2022 대한소아재활발달의학회 춘계연수강좌

Lower Limb Robotic Rehabilitation

나 동 욱, MD, PhD

재활의학과 교수, 세브란스 재활병원, 연세대학교 의과대학

CBO(Chief Business Officer), 엔젤로보틱스

세브란스 재활병원
SEVERANCE REHABILITATION HOSPITAL

ANGEL ROBOTICS
ROBOTICS FOR BETTER LIFE

나 동욱 MD, Ph.D

- 연세대학교 재활의학교실 교수
  - 연세의대 졸업 및 석, 박사 취득
  - 세브란스 전공의 수련
  - 세브란스 소아재활 전임의
- 소아재활 전문의
- 동작분석실 및 로봇재활치료센터 책임교수

나 동욱 MD, Ph.D

- 스탠포드 대학교 방문교수(2012-13)
  - MotionLab of Lucile Packard children's hospital, Stanford medical center
  - Bioengineering dept., Stanford univ. (NMBL)
- BMRR(BioMechanics and Robotic Rehabilitation) laboratory

  http://biomechanics.yonsei.ac.kr

엔젤로보틱스 창업 (2017~)

CEO/CRTO (Chief Robotic Technology Officer)

공경철 대표이사

ANGEL ROBOTICS 설립
U.C., Berkeley 기계공학 박사
KAIST 기계공학과 부교수

구동기, 드라이버, 제어 등 로보틱스 기술

2011 ~ 2018	서강대학교 부교수
2012	한국연구재단 우수신진연구자 선정 (로봇분야 유일)
2016	국제 자동제어학회(IFAC) 젊은 과학자상 수상 한국로봇학회(KROS) 학보ART상 수상 제어로봇시스템학회(ICROS) 학술활동상 수상 UAE AI & Robotics for Good 결선진출 ICRA Best Start-up Pitch 수상 평창올림픽 개폐막식 자문위원
2017	산자부 웨어러블로봇 플랫폼 사업 기획위원 한국공학한림원 미래기술주역 대한민국발명특허대전 대통령상
2019 ~ 현재	KAIST 기계공학과 부교수

ANGEL ROBOTICS
ROBOTICS FOR BETTER LIFE

(Chief Medical Business Officer, Chief Clinical Technology Officer) **CMBO/CCTO**

나동욱 이사

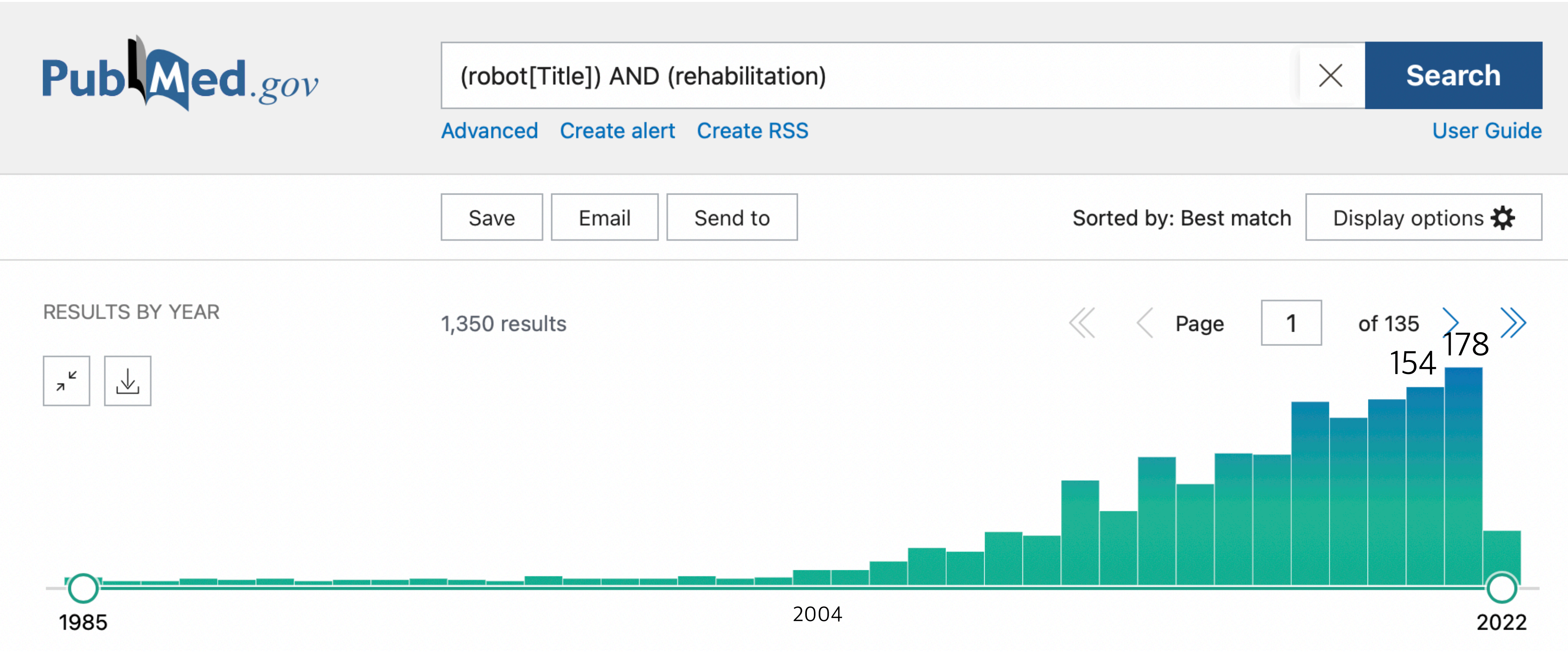
ANGEL ROBOTICS 설립
연세대학교 의과대학 박사
신촌세브란스 재활병원 전문의

임상적 검증 의도파악 알고리즘 등 임상기술

2001 ~ 2005	연세의대 재활의학과 전공의
2006	재활의학과 전문의 취득 (전체수석)
2006 ~ 2007	연세의대 재활의학과 전임의
2007 ~ 2012	연세의대 재활의학과 조교수
2011	대한재활의학회 젊은 연구자상
2012 ~ 2013	Stanford University 생역학과 방문교수
2013 ~ 2017	연세의대 재활의학과 부교수
2018 ~ 현재	연세의대 재활의학과 교수 연세대 대학원 융합의학과 겸임교수

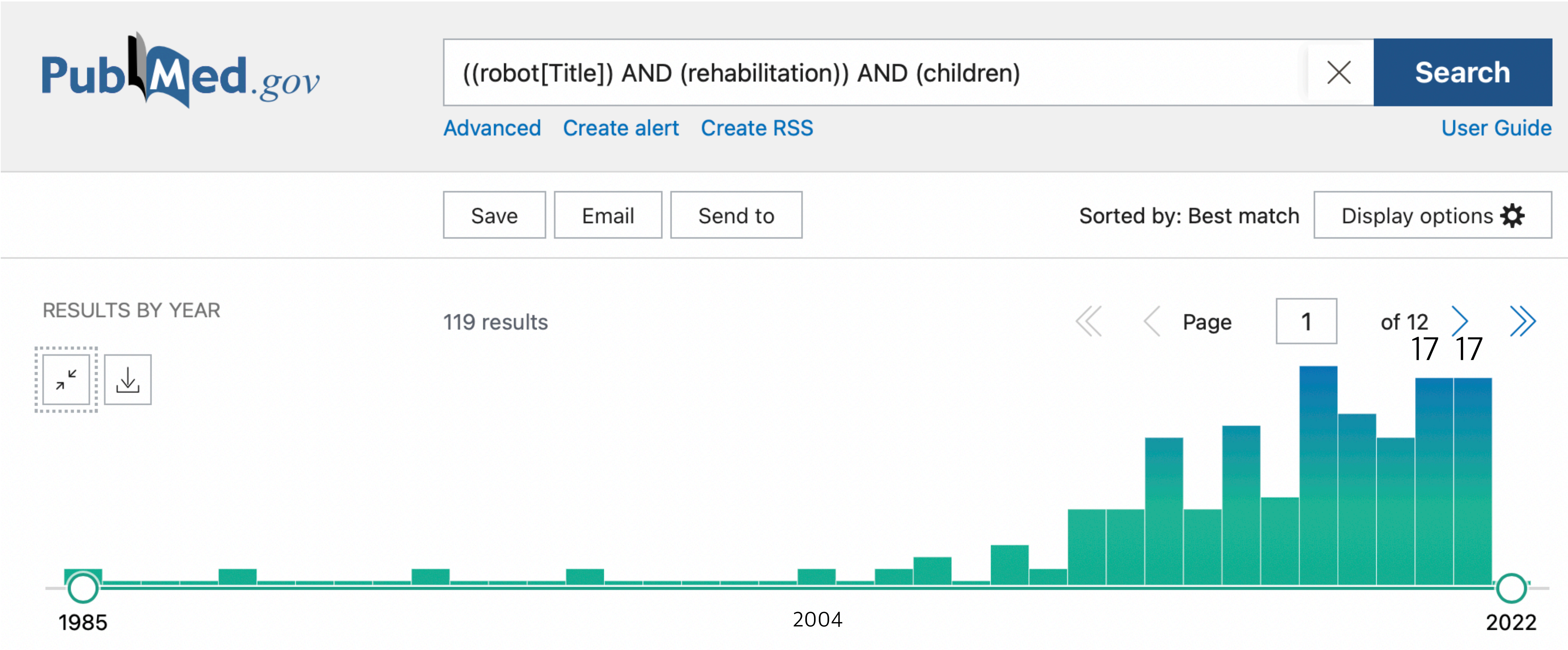
Robot-assisted Gait Therapy (RAGT)

