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# Aquatic treadmill : applications for stroke patients

**Marcel Hulselmans, PT, Senior Haliwick Lecturer I.H.T.N.**
**humaqua@gmx.de**

**Werner Wicker Klinik Bad Wildungen, Germany**

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# Stroke :

- Main cause for remaining invalidity in industrial world .
- 200.000 stroke patn. in Germany per year.
- 60% of those suffer from significant limitations in gait and gaitdistance .
- 20% remain wheelchair bound.

(Kominsky-Rabas et al, 2006)

# Stroke in Germany :

- 70% of patients suffers of cariovacular dis. (C.V.A.)
- Cardiac failure main cause of death after stroke

(Kominsky-Rabas et al, 2006)

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## Common symptoms in post acute/chronic stroke :

- singlesided paresis leg/arm
- hyperreflex activity
- muscular hypertonia (rigor)
- Sensory loss/hypersensitivity
- Loss of extrapyramidal trunkstability
- Shift of actual centre of bodymass to non affected side

# Common symptoms in post acute/chronic stroke (2) :

- Aphasia
- Apraxia
- Shift of perceived centre of bodymass (pushing)

**Chronology of stand/gaittraining in strokerehab.:**

- Trunkstability/sitting
- Standing up/transfer wheelchair
- Standing
- Shift of bodymass centre while standing
- ***Gaittraining***
- Stair climbing /toilet management etc.
- Other functional activities using gait

**An ideal therapy environment would provide (1):**

- Maximum security (no risk of falling)
- Reduction of the weight of the  the limbs to facilitate gait movement.
- Decrease  hypertone muscles and hyperreflexia

**An ideal therapy environment would(2):**

- reduce impact strain on joints
- Enhance exteroceptive feedback during movement.
- give the patient ***more time*** for problemsolving and balance restoration

**An ideal therapy environment would (3):**

- Increase suppleness of connective tissue
- reduce pain
- Reduce oedema

**An ideal therapy environment would (4) :**

- Easy and quick change between varied range of functional training options.
- relief for the therapist
- Reduce the number of therapists needed for support of patients.

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**Water** has all these advantages……

# Regaining gate :

- **Nr. 1 goal** of patients , regardless the gaitpattern used .

- Nr 2 goal = functional gaitvelocity.

(Bohannon R ,1988)

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# (re)learning to walk no 1 goal :

Being able to walk,
even a few steps,
means
independence ,
dignity……….

## Lokomotion Therapy : Treadmill training

- History : spinalised cat can learn to walk again
  by means of systematic and specific
  treadmilltraining
  (*Barbeau et al 1987*)

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# Central Pattern Generator 1 :

- Gait experience during life leads to spinal lokomotion centre (interneurons)=C.P.G.

# Central Pattern Generator 2:

- In healthy adults centre in brain (Pons) controlls spinal CPG.

# Central Pattern Generator 3 :

- Afferent input (extero-/proprioceptive) from legs influence spinal cord CPG as well.

Sensory input from skin (footsole) and leg-joints can stimulate CPG. **on a treadmill**

(V and ROM ,reps.needed)

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# Central Pattern Generator 4 :

- So (incomplete) spinal cord laesion patients can learn how to walk again.(*Dietz V, 1994*)
- And hemiplegics as well (*Pohl M et al,2002*)



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# Advantages of land TMT (1):

- Stationary
- Controllable,variable,measurable intervention
- Weight reduction possible
- Relieves Therapist

# Advantages of land TMT (2):

- CPG triggering possible :

V ↑ **25 %** of CWS (*Hesse S et al 2001*)

Speed dep.TMT (STT) 5x10% V progress.in one session (*Pohl M et al 2002*)

# Evid. of efficacy land TMT in stroke :

- Velocity
- Cadence
- Stridelength
- Energy efficiency

# Evidence of efficacy land TMT (2):

- Distance (endurance)
- Cardiovascular fitness
- ***No*** deterioration of gaitpattern (*)
- *(Hesse S, 2007; Pohl M et al,2002;*Kuys S et al , 2008)*

**Change in physiological gait pattern and energy efficiency (2):**

- more complex laesion/loss of function/joint immobility

results in decreasing gait efficiency and increase in energy expenditure .

