Hyperbaric Oxygen Therapy combined with LOKOMAT (Robotic Exoskeleton Walking) assisting Neuroplasticity in Brain and Spinal Cord disabilities
MALCOLM R. HOOPER

- OXYMED Australia (HyperMED). Over the past twenty-five years, he gained international renown for providing the wider ‘off-label’ applications of Hyperbaric Oxygenation.

- In 1983, Hooper’s humble beginnings were as a chiropractor including Masters App Sci. Hooper established the multidisciplinary clinic known as Spinal Rehabilitation Group, integrating orthodox medical and allied treatment approaches.

- Then, in 1993, tragedy struck when their 18-month old daughter fell into a smouldering ash fire and suffered third degree burns. It was during this period he became acquainted with the use of Hyperbaric Oxygen for treating burns and other neurologic disorders.

- In 1996, Hooper incorporated the use of Hyperbaric Oxygen into the multidisciplinary rehabilitation model with focus on orthopaedic and neurologic disorders. The reputation of the clinic grew, especially in 1999 when a quadriplegic patient gained significant functional changes. This was a remarkable breakthrough as this individual was 6-years post injury and classified as “C7 complete”.

- This took Hooper on the path of utilising Body Weight Support innovations to promote the evergreen concept of ‘neuroplasticity’. In 2006, he introduced Australia’s first LOKOMAT – Adult and Paediatric Robotic Gaited Assisted Walking Machine. The pioneering applications of HBOT and Lokomat – a ‘world first’.

- Hyperbaric Oxygen Therapy enhances stem cell mobilisation and epigenetic modulation. The ‘penumbra state’ describes cells and neural pathways in a ‘dormant’ low metabolic state due to hypoxia. The effects of HBOT combined with LOKOMAT repetitive gait assisted movement enhances neuroplasticity and functional changes.

- In Australia, Hyperbaric Oxygen Therapy and LOKOMAT are viewed as “novel and unique”. Hooper has not practiced as a “traditional chiropractor” for over 25 years.

- An International Executive Board Member serving both the International Hyperbaric Medical Foundation (IHMF) & International Hyperbaric Medical Association (IHMA).
Stem cell mobilization by hyperbaric oxygen.

Thom SR1, Bhogale VM, Velazquez OC, Goldstein LJ, Thom LH, Ruerk DG

Abstract
We hypothesized that exposure to hyperbaric oxygen (HBO(2)) would mobilize stem/progenitor cells from the bone marrow by a nitric oxide (NO)-dependent mechanism. The population of CD34(+) cells in the peripheral circulation of humans doubled in response to a single exposure to 2.0 atmospheres absolute (ATA) O(2) for 2 h. Over a course of 20 treatments, circulating CD34(+) cells increased eightfold, although the overall circulating white cell count was not significantly increased. The number of colony-forming cells (CFCs) increased from 16 +/- 2 to 25 +/- 3 CFCs/100,000 monocytes plated. Elevations in CFCs were entirely due to the CD34(+) subpopulation, but increased cell growth only occurred in samples obtained immediately posttreatment. A high proportion of progeny cells express receptors for vascular endothelial growth factor-2 and for stromal-derived growth factor. In mice, HBO(2) increased circulating stem cell factor by 50%, increased the number of circulating cells expressing stem cell antigen-1 and CD34 by 3.4-fold, and doubled the number of CFCs. Bone marrow NO concentration increased by 1,008 +/- 255 nM in association with HBO(2). Stem cell mobilization did not occur in knockout mice lacking genes for endothelial NO synthase. Moreover, pretreatment of wild-type mice with a NO synthase inhibitor prevented the HBO(2)-induced elevation in stem cell factor and circulating stem cells. We conclude that HBO(2) mobilizes stem/progenitor cells by stimulating NO synthesis.
Case Study – T4 complete

Young Isabel has never walked. At 8-months age Isabel, was operated on for a benign tumour resulting in her becoming a ‘T4 complete paraplegic’.
Syringomyelia, cord atrophy

