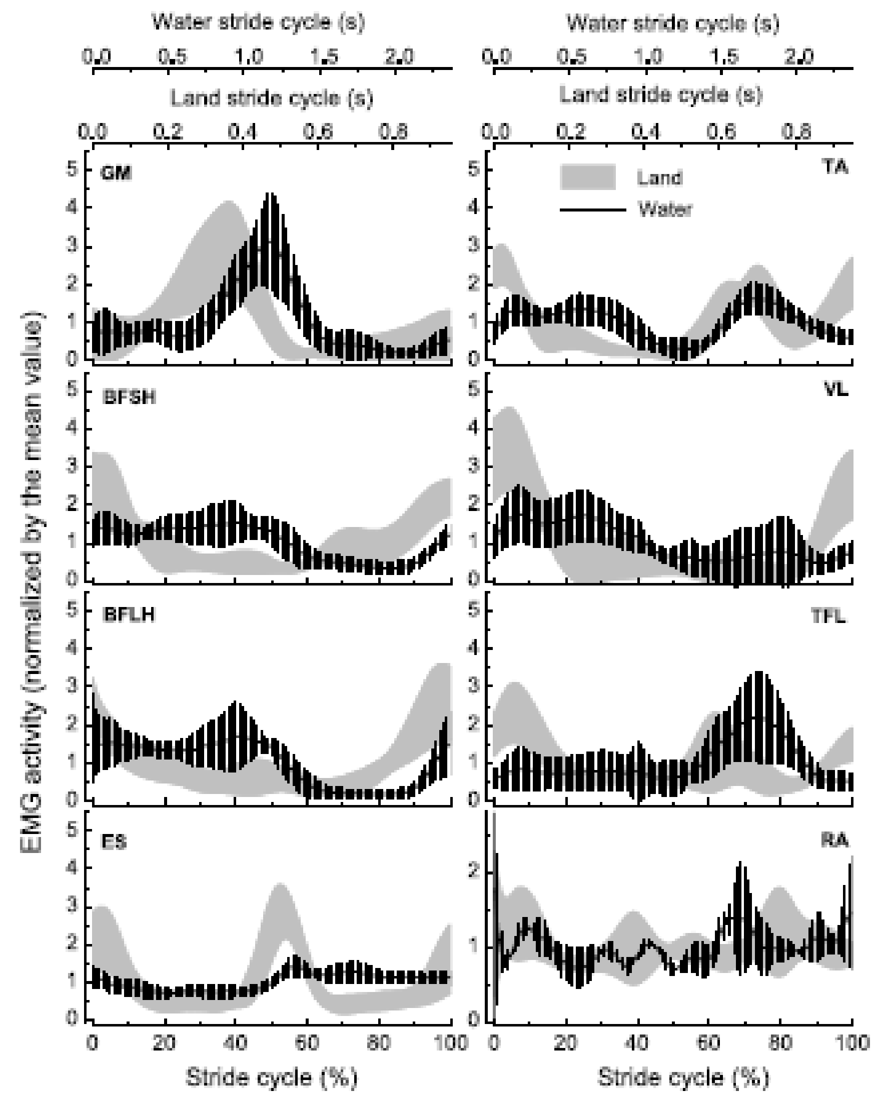
ROM roughly the same on land and in water

Barela etal, 2006a: young adults

Barela & Duarte 2006b: elderly



Barela et al 2006a: adults



Barela & Duarte 2006b: elderly

EMG‘s show less peaks and show more tonic muscle activity

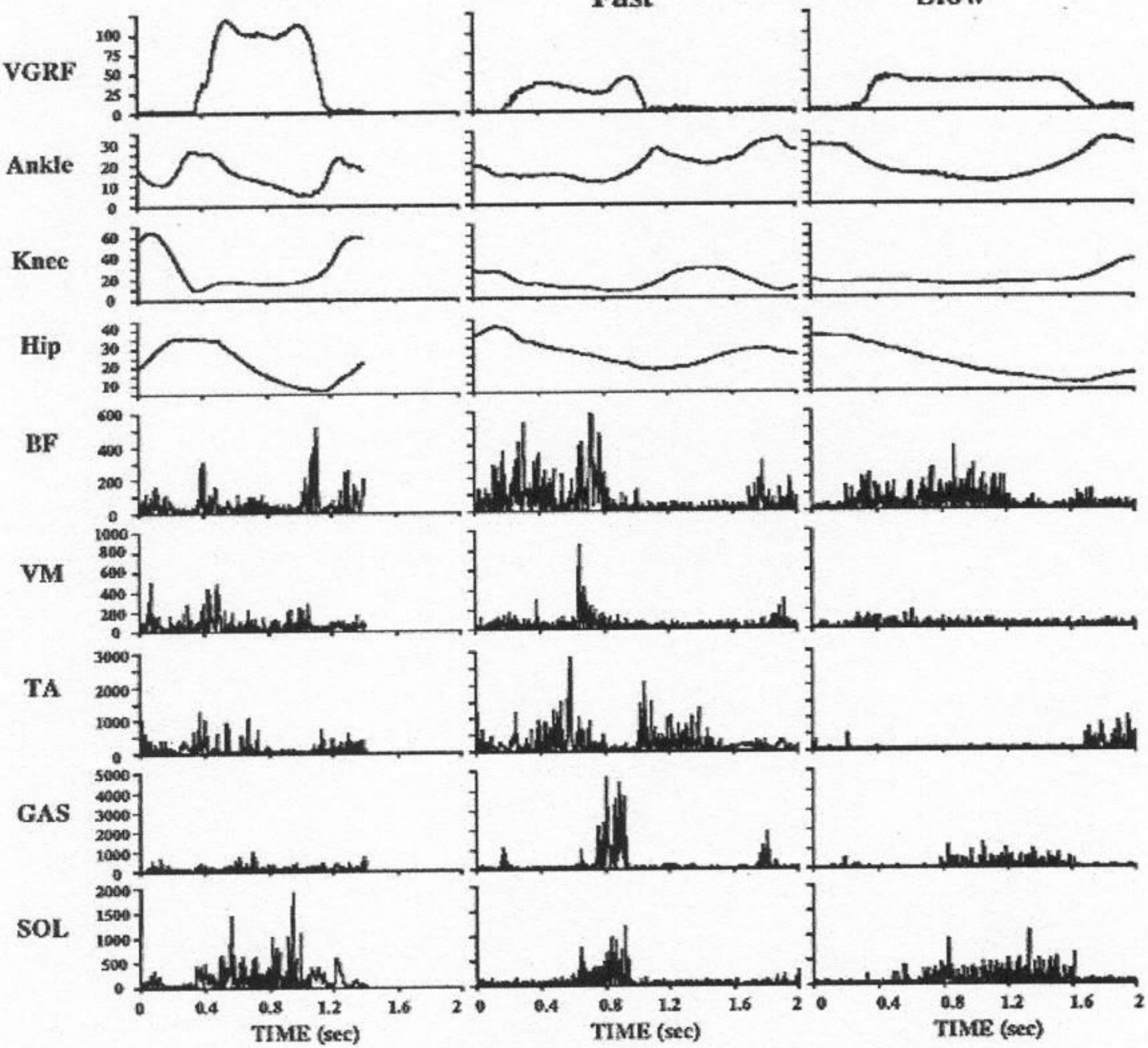


Fig. 1 Ground reaction forces; VGRF (%BW), lower joints displacement; Hip, Knee, Ankle (deg), and full-wave rectified EMGs (a.u.) during the three different walking conditions.

EMG acivity depends on walking speed:

Biceps femoris

Vastus medialis

Tibialis Anterior

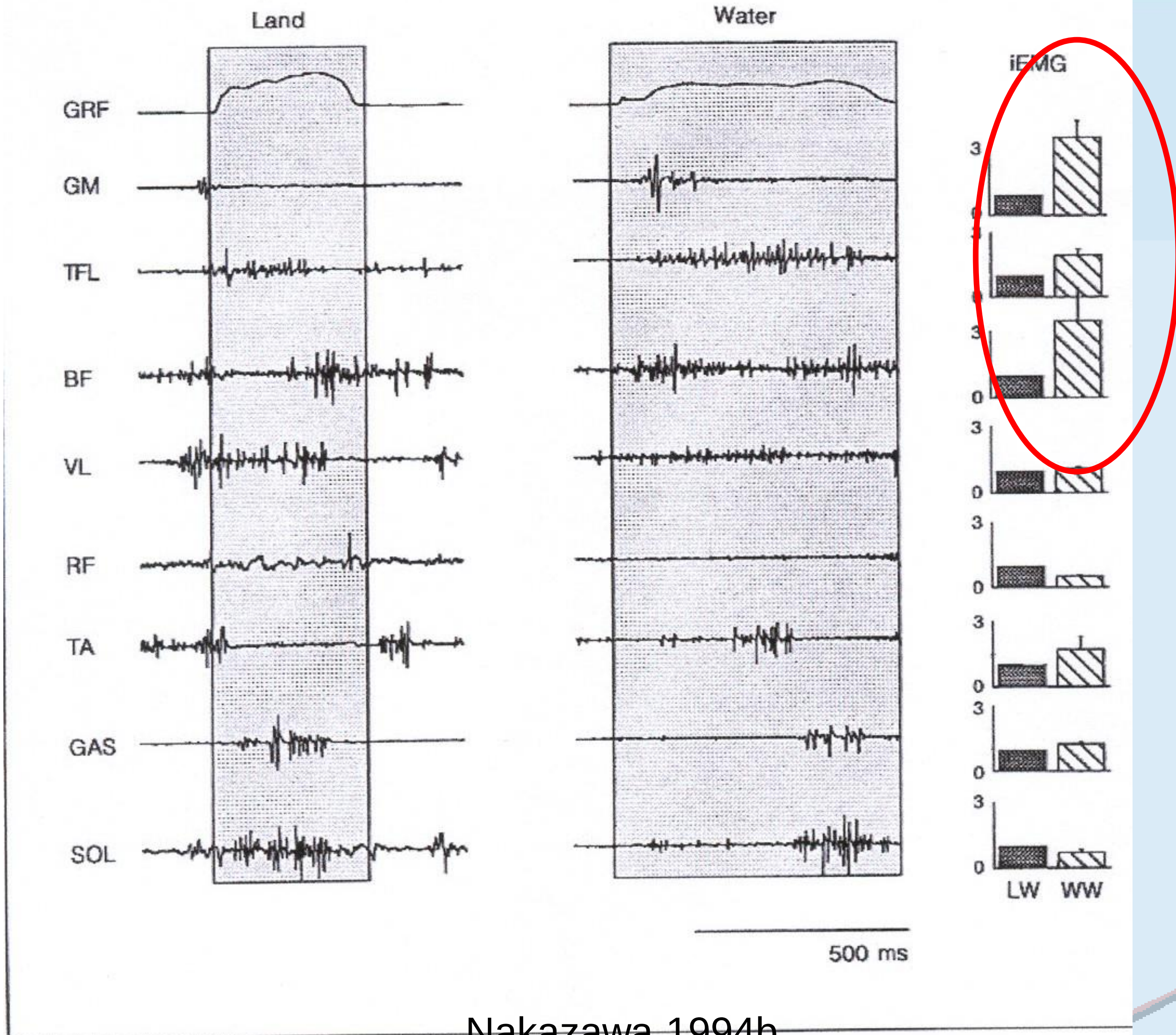
Gastrocnemius

Soleus

Nakazawa 1994

1.30 depth

Speed not quantified



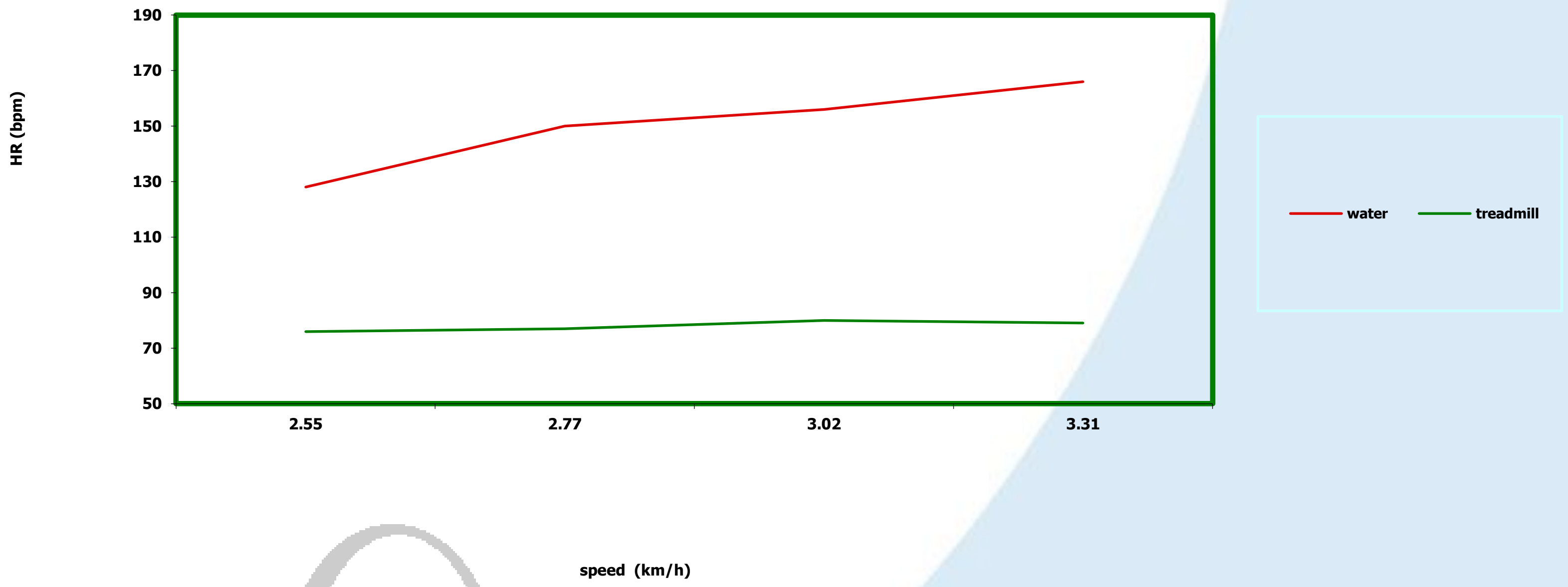
Nakazawa 1994b

Gluteus medialis, tensor fascia lata and biceps femoris are very active

Conclusion

- Walking in a pool, especially on a treadmill, kinematically resembles walking on land
- Kinetics = the forces are quite different = mostly lower
- BUT depending on depth
  - Less vertical peak forces
  - Less a-p braking forces
  - More time till maximum loading