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## Velocity ,Cadence and O2-cost at everage preferred walking speed

| Land walking | Velocity (m/min.) | Cadence (steps/min) | O2-cost O2 rate/V in ml(kg/min) |
|---|---|---|---|
| **men** | 82 (4,9 km/h) | 108 | 0,14 |
| **women** | 78 (4,7 km/h) | 118 | 0,15 |
| **Seniors (> 60 y.)** | 74 (4,4 km/h) | ? | 0,16 |
| **ambulant hemipl.(*)** | 30 (1,8 km/h) | ? | 0,54 |
| (* Hash D, 1978) | | | |

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# Energy expenditure at defined walking distance

| pathology | Gaitvelocity in % of ref value (82m/min) | Energy expenditure in Kcal. referr to normal value |
|---|---|---|
| Spinalcord thor.laesion (with orthosis) | 6% | 9 x < |
| Spinal cord lumbar laesion (with orthosis)(*1) | 25% | 3 x < |
| Ambulant hemiplegia at end of strokerehab. (N=155)(DEGAS study) | 72 % < 58%<br>(max range 200-300 m)<br>28% ≥ 58% (*2) | 1,5-2 x<br>(*3) |

*1 Clinkingbeard 1964, *2 Pohl et al, 2007, *3 Macko et al ,2001

## In stroke population we find :

- Decreasing cardiovascular capacity due to aging and immob. after stroke

- Increased demand for cardiovascular fitness due to increased energy exp. e.g. in walking

- Need for :  cardiovascular training

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For adequate therapy we need a therapy environment in which the stroke patient can perform and can reach cardiovascular trainingintensity .
(activating 20% of  body muscle mass)

Gaittraining is obligatory

Treadmill walking cuts both ways .

- Trains (pat nr. 1) functional activity , walking
- Cardiovascular training (at least 20 % of total muscle mass active )

# Why is velocity in gaittraining so important?

- Struggle for life : daily living demands walking velocity.

- 2,4 km/H allows for safe crossing of 90% of all trafficlight controlled zebras in Berlin . (Hesse S, 2009)

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# Gait velocity in stroke as a predictor for selfreliant gait and need of care :

| Gait velocity (Comf Walk Speed) | Will stay indoors | Will go outdoors | Chronic need of daily care |
|---|---|---|---|
| < 1,4 km h (< 24 m/min.) | X | | |
| < 2,8 km/h (< 48 m/min) | | x limited range | |
| >2,8 km/h (> 48 m/min) (*1) | | x unlimited range | |
| ≥ 1,5 km/h ( ≥ 25 m/min) (*2) | | x in /around home | |
| < 0,54 km/h (< 9 m/min) (*3) | | | X |
| (*1)Hesse S et al ,2010, (*2) Perry J, 1995, (*3)Goldie et al , 1996 | | | |

# Motor (re)learning

Has 2 important rules when learning an activity (like walking)

1. The training activity must resemble the activity you want to improve (dry land gait)
2. Options for variation of practice, vary elements of activity.

# Does (treadmill) walking in water resemble walking on land?

**Physiological responses to running and walking in water at different depths:** (Pohl M B, McNaughton L R;2003)

## Protocol:

- N = 6 (students ), age : 23,2 (+/- 2,9 years)

  height :179,5 cm(+/- 9,9 cm)

  weight : 66,3 kg(+/-11,3 kg)

Standard activity : walking at 4,0 km/h on a treadmill in water at different depths ;

thighdeep(**TD**)= WL between patella SIAS waistdeep (**WD**)= WL on SIAS

# Physiol.responses to walking on treadmill in water (33 C ) at diff. depths (TD and WD):

| 4 km/h walking on treadmill (n=6) | On land | In Thigh Deep water | In Waist deep water | Running on land (7km/h) |
|---|---|---|---|---|
| VO**2** (ml/min/kg) | 9.84( +/- 0.84) | 20.16(+/- 2.32) | 17.48(+/- 2.47) | 23.64 ( +/- 0.84) |
| HR (beats/min) | 78 (+/- 10) | 104 (+/- 5) | 96 (+/- 5) | 124 (+/- 7) |
| Stride Freq. Str/min. | 101 (+/- 6) | 96 (+/- 7) | 92 (+/- 10) | 149 (+/- 12) |
| VO**2**/stride (ml/kg/min) | 0.10 (+/- 0.01) | 0.21 (+/- 0.04) | 0.19 (+/- 0.04) | 0.16 (+/- 0.03) |

# Conclusion :

- Walking in TD water elicits a cardiovascular workload that comes close to running on dry land . So an excellent cardiovascular training!