MRI 13-03-07: “Comparison is made with the last examination dated 10-10-05. Again, demonstrating the enhancing intraspinal lesion posteriorly in the spinal canal at the level of T4-T6. It is again seen to measure 2.8cm cranio caudal and 1cm AP. The T2 imaging again shows cord atrophy with hydromyelia from T1 to at least the inferior border of the lesion”.
4 months after intensive HBOT & LOKOMAT
Case Study – T12 Spinal Cord Injury

Kyle was told he would “never walk again”.
Now Kyle is walking limited distance with calipers.
Have to love his attitude
Case Study – Stroke Victim

Marco - massive arteriovenous malformation
Case Study – Drowning Victim

Young Chloe – near drowning victim.
Case Study – Cerebral Palsy
Case Study – C3/4 Quadriplegia
How to work with spasticity
Old Rehabilitation Model
Robotic Exoskeleton Assisted Walking

OLD REHABILITATION MODEL - “Living and coping with disability”

BODY WEIGHT SUPPORT TREADMILL TRAINING

- Two or more physical therapists manually move the patient’s legs in a walking pattern. However, the labour-intensive, strenuous nature and variability of the manual method can limit the frequency, quality and duration of the therapy.

ROBOTIC EXOSKELETON ASSISTIVE TECHNOLOGIES

- The patient is suspended in a harness over a treadmill and the exoskeleton frame of the robot, attached to the outside of the legs, moves the legs in a natural walking pattern.
- Neuroplasticity mechanisms work on the basis that by controlling the repetitive walking pattern we can help the brain and spinal cord work together to re-route signals that were interrupted by injury or illness.
- Robotics assisted walking helps to strengthen muscles and improve circulation.
- The robotic device does the heavy work - pattern and pace are consistent and the exercise can be sustained over longer training time.
- Typically patients undertake 3-5 sessions per week for 30-60 minutes durations over 8-12 weeks initially.
Acquired negative neuroplasticity
Hypoxic Ischemic Encephalopathy (HIE)
Hypoxic Ischemic Encephalopathy (HIE)
Hypoxic Ischemic Encephalopathy (HIE)
Hypoxic Ischemic Encephalopathy (HIE)
Periventricular Leukomalacia (PVL)
Hypoxic Ischemic Encephalopathy (HIE)
Periventricular Leukomalacia (PVL)
C5/6 Spinal Cord Ischemia
Whole Body Vibration
Effects of whole body vibration on muscle spasticity for people with central nervous system disorders: a systematic review.

Huang M1, Liao LR1,2, Pang MY1.

Abstract

OBJECTIVES: To examine the effects of whole-body vibration on spasticity among people with central nervous system disorders.

METHODS: Electronic searches were conducted using CINAHL, Cochrane Library, MEDLINE, Physiotherapy Evidence Database, PubMed, PsycINFO, SPORTDiscus and Scopus to identify randomized controlled trials that investigated the effect of whole-body vibration on spasticity among people with central nervous system disorders (last search in August 2015). The methodological quality and level of evidence were rated using the PEDro scale and guidelines set by the Oxford Centre for Evidence-Based Medicine.

RESULTS: Nine trials with totally 266 subjects (three in cerebral palsy, one in multiple sclerosis, one in spinocerebellar ataxia, and four in stroke) fulfilled all selection criteria. One study was level 1b (PEDro>6 and sample size>50) and eight were level 2b (PEDro<6 or sample size <50). All three cerebral palsy trials (level 2b) reported some beneficial effects of whole-body vibration on reducing leg muscle spasticity. Otherwise, the results revealed no consistent benefits on spasticity in other neurological conditions studied. There is little evidence that change in spasticity was related to change in functional performance. The optimal protocol could not be identified. Many reviewed studies were limited by weak methodological and reporting quality. Adverse events were minor and rare.