Research trends
of robotic rehabilitation



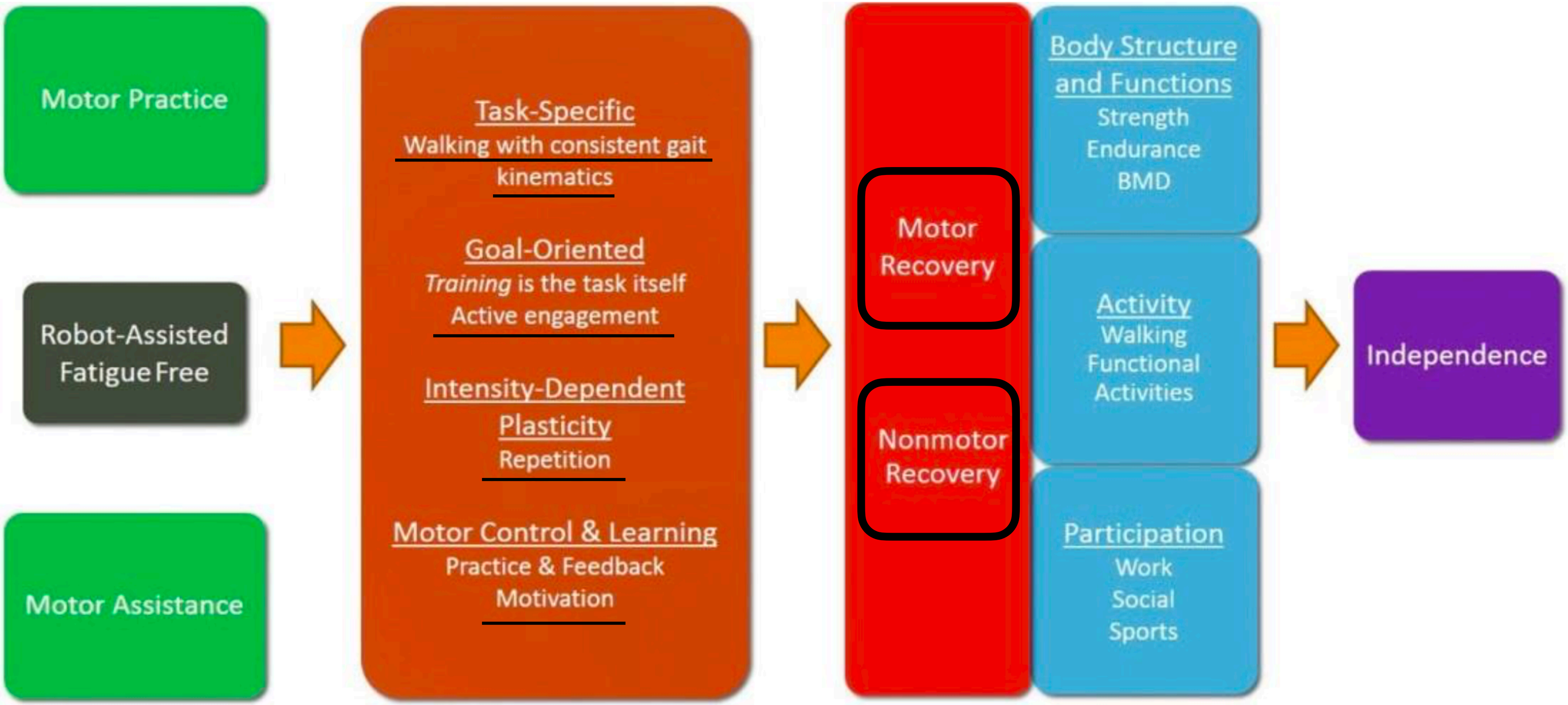
PubMed

Research trends of robotic rehabilitation in pediatric patients



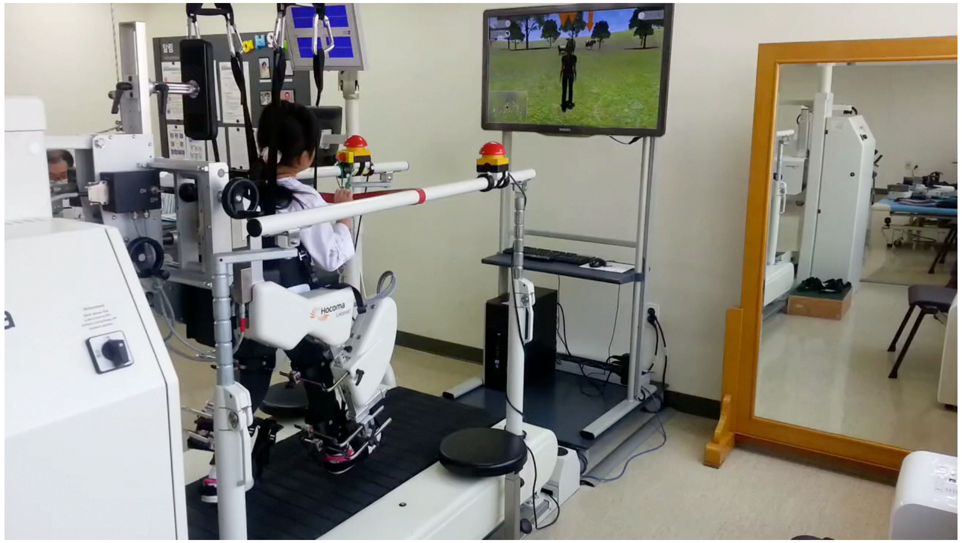
PubMed

Principle of robotic rehabilitation



DeLisa's Physical Medicine and Rehabilitation, 6th edition

Strategy using robot for rehabilitation



Challenge-based strategies
(Motor practice)

Assistive-based strategies
(Motor assistance)

Theory of motor learning

- Reflex model : closed-loop-control
- Hierarchical model : pre-programmed instruction & anticipatory-control

➡ Reflex-Hierarchical : **Neuro-developmental therapy**

- System model : task-oriented approach, importance of interaction with environments

Current gait training by therapists

Trunk control

Sitting balance

Standing balance

Gait independence with weight shifting

Gait adaptability

? ?