- $VO_2$ 6 km/h on land ≈ $VO_2$ 3,5 km/h WTM
- Equal E.exp. in water at 0,5 Velocity land
- Cadence ↓ dep. of WL

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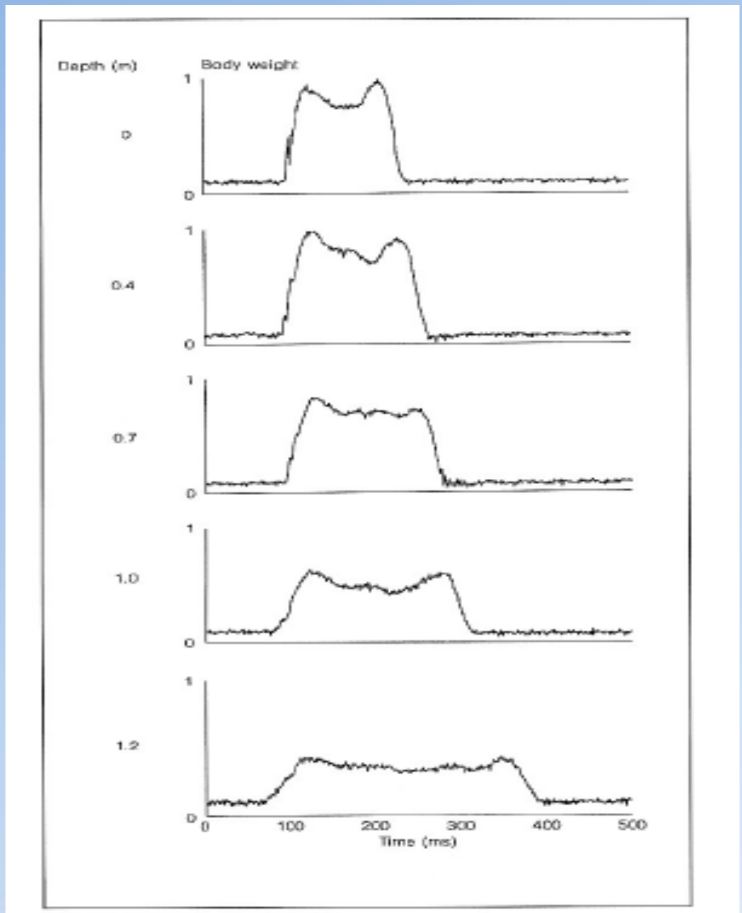
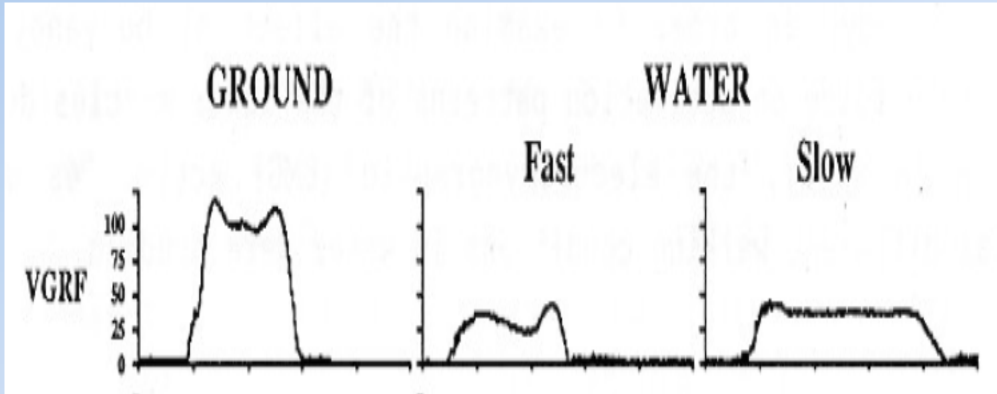
## Waterresistance and upthrust :

- Waterresistance  causes higher workload during walking in water as on land, dependent on WD.
- Upthrust decreases the load of the body ,dependent on WD, dampens joint impact.
- In  between TD and WD(SIAS)
  upthrust and WR allow for a „landlike“ gait

# GRF : influence of depth and V
(Nakazawa 1994 )




**(Nakazawa 1994)**

**Slow = slower thancomfortable**
**Fast = faster than comfortable**

**Nakazawa 1994b**
**Differences in depth**

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# Biomechan adapt. in gait land v water (I):

(unpublished res.,courtesy of Lambeck J )

| Waist D water CWS | Land | water | water treadmill |
|---|---|---|---|
| legg swing ph. hipflex. | Almost passiv | active | active |
| Stance ph.: Heel strike | Vert mech impact↑ | Vert mech imp.↓ | Vert mech imp↓ |
| toe off | propulsive | propulsiv ↓ | propulsiv↓ |
| Arm swing | Almost passiv | active w elbow flex | active w elbow flex |

# Biomechan adaptions land v water (II):

(unpublished res.,courtesy of Lambeck J )

| Waist Deep water CWS | Land | water | water treadmill |
|---|---|---|---|
| Walking pattern | cross lateral | tendency to ipsilateral | cross lateral |
| Trunk alignment | slight forward | Trunk forward+ hip in flex. | slight forward |
| Ankle : Peek dors.flex | normal | ↓ | ↓ |
| Peek plant flex | normal | ↑ | ↑ |