Walking and heart rate

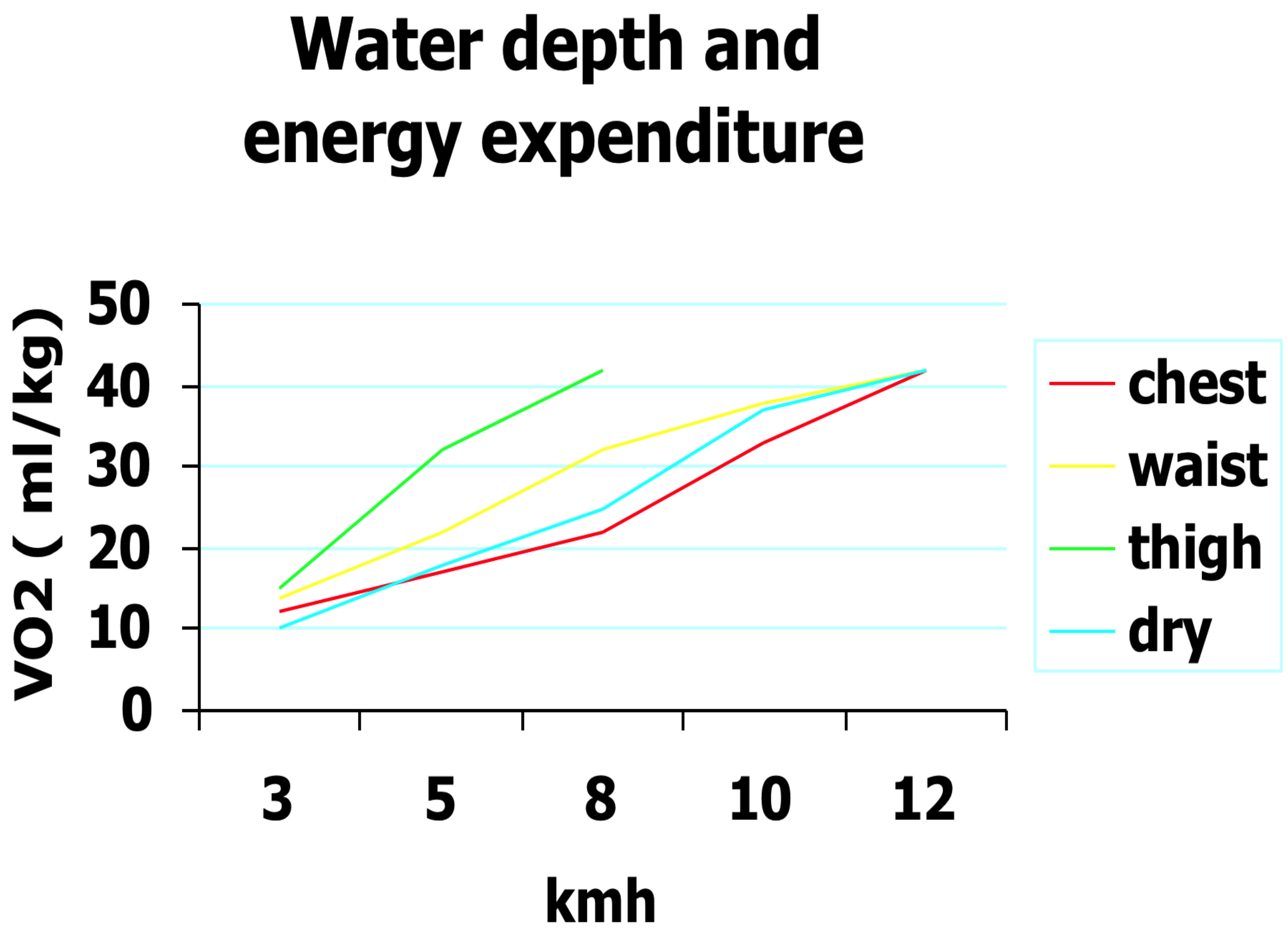


In water: 50-60% of the land speed: similar cardiovascular response

Whitley & Schoene, 1987

Results:

Significant, effects on;
VO_2 max
BMI
Body mass and girth
Body composition
>> same effetcs as land treadmill training



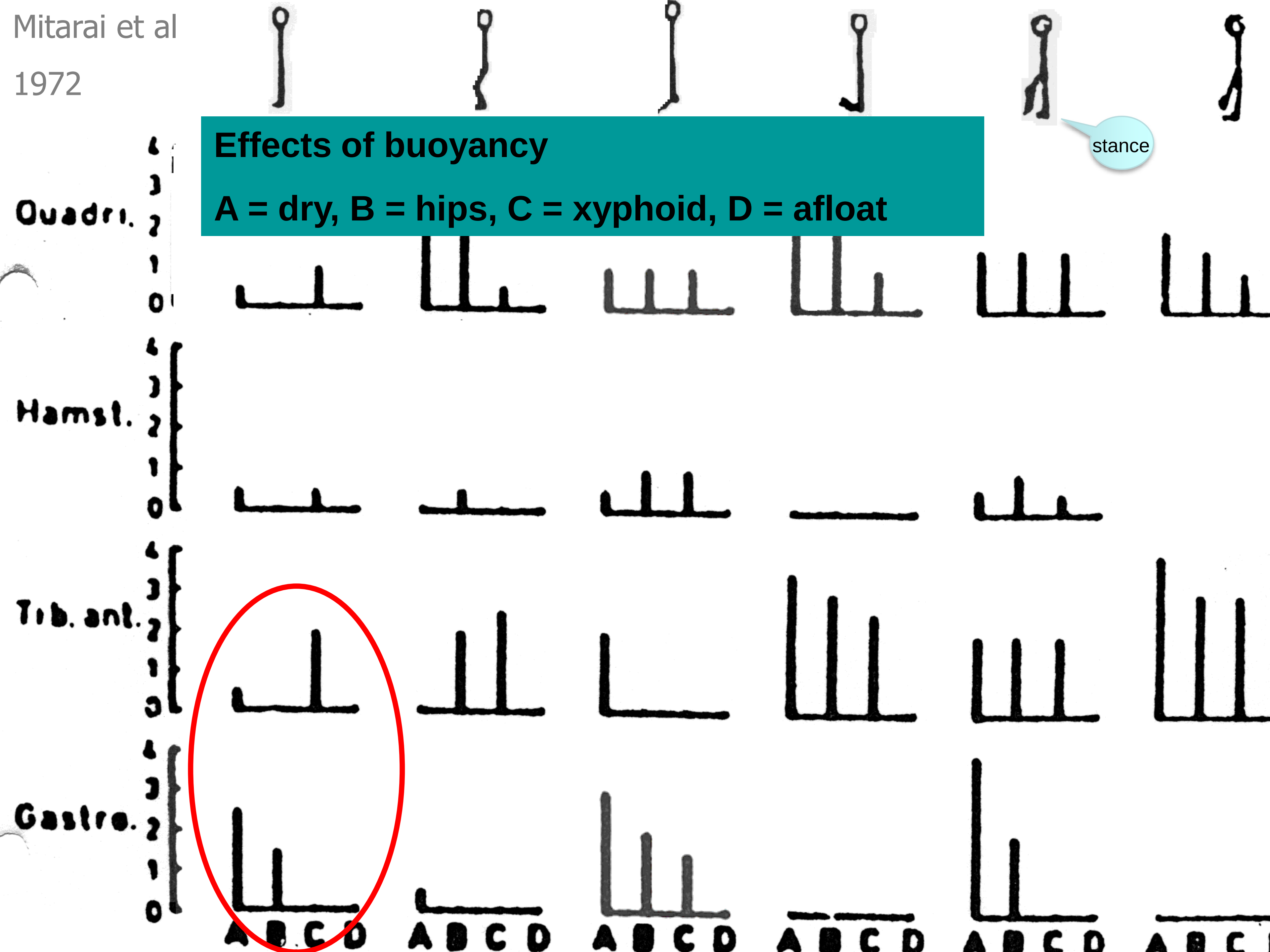
Napoleton, undated. Aquaciser study pack

Physiological responses to running, and walking in water at different depths:

(Pohl M B, McNaughton L R;2003)

- 6 healthy students: walking at 4,0 km/h on a treadmill in water at thighdeep(**TD**) or waistdeep (**WD**), 33^0 C.
- Walking in TD water elicits a cardiovascular workload that comes close to running with 7 km/h on dry land .

Standing



Mitarai et al
1972
Effects of buoyancy
A = dry, B = hips, C = xyphoid, D = afloat
stance
Quadri.
Hamst.
Tib. ant.
Gastro.
0
1
2
3
4
A B C D

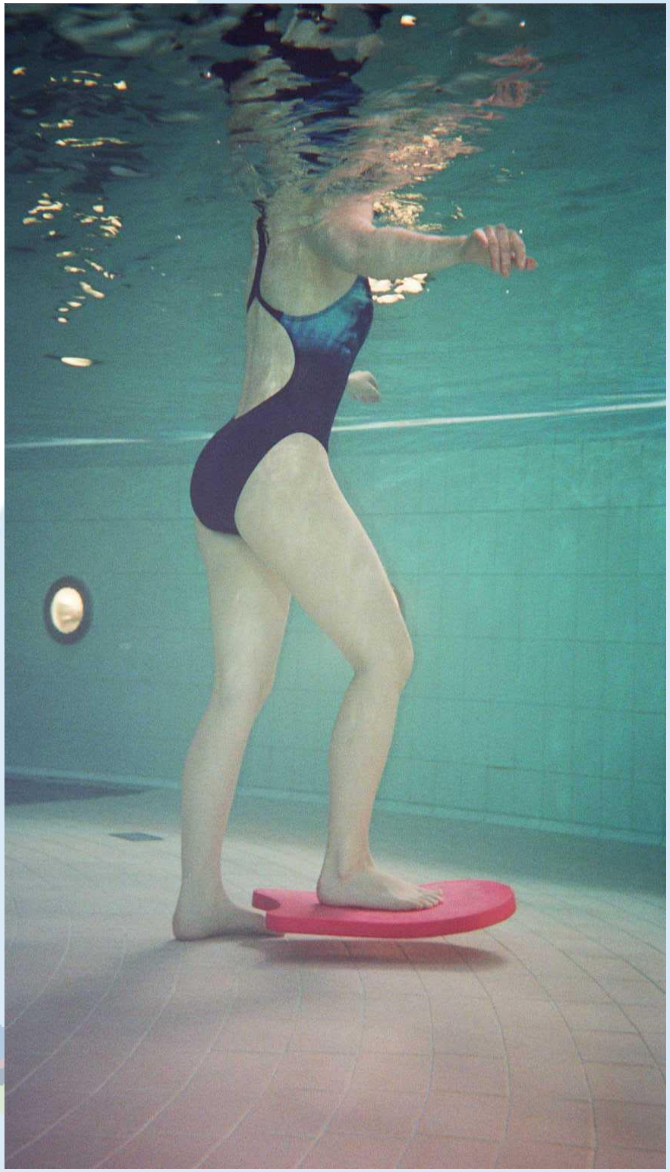
Balance and Proprioception

Patient can safely fall, therefore reducing fear of falling

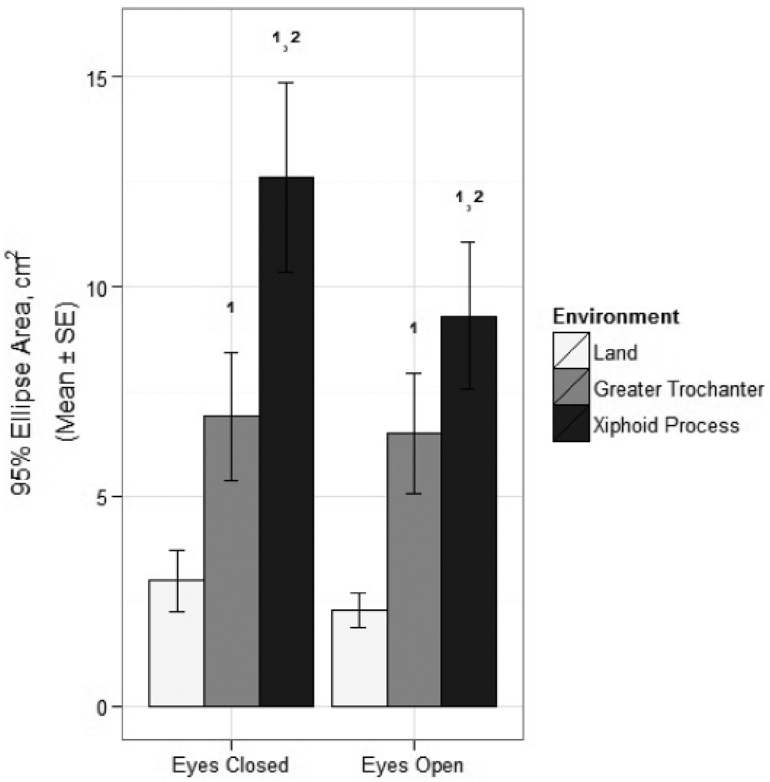
Hydrostatic pressure and buoyancy help to maintain postures previously difficult to achieve due to the effects of gravity.