Lower extremities motor control

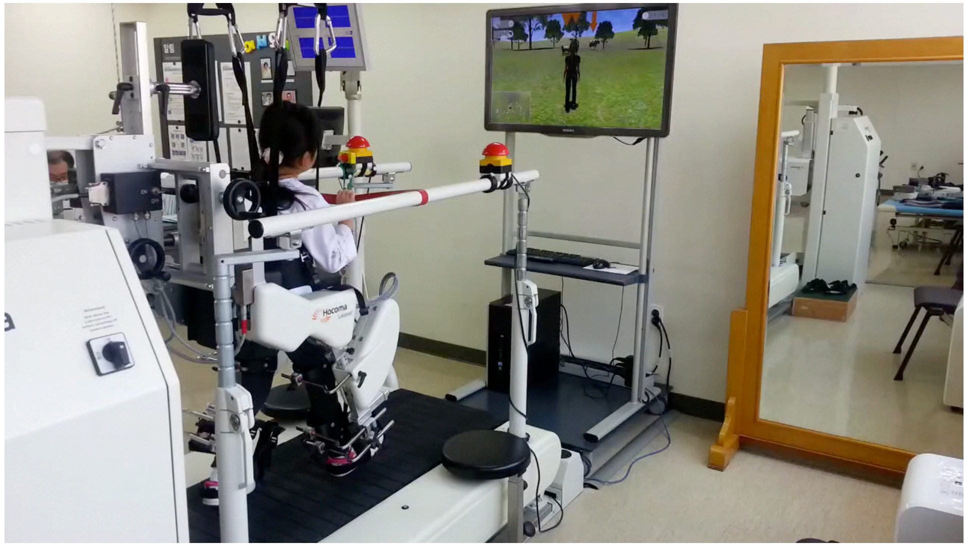
Gait pattern

Intensive gait training
- Partial Weight Bearing Treadmill Training -

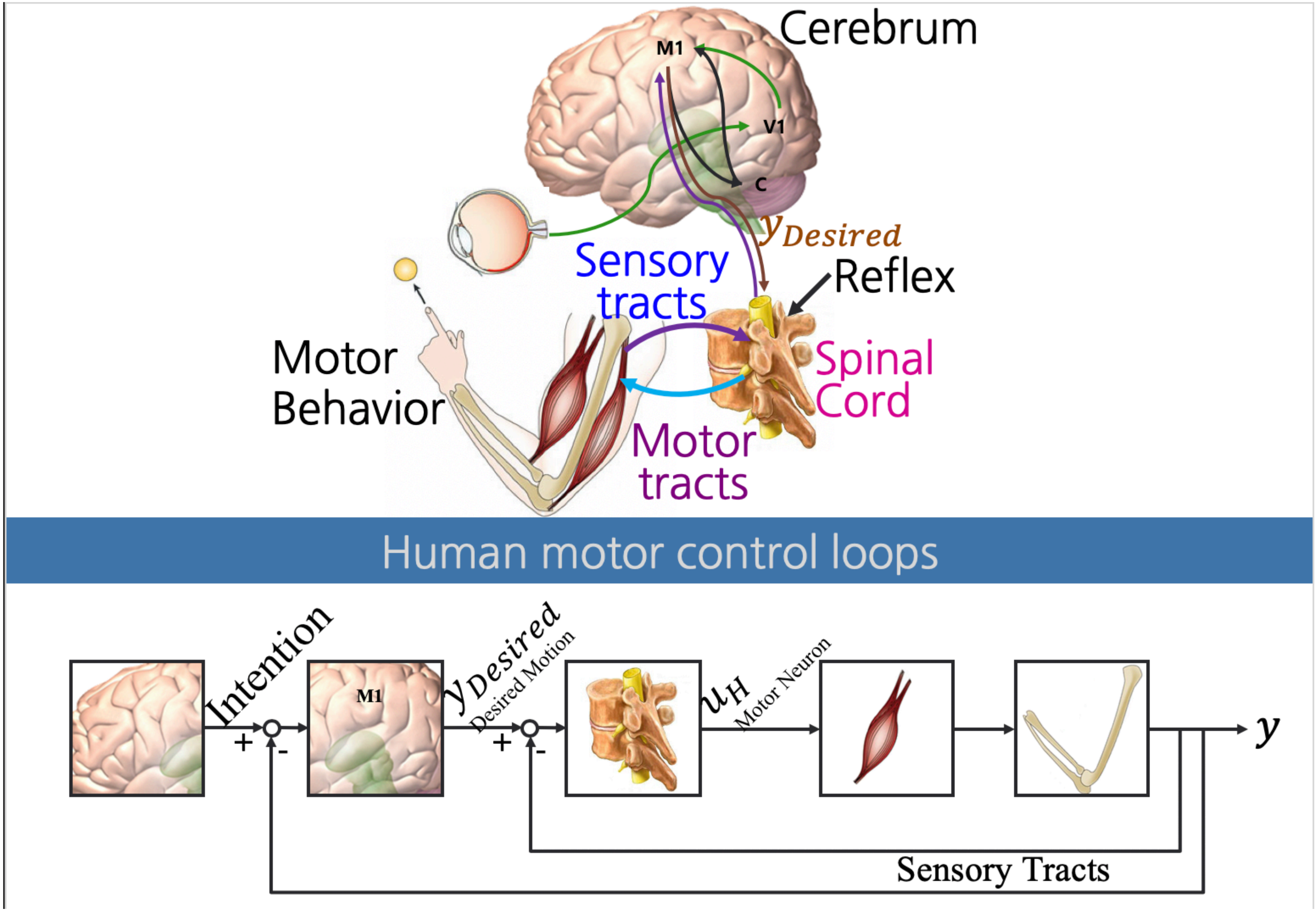
- intensive, repetitive gait training

  ➡ more effective for recovery of gait function

  But, unrealistic massive amount of labor by therapists

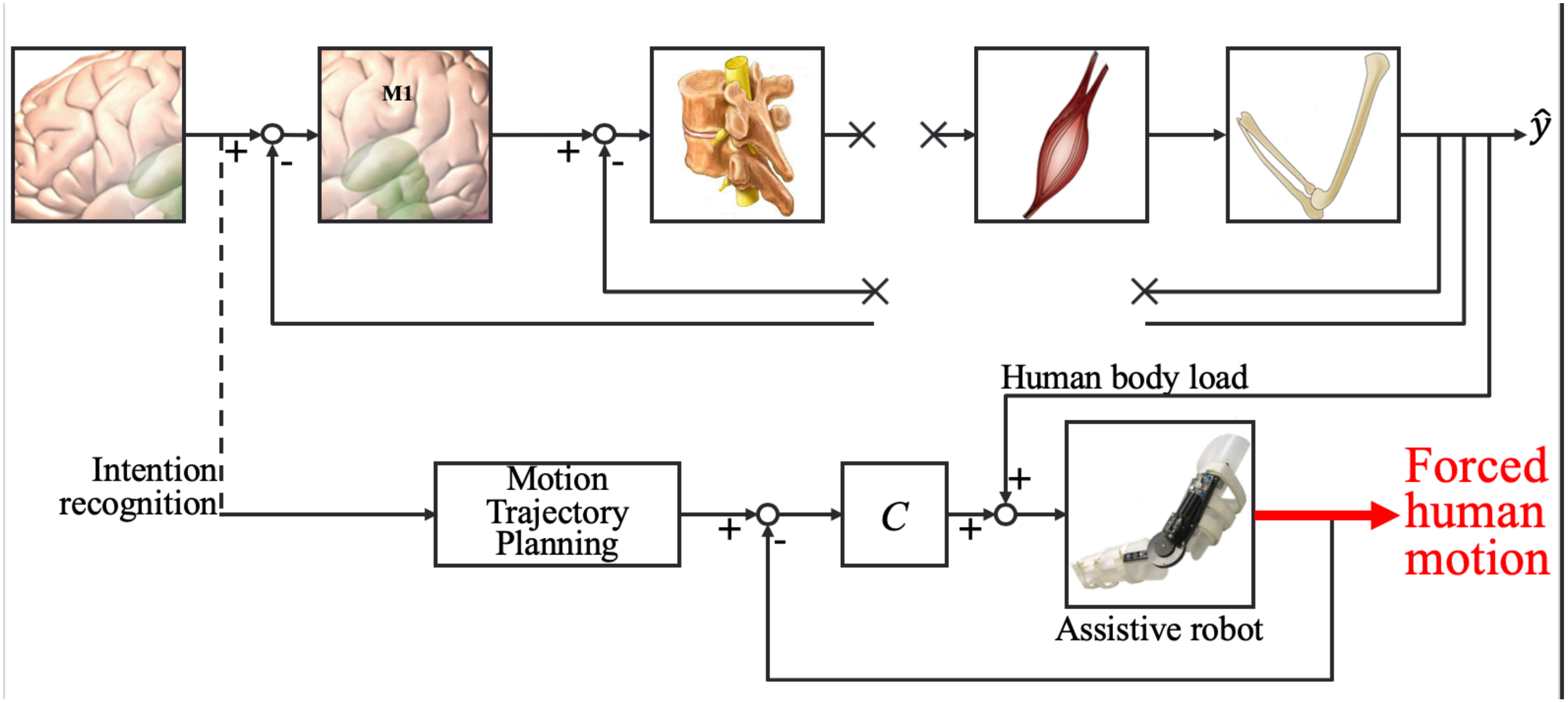


Robot-assisted Gait Training (RAGT)


Cerebrum
M1
V1
C
$y_{Desired}$
Sensory tracts
Reflex
Spinal Cord
Motor Behavior
Motor tracts
Human motor control loops
Intention
M1
$y_{Desired}$
Desired Motion
u_H
Motor Neuron
+
-
+
-
y
Sensory Tracts

Basic assistance strategy for **complete** paraplegics

- When the muscles are completely paralyzed

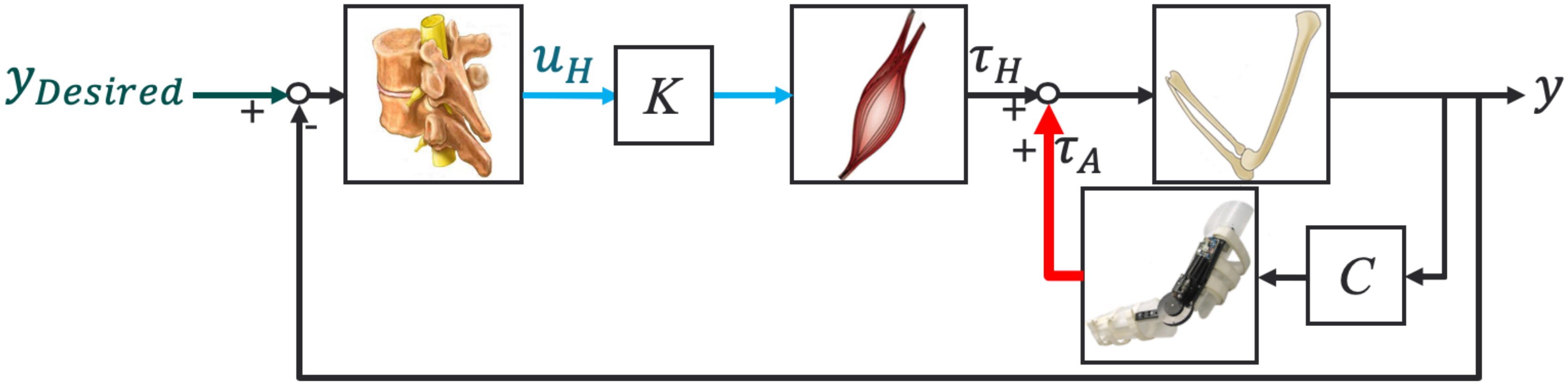


Control variable of the assistive robot is “motion”.