# Summary kinematics in water TMT in TD-WD water :

- Shows less peek dorsiflex. and more peek plantar flexion .
- Stride length ↑(dep.on V)
- Stride time ↑ equal % stance/swing
- Cadence ↓

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## Summary kinematics in water TMT in TD-WD water (2):

- Torques and impulses are quite different (drag and buoyancy)
- Comfortable V water is +/- 50% land
- Joint angles are roughly identical
- Gross resembl. gait pattern on land (**TD-WD**)

# Muscle activity during walking on dry land and in water 1 (Masumoto et al 2004) → (proc. xiphoid.)

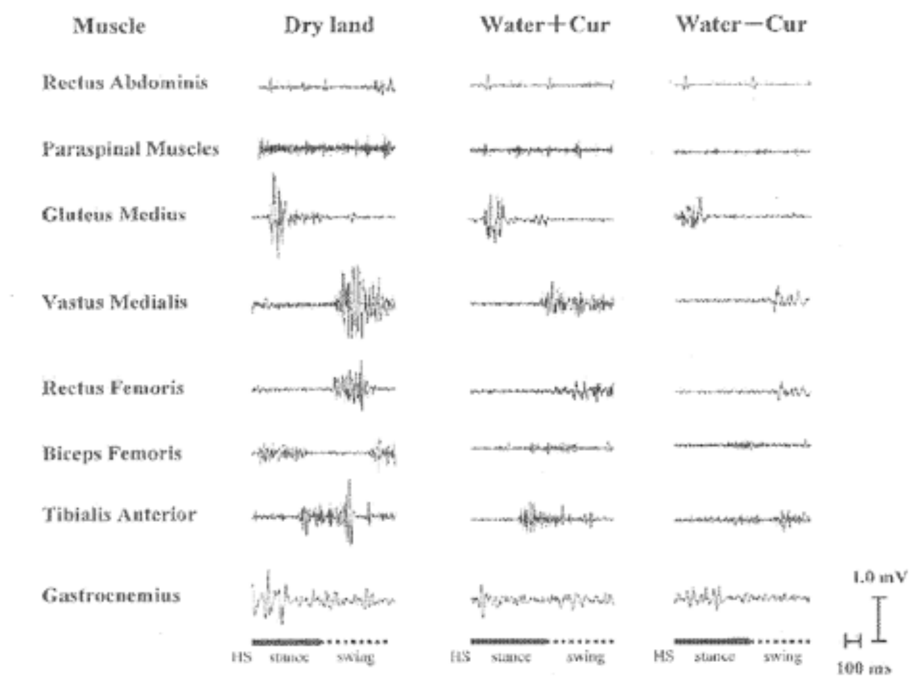


Fig. 1 Typical EMG data per gait cycle of a subject performing trials at moderate speed. HS; heel strike. Water+Cur; walking in water wit

# EMG : land versus water

(Nakazawa 1994)