Increase in activity of sensory receptors, particularly baroreceptors in skin and improved function of joint mechanoreceptors

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



Static balance



- Louder 2014
  - COG displaces more in water than on land: = inherent aquatic instability as basis for neuromuscular training
  - Largest displacement in xypoid deep water
  - Water depth influences COG movements

Training

- Berger 08 / Roth 06
  - This added instability doesn't increase training effects on static balance in healthy young and elderly persons. Land and water training yield similar effects.

- In pathology: statistical significant and clinical relevant increases of postural control in balance tests, e.g. in stroke

Bae 2005, Noh 2008, Chan 2010, Lee 2010, Park 2011, Han 2012

Tests: Berg Balance scale, Tinetti static, posturometry

Wobble boards:

Nobes 00 > medial collateral lig sprain
Kim 10 > LE ligament injury
Vivas 11 > Parkinson
Han 12 > chronic stroke
Asimenia 13 > functional ankle instability
Beneka 03 > Achilles tendinopathy
Roth 06 > healthy persons

Added effects of wobble boards??

Table 1. *Aquatic versus land-based exercises for the early functional rehabilitation of acute lower extremity ligament injuries*

	Aquatic Exercise		Land-based Exercise	
	Ankle	Knee	Ankle	Knee
PRICE (1 week)	Braces (short-term if necessary), ice pack, compression sleeve, elastic wraps, leg elevation			
ROM exercise (2-4 weeks)	Active ROM: pain-free Achilles tendon stretching Isometric strengthening (pain-free per direction)	Active ROM: pain-free Quadriceps/hamstring stretching Isometric strengthening (pain-free per direction)	Active ROM: pain-free Achilles tendon stretching Isometric strengthening (pain-free per direction)	Active ROM: pain-free Quadriceps/hamstring stretching Isometric strengthening (pain-free per direction)
Strengthening exercise (2-4 weeks)	Isotonic contraction: full ROM (plantar/dorsiflexion, inversion/eversion)	Isotonic contraction: full ROM (flexion/extension)	Isotonic contraction: full ROM (plantar/ dorsiflexion, inversion/eversion)	Isotonic contraction: full ROM (flexion/extension)
Proprioceptive training (3-4 weeks)	Wobble boards (full weight bearing) with eyes open or closed, with or without resistance, initial two legs to one leg			
Functional exercise (3-4 weeks)	Walking-jogging-running, figure of 8 drills, lateral cutting drills, double leg jumping, single leg hopping			

PRICE = protection, rest, ice, compression, elevation; ROM = range of motion.

Conclusions: For elite athletes with acute ligament sprains in the lower limb, aquatic exercises may provide advantages over standard land-based therapy for rapid return to athletic activities. Consequently, aquatic exercise could be recommended for the initial phase of a rehabilitation program.

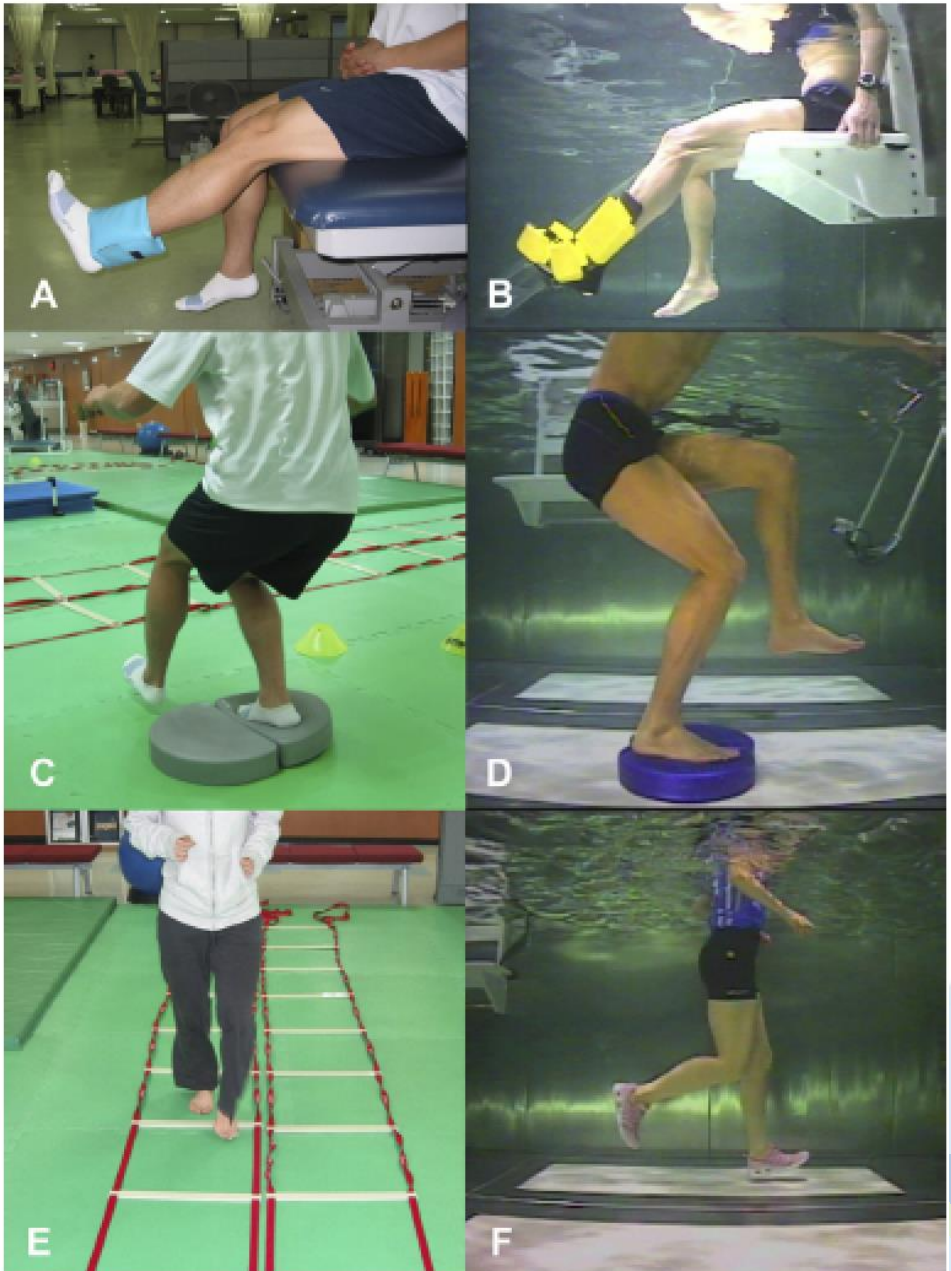
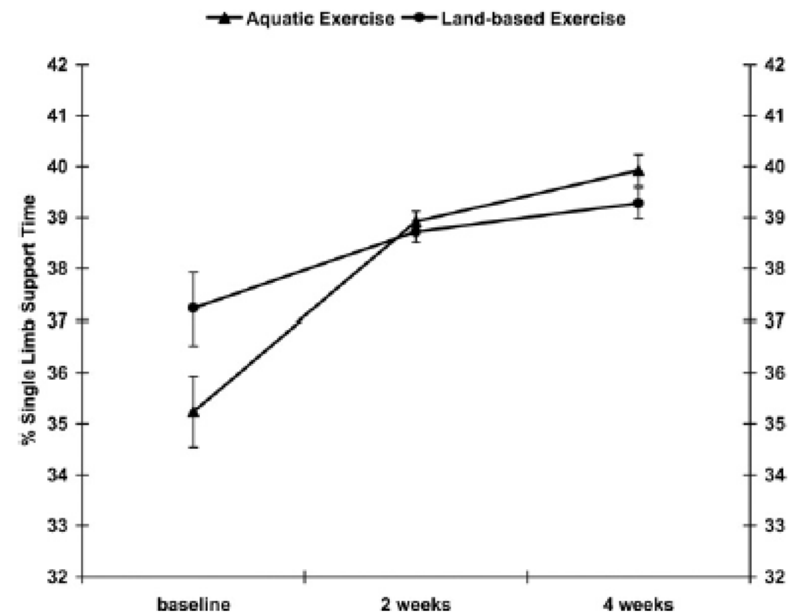


Figure 2. Land-based exercise and adapted aquatic exercise showing strengthening exercise (A, B), proprioceptive t
(C, D), and functional exercise (E, F). Athlete is running on the underwater treadmill (F).



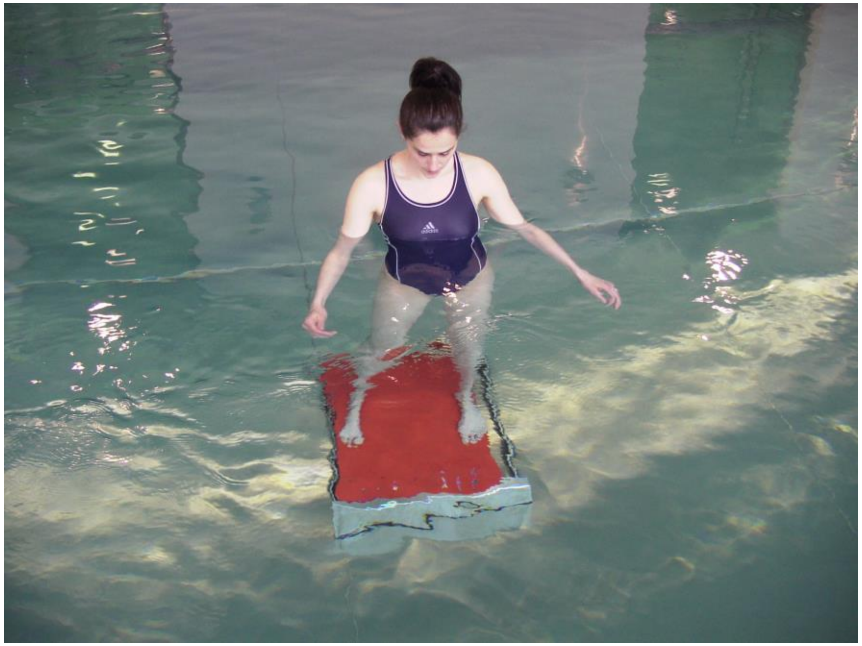
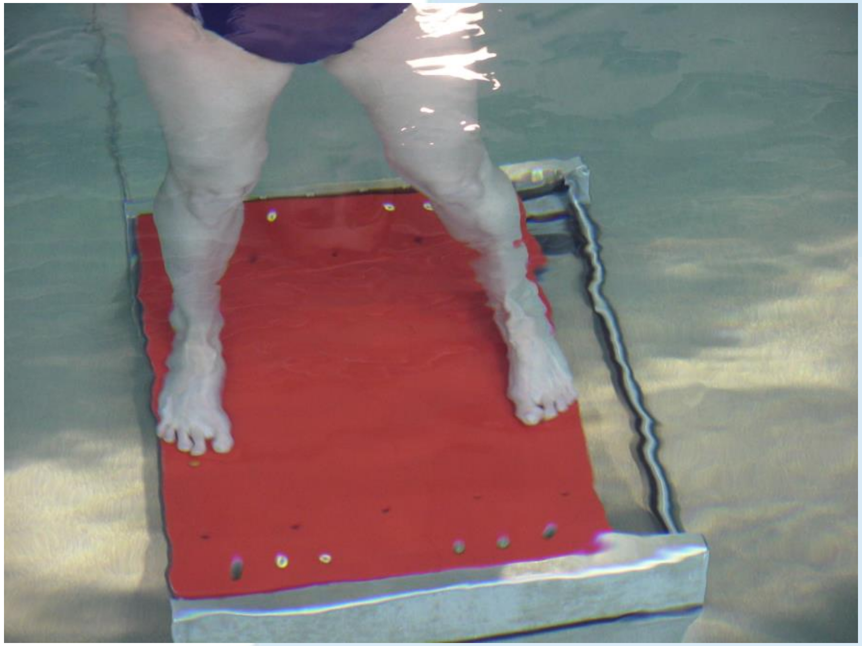
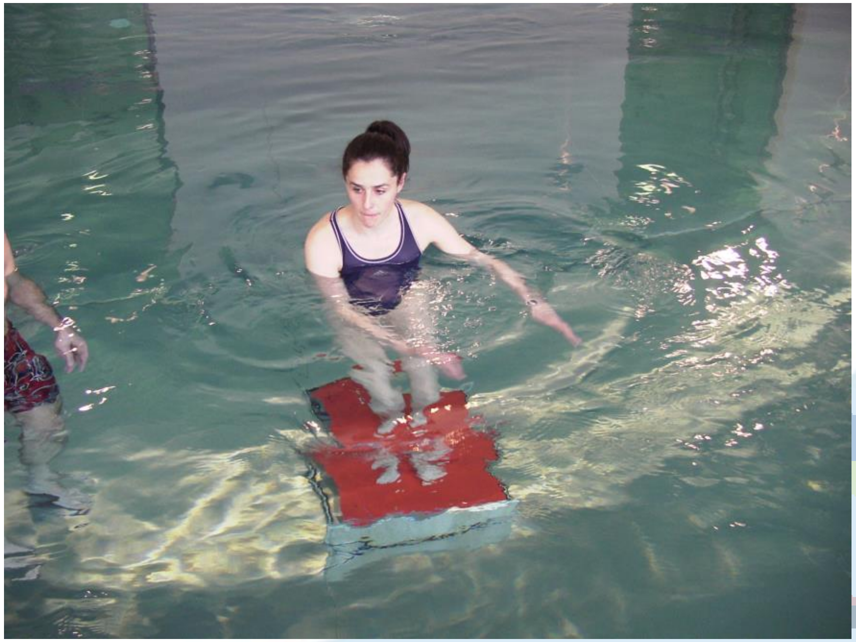
Kim et a 2010l: elite athletes with LE ligament rupture

Physical Medicine & Rehabilitation

Table 3. *Effects of the early functional rehabilitation on outcome measures at baseline, at 2 and 4 weeks in both groups*

	Aquatic Exercise*			Land-based Exercise†			Interaction Effect‡
	Baseline	2 Weeks	4 Weeks	Baseline	2 Weeks	4 Weeks	
VAS for pain	5.70 (0.361)	1.25 (0.362)	0.17 (0.157)	5.66 (0.361)	2.19 (0.362)	0.73 (0.157)	$F = 3.75$, $P = .033$
Stability Index at level 5	5.21 (1.017)	2.65 (0.474)	1.80 (0.355)	4.28 (1.017)	3.50 (0.474)	2.67 (0.355)	$F = 2.56$, $P = .124$
Stability Index at level 3	7.61 (1.045)	3.55 (0.540)	2.38 (0.405)	5.70 (1.045)	4.05 (0.540)	3.26 (0.405)	$F = 5.64$, $P = .027$
Test completion time (s)	196.67 (15.116)	148.18 (11.800)	131.98 (9.331)	178.69 (15.116)	166.36 (11.800)	150.92 (9.331)	$F = 8.23$, $P = .005$
%Single limb support Time	35.24 (0.702)	38.92 (0.205)	39.93 (0.302)	37.23 (0.702)	38.72 (0.205)	39.28 (0.302)	$F = 4.16$, $P = .049$

*†Values are adjusted mean by covariates ± standard deviation in parentheses.