→ Position control problem.

Basic assistance strategy for **incomplete** paraplegics

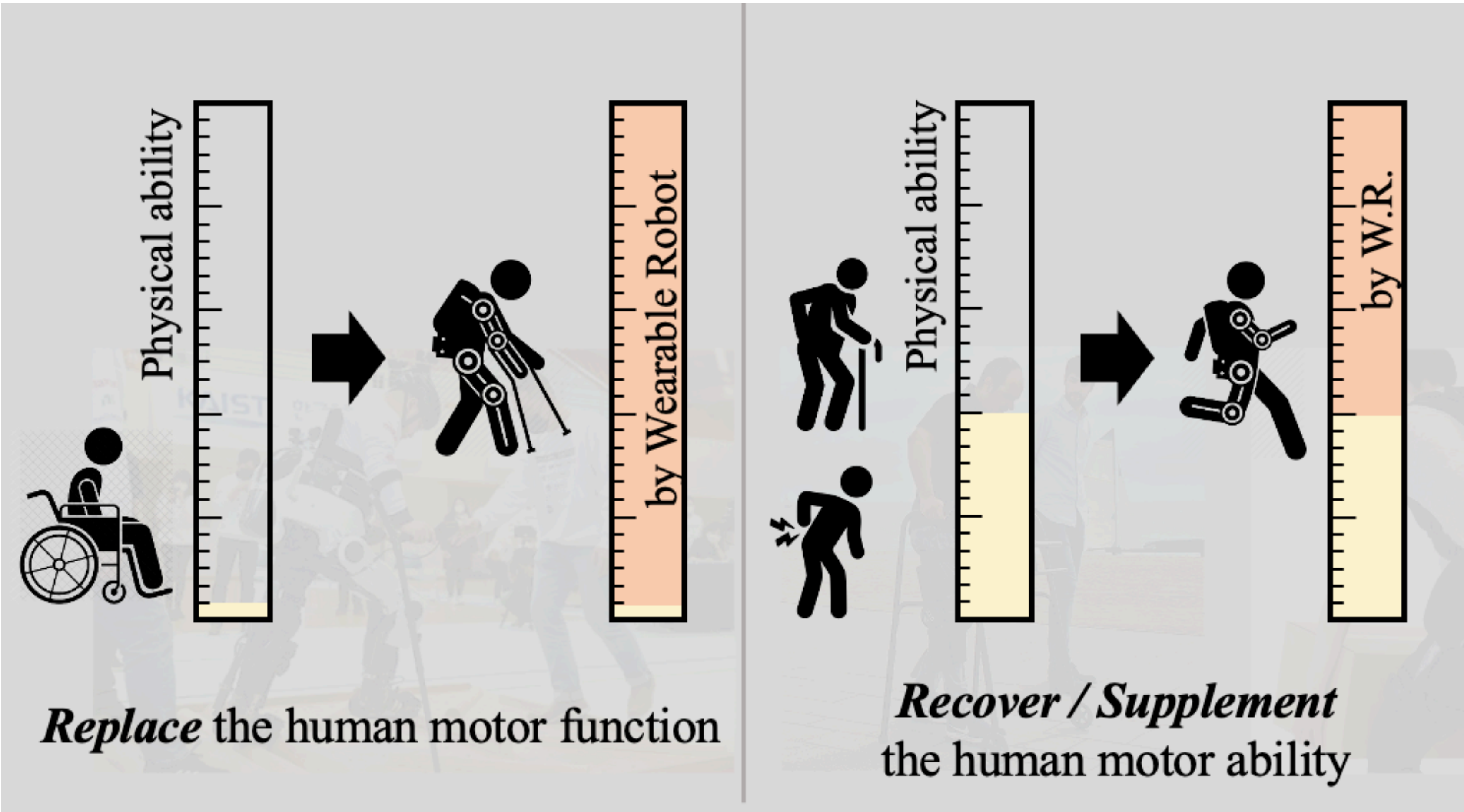
- When the muscles are weakened



Control variable of the assistive robot is “force”.

→ Force control problem.

Strategy for **complete & incomplete** paralysis



Joint trajectory-control

Joint torque-control

Hierarchical application of RAGT

Injury

Disease

Challenge-based strategy

(Challenging, but Not disappointing!!)