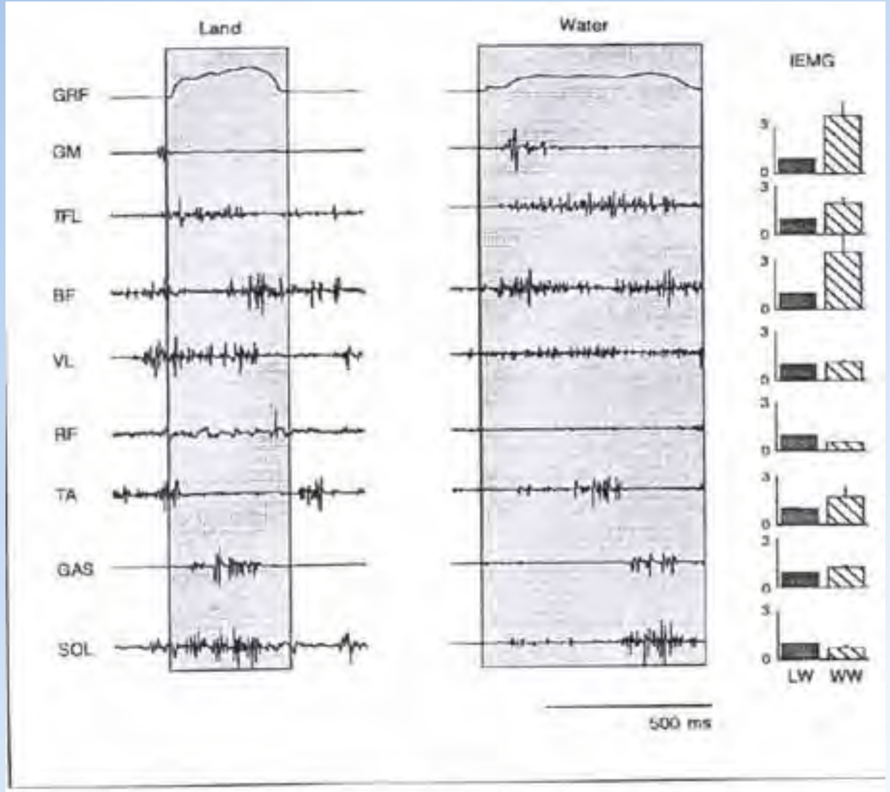


*Fig. 4.* An example of GRF and EMGs from eight lower muscles during walking on land and in water. The bar graphs represent relative iEMG magnitude to that for land walking (mean ± SD, n = 2).

# Summary biomechan.EMG charact. of WTM gait:

- EMG : less peaks , flattened signals.
- Between TD and WD water muscle activity resembles land gait.
- Biceps fem . shows increased activity
- Vast. med. and tib.ant incr. activity when walking fast.

# Comparing gait characteristics at same comfort. walking speed on Land and Water Treadmill Walking in Individuals with Stroke :

N=9; M=7,F=2, age range=50-76 y.
mean age 55.

(Rambhatla R et al , 2010.)

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| On Water Treadmill: | hemiplegic leg | non affected leg | N=9; M=7,F=2, age 50-76 y mean 55 y |
| --- | --- | --- | --- |
| Cadence | ↓ | ↓ | ($p > 0,05$) |
| Stridelength | ↑ | ↑ | ($p > 0,05$) |
| Stridetime | ↑ | ↑ | ($p > 0,05$) |
| Hip movement | No diff. | No diff. | |
| Peek Knee flex. angle | No diff. | ↓ | |
| Peek Knee ext. angle | No diff. | ↑ | |
| Peek Ankle dorsi flex. | ↓ | ↓ | ($p > 0,05$) |
| Peek Ankle plant. Flex. | ↑ | ↑ | ($p > 0,05$) |

(Ramblatha K, 2010)

# Conclusions Rhambhatla et al :

- Aquatic TMT can be used to improve stride length of people with stroke.

- Attention for patn. with ankle deformities due to increased plantar flex. In aq.TMT.

# Aquatic orthesis for dorsiflexparesis

Pöyhönen Tapani[1], Valtonen Anu[1], Sipilä Sarianna[2,3], Heinonen Ari[2]

[1]Kymenlaakso Central Hospital / Rehabilitation and Pain Unit, Kotka, Finland

[2]Department of Health Sciences, University of Jyväskylä, Finland

[3]Finnish Centre for Interdisciplinary Gerontology Jyväskylä, Finland

# Original Articles

Pöyhönen T, Avela J. Effect of water immersion on the neuromuscular function of the plantarflexor muscles: Aviation, Space and Environmental Medicine, 2002, 73 (12): 2103 – 2109.

Pöyhönen T, Sipilä S, Keskinen KL, Hautala A, Savolainen J, Mälkiä E. Effects of aquatic resistance training on neuromuscular performance in healthy women. Medicine and Science in Sports and Exercise, 2002, 34 (12): 2103 – 2109.

# Tendon- and H-reflex measurements in dry and water conditions

## H –reflex

The H-reflex is a reflectory reaction of the muscle after electrical stimulation of the innervation nerve (tibial nerve).

The EMG response is measured from the muscle (soleus) and that response is a clear wave called H –wave, H- reflex.