Aquatic training for ankle instability

Asimenia G et al, 2013

- RCT (n=30) physically very active collegial students with ankle sprains and instability as measured by the Biodex stability system.
- AT and land wobble board training were compared
- Both groups: ss increases, no intergroup difference

Table 1.

Balance Training Program.

Exercises performed on (*a*) "hard balance board" and (*b*) on "air disk"
1. Attempt to maintain single-limb stance"
2. Attempt to maintain single-limb stance and try to bend and extend the knee
3. Attempt to maintain single-limb stance and try to move the unsupporting leg in front and back
4. Attempt to maintain single-limb stance and try to catch and return the ball to the trainer
5. Attempt to maintain single-limb stance while the trainer from the back passes the exerciser

Neuromuscular training (NMT)
Grindstaff 2006

- Tendinopathy: therapy and secondary prevention
  - Proprioceptive balance training
  - Training of (eccentric) strength, velocity and agility
  - Plyometrics
  - Sportspecific techniques

Components of therapy in tendinopathy

- Eccentric strength
  - For trauma of hamstrings , patella tendon and tendinoses of the achilles tendon
    - Arnason 07, Johnson 08, Visnes 07
- Trunk stabilization
  - Control movement and position of the trunk relative to the pelvis, as a basis for peripheral force production
    - Kibler 06, Zazulak 07
- Velocity and agility
  - Training of walking / running technique (drills)
- Proprioceptive balance training
  - To increase function of CT, strength and proprio.
    - Gauffin 98, Sheth 97

Exercise: anti-inflammatory properties

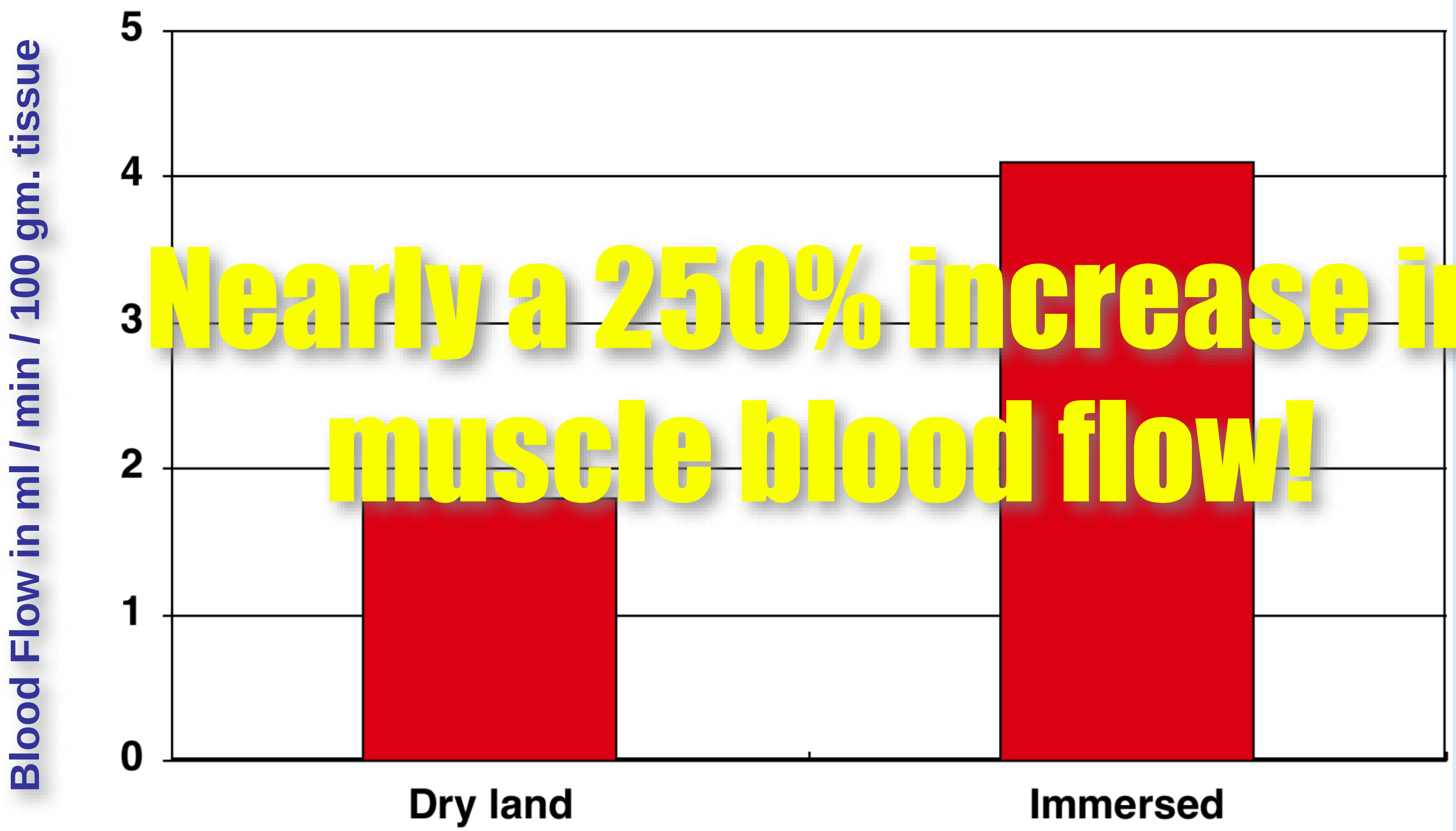
Teixeira 2011, *Cardiovascular Diabetology*

- Regular aquatic exercise:
  - ❿ ↓ pro-inflammatory cytokines: IL-6, TNF-α, CRP
  - ❿ ↑ 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-α (which increases insulin resistance)

Muscle Blood Flow with Immersion

Thermoneutral temperature, neck depth, seated



Nearly a 250% increase in muscle blood flow!

Balldin, Aerospace Med 42:489-493, 1971

Eccentric vs. Concentric Training

6 weeks eccentric and concentric training on leg extension machine. One leg concentric, other eccentric.

Isokinetic force increases in both trainings

Concentric 18% $p < 0.01$

Eccentric 31% $p < 0.001$

Spurway NC et al: Eur J Appl Physiol: 2000; 82 (5-6) 374-80

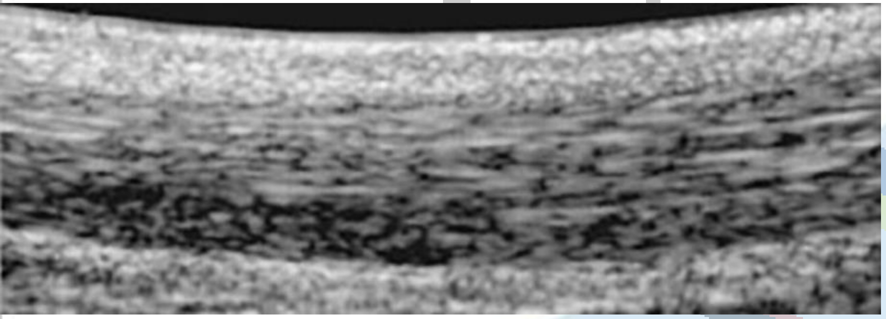
Healing of chronic connective tissue problems

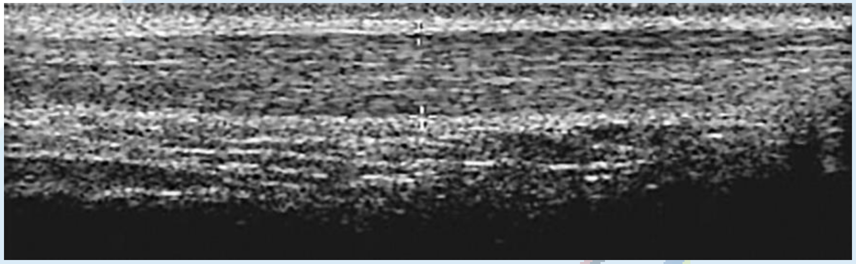
Eccentric training normalises tendon structure and thickness in chronic achillodynia

n = 25, 19 ♂, 6 ♀, 12 w eccentric calf muscle training

Diameter Achilles tendon in mm

	T0	T1 3.8y	p
Exp.	8.3 +/- 3.0	7.6 +/- 2.3	P<0.005
Contr.	5.3 +/- 1.3	5.9 +/- 0.8	n.s.





Ohberg L et al: Br J Sports Med 2004

Plyometric aquatic training

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EU Aqua-outcome project
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Plyometric contraction

- 1. Intensive eccentric contr
  - ROM not too much
  - Eccentric phase not too long
- 2. Amortization / transition phase
  - Less then 250 ms
- 3. Rapid concentric contraction
- = stretch-shortening cycle CCS
- In plain words: bouncing

Plyometrics:

- Why
  - To store elastic energy of serial connective tissue
  - To use the (pre)stretch reflex = preactivation of extra cross bridges during the eccentric phase
  - To inhibit antagonistic activity at spinal level
- Effects: better than with conventional training:
  - Acceleration / explosiveness
  - Strength (both fiber types 1 and 2) and power
  - Proprioception
- Disadvantage: chance of overuse injuries, DOMS

Aquatic plyometrics

- Reduced forces on tissue during the impact
- Less “traumatic” and same effects as on land
- Also a possibility to increase the volume of training before reaching the injury treshold
- Less weight bounce and therefore probably a more rapid amortization phase (questioned by Miller 2009)

Aquatic plyometric training

- In healthy young subjects aquatic plyometric training has been shown to
  - Improve sprint time
  - Lower limb strength
  - Increase vertical jump height
- 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
- Triplett et al (2009) compared concentric and impact forces of single leg jumps in an aquatic environment versus on land.
  - Peak concentric force and rate of force development was higher in aquatic group
  - Significantly less impact force in aquatic group
- Considering the benefits and low risk would this plyometric training be a possible treatment method?
  - Reduced forces on tissue during the impact
  - Less "traumatic" and same effects as on land
  - Also a possibility to increase the volume of training before reaching the injury treshold

Robinson et al 2004,
Gulick et al 2007,
Ploeg et al 2010,
Triplett et al, Med, Sci. Sports exercise 2009
Arazi and Asadi 2011
Donoghue et al, Sports health 2011

Present RCT's: practical

	Miller 02	Robinson 04	Martell 05	Gulick 07	Miller 07	Ploeg 10
Age	22	20	15	23	25	22
Trained	no	yes	yes	yes/no	no	no
Length + times.wk	8/2	8/3	6/2	6/2	6/2	6/2
Water depth	waist	122-137	122	?	Chest Waist	107
Temp	?	26	28	?	?	30-31
Foot contacts	80-120	300+	Skip/spike/bound 24.4-61m jump 3-4 x 10-30s box jumps 3-15	120-180	80-120	?

