Intensive robot-assisted rehabilitation improves motor function in children after cerebral hemispherectomy

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Introduction

Certain severe epilepsy conditions require treatment with hemispherectomy, a surgery that removes or disconnects the affected cerebral hemisphere, but leaves the individual with many impairments including significant hemiparesis.

Limited data exists on rehabilitative techniques or the process of neural plasticity and neural reorganization after hemispherectomy.

This study evaluated the feasibility and efficacy of high-intensity task-oriented rehabilitation, delivered by robot-assisted therapy in an enriched day-camp setting, for improving motor function in patients after cerebral hemispherectomy, as well as the anatomic changes in the brain as a result of the paradigm.

Methods

Seven post-hemispherectomy patients (11.2±0.9 years, age at time of first surgery 0.25-9 years) participated in a 2-week rehabilitation day camp. All were > 1 year from hemispherectomy surgery. See Table 1.

Each received 8 days of rehabilitation, three hours/day:
- 1 hour of Hocoma Lokomat®,
- 1 hour of InMotion ANKLE™
- 1 hour of InMotion ARM™)

Additionally, subjects 1 and 3 received 1 hour/day of InMotion WRIST™ for 8 days and 7 days, respectively.

Supplemental activities consisted of adaptive yoga, recreational therapy, virtual reality rehabilitation, and miscellaneous fun (1 hour of each per day for 8 days) .

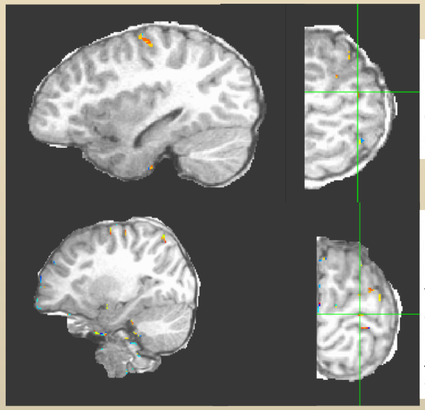
Outcome measures were assessed pre- and post-intervention on the hemiparetic side using Upper Extremity Fugl-Meyer Assessment, Wolf Motor Function Test, Modified Ashworth Scale, Six-Minute Walk Test, 10 Meter Walk Test, and GAITRite® Portable Walkway.

In five subjects, MRI data was acquired immediately before and after the rehabilitation program.

Table 1. Baseline characteristics of subjects

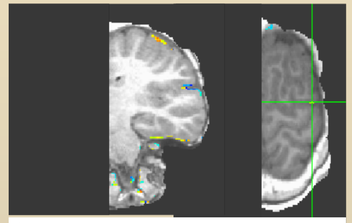
	Age	Age at Hemispherectomy	Gender	Hemisphere operated	Diagnosis leading to hemispherectomy
Subject 1	10 yrs	9 yrs	Female	Right	Sturge-Weber syndrome
Subject 2	11 yrs	4 yrs	Female	Right	Rasmussen's
Subject 3	11 yrs	2.5 mo	Female	Right	Cortical dysplasia
Subject 4	10 yrs	6 yrs	Female	Right	Complications of neurosurgical procedure
Subject 5	12 yrs	6 yrs	Female	Right	Rasmussen's
Subject 6	12	4.5 yrs	Male	Left	Hemimegalencephaly
Subject 7	10	4 yrs	Male	Right	Intracranial hemorrhage

Figure 1. T1-weighted MRI data, before and after rehabilitation, measuring cortical thickness. Increase in gray matter near the "hand knob" area of primary motor cortex was detected in 3 out of 5 subjects.