CONCLUSION: Whole-body vibration may be useful in reducing leg muscle spasticity in cerebral palsy but this needs to be verified by future high quality trials. There is insufficient evidence to support or refute the notion that whole-body vibration can reduce spasticity in stroke, spinocerebellar ataxia or multiple sclerosis.
Robot Lokomat helps teach seven-year-old girl with cerebral palsy to walk

ABC Radio Adelaide  By Brett Williamson
Updated 10 Nov 2015, 3:53pm

PHOTO: By using a robotic physiotherapy aid, Annie Goldsmith has been able reverse some of the symptoms of cerebral palsy and learn how to walk. Physiotherapist Rosemary Nelson monitors her progress. (Supplied: Kathryn Goldsmith)
Neurodegenerative disorders
Neurorecovery ‘gymnasiums’
Monorail Walking
Spasticity issues – prime with WBV

Effects of whole body vibration on muscle spasticity for people with central nervous system disorders: a systematic review.

Huang M1, Liao LR1,2, Fang MY1.

Author information

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Effects of Three Weeks of Whole-Body Vibration Training on Joint-Position Sense, Balance, and Gait in Children with Cerebral Palsy: A Randomized Controlled Study.

Ko MS\textsuperscript{1}, Sim YK\textsuperscript{2}, Kim DH\textsuperscript{3}, Jeon HS\textsuperscript{4}

Abstract in English, French

Purpose: To observe the effects of whole-body vibration (WBV) training in conjunction with conventional physical therapy (PT) on joint-position sense (JPS), balance, and gait in children with cerebral palsy (CP). Methods: In this randomized controlled study, 24 children with CP were randomly selected either to continue their conventional PT or to receive WBV in conjunction with their conventional PT programme. Exposure to the intervention was intermittent (3 min WBV, 3 min rest) for 20 minutes, twice weekly for 3 weeks. JPS, balance, and gait were evaluated before and after treatment. Results: Ankle JPS was improved after 3 weeks of WBV training ($p=0.014$). Participants in the WBV group showed greater improvements in speed ($F_{1,21}=5.221$, $p=0.035$) and step width ($F_{1,21}=4.487$, $p=0.039$) than participants in the conventional PT group. Conclusion: Three weeks of WBV training was effective in improving ankle JPS and gait variables in children with cerebral palsy.
Effects of whole-body vibration training on physical function, bone and muscle mass in adolescents and young adults with cerebral palsy.

Gusso S1, Munney CE2, Colle P1, Derraik JG1, Berry JB1, Cutfield WS1, Hoffman PL1

Abstract

We performed a clinical trial on the effects of whole-body vibration training (WBVT) on muscle function and bone health of adolescents and young adults with cerebral palsy. Forty participants (11.3-20.8 years) with mild to moderate cerebral palsy (GMFCS II-III) underwent 20-week WBVT on a vibration plate for 9 minutes/day 4 times/week at 20 Hz (without controls). Assessments included 6-minute walk test, whole-body DXA, lower leg pQCT scans, and muscle function (force plate). Twenty weeks of WBVT were associated with increased lean mass in the total body (+770 g; p = 0.0003), trunk (+410 g; p = 0.004), and lower limbs (+240 g; p = 0.012). Bone mineral content increased in total body (+48 g; p = 0.0001), lumbar spine (+2.7 g; p = 0.0003), and lower limbs (+13 g; p < 0.0001). Similarly, bone mineral density increased in total body (+0.008 g/cm²; p = 0.013), lumbar spine (+0.014 g/cm²; p = 0.003), and lower limbs (+0.023 g/cm²; p < 0.0001). Participants reduced the time taken to perform the chair test, and improved the distance walked in the 6-minute walk test by 11% and 35% for those with GMFCS II and III, respectively. WBVT was associated with increases in muscle mass and bone mass and density, and improved mobility of adolescents and young adults with cerebral palsy.
Sitting balance & coordination

The effect of a whole-body vibration therapy on the sitting balance of subacute stroke patients: a randomized controlled trial.

Lee JH¹, Kim SB², Lee KW³, Lee SJ⁴, Park H², Kim DW⁴.