Severe impairments → Mild impairments

Recovery

Trajectory control
Body weight support
Treadmill

Torque control
Overground walking




Hierarchical application of RAGT

≠

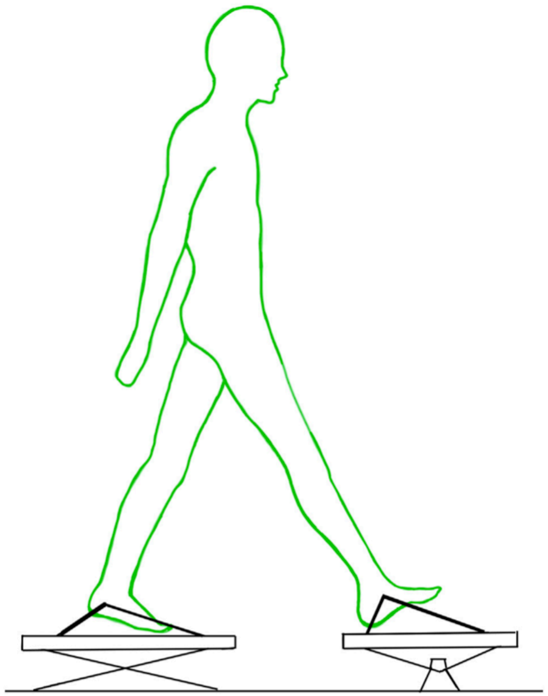
Challenging task

Hierarchical application of RAGT

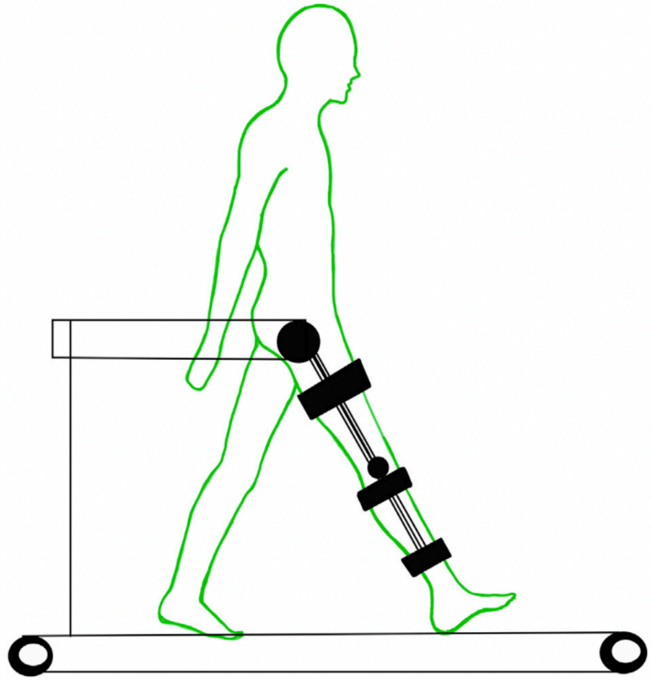
$\neq$

Task-specificity of motor learning

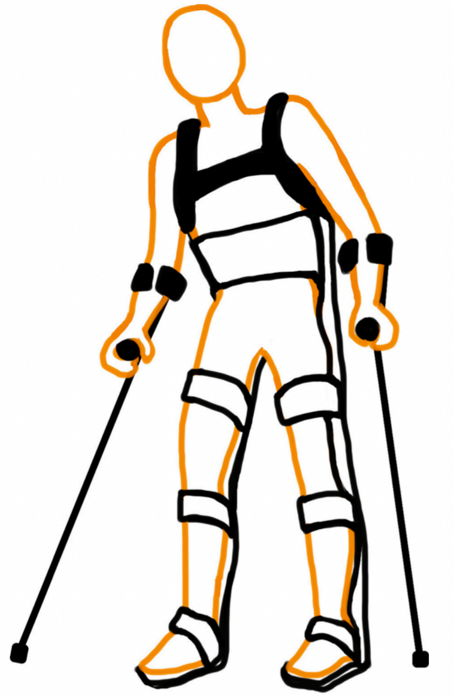
Types of robot for gait rehabilitation



end-effector



exoskeletal
tethered

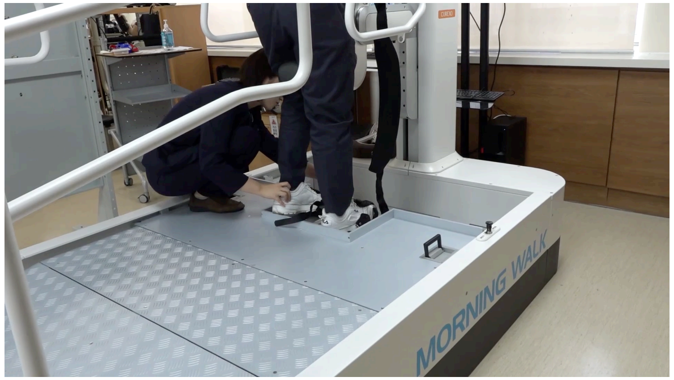


exoskeletal
overground

F. Molteni et al. / PM R 10 (2018) S174-S188

Hierarchical application of RAGT

exoskeletons



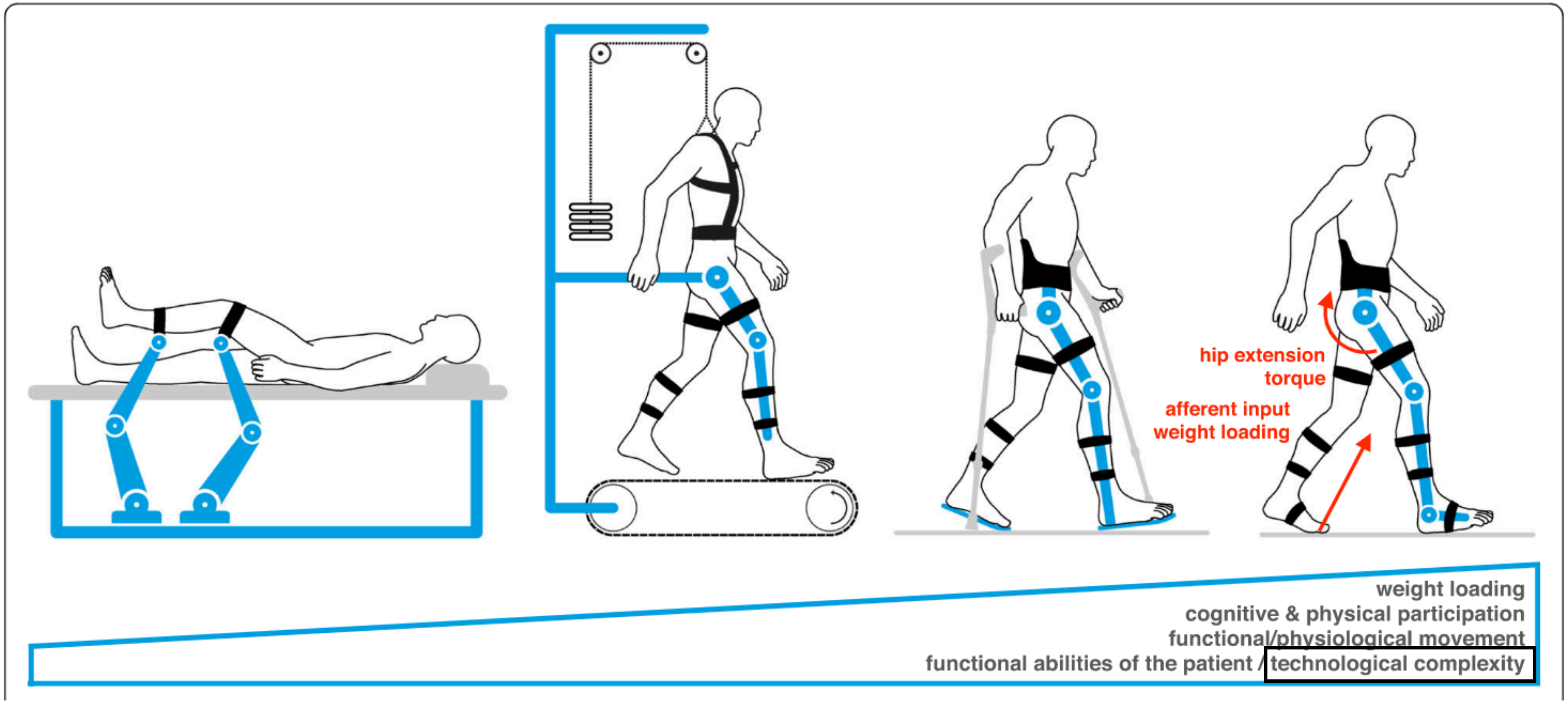
end effector

Tethered robots
(trajectory control)

Wearable
overground
exoskeletons
(torque assist)

Task-specificity of motor learning

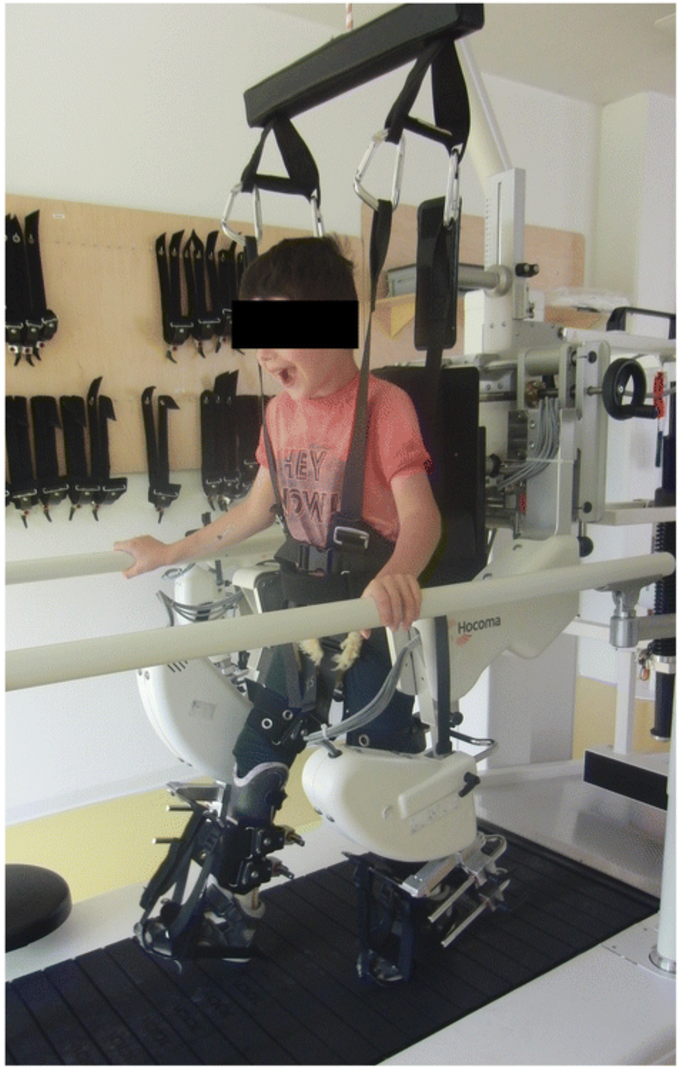
Hierarchical application of RAGT



Gassert and Dietz *Journal of NeuroEngineering and Rehabilitation* (2018) 15:46

RAGT in Cerebral Palsy

Exoskeletal on Treadmill type



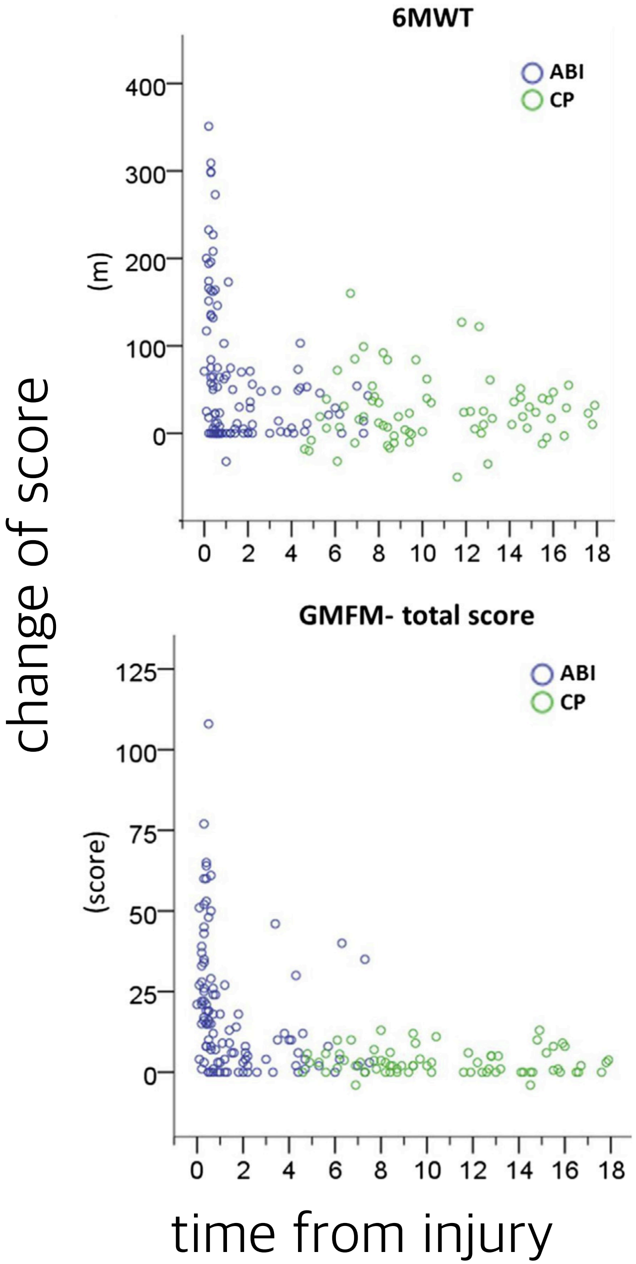
- PeLoGAIT trial (Randomized pragmatic crossover design)
- Lokomat® (Hocoma, Swiss)
- 16 children (mean 11.3 years, 6.0~15.3) of CP – early stop d/t recruitment problem
- GMFCS II~IV
- 5 weeks (3 days/week, 45 min)

  ➡ **no** superiority : GMFM, 10MWT, 6MinWT

➡ RAGT as a single intervention – **not** effective
➡ Should be embedded in a holistic Tx

Journal of Pediatric Rehabilitation Medicine: An Interdisciplinary Approach 13 (2020) 137–148

Exoskeletal on Treadmill type



- Lokomat® (Hocoma, Swiss)
- 182 children (110 ABI, 72 CP), GMFCS I~IV
- evaluated retrospectively in 2 centers
- 20 sessions of RAGT + 20 sessions of PT
- 4 weeks (5 days/week, 45 min of each)

➡ ABI : 6MWT, GMFM

➡ CP : 6MWT, GMFM (only on GMFCS III)

Arch Phys Med Rehabil. 2020 Jan;101(1):106-112.