Subject 1
Fugl Meyer improved from 31 to 38
Increase in gray matter detected near the "hand knob" area of primary motor cortex
Size of cluster: 31 voxels

Subject 3
Fugl Meyer remained 22 (pre & post)
Increase in gray matter detected medial to the "hand knob" area of primary motor cortex
Size of cluster: 20 voxels
Also secondary cluster in primary sensory cortex



Subject 5
Fugl Meyer improved from 21 to 24
Increase in gray matter detected lateral to the "hand knob" area of primary motor cortex
Size of cluster: 27 voxels

Results

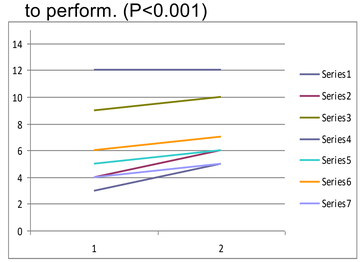
Motor Outcomes

Significant improvements were seen for Upper Extremity Fugl-Meyer (P=0.02), Wolf Functional Ability (P=0.005), Wolf Time (P<0.001), and Six Minute Walk Test distance (P=0.04). Gait showed improved symmetry of steps and improved toe in/out.
No significant difference was seen in Modified Ashworth Scale or 10 Meter Walk Test.

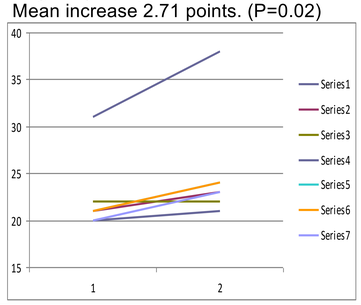
MRI

Single subject analyses using FMRIB Software Library's SIENA package demonstrated an increase in the gray matter volume of primary motor cortex in the non-affected hemisphere in 3 of the 5 subjects (cluster size = 20 voxels). See Figure 1.
Group analyses using FreeSurfer showed a cluster increase in gray matter in the Supplementary Motor Area.

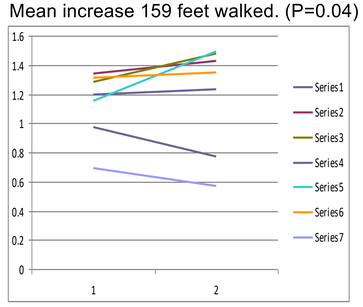
Wolf Motor Function Test
Mean increase 1.14 more tasks capable of performing (P=0.005)
Mean 9.67 seconds decrease in time to perform. (P<0.001)



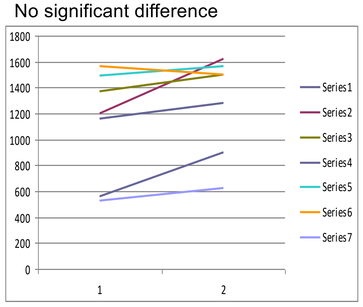
Fugl Meyer, Upper Extremity
Mean increase 2.71 points. (P=0.02)



Six Minute Walk Test
Mean increase 159 feet walked. (P=0.04)



Ten Meter Walk Test
No significant difference



Conclusions

A high-intensity, short-duration regimen of robot-assisted rehabilitation:
1. Improved upper extremity function and gait endurance
2. Increased cortical thickness in motor areas (primary motor cortex and supplementary motor area).
3. Elicited functional improvements and neuroanatomical changes after just eight days of training
4. Elicited improvements even though participants were out of the acute recovery period
5. Was feasible and efficacious delivered in an enriched day-camp setting

This is the first study to show an increase in functional task performance associated with an increase in cortical thickness in post-hemispherectomy individuals. This study used robot-assisted rehabilitation in a program of short-duration, high-intensity, task-specific training.

Future questions include optimal schedule (intensive, massed practice vs. more distributed therapy dosages), retention of the results, the role of the enriched camp environment, and whether combination with other therapies can further augment gains.

Special thanks to Brain Recovery Project, Las Floristas, Women's League of Downey, Allergan Inc., Kiwanis Club of Downey Los Amigos, Los Angeles County Supervisor Don Knabe, Hemispherectomy Foundation, Cyberonics Inc. and Rancho Research Institute.