In-Bed Passive and Active Movement Rehabilitation of Patients with Traumatic Brain Injury

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INTRODUCTION

The applications of rehabilitation robotics have grown substantially during the past 10 years. Studies of lower limb robot-assisted therapy for children with moderate to severe cerebral palsy have shown significant gains compared with before and after 6 weeks training in balance, coordination, spasticity, strength and range of motion [1, 2]. While attempts to increase the application of robotic therapy in acute trauma brain injury (TBI) patients continue, our labs have recently extended our focus to rehabilitation of the children with lower-limb impairments in the hospital setup.

METHODS

Seven inpatients with traumatic brain injury (TBI) (5 girls, 2 boys, 12.8 ± 4.4 year old) recovering in hospital ward participated in this study. All had impaired lower-limb function with reduced or zero voluntary movement of the ankle and reduced selective motor control of the lower extremity.

A wearable rehabilitation robot with computer game interface was used to conduct guided motor relearning, passive stretching and active movement training and evaluate the outcome in terms of biomechanical and neuromuscular changes. The robotic device was equipped with a servomotor, a force sensor, and a digital controller. It was connected to a touchscreen computer for display and user interface (Figure 1). The interface allowed adjustment of the applied torque value, velocity, and difficulty levels of the exercise games, such as assistance or resistance level, according to each participant’s ability.

The robot-aided therapy was conducted in the patient’s ward 3~5 times a week (depend on patients’ schedule and length of stay in hospital) for a total of about 18 sessions. The training in each session involved 10 minutes of passive stretching, 20 minutes of and assisted/resisted active movement, followed by 10 minutes of passive stretching.

Figure 1: Diagram of the wearable robot for TBI inpatient rehabilitation.

Figure 2: Training setup. Participant lay supine on bed with the knee extended. The leg was supported by a pillowcase and foot was strapped onto the robotic boot with the ankle joint aligned with the robot rotation axis.
Children with TBI lay supine on bed with partially back and foot support by pillowcase. They wore the wearable robot on the ankle, the touchscreen computer placed in front of them with height and angle adjusted for proper view (Figure 2).

The same robot was used for training and evaluations. The participant’s ankle was aligned with the rotation axis of the robot, and the joint ROM and torque limits were determined for passive stretching and controlled by an intelligent algorithm that allows strenuous and safe passive stretching [3]. Two types of active movement training were completed by the participants in which they voluntarily dorsiflexed and plantar flexed their ankle to play computer games. The choice of which type of active movement depended on the severity of disability of participants.

Clinical and biomechanical evaluations were done before and after the 18 sessions training period including the Modified Ashworth Scale (MAS) for spasticity, the Pediatric Balance Scales (PBS), and the Selective Control Assessment of the Lower Extremity (SCALE), passive range of motion (PROM), active range of motion (AROM), and muscle strength.

RESULTS AND DISCUSSION

All seven participants completed 18 sessions of training. Paired t-test showed improvements in biomechanical properties. The passive dorsiflexion was $19.14 \pm 10.42^\circ$ and $26.04 \pm 5.75^\circ$ (mean ± SD) before training and after training, respectively ($P=0.0497$), whereas the active dorsiflexion was $3.27^\circ \pm 7.96^\circ$ prior to training and $12.68^\circ \pm 13.68^\circ$ after training ($P=0.0255$); Averaged joint stiffness was reduced with training from 0.28 Nm/° before training to 0.21 N m/° after training. The dorsiflexor strength increased from 2.63 ± 2.09 Nm before training to 7.47 ± 4.04 Nm after training ($P = 0.0165$, Figure 3); the plantarflexion strength increased from 12.93 ± 9.51 Nm before training to 17.13 ± 11.42 Nm ($P= 0.129$). The MAS score at the ankle was $1.67 \pm 0.74$ before training and $0.67 \pm 0.74$ afterwards ($P=0.070$). The participants showed functional improvements in terms of SCALE, balance and locomotion with increasing scores, which were not significant due to missing measurements before training.

![Figure 3: Biomechanical measures (AROM and strength of dorsiflexor).](image)

CONCLUSIONS

Passive stretching combined with engaging active movement training was of benefit to children with TBI as seen in this pilot study. They demonstrated improvements in joint biomechanical properties, motor control performance, and functional capability in balance and mobility. The positive outcome of this study suggests that future studies include a larger sample of children with TBI in clinical settings to explore the impact of combined passive and active training on a single joint and adjacent joints. Further studies are needed to include control subjects and determine the optimal dose of therapy and examine translation of the observed gains to daily functional performance and participation in daily life.

REFERENCES