No consistent results

- Miller 02
  - Similar results in both groups, do DOMS differences
- Robinson 04
  - Ss ↑ : VJ, peak torque, peak velocity in both land / AT
  - No group differences but less DOMS in AT
- Martell 05
  - Ss ↑ : Vertical jump, knee peak torque after 6 weeks
  - No difference between land / AT groups. Less DOMS
- Miller 07
  - No differences between waist/chest deep plyometrics
  - No intra- and intergroup differences pre-post test

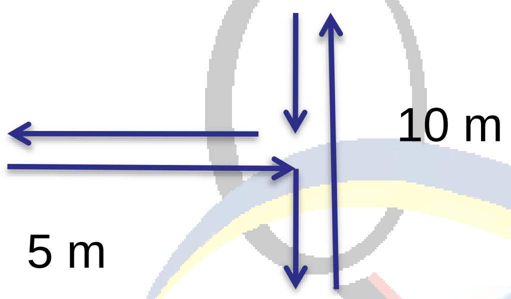
Gulick DT et al

- n = 42 healthy pp
- 2 phases:
  - Phase 1: 4 ex (3*10 reps): 120 foot contacts
  - Phase 2: 5 ex (3*12 reps): 180 foot contacts
- 3 arms: Land – water – control
- Measurements of Quads:
  - Strength, power, agility
- Conclusions: comparable results

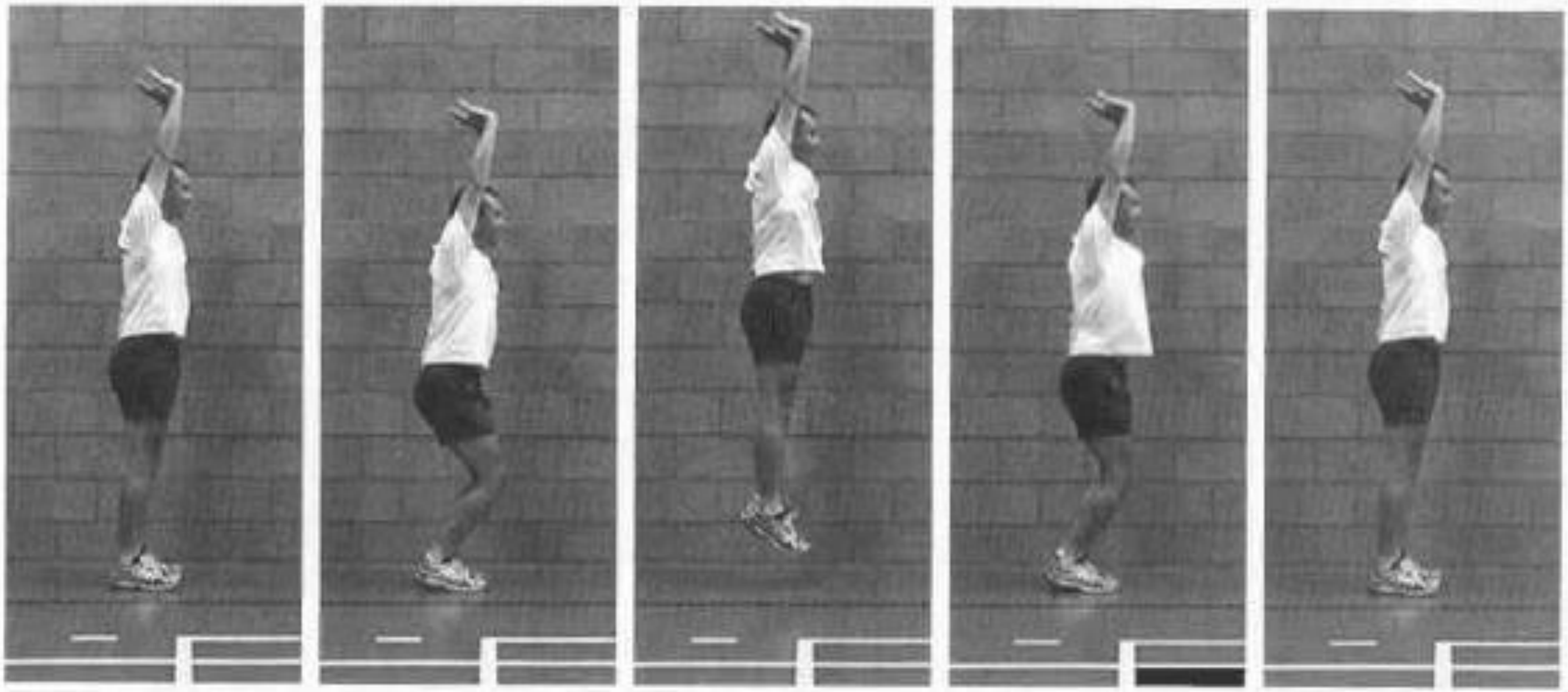
Gullick

- Strength: at 45˚ kneeflex, 3 sec max isometric, with Microfet
- Peak power (W):
  - 61.9 * jump height + 36 * body mass – 1822
- Agility: timed T test run: forward / sidesteps /

  backward



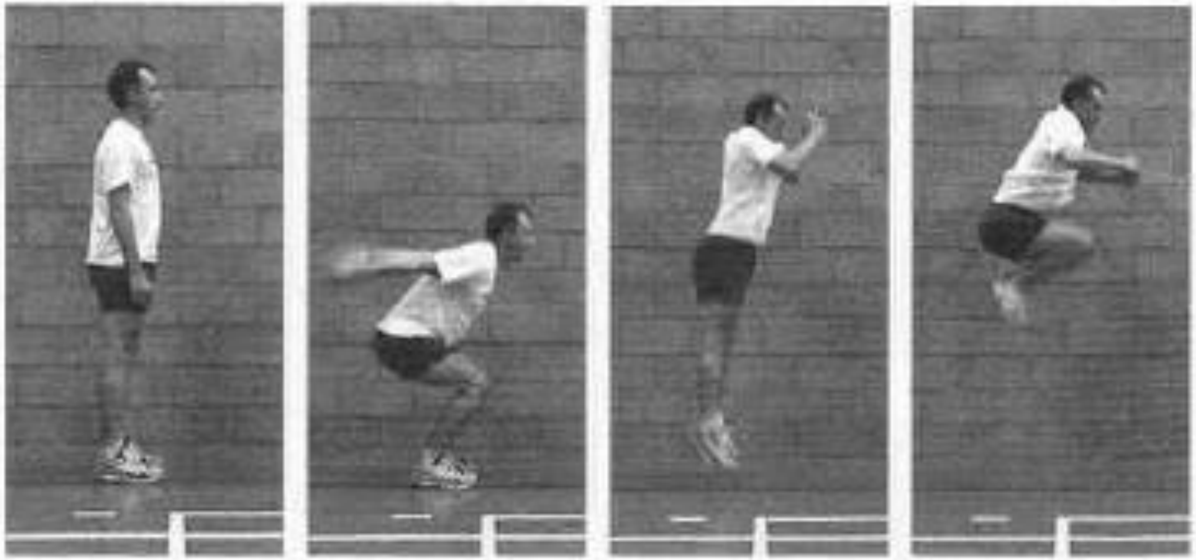
Ps: different protocols and formula exist



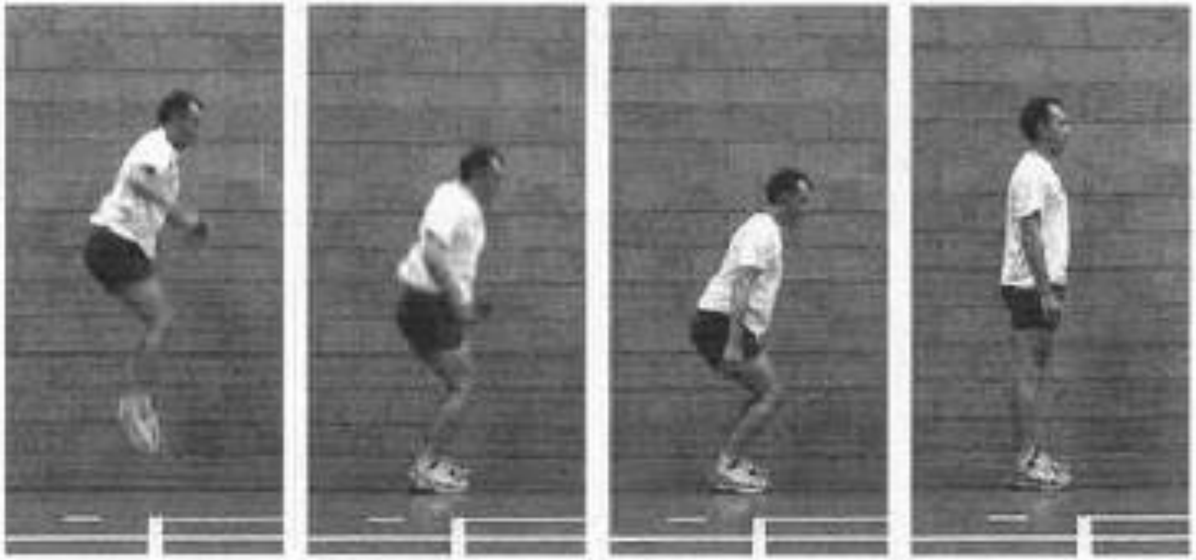
A Wall jump.

Plyometrics

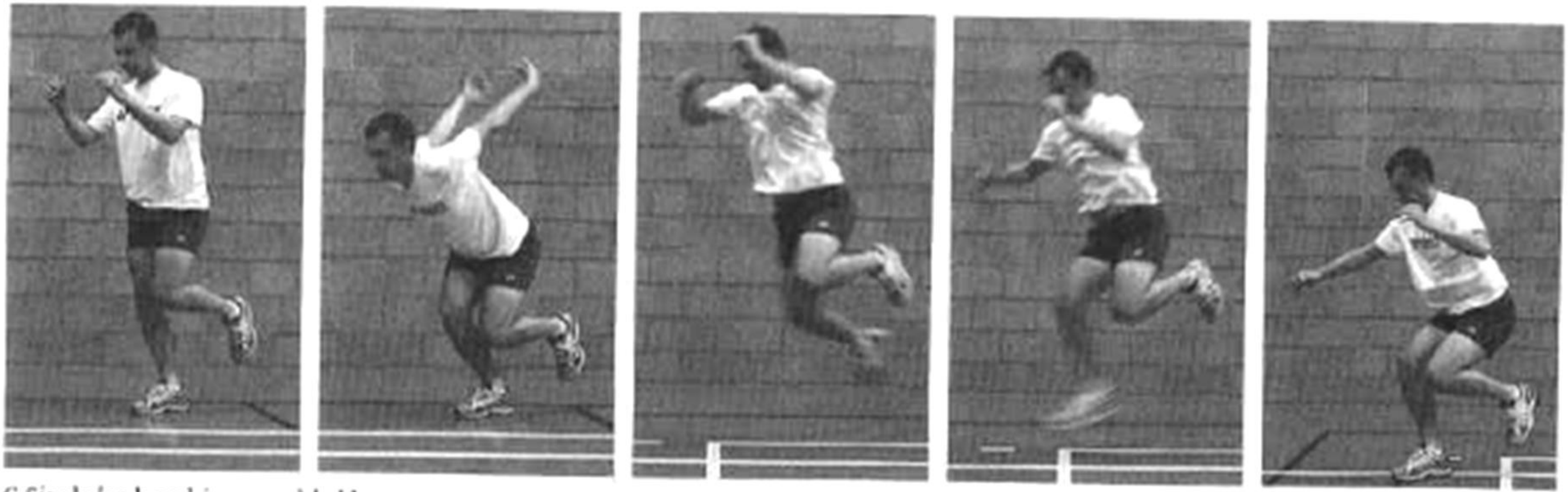
Related to landing after the jump, also including strength of the hamstrings to prevent anterior shift of tibia



B Tuck jump.