End-effector type

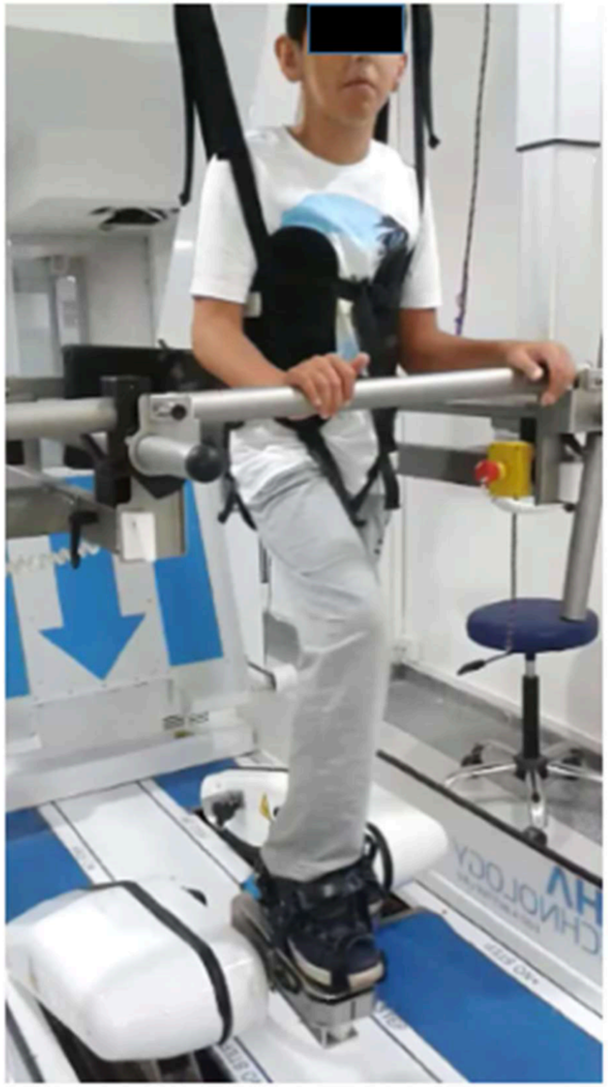


Figure 1. RAGT with G-EO systems including walking and stair climbing.

- Single arm prospective study
- G-EO robotic system® (Reha Tech., Swiss)
- 17 children (12.83±5.41 years) of CP
- GMFCS II, III
- 10 weeks (3 days/week, 45 min)

➡ improved GMFM(D,E), PBS

Journal of Exercise Therapy and Rehabilitation. 2019;6(3):156-162

End-effector type

- Single arm prospective study
- Morning Walk® (Curexo, Korea)
- 22 children (12.4 ± 4.3 years)
- 10 quadriplegia, 6 hemiplegia, 6 diplegia
- 24 sessions (5 days/week, 30 min)

➡ improved FAC

➡ Feasible and safe

Brain Neurorehabil. 2020 Mar;13(1):e6

Wearable overground type

- 6 cases (13~24 years)
- HAL® (CYBERDYNE, Japan)
- GMFCS II~IV
- 12 sessions (2-4 days/week, 20 min)

  ➡ improved gait speed, cadence, single leg support, 6MinWT, GMFM

  ➡ Feasible and safe

Brain & Development 40 (2018) 642–648

Wearable overground type

- single case report
- HAL® size S (CYBERDYNE, Japan)

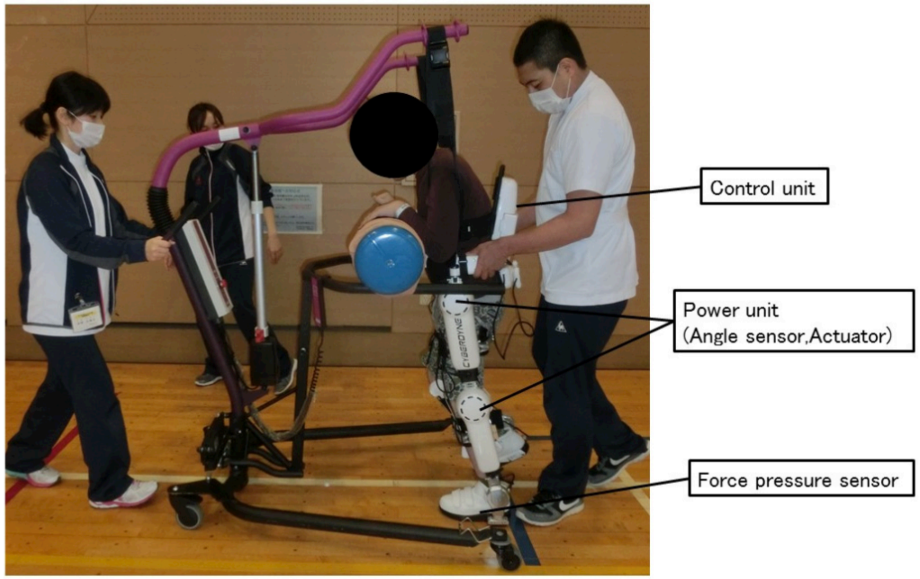
  target 145-165cm of height
- 11 years old boy (138cm, 30kg)
- 12 sessions (2-4 days/week, 20 min)

  ➡ improved gait speed, cadence, step length, 6MinWT, GMFM

  ➡ Feasible and safe

Brain & Development 42 (2020) 468–472

Wearable overground type



- 19 children of bilateral & unilateral spastic CP

  (9-29 yrs old, height 131cm-168cm)

  (GMFCS I~II : 5, GMFCS III~IV : 14)

- HAL® (CYBERDYNE, Japan)

- a 20 min **single** sessions

  (10 min rest, 20 min attach/detach)

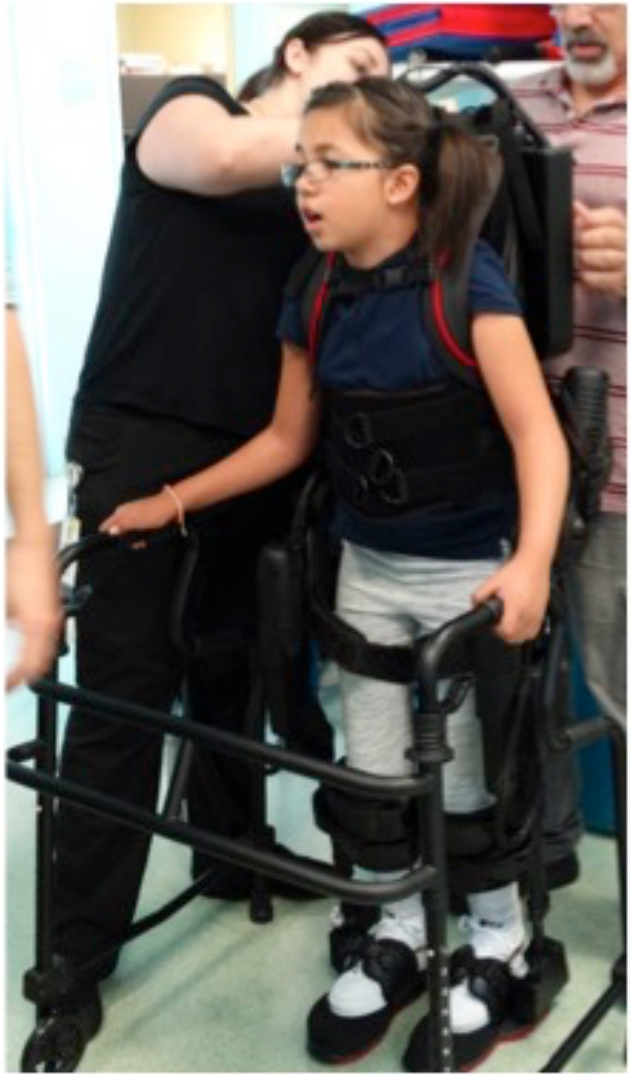
  ➡ **immediate improve in 10MWT**

  - gait speed, cadence, stride length

  - gait symmetry

medicina *Medicina* **2020**, *56*, 673

Wearable overground type



- 26 children of bilateral spastic CP

  (GMFCS I~II : 17, GMFCS III~IV : 9)