Author information

Abstract

BACKGROUND: The use of a whole-body vibration (WBV) therapy has recently been applied and investigated as a rehabilitation method for subacute stroke patients.

OBJECTIVE: To evaluate the effects of a WBV therapy on recovery of balance in subacute stroke patients who were unable to gain sitting balance.

METHODS: The conventional rehabilitation group (CG) received conventional physical therapy, including sitting balance training by a physical therapist, for 30 min a one session, for twice a day for five days a week for two weeks. The whole-body vibration group (VG) received one session of conventional physical therapy, and received WBV therapy instead of conventional physical therapy for 30 min a day for five days a week for two weeks.

RESULTS: There were 15 patients in the CG and 15 patients in the VG who completed the two-week therapy. After the two-week therapy, both groups showed functional improvement. Patients in the VG improved functional ambulation categories, Berg balance scale, trunk impairment scale scores. But, no statistically significant correlations between the therapeutic methods and outcomes were observed in either group.

CONCLUSION: Our results suggest that WBV therapy led to improvement of the recovery in balance recovery for subacute stroke patients. Because the WBV therapy was as effective as conventional physical therapy, we can consider a WBV therapy as a clinical method to improve the sitting balance of subacute stroke patients.
Gait improvement, knee extension control

**Whole Body Vibration Training Improves Walking Performance of Stroke Patients with Knee Hyperextension: A Randomized Controlled Pilot Study.**


**Abstract**

**OBJECTIVE:** To investigate the effect of 8-week whole body vibration training on gait performance and lower extremity function in stroke patients with knee hyperextension.

**METHODS:** Total 30 subjects with stroke were randomized into the control group (n=15) or the intervention group (n=15). The patients of intervention group were treated with whole body vibration while the control group was treated with placebo. The walking function, lower limb function and knee hyperextension times were assessed in this study. Gait performances were evaluated by 10-meter walk test. The knee hyperextension times was visually observed and counted. The lower limb function was evaluated by Fugl-Meyer motor assessment.

**RESULTS:** The times of the knee hyperextension of the intervention group was significantly decreased compared with control groups (P=0.000, d=1.749, 95%CI[2.915,7.285]). The walking function assessed by 10-meter test of intervention group was significantly improved compared with control group (P=0.001, d=1.345, 95%CI[1.896,6.704]). The performances of all the three tests were improved after training in both groups (P=0.000/P=0.000, d=1.500/d=1.952, 95%CI[3.309,9.891]/95%CI[5.549,12.45]; P=0.000/P=0.000, d=2.015/d=2.952, 95%CI[5.214,11.39]/95%CI[9.423,15.68]; P=0.000/P=0.000, d=3.537/d=5.108, 95%CI[19.05,12.35]/95%CI[16.52,22.28]).

**CONCLUSION:** The results suggest that 8 weeks whole body vibration training can reduce knee hyperextension and increase ambulatory speed in stroke patients.
Contracture, spasticity - reduction of Satellite Cells

Children with cerebral palsy suffer impaired muscular growth and contractures.

Satellite cells are muscle stem cells critical for post-natal growth, regeneration and repair of skeletal muscles.

Conclusion:

- Loss of satellite stem cells results in increase in collagen deposition causing muscle stiffness - a result of non-use.
- Children with spastic CP have a reduced number of satellite stem cells.
- Reduced satellite stem cells results in impaired muscle growth and a decreased responsiveness of CP muscle to exercise.
Conclusion:

- Satellite cells are myogenic progenitor cells.
- Oxygen levels regulate myogenesis and muscle regeneration.
- Hypoxia impairs the regenerative capacity of injured muscles.
- Hypoxia impairs satellite cell activity and myogenesis through mechanisms associated with (HIF) hypoxia-inducible factor-1α.
HBOT increases satellite cell differentiation


Horie M, Enomoto M, Shimoda M, Okawa A, Miyakawa S, Yagishita K

Abstract:

• The use of hyperbaric oxygen (HBO) treatments by elite athletes to accelerate recovery from muscle injuries has become increasingly popular.
• Study: Rats were placed in an animal chamber with 100% oxygen under 2.5 atmospheres absolute for 2 h/day, 5 days/wk. for 2 wk.

