Emerging Robotic Gait Training

Emerging RGT technologies addressing GT ‘limitations’

Off-axis minor axis training means
Intervention in axial and frontal planes

Frontal Plane
Sagittal Plane
Axial Plane

Sagittal Plane
Axial Plane

Frontal Plane
Hyp. Add./Abduction
Med.-Lateral motion

Axial Plane
Ext.-Int. motion

Impairments seen in patients with Cerebral Palsy

- Children with CP often have axial and frontal plane deformity and instability, and difficulties in weight bearing and transfer in their paretic limb.
  - Off-axis instability could cause asymmetric movement during standing and ambulation.
  - Balance and strength of muscles are poor may lead to falling.
  - Related to rotational instability, off-axis weakness of hip abductors and external/internal rotators, and mediolateral motion.
3D Pediatric Robotic Gait Training System

- RERC / NIDRR supported research and development with a focus on improving ambulation in children with CP.
- Applies synchronized forces to the pelvis and lower extremities (LE) in sagittal and frontal planes.
- Compliant cable driven backdrivable system with 4 degrees of freedom, allowing for greater voluntary movement.
- Surface EMG, position sensors, resistive/assistive forces.

Cable Driven Apparatus

3D robotic gait training system that works in conjunction with a body-weight support system and motorized treadmill.
- Applies controlled loads to the pelvis (in the frontal plane) and legs (in the sagittal plane).

3D Cable Driven RGT Feasibility Data

- Subjects: Five children (two girls and three boys) with cerebral palsy were recruited to participate in this study over 2 test sessions. Mean age was 9.8 ± 2.4 years old. Mean weight was 30.03 ± 13.56 kg. GMFCS levels were I or II.
- Overground gait speed significantly increased after one session (~25-35 minutes) of robotic treadmill training using the 3D cable-driven robot in children with CP. Specifically, the walking speed increased from 0.82 ± 0.12 m/s to 0.94 ± 0.16 m/s (ANOVA, p = 0.03). The step length increased from 0.46 ± 0.03 m to 0.51 ± 0.05 m (p = 0.03). The step frequency also increased from 113 ± 10 step/min to 119 ± 14 step/min (p = 0.03), although not significant.
Following 6 weeks of robotic treadmill training, the OG gait speed improved for both resistance and assistance training groups. Specifically, self-selected and fast walking speed increased from 0.51 ± 0.39 m/s to 0.61 ± 0.21 m/s, and from 0.85 ± 0.48 m/s to 0.91 ± 0.40 m/s, respectively, after 6 weeks of robotic resistance treadmill training (n = 3). 6 min. walking increased from 148.99 ± 35.49 m to 203.72 ± 55.06 m after 6 weeks of resistance training.
2D Resistance Training Feasibility Data

![Graph showing data before and after training](image)

2D Resistance Training

Needs for Off-axis RGT Non TT Devices

- Lack of effective rehabilitation equipment and programs to train off-axis lower-limb neuromuscular control and stability.
- Existing rehabilitation/training protocols and exercise/training equipment (e.g., elliptical machines, stair climbers, steppers, recumbent bikes, leg press machines) are mostly focused on sagittal plane movement.
- On the other hand, training on isolated off-axis motions such as rotating/abducting the leg when seated/standing posture may not be functional or effective.
Off axis Equipment

- Strong need for practical rehabilitation equipment and protocol to improve off-axis lower-limb neuromuscular control
- Need for interventions to improve balance, muscle coordination and selective control of lower limb to improve walking ability in target populations

- Mediolateral Sliding
  - Perturbations
  - Free Sliding
- Pivoting
  - Perturbation
  - Free Rotating

Conceptual Model & Technology

- Use an existing elliptical machine and add the pivoting and sliding functions in the axial and frontal planes.
- Footplates replaced with a pair of custom pivoting-sliding assemblies. Each is driven by two servomotors through a cable-driven rotation mechanism and a linear guide for axial rotation and mediolateral sliding respectively.
- The foot rotation and sliding can be controlled individually for isolated pivoting or sliding training, or they can move simultaneously for combined pivoting and sliding movements.

Frontal Plane Off-axis Elliptical training in CP

- 17 year-old
- Spastic Diplegic CP
- 3 sessions/week
- 6-week
- Evaluated Before/After 18-sessions
Frontal Plane Off-axis Elliptical training in CP

Improvement in Stability

Free rotating
5 sessions of training

Improvement in Proprioception & Reaction Time

Before vs. After exercise

Slow: 1 /sec
Fast: 65 /sec
Off Axis training - Pivotal Elliptical Training

- Foot contact improved with + changes in COF and balance/stability in stance
- Improved weight bearing and transfers
- 6-min walk

Robotic team

Geppetto Counterweight System

- Low cost, spring-loaded pulley/cable system
- Uses gray ‘therabands’ ~ 2.5# (single band)
- Provides assistive forces ~ 5-10% of patient’s body weight
- Variable assistance during limb swing
- Allows for setting higher TT speeds and greater stepping practice
- 0.6-1 mph faster stepping speed using Geppetto unassisted