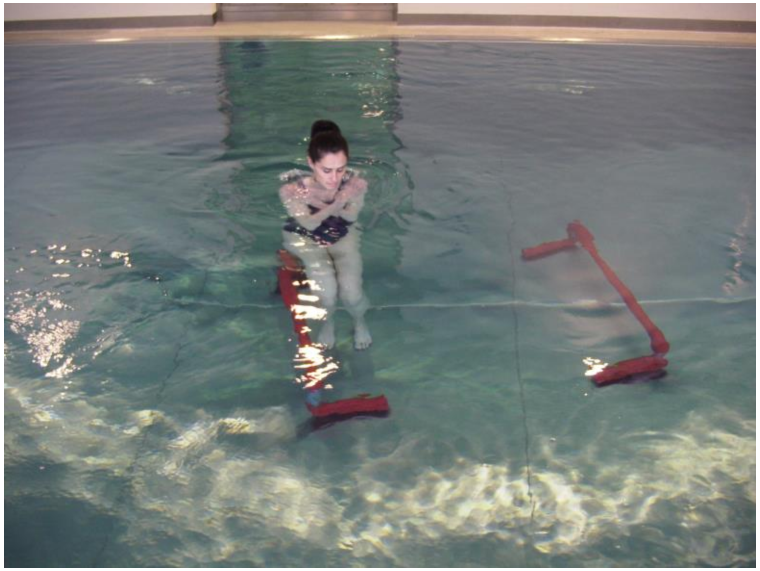
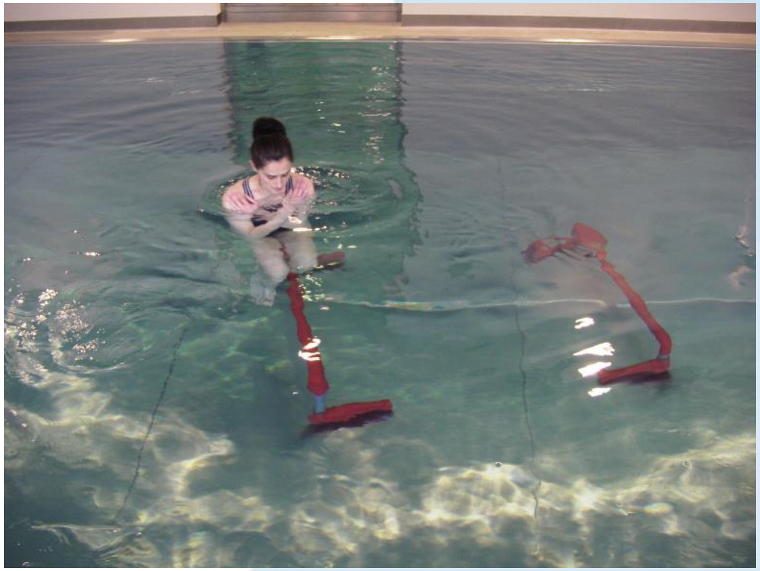
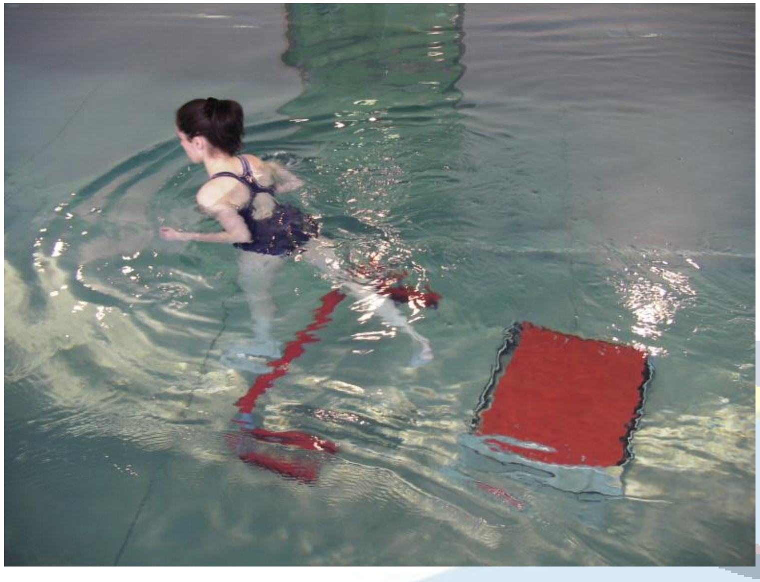
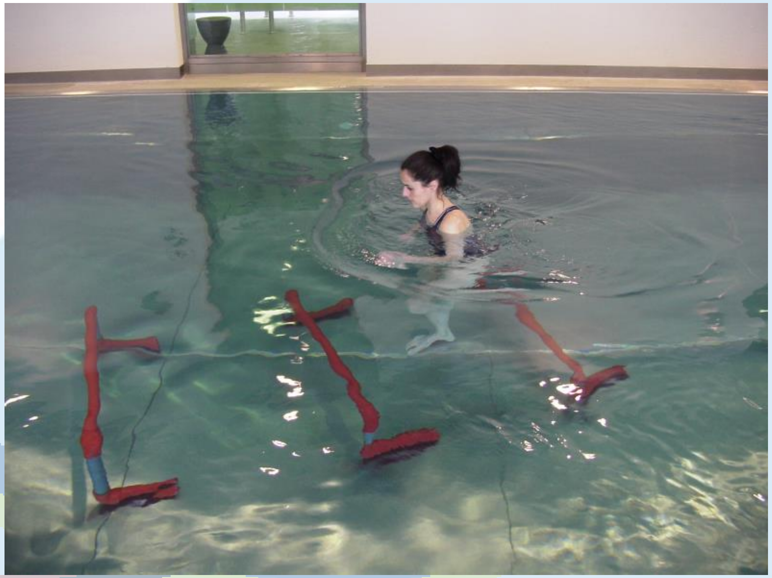
D 180° jump.



C Single leg broad jump and hold.

Plyometric progressive training:

1. Wall jump - with little knee flexion - to tuck-jump
2. Normal high jump to jump with displacement and 180º rotation jump
3. Two-leg to one-leg jumps with hold
4. Squat jumps: > 90º flexion at start, to activate the hamstrings

Ploeg AH et al

- 4 Groups
  - AquaPly1 – AquaPly2 – LandPly – Control
  - Volume AquaPly1 = volume LandPly
  - AquaPly2 has doubled the volume
- Measurements
  - Vertical Jump,
  - Peak power and torque of knee-ext

Ploeg: results

- NO ss differences between the 4 groups in all 3 variables!
- In the first week ss less DOMS in aquatic groups
- Conclusions
  - training should take more than 6 weeks (according to some of the previous studies)
  - Plyo works better in trained persons than in untrained (based on previous articles)
  - Volume is as yet unknown in untrained persons

Pooldepth = 1.07 m

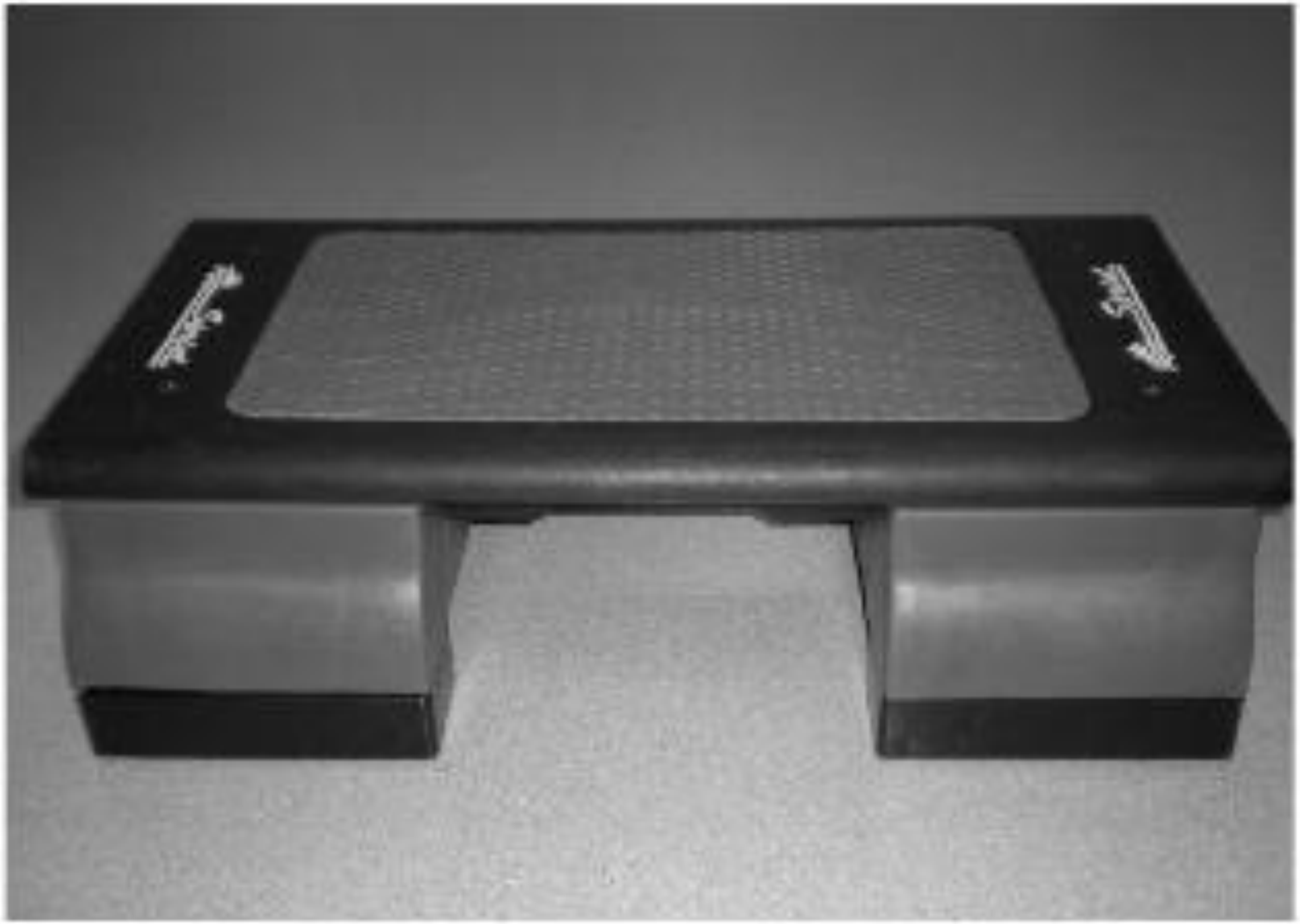


Figure 1 — Aquatic plyometric box with lift attached (18.5cm).

Week 1 and 2: 18.5 cm
Week 3 and 4: 23 cm
Week 5 and 6: 27.5 cm
Also a cone of 23 cm was used

Table 1 6-Week Plyometric Training Program Protocol Developed by Miller and Colleagues

Training Week	Training Volume	Plyometric Drill	Sets × Repetitions	Training Intensity
Week 1	90	Side to side ankle hops	2 × 15	Low
		Standing jump and reach	2 × 15	Low
		Front cone hops	6 × 5	Low
Week 2	120	Side to side ankle hops	2 × 15	Low
		Standing long jump	2 × 15	Low
		Lateral jump over barrier	6 ×5	Medium
		Double leg hops	10 × 3	Medium
Week 3	120	Side to side ankle hops	2 × 12	Low
		Standing long jump	2 ×12	Low
		Lateral jump over barrier	6 × 4	Medium
		Double leg hops	8 × 3	Medium
		Lateral cone hops	2 × 12	Medium
Week 4	140	Single leg bounding	2 × 12	High
		Standing long jump	3 × 10	Low
		Lateral jump over barrier	8 ×4	Medium
		Lateral cone hops	3 × 10	Medium
		Tuck jump with knees up	4 × 6	Medium
Week 5	140	Single leg bounding	2 × 10	High
		Jump to box	2 × 10	Low
		Double leg hops	6 × 3	Medium
		Lateral cone hops	2 × 12	Medium
		Tuck jump with knees up	6 × 5	High
		Lateral jump over barrier	3 × 10	High
Week 6	120	Jump to box	2 × 10	Low
		Depth jump to prescribed height	4 × 5	Medium
		Double leg hops	6 × 3	Medium
		Lateral cone hops	2 × 10	Medium
		Tuck jump with knees up	4 × 5	High
		Lateral jump single leg	2 × 10	High

References

- Miller GM et al. Comparisons of land-based and aquatic-based plyometric programs during an 8-weel training period. *J Sports Rehabil,* 2002, 11, 268-283.
- Robinson LE et al. The effects of land vs aquatic plyometrics on power, torque, velocity and muscle soreness in women. *J Strength Cond Res,* 2004, 18, 84-91
- Martel GF et al. Aquatic plyometric training increases vertical jump in female volleyball players. *Med Sci Sports Exerc,* 2005, 27, 1814-1819.
- Miller GM et al. Chest- and waist-deep aquatic plyometric training and average force, power and vertical-jump performance. *IJARE,* 2007, 1, 145-155.
- Gulick DT et al. Comparison of aquatic and land plyometric training on strength, power and agility. *JAPT,* Spring 2007, 15, 11-18
- Ploeg AH et al. The effects of hight volume aquatic plyometric training on vertical jump, muscle power and torque. *IJARE*, 2010, 4, 39-48.

Effects of Water Exercises on Neuromuscular Function and Muscle Mass in Healthy Women

[1]Pöyhönen T, [1]Sipilä S, [2]Keskinen KL, [3]Hautala A, [1]Mälkiä E

[1]Department of Health Sciences, [2]Department of Biology of Physical Activity, the University of Jyväskylä, [3]Central Hospital of Kymenlaakso, Kotka, Finland

Purpose

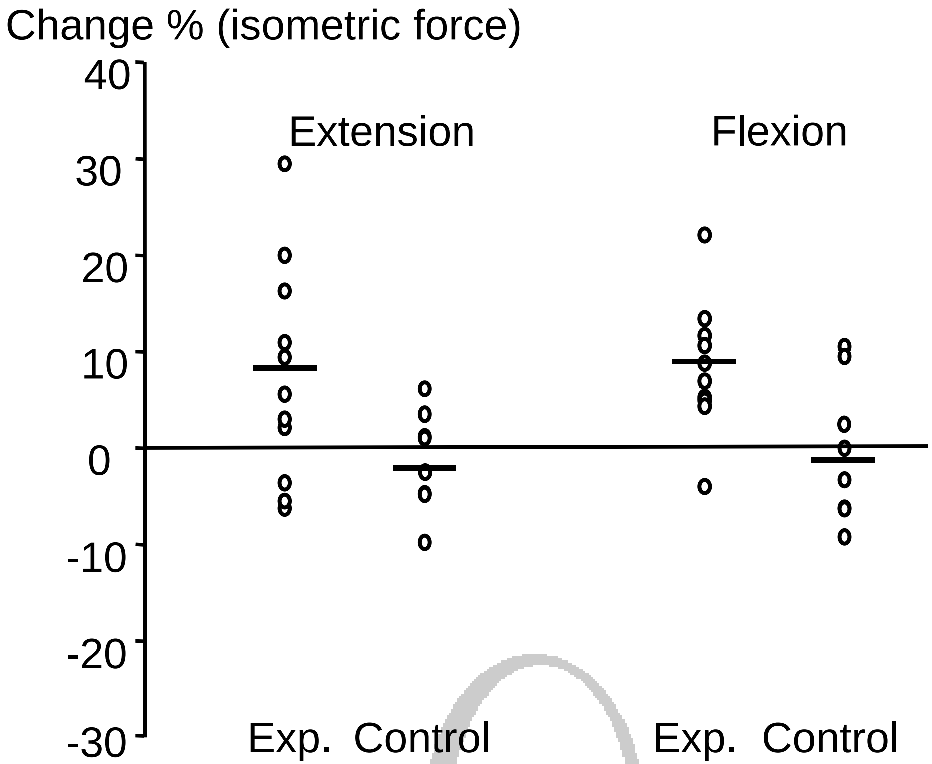
- To study the effects of 10-weeks water training on isometric force and isokinetic torque production, EMG activity and cross-sectional area (CSA) of the quadriceps muscle in healthy women