Results:

• The cross-sectional areas and maximum force-producing capacity of the regenerating muscle fibers were increased by HBO treatment after injury.
• The mRNA expression of MyoD, myogenin, and IGF-1 increased significantly in the HBO group at 3 and 5 days after injury. The number of Pax7(+)/MyoD(+), Pax7(-)/MyoD(+), and Pax7(+)/BrdU(+) positive nuclei was increased by HBO treatment.

Conclusion:

• HBO treatment accelerated satellite cell proliferation and myofiber maturation in rat muscle.
• HBO treatment accelerates healing and functional recovery after muscle injury.
11 CP patients were enrolled in this study, of which 4 patients underwent oxygen therapy. Before oxygen therapy and at the end of 40 sessions of oxygen treatment, SPECT was performed, and the results were compared.

RESULTS:
- 11 CP patients; 7 females and 4 males age range of 5-27 years.
- SPECT studies - all the patients showed perfusion impairments.
- The region most significantly involved was frontal lobe (54.54%), followed by temporal lobe (27.27%), occipital lobe (18.18%), visual cortex (18.18%), basal ganglia (9.09%), parietal lobe (9.09%), and the cerebellum (9.09%).
- Frontal-lobe hypoperfusion was seen in all types of cerebral palsy.

CONCLUSION:
- Study demonstrated decreased cerebral perfusion in CP patients.
- Two out of 4 patients (2 males and 2 females) who underwent oxygen therapy revealed brain perfusion improvement. HBOT improved cerebral perfusion.
- Larger study is required to strengthen a link this approach may have some value.
LOKOMAT Australian Experience: Robotically Gait Assisted Body Weight Support Treadmill Training (BWSTT) – Lokomat Gait Training. Is it an effective and financially feasible treatment?


Abstract: Growing number of adult and pediatric spinal cord injury (SCI) and traumatic brain injury (TBI) cases each year indicates an increasing need for treatment modalities, like Body Weight-Supported Treadmill Training (BWSTT) to assist functional recovery. In addition to treatment of SCI cases, BWSTT has been used for managing other various neurological diseases such as stroke and multiple sclerosis (MS), cerebral palsy and other neurodegenerative states. Robotically Gait Assisted BWSTT (Lokomat) has been shown to be more accurate and financially feasible, compared to the other BWSTT modalities. In this article, we intend to review related articles and evidence to explain the medical and financial feasibility of using this treatment modality for neurological diseases.

Keywords: locomotion, exoskeleton, locomotor training, bodyweight support, robotics

Corresponding author: Malcolm R. Hooper Director Rehabilitation HyperMED NeuroRecovery Australia 13th floor 15 Collins St Melbourne 3001. Email info@hypermed.com.au T: +61 3 9650 3136 F: +61 3 9650 3150.
Children with cerebral palsy have an acquired dysfunction which their central nervous system function deems normal. This is evident when CP children undertake an intensive Lokomat Gait Training protocol. Many of these children demonstrate a ‘normal gait’ whilst on the Lokomat which raises question of acquired neural pathways and motor function wrongly developed and reinforced over time. When these same children come off the Lokomat they immediately return back to the acquired gait. Intensity and repetition enables the CP child to generate a new functionality which resembles a ‘normal gait’. It is a frequent finding to observe the bewilderment of both parents and CP child when the child sees themselves ‘walking normal’ on the Lokomat. Visualization whilst on the Lokomat is an important paradigm shift for not only the CP child and parent but also the therapist.
Robotic assisted fluidity – matching the patient
LOKOMAT settings

- Select patient
- Prepare device
  - Cuff sizes & harness
  - Leg lengths & cushions
  - Cuff positions & locks