Information about the reflex arch activity

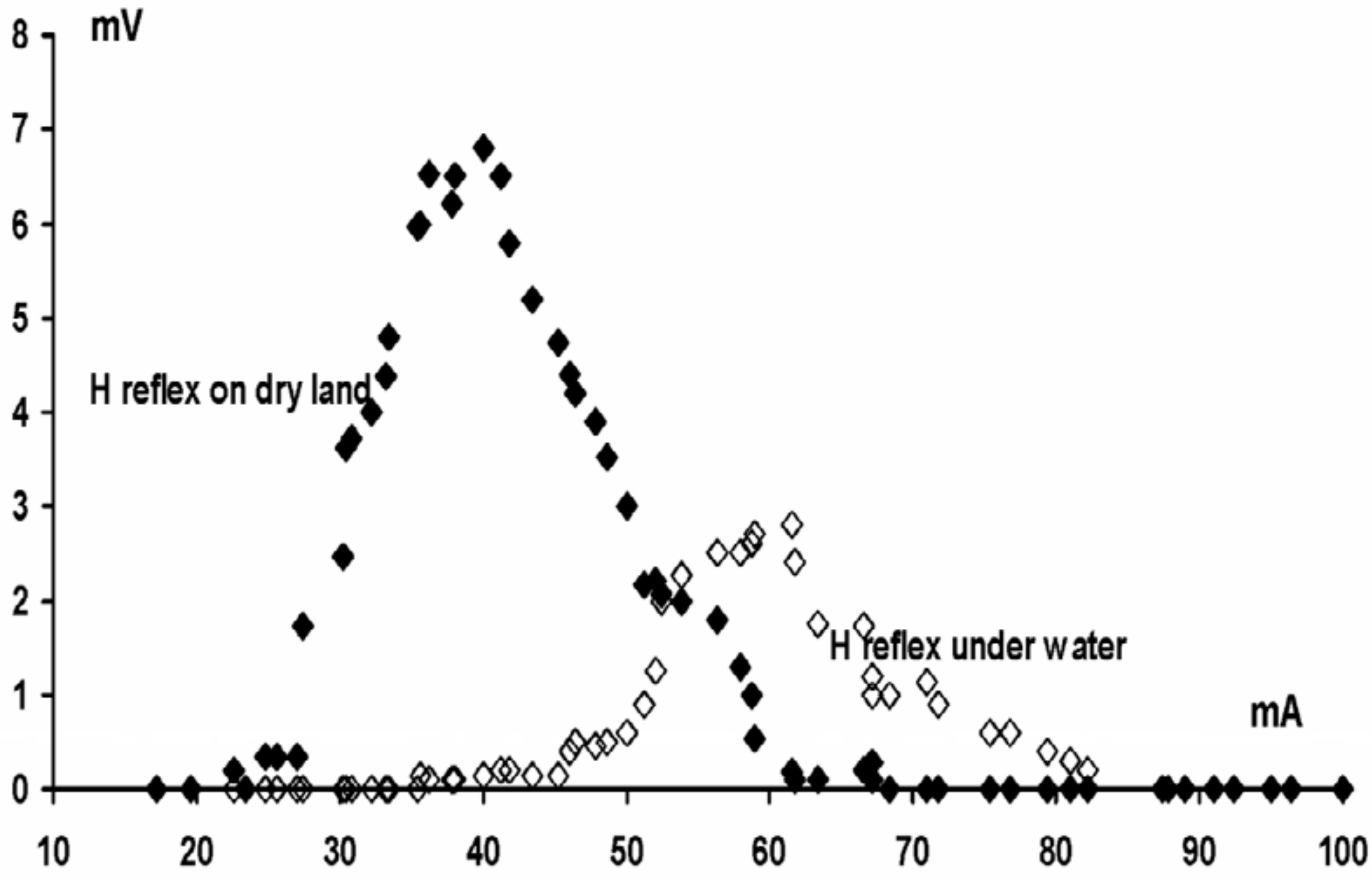
## Tendon reflex

The set-up for force measurements of the Achilles tendon reflexes. A waterproof reflex hammer with an accelerometer and dynamometer attachment around the forefoot.

EMGs were recorded from the soleus and medial gastrocnemius muscles

Result: tendon reflexes were decreased in water!

# Hoffman- reflex (H-reflex)



# Biomech. adaptations on W –treadmill

(WD between TD and WD) (1)

- Joint angles are slightly altered but gross
  gait still resembles a land gate cycle

- Cross lateral (physiolog.)walking pattern with active armswing at TD to WD waterlevel

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## Biomech. adaptations of gait on W –treadmill

(WD between TD and WD) (3)

- Stridelength ↑
- Stridefrequency ↓
- Stride time ↑

# Biomech. adaptations on W –treadmill

(WD between TD and WD) (2)