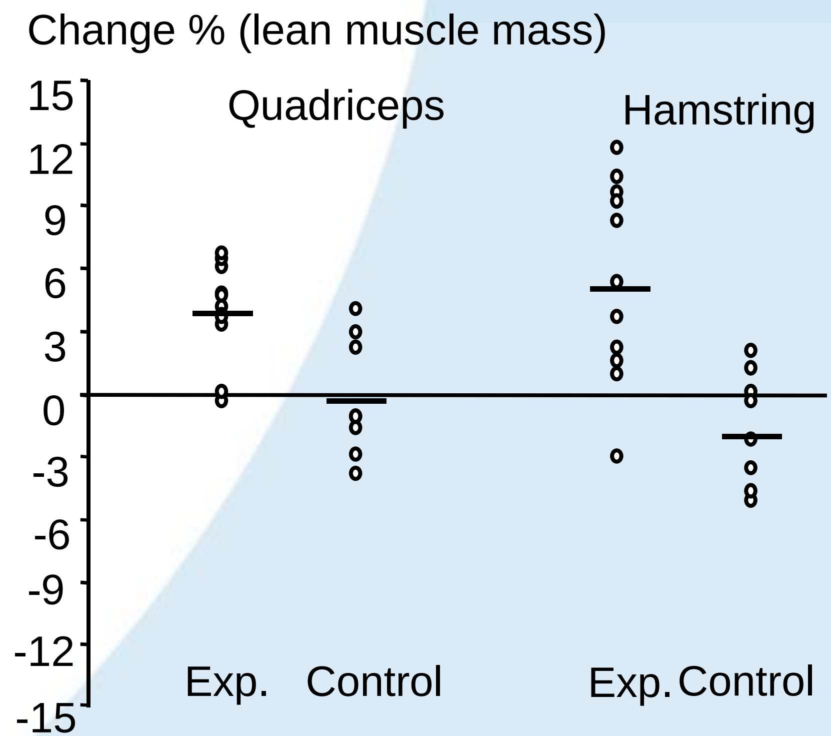
Design

- Supervised training for 10 weeks
  - 2 - 3 training sessions per week
  - 40 - 60 min per session
- 5 exercises for knee extension - flexion
  - single legs while sitting and standing, “water kick”, hip ext-flex, abd-add
  - double legs while sitting
- Pre and Post measurements

Training schedule for 10 weeks

- Weeks 1-2: two training sessions, 2-3 sets á 20-25s (small resistance)
- Weeks 3-6: three training sessions, 3-4 sets á 20-35s (medium resistance)
- Weeks 6-10: three training sessions, 3-4 sets á 20-35s (large resistance)





Isometric Force Production Lean Muscle Mass

Major Findings

- Isometric and isokinetic force production of knee extensors and flexors increased significantly in exercise group of healthy women
- Both neural (EMG) and muscular (CSA, LCSA) mechanisms demonstrated significant increase after 10 weeks of intensive water training

Conclusions

- Water exercises can be used effectively to increase muscle force and muscle mass in habitually active women
- Resistance boots can be used to generate progression for exercise programmes
- Water is a relevant medium for muscular conditioning in healthy adults

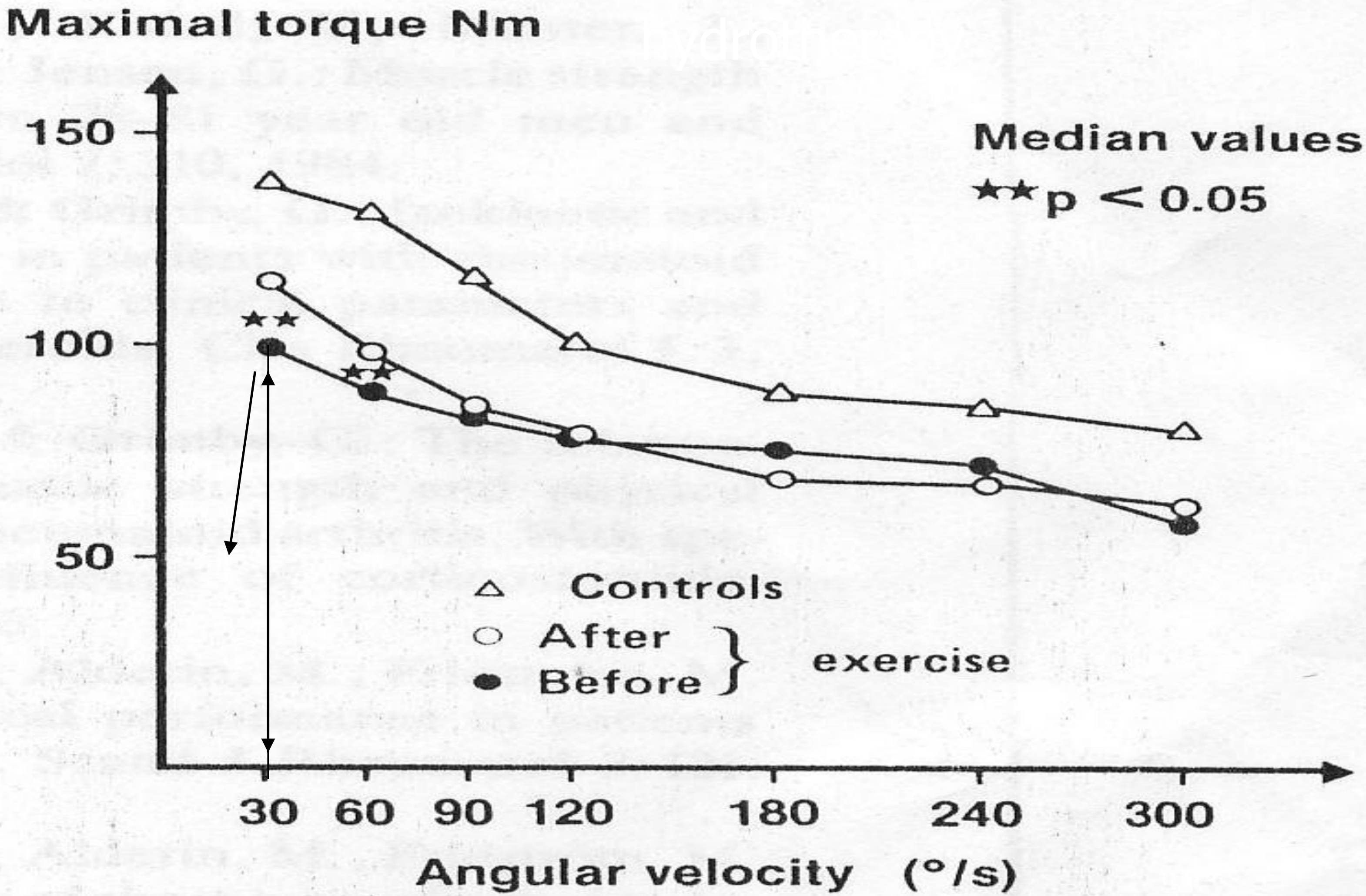


Fig. 3. The force velocity curves in patients with rheumatoid arthritis before and after two months of water exercise. The upper curve belongs to a control group.

Scand J Rehab Med 19

Aquatic resistance training

- Repeated flexion/extension has concentric and eccentric components (= stretch shortening cycle type of exercise).
- This type results in greater gains in power and strength than pure concentric movements in water.
    - T Pöyhönen et al. Med sci sports exerc, 2002

Force production and EMG

- Force production water/land: the same. But:
- In max and submax contractions of the Quadriceps and Hamstrings: ss EMG decrease in water of 20% to 14% (max to submax contraction)

- EMG ↓ because of electromechanical and neurophysiological explanations
  - Mm spindle activity is reduced in reduced gravity
    - T Pöyhönen et al. Eur J Appl Physiol, 1999

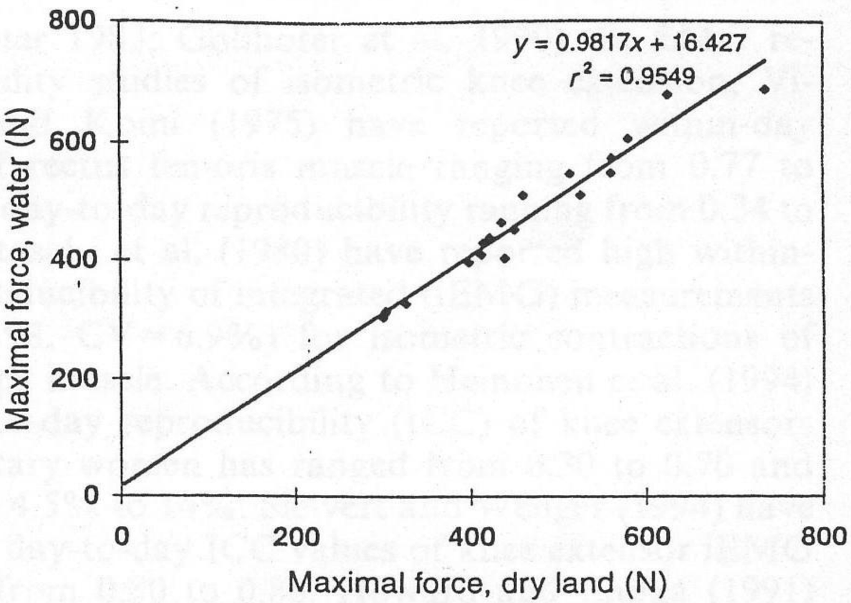


Fig. 2 The relationship between maximal force on dry land and in the water during the 2nd measurement day

- T Pöyhönen et al. Eur J Appl Physiol, 1999
- T. Pöyhönen et al. Clin Biomech 2001 & Arch Phys Med Rehabil 2001.

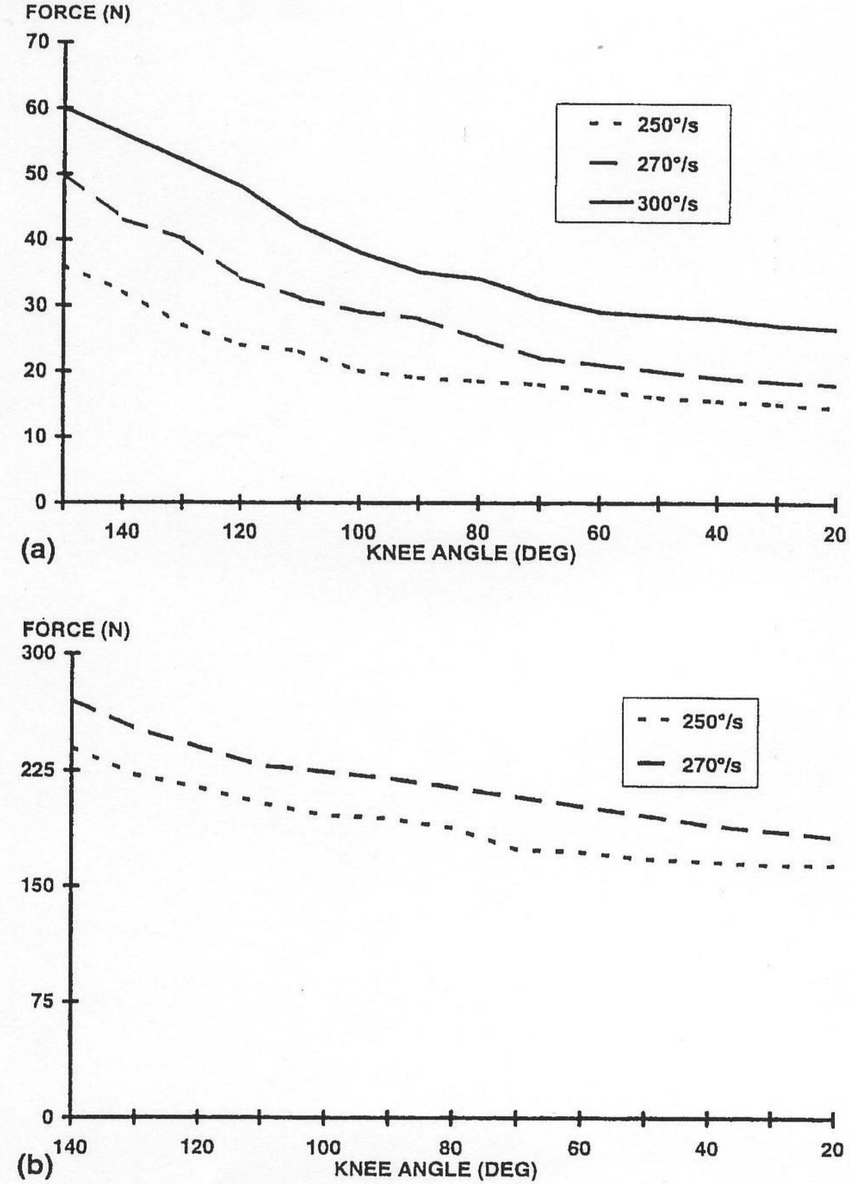
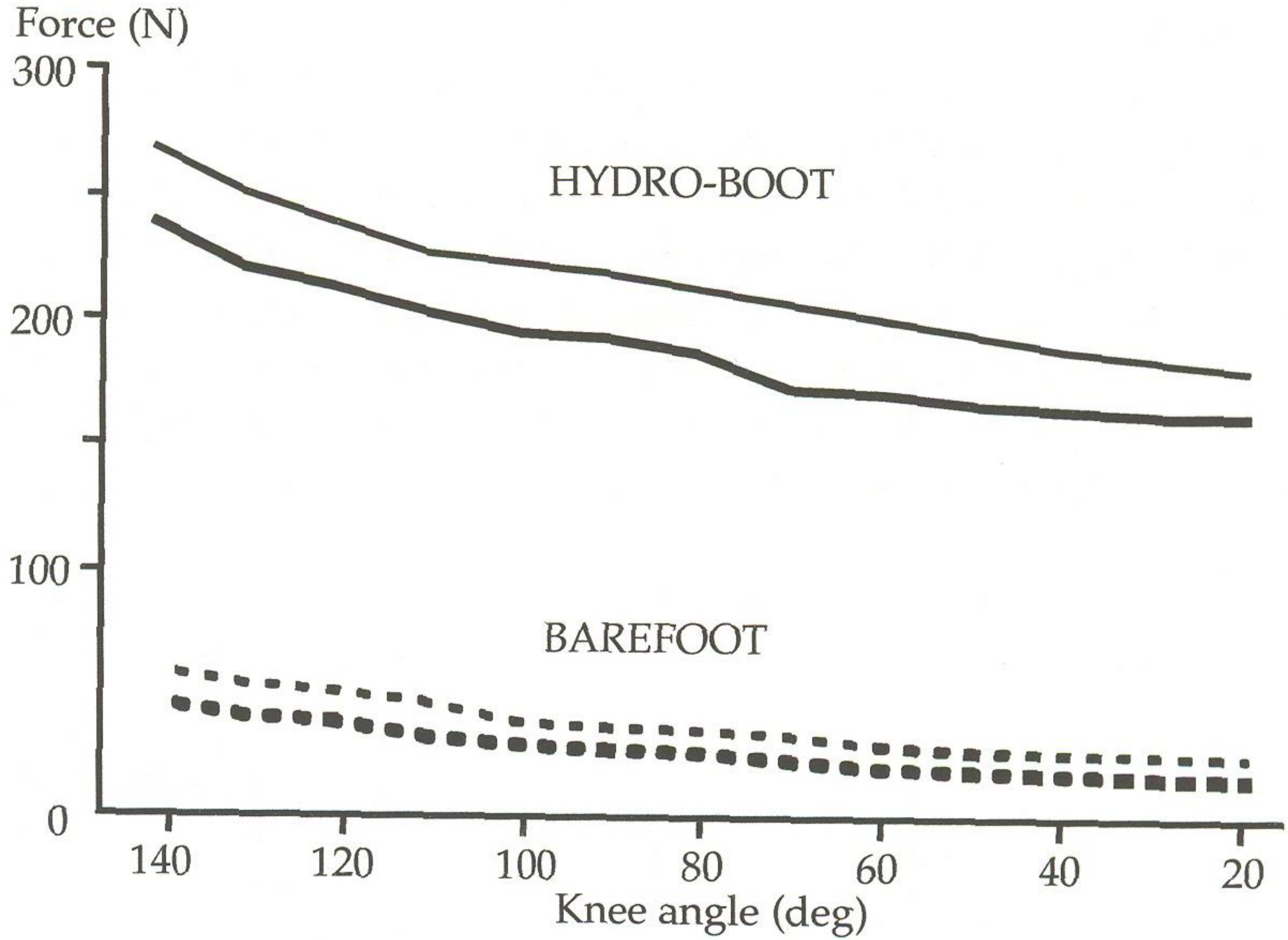