Device setup:
- Symmetric
- Asymmetric

Harness size: M
Leg straps: M

We move you
Gait Pattern

Lokomat® Pro

ADJUST GAIT PATTERN

DISPLAYED ON PATIENT SCREEN

CURVE PURSUIT

SYMERIC

ASYMERIC

SENSITIVITY

PELVIS LATERAL MOVEMENT [cm]

HIP LEFT ROM [*]

HIP RIGHT ROM [*]

HIP LEFT OFFSET [*]

HIP RIGHT OFFSET [*]

KNEE LEFT ROM [*]

KNEE RIGHT ROM [*]

KNEE LEFT OFFSET [*]

KNEE RIGHT OFFSET [*]

PATHCONTROL ACTIVATION

ON

OFF

TUNNEL WIDTH

SMALL

TREADMILL SPEED [km/h]

ORTHOSS SPEED

AUTO

ASSIST THROUGH TUNNEL [%]

100

GUIDANCE FORCE [%]

REAL BODY WEIGHT SUPPORT

34 kg

50 %

DISTANCE: 125 m

END SESSION
Patient challenge programs

Lokomat® Pro

ADJUST GAIT PATTERN

CHALLENGE PATIENT

AGRIAT’S THERAPY PLAN
3 items, 15 minutes

CURVE PURSUIT
DURATION [min] 5

BALLOON CHASE
5 min

BODY WEIGHT SUPPORT
5 min

LEFT TURNING DIFFICULTY

RIGHT TURNING DIFFICULTY

AVATAR TYPE
ROBOT

TREADMILL SPEED [km/h] 1.5

ORTHOSIS SPEED
AUTO

GUIDANCE FORCE [%]

REAL BODY WEIGHT SUPPORT
34 kg 50 %

END SESSION
## Tracking

### Lokomat®Pro

### End Session

### Report Summary

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### Next Actions

- **Locomat Training**
- **Manual Training**
- **Assessment**
- **Report**
- **Select Next Patient**

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OXYMED

Melanomas Congress 2018
Melbourne, Australia
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Dr Norman Doidge - neuroplasticity
Practise makes perfect
Work with your patient
As opposed to working against your patient
Neuroplasticity finds a way
Neuroplasticity recruitment with purpose
Hard work is required by therapist and patient
THREE KEY PRINCIPLES OF MOTOR LEARNING -

1. Practice
- More functional learning will occur with more 'accurate practice'.

2. Specificity
- The best way to improve performance of a motor task is to 'execute that specific motor task repeated many times.'

3. Effort
- Individuals need to maintain a high degree of **focus, participation and involvement** to facilitate motor learning – *not* watching “days of our lives” and taking another ‘generic’ tablet.

These three principles are critical to promoting activity-dependent plasticity – by altering the excitation patterns of neural pathways by activating those pathways. Plasticity occurs in neural pathways that are both active and inactive – **penumbra state**.
Activity stimulates plasticity, neurogenesis

The field of neurorehabilitation is changing. After years of evidence the old, deep rooted rehabilitative principles of compensation and adaptation are slowly starting to change.

The adult injured central nervous system is capable of reorganization allowing for significant improvement following injury.

Reorganization and plasticity occurs: cortical, subcortical, spinal cord, and in the peripheral nervous system.

The repair process is referred to as synaptic plasticity and occurs in pre-existing connections (peripheral and central) resulting in sprouting and formation of new connections.

“Neuroplasticity” refers to the remyelination and new cell birth correcting, restoring, and replacing the damaged nerve cells.

Neurogenesis reported in adult brain: hippocampus and olfactory system.

Physical activity stimulates neurogenesis - proliferation of neuronal stem cells.

Activity reverses decline in neurogenesis associated with aging.

Exercise activates neighbouring axons and proliferates precursor cells.
Neural Plasticity occurs through life

NEURONAL PLASTICITY OCCURS THROUGHOUT LIFE
- neurogenesis, synaptic-dependent activity and the reorganization of neuronal networks.

The hippocampus dentate gyrus is a ‘highly plastic region’ able to generate new neurons, and can double or triple in size after physical exercise.