- Ekso GT® (Ekso Bionics, USA)

- 30 sessions (45 min/session)

  10/2wks - break - 10/2wks - break - 10/2wks

  ➡ **no** change

  - spatiotemporal parameters of gait

  - joint kinematics during gait

frontiers in Neurology Front Neurol. 2021 Dec 23;12:724009.

sensors

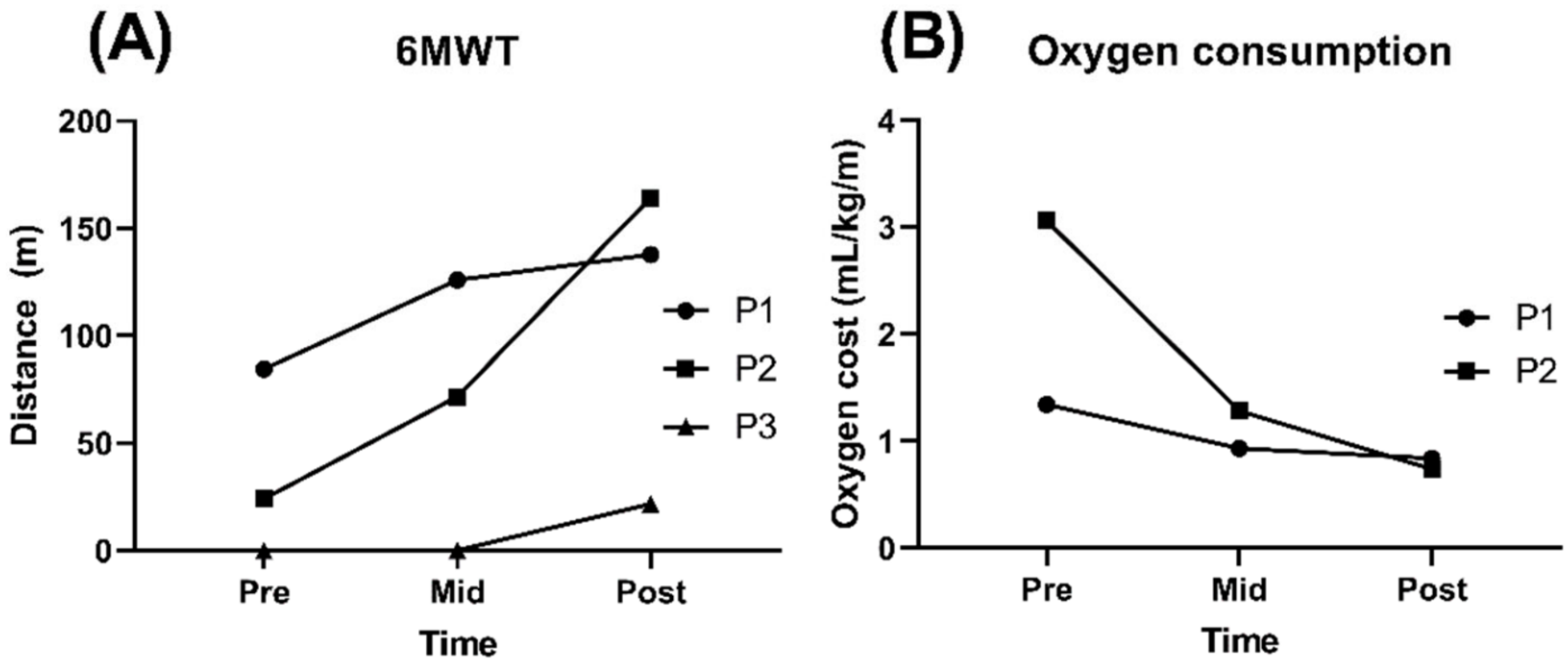
Sensors **2021**, *21*, 2087

MDPI

Article

Overground Robot-Assisted Gait Training for Pediatric Cerebral Palsy

Seung Ki Kim [1], Dongho Park [2], Beomki Yoo [2], Dain Shim [2], Joong-On Choi [2], Tae Young Choi [2] and Eun Sook Park [2,*]



Researches using Angel Legs M

sensors

Case Report

The Effects of Over-Ground Robot-Assisted Gait Training for Children with Ataxic Cerebral Palsy: A Case Report

sensors

Case Report

Effectiveness of Robotic Exoskeleton-Assisted Gait Training in Spinocerebellar Ataxia: A Case Report

applied sciences

Article

Assistance of a Person with Muscular Weakness Using a Joint-Torque-Assisting Exoskeletal Robot

sensors

Article

Overground Robot-Assisted Gait Training for Pediatric Cerebral Palsy

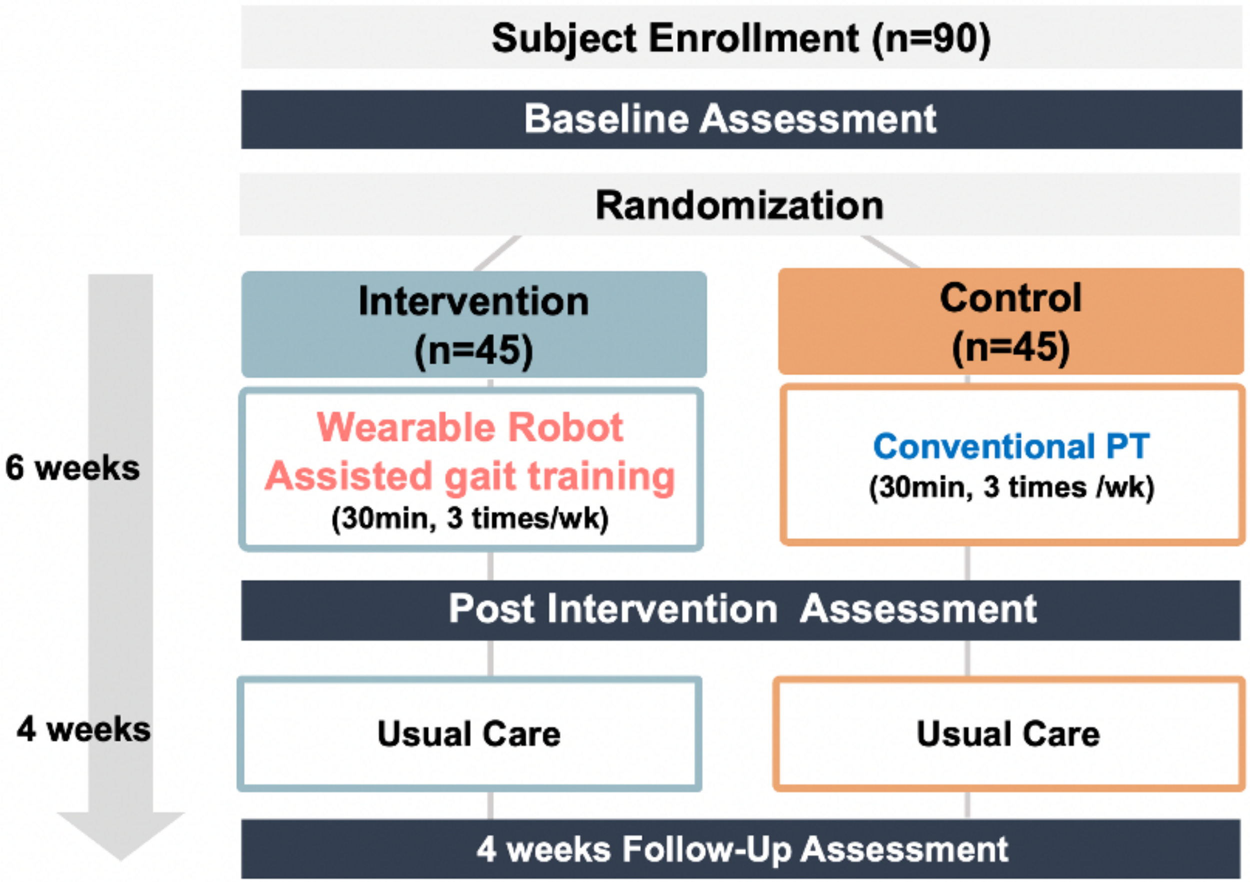
The Effects of Over-Ground Robot-Assisted Gait Training for Children with Ataxic Cerebral Palsy A Case Report (sensors-21-07875)

Effectiveness of Robotic Exoskeleton-Assisted Gait Training in Spinocerebellar Ataxia: A Case Report(sensors 21-04874)

Assistance of a Person with Muscular Weakness Using a Joint-Torque-Assisting Exoskeletal Robot(applsci-11-03114)

Overground Robot-Assisted Gait Training for Pediatric Cerebral Palsy(sensors-21-02087)