Fig. 2. (a) The measured drag force curves (N) in barefoot condition (250°/s, 270°/s and 300°/s) in relation to knee angle for the model during underwater knee extension; (b) the measured drag force curves in hydro-boot condition (250°/s and 270°/s) in relation to knee angle for the model during underwater knee extension.



The measured drag force curves (N) of the leg and foot model at the angular velocities of 250 (thick lines) and 270 $deg \cdot s^{-1}$ (thin lines) in the barefoot and hydro-boot conditions at varying knee angles for simulating underwater knee extension.

Force production with resistance

- Hydrotone boots provide much more drag compared to bare feet (180°/s), but EMG patterns and amplitude the same.
- Max drag force of knee extension
  - Bare foot at 300°/s: 61 N
  - Bare foot at 270°/s: 50 N
  - Hydrotone at 270°/s: 270 N
- T. Pöyhönen et al. Clin Biomech 2001 & Arch Phys Med Rehabil 2001.

- Manual resistance during BRRM could have the same effects as the Hydrotone boot.

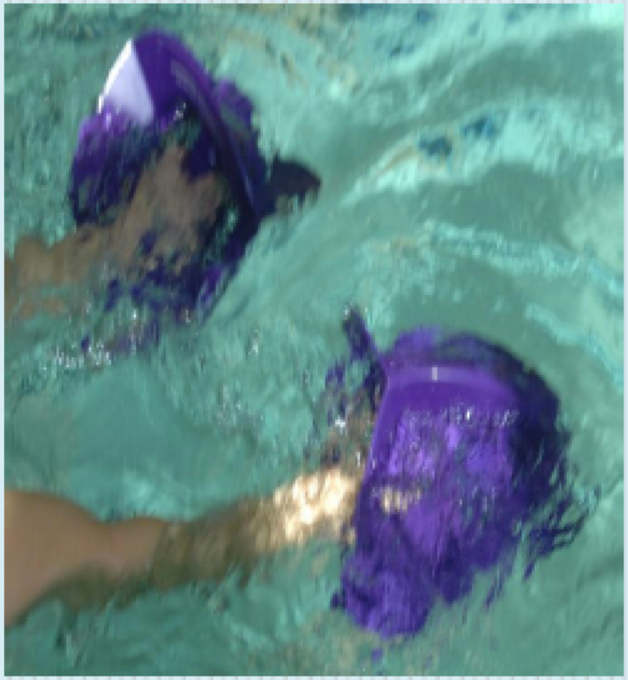
SHALLOW WATER STRENGTH TRAINING

- Target all the major muscles
- Modifications & Progressions
  - Wall for support to free standing
  - Hand positions
  - Lever length
- Base of Support
  - Stable stance (lunge or center)
  - Less stable stance (tandem or single leg support)

M. Wykle: Warrior aquatic programme

UPPER EXTREMITY STRENGTH EXERCISES

- Crossovers
- Front and lateral pull downs
- Chest flyes
- Paddle wheels
- Karate punches
- Biceps curls
- Triceps kickbacks
- Uppercuts
- Trunk twists
- Shoulder shrugs
- Tucks with pull under



SELECTING APPROPRIATE EQUIPMENT

- Can the individual perform the exercise with no equipment?
- Does the equipment provide the appropriate resistance?
- What is the water depth?
- What muscles are you trying to strengthen?
- Safety concerns

FLEXIBILITY STRETCHES

- Calf stretch/Achilles stretch
- Narrow calf stretch/Gastrocnemius
- Full leg and Foot stretch
- Inner thigh stretch
- Hip stretch/Piriformis stretch
- Back and chest stretch

BALANCE and CORE STABILITY

- Accomplished with minimal risk of injury
- Water relieves much of weight bearing forces
- Water slows movement allowing additional reaction time
  - Reduces the fear of falling
  - Buoyancy assist balance practice
  - Exercises such as yoga
- Core Strength is a component of Core Stability
  - Foundation of balance & movement
  - Essential for maintaining upright posture

EXERCISES with a NOODLE or ball

- Squats
- Lateral pull down, push down
- Figure 8 moves
  - Diagonal – across body
  - Figure 8's (under surface)
- Ball toss with partner
  - Standing
  - Sitting on noodle
- Rotational ball pass with partner
- Standing on noodle
  - Squats
  - Tandem stance, ball push challenge
- Dueling noodles (aka rope challenge)

SHALLOW WATER AGILITY

- High knee run
- Run to "points" and back
- High knee jumps
- Bounding
- Water steps
- Small step run with directional changes
- Jump rope
- Karate kicks
- Partner drills w/resistance bands or tubing

POWER EXERCISE – Boxing combinations

- Jabs – Karate punches
  - Same arm – designate number
  - Alternating arms
- Cross jabs
  - Same arms – designate number
  - Alternating arms
- Upper cuts
  - Same arms – designate number
  - Alternating arms
- Combos
  - Punch – punch – cross punch – upper cuts

Power exercise – medicine balls

- Push downs
- Under water figure 8's
- Distance tosses
- Underwater passes to partner
- Bounce passes to partner
- Rotational passes
- Throws against pool wall

When to go to land
Based on Beth Scalone

- Can the athlete maintain good alignment of the kinetic chain during movement?
- Is the motion pain-free?
- Has the injured tissue healed adequately to handle additional gravitational forces and weight-bearing stresses?
- Has the athlete demonstrated the ability to perform several repetitions of a movement without losing quality or control of the motion?

After an athlete begins strength training, ROM, stair work and even linear running on land, there's still a place for aquatic-based plyometric work. Because water is buoyant, athletes can perform bounding, hopping, sprinting and other ballistic power moves in the water with a 50 percent to 75 percent weight-bearing reduction.

You must determine when it's safe to resume the rigors of land-based work. Scalone says to ask several questions to determine if plyometrics can be safely performed out of the protective pool environment.

- Does the athlete have nearly normal ROM?
- Does the athlete have footwear with good shock-absorbing qualities? Will the plyometric drill take place on a cushioned surface?

- Has the athlete participated in a strength rehab program for a minimum of 2 to 4 weeks?
- Can the athlete demonstrate eccentric strength and control in a closed-chain exercise?
- For upper extremity plyometrics, does the athlete have at least 80 percent of normal strength and 90 percent to 95 percent ROM?
- For lower extremity plyometrics, can the athlete perform a single-leg stance for 30 seconds with the eyes open and closed without noticeable shaking or wobbling?
- For dynamic jumping, can the athlete demonstrate a single quarter squat or half squat without wobbling?

24 year old professional super-heavy weight boxer with shoulder pain

Symptoms & Assessment

- Unable to effectively throw a punch
- Attended on Thursday - needed to fight the following Saturday
- Examination showed decreased internal rotation of the shoulder to 0
- Diagnosis GIRD (glenohumeral internal rotation deficiency)

Treatment

- Treatment addressed the biomechanics of his thoracic and shoulder rotation and elbow and wrist movement.
- Treatment consisted of mobilisation of his spine and shoulder, muscle energy techniques to repower his shoulder, soft tissue work, neuromobilisation, dry needling of the back of his shoulder and scapula.
- After an extended session on Thursday he regained 45 degree of rotation (60 on L), he was already pain free
- After another long session on Friday he regained full flexibility of his shoulder, elbow and wrist.

28 year old lady amateur power lifter with hip pain

Symptoms & Assessment

Severe pain and unable to squat fully with weight above 20 kg

Examination showed decreased hip flexion and rotation, very weak gluteal muscles, and poor kinetic control. She was also extremely hypermobile (very flexible). It can take longer to regain power in comparison to normal flexibility.

Treatment & Outcome

Treatment worked on the flexibility of her hip with joint mobilisations and stretches, and a progressive strengthening program of loading in squat position with narrow shallow squats-progressing to sumo wide squats.

The physiotherapist also worked closely with the client's powerlifting trainer with regular reviews and

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63 year old primary school teacher with foot pain

Symptoms & assessment

- 63 year old teacher - on her feet a lot
- Regular gym and running (up to 5 kms)
- 4 month history of right forefoot pain and swelling
- Keen to have check-up, diagnosis and advice on exercises to fix it
- Assessment showed moderate swelling in the web space between the 1st and 2nd toes, marked stiffness of the right 1st toe and also right hip into internal rotation and stiffness of the mid-spine. Slight swelling of both knees were also noticed even though client had no knee symptoms.
- Diagnosis: biomechanical contribution to overloading onto big toe -possible early degenerative changes at big toe and also knees (family history).

Treatment

- Aimed at improving the mobility of the mid-spine, hip and big toe along with a strengthening programme for the muscles around the hip. Strengthening exercises were also shown for the knees to lessen loading on the joints
- Client worked on the home exercise programme and attended for a few sessions of joint mobilisation and soft tissue release for the toe.

51 year old professional violinist musician with shoulder and neck pain

Symptoms & Assessment

- Pain in right shoulder following doing lunges in the gym with a 2kg weight
- Now affecting playing her instrument, interrupting her sleep and getting worse.
- Unable to do her usual exercise which was swimming due to the pain.
- On examination, pain with shoulder movements above shoulder level and also with neck movements on palpation. Stiffness of the neck and upper spine, tenderness of the rotator cuff muscles of the shoulder.

Diagnosis: Rotator cuff strain of the shoulder aggravating early degenerative changes in the neck.

Treatment

Worked on soft tissue work around the shoulder, spinal joint mobilisations and a home programme of stretches and strengthening exercises.

33 year old, right handed cyclist seen following shoulder surgery

Symptoms & Assessment

- cycling injury causing collar bone joint disruption, surgically repaired.
- advice given by surgeon to mobilise below shoulder level and avoid lifting and loading for 6 weeks.
- seen at 7 weeks for rehabilitation and to 'top up' his NHS physiotherapy.
- treatment aims were to restore full mobility and get him back to full function
- on examination, main movement restriction was overhead and crossing the arm across the body with a tendency to overuse the chest muscles.

Treatment

Mainly exercise programme to regain full movement and early strengthening within the limits of pain.

Lots of work on improving the shoulder girdle strength and stability to counteract the dominant chest muscles.

38 year old IT worker with calf and lower back pain

Symptoms & Assessment

- Physically active, practices different sports regularly, daily work out regime, takes part in marathons and cycles long distances
- Experiences muscular pain and tension in particular after intense bursts of physical activity

Treatment

He was treated with deep tissue massage, mobilisations to his lower back and pressure points to gluteal muscles. He was also advised to buy a foam roller to aid release of tension in in his gastrocnemius (calf) muscles.

29 year-old runner with knee pain

Symptoms & Assessment

A keen runner who was preparing for the marathon attended the clinic complaining of knee pain following increasing his running distance.

On examination, the source of the pain was found to be under the kneecap. Tightness of the thigh muscles and poor leg control were also identified as possible contributing factors.

Treatment and Outcome

During the appointment, the client was treated with soft tissue release and stretches. He was given home exercises to help improve his leg control while running. He was also advised on how much running load he could undertake on the following days and how he could optimise his training in preparation for the event.