Physical exercise induces hippocampal plasticity – neurogenesis, cell proliferation and dendritic branching.

Brain Derived Neurotrophic Factor (BDNF) is one of the major modulators of the CNS and brain plasticity. In 1995, Neepet al. demonstrated that physical exercise enhanced BDNF gene expression in the hippocampus.

NEUROTROPHIC FACTORS UP-REGULATED BY PHYSICAL EXERCISE
- Nerve Growth Factor (NGF), Vascular Endothelial Growth Factor (VEGF), Fibroblast Growth Factor 2 (FGF-2), BDNF and Insulin Growth Factors (IGFs)

Insulin Growth Factor (IgF1) - promotes growth, differentiation and cellular survival. Is upregulated in the hippocampus. Has neurotrophic effects in the CNS and involved in differentiation, proliferation, synaptic plasticity and neurogenesis. IgF1 is increased in neurogenesis & cognitive function.

- Physical exercise and task specific activity requiring hippocampus-dependent memory expressed higher circulating levels of IgF1 and BDNF in the hippocampus, cerebellum and spinal cord.
• Physical exercise, similarly to injury, is a compelling stimulant of new vessels (angiogenesis) and endothelial cell proliferation - VEGF.

• Neurogenesis and plasticity appear to be mediated by IGF-1, BDNF and VEGF.
• Resistance training and aerobic exercise upregulates IGF-1, BDNF and VEGF in the hippocampus and peripheral circulation.

• Using arterial spin labeling MRI in humans, an increase in the was verified in elderly individuals exposed to 4 months of aerobic exercise. cortical hippocampal flow
• Cerebral blood volume (CBV) in the DG was also increased in young subjects after 3 months of aerobic training.
• Cognitive improvements were also associated with aerobic training and increased cerebral blood volume.

• Physical conditioning increased the number of small blood vessels in elderly individuals indicating angiogenesis.
• In contrast sedentary individuals displayed increased numbers of vessel tortuosity in both brain hemispheres.
Robotic resistance vs Overground walking

Training with robot-applied resistance in people with motor-incomplete spinal cord injury: Pilot study

Tania Lam, PhD;1-2* Katherine Paulh, MSc;1-2 Amanda Ferguson, BScPT;3 Raza N. Malik, BKin;1-2 Andrei Krassilov, MD, PhD;2-4-5 Janice J. Eng, PhD2-5-6

1School of Kinesiology and 2International Collaboration on Repair Discoveries, University of British Columbia, Vancouver, British Columbia, Canada; 3NeuroMotion Physical Therapy, Vancouver, British Columbia, Canada;
4Department of Medicine, Division of Physical Medicine and Rehabilitation, University of British Columbia, Vancouver, British Columbia, Canada; 5GF Strong Rehabilitation Centre, Vancouver, British Columbia, Canada 6Department of Physical Therapy, University of British Columbia, Vancouver, British Columbia, Canada

• Journal Rehabilitation Research & Development 2015: Almost half of all people with incomplete spinal cord injury (SCI) have some voluntary motor function below the level of injury. People with motor-incomplete SCI can recover basic walking with intensive, task-specific gait training.

• ‘Scientific evidence suggests’ that ‘BWSTT is not better than overground gait training’ in SCI or other neurologic disorders. [There was debate as to whether the overground training used in this clinical trial was reflective of a realistic ‘conventional therapy’ ie BWSTT vs living with disability.]

• The results were consistent – intensive practice and task-oriented gait retraining (whether it is provided by BWSTT or overground practice) can result in improved walking outcomes.