Researches using Angel Legs M



CNU HOSPITAL 충남대학교병원

전남대학교병원 CHONNAM NATIONAL UNIVERSITY HOSPITAL

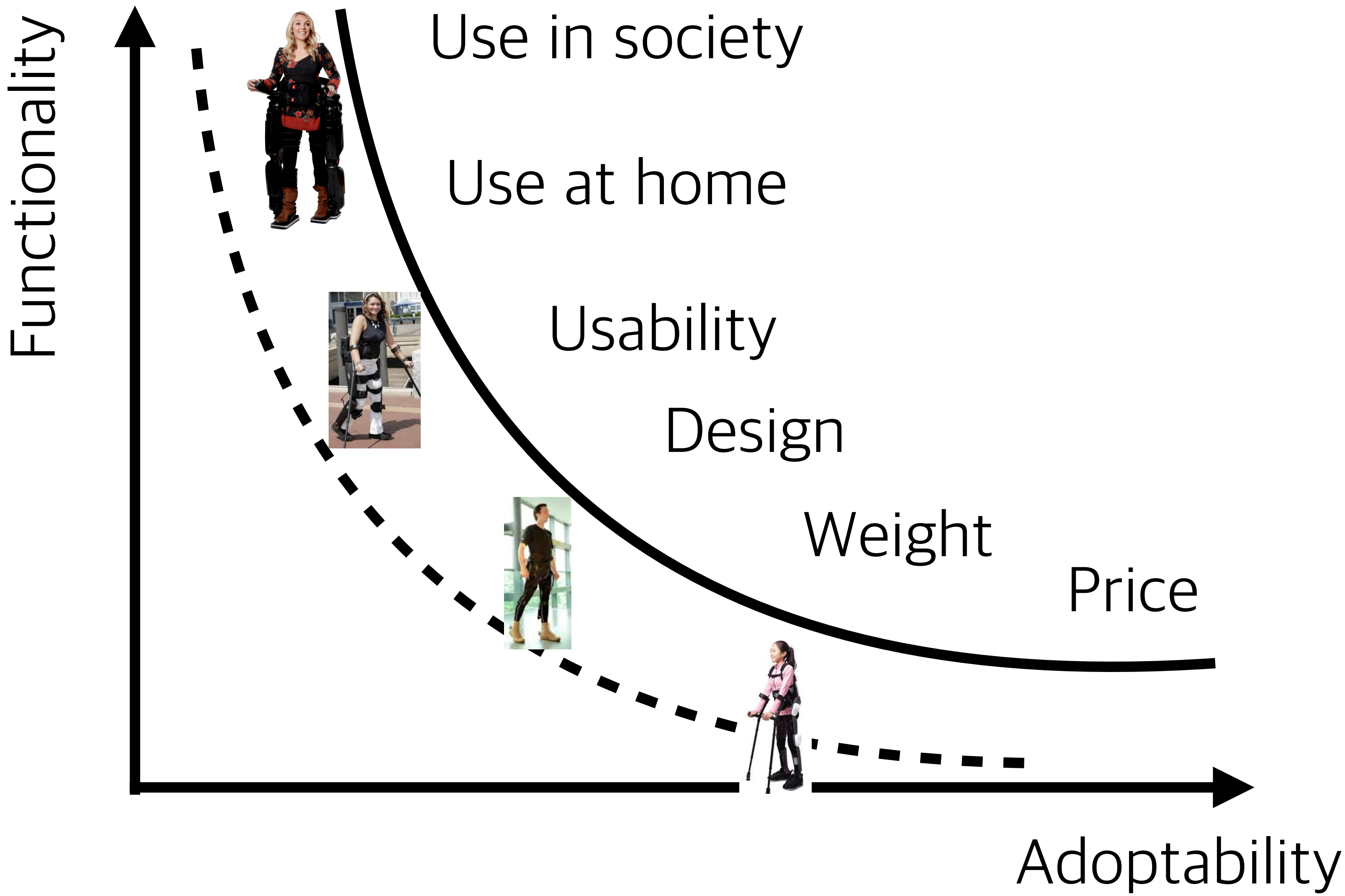
SRH 서울재활병원

세브란스 재활병원 SEVERANCE REHABILITATION HOSPITAL

용인세브란스병원 YONGIN SEVERANCE HOSPITAL

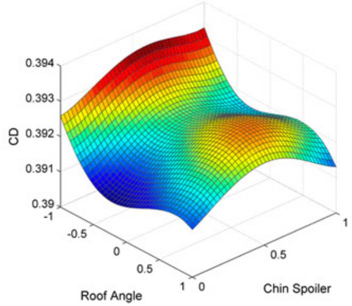
Closing remarks

Functionality and adoptability for innovative technologies

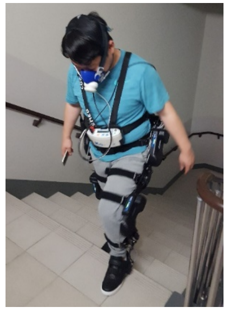


Role of rehabilitation professionals

Pre-evaluation
compatibility for RAGT



Optimizing assist algorithm
function, task



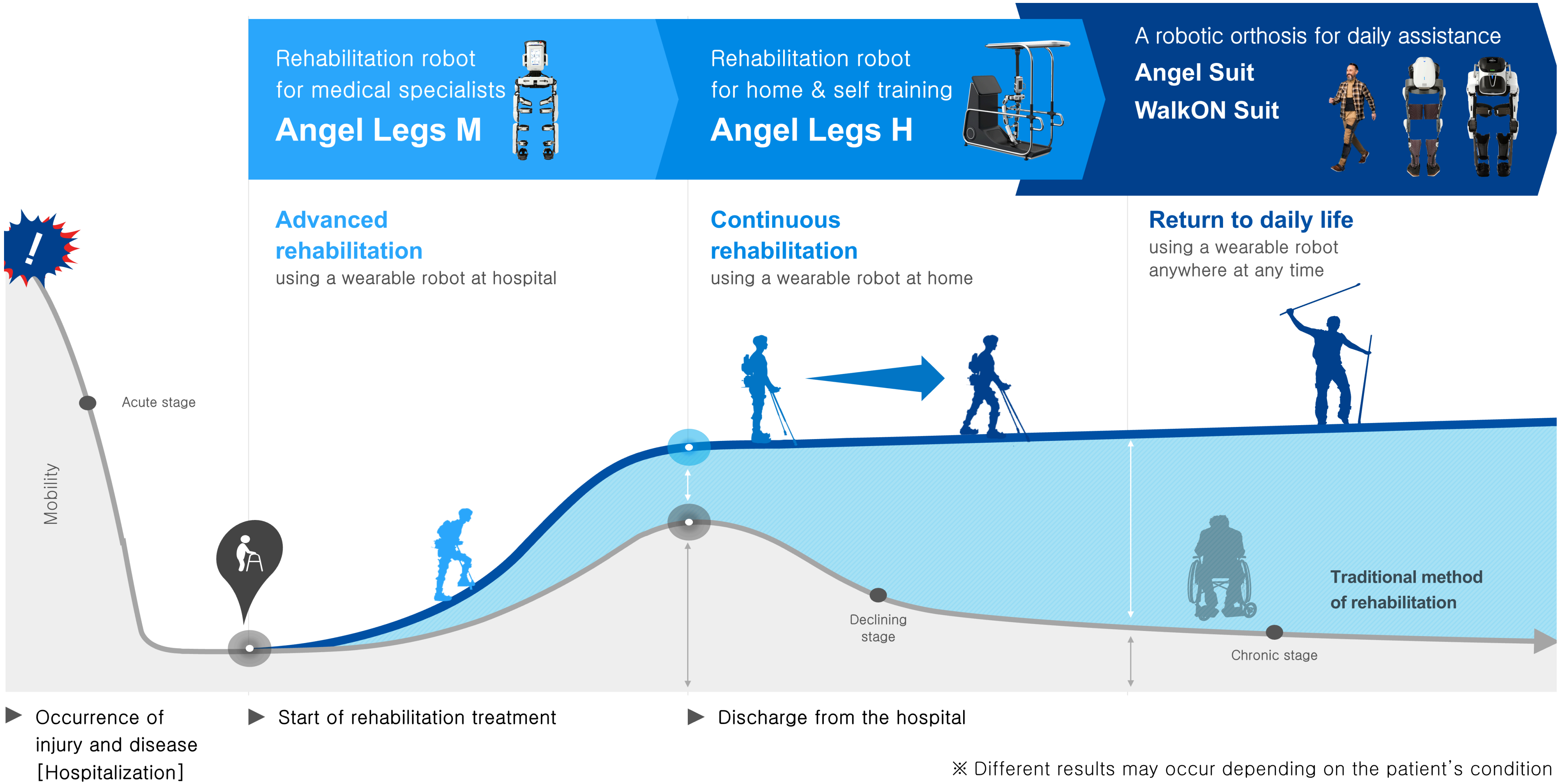
Assessment of effects
gait efficiency, fitness, kinematics

Choose proper robot for patients
exoskeletal, end-effector, wearable

Gait training
embodiment

Robots for Entire Rehabilitation Process

ANGEL ROBOTICS
ROBOTICS FOR BETTER LIFE



※ Different results may occur depending on the patient's condition

“Thank you for listening.”

BMRR Laboratory
(BioMechanics and Robotic Rehabilitation)

- http://biomechanics.yonsei.ac.kr
- bmrr.lab@gmail.com

Dong-wook Rha
Supervisor

Juntaek Hong
Research fellow

Beom Gi Yoo
PhD candidate

Da In Shim
PhD candidate

Joong-on Choi
MS candidate