- Similar muscle chains active
- Ankle dorsiflex ↓
- Ankle plantar flex. ↑

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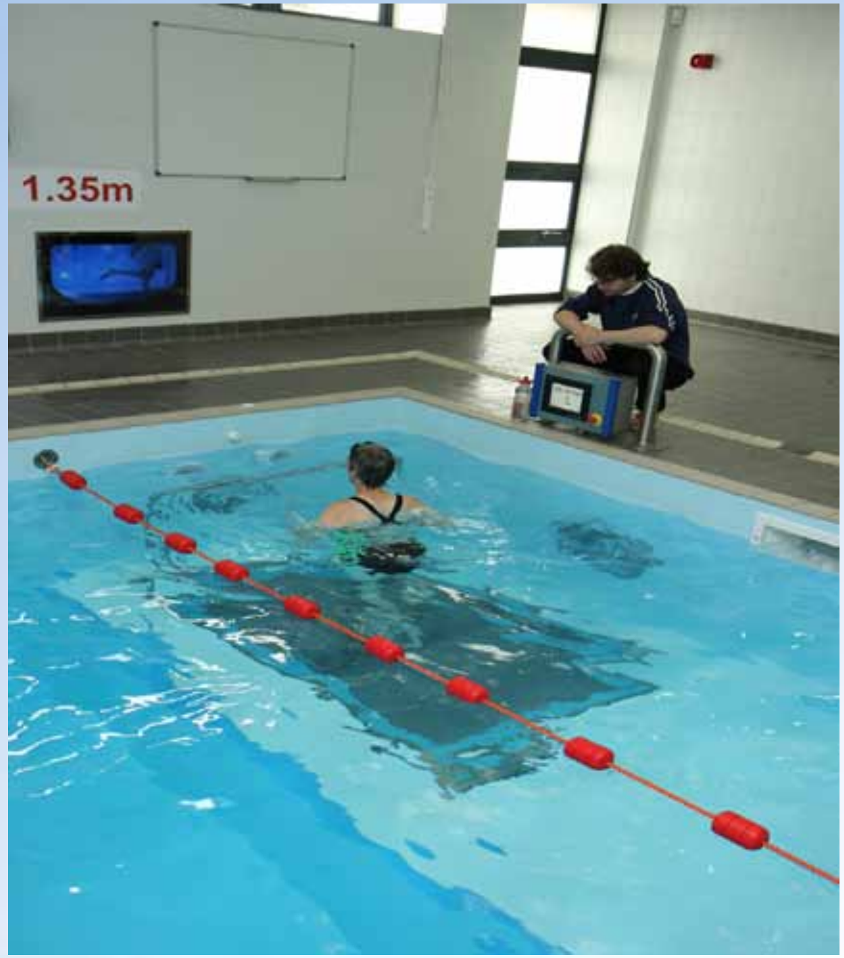
# What does it look like ?



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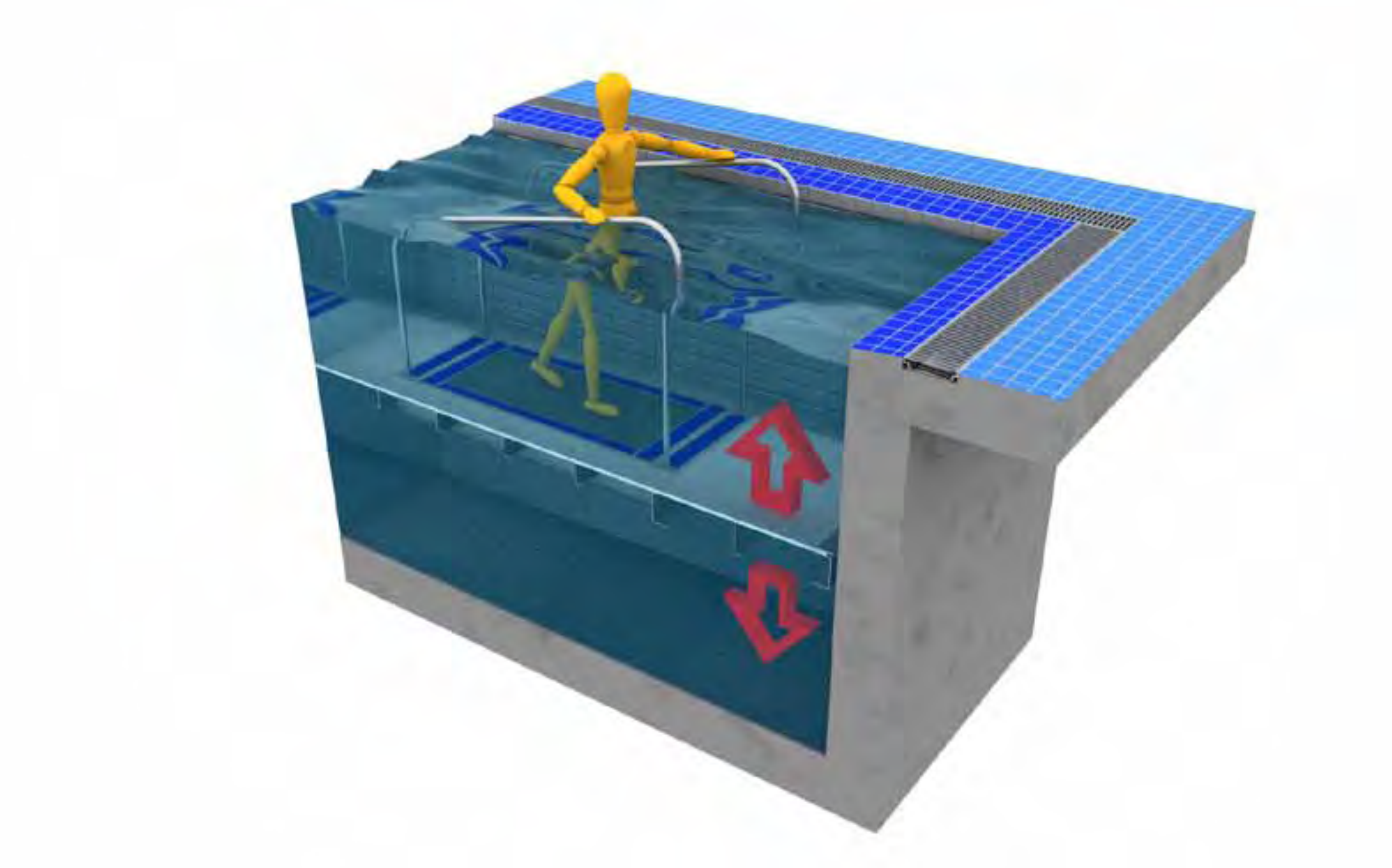