• A major shift and focus is now on the potential efficacy of Robotic-applied resistance (Robotic-R) training on functional ambulation, overground walking with chronic m-iSCI and other neurologic disorders.
Resistance & “Noise”

- Task-specific locomotor training adopting alterations in the movement can mediate ‘feedback-error learning’.
- Feedback-error learning during walking can be used to elicit locomotor adaptations.
- Short-term adaptation to robot-applied resistance against hip flexion demonstrates a longer stride length that persists overground immediately after walking against resistance.
- Diminished hip, knee and ankle flexion observed during swing phase, compromising foot clearance height – toe stabbing.
- Improvements in overground walking speed and distance but also in skilled walking tasks, obstacle crossing and stair climbing, as well as the kinematic quality of the gait pattern.
- Variability during practice is seen as a key feature for facilitating learning - repeated (and varied) opportunities to experience errors and solve motor problems.
- Variability or ‘noise’ during training helps to reinforce convergent synaptic connections from central and sensory inputs to the locomotor circuitry. (Learning not to fall).
- Robotic applied ‘resistance’ would also have required greater engagement during training to avoid toe drag and stumbling.
- Greater cognitive engagement during training elicited greater involvement of cortical regions associated with gait adjustments of motor output during swing.
- Indeed, it has been shown that corticospinal excitability is tuned according to the level of cognitive engagement during gait training and resistance.
Robotic accuracy & repetition

A patient-specific muscle force estimation model for the potential use of human-inspired swing-assist rehabilitation robots

Ye Ma, Shengquan Xie & Yanxin Zhang
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GAIT REHABILITATION ROBOTS, WHICH ARE PRECISE

- Swing-phase deviations are related to quadriceps spasticity, hip flexion weakness, ankle dorsiflexion weakness or spasticity, hamstring contracture, spasticity and quadriceps weakness, which will lead to inadequate knee joint flexion and extension as well as excessive knee joint flexion and extension.

- Clinical evidence shows that task-oriented repetitive intensive movement swing-phase training improved walking speeds, endurance and performance on functional tasks for individuals with neurologic gait disability.

- Gait rehabilitation robots, which are precise, rehabilitation effectiveness with high accuracy, could yield better training outcomes than traditional physiotherapists.

- Optimal control strategy should comprise task-specificity, repeatability, intensity and optimal physical and mental engagement.

- Robotic swing-assistance task-specific, intensive and non-fatigue training, can improve the locomotion ability of the incomplete SCI patient and other neurologic gait dysfunction.
Robotic Exoskeletons assisting neurodevelopment disorders

Prospective controlled cohort study to evaluate changes of function, activity and participation in patients with bilateral spastic cerebral palsy after Robot-enhanced repetitive treadmill therapy.
Schroeder AS1, Homburg M2, Warken B2, Auermann H2, Koerte I3, Ronweck S4, Jahn K5, Haenen E2, Borregaard J6

Comparison of a robotic-assisted gait training program with a program of functional gait training for children with cerebral palsy: design and methods of a two group randomized controlled cross-over trial

Robot-assisted gait training might be beneficial for more severely affected children with cerebral palsy.
van Hedel HA1,2,3, Meyer-Heim A1,2,3, Rösch-Bohlt C1,2.

Robotic-assisted gait training improves walking abilities in diplegic children with cerebral palsy.
Wallard L1, Dietrich G2, Kerinzi Y2, Bredin J3.
Optimal rehabilitation should involve:

- Robotic assisted devices combined with overground walking
- Active (patient) participation and engagement
- Training involving many repetitions, but continues to challenge the skill
- Resistance training
- Feedback error learning – changing and challenging environment
- Motivation and reward
- Intensive training and practice over a long time
- Combination training - overground training activities
- “Learn to walk by learning not to fall”
“Learning not to fall”
Variable Assist Exoskeletons

NEUROREHAB IMPROVEMENTS USING PERSONAL ROBOTIC EXOSKELETONS

• Originally “passive assist” - guide the lower limbs of patients applying pre-programmed physiological gait patterns in the hip and knee joints.

• Today and emerging - new powered gait orthosis featuring programmable “variable assist” movements in the hip and knee joints enabling independent training and neurorehabilitation in a clinical environment and at home.
Variable Assist Exoskeletons
Variable Assist Exoskeletons
Lifestyle Assist Exoskeletons
Lifestyle Assist Exoskeletons

[Image of exoskeletons in different positions, showing various parts and interfaces.]
Industrial and Military Exoskeletons