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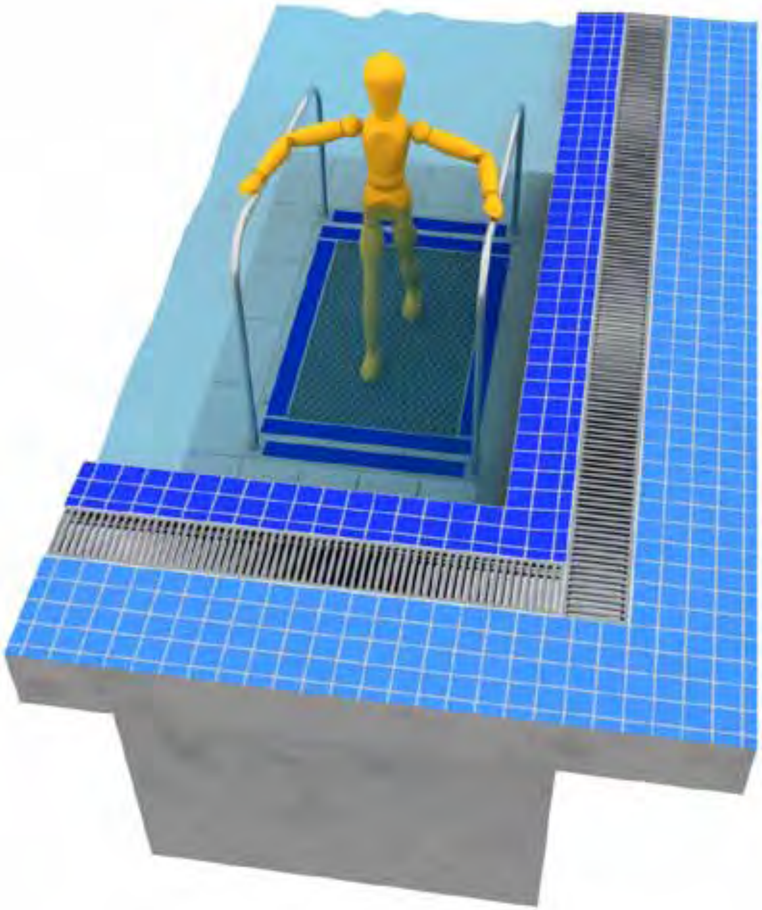

## Summary :Watertreadmill gait training in stroke population offers(1):

- Option for regaining gait in early rehab.

- Most of the advantages of land TMT, no need for a jacket

## Summary :Watertreadmill gait training in stroke population offers (2):

- all the advantages of water based therapy (immersion) „on target“ for stroke patients.

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## Summary :Watertreadmill gait training in stroke population offers (3):

- At TD-WD depth an excellent cardiovascular training option ,so needed in stroke

  Resembles gait pattern on land (**TD-WD**)

- A challenging environment without fear of falling,people ***dare*** to move, go to their limits.

## Summary :Watertreadmill gait training in stroke population offers (4):

- Unresticted 3-D movebility without jacket
- On the spot combination with other ADL oriented  watertherapy. (Halliwick)

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**Watertreadmill gait training in other populations :**

- Osteo Arthritis
- Rheumat.Arthr
- Endoprothesis
- Obesitas
- Muliple scler.
- Braintrauma
- Spinal cord
- geriatrics