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Effect of robot-mediated therapy on upper extremity dysfunction post-stroke—a single case study

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Abstract

Objectives Studies of neuroplasticity suggest that repetitious movements optimise changes at brain level, and that this response is optimised if the task is challenging and engaging. The evidence to date on physiotherapy interventions suggests that an increased intensity of therapy provides better outcomes and that exercise-based interventions demonstrate positive treatment effects. Robot-mediated therapy (RMT) is an innovative way of providing these components. This study investigated the effect of RMT on upper extremity function post-stroke.
Design Single case study using an ABC design.
Setting Physiotherapy outpatient department.
Participant A 79-year-old female, 22 months following right cerebrovascular accident.
Interventions Phase A consisted of a series of nine baseline measurements, phase B consisted of nine 30-minute sessions of RMT, and phase C consisted of nine 30-minute sessions of sling suspension.
Main outcome measures Fugl-Meyer Assessment, the Motor Assessment Scale and the Short-Form-36 (SF-36) questionnaire.
Results The rate of recovery during the RMT phase B was greater than that with no treatment (A) and that with sling suspension (C) for the Fugl-Meyer Assessment and the Motor Assessment Scale. Improvement was seen only in those domains addressed by the RMT system. No change in quality of life as measured by the SF-36 was noted.
Conclusions Treatment delivered by this RMT system had a positive effect on the rate of recovery at the level of impairment of body function and at the level of activities. The superiority of RMT over sling suspension is consistent with the theories of neuroplasticity which suggest that repetitious movements must be challenging and meaningful. While these initial results concur with those of previous studies of RMT, further evidence is required before this form of intervention should be incorporated routinely into clinical practice.

Keywords: Physiotherapy; Stroke; Rehabilitation; Robotics; Upper extremity

Introduction

Robot-mediated therapy (RMT) has been developed in response to the emerging themes from neurophysiological and physiotherapy research. At a neurophysiological level, studies in monkeys with induced lesions suggest that the area of cortex responsible for upper extremity movement generation is enlarged with practice of repetitive tasks [1]. This response is optimised if the task/exercise requires skill and is both challenging and engaging [2]. The re-organisation of human cortical maps, associated with improvements in function, has been observed following constraint-induced movement therapy [3], with the authors suggesting that it is the repetitious massed practice component of this intervention that is responsible for these changes.

A systematic review of existing physiotherapy research suggests that exercise-based interventions are the only interventions for which there is a body of positive evidence [4]. It is also accepted that an increased intensity of physiotherapy produces an improved outcome [5,6], although information on the direct relationship between intensity and outcome in physiotherapy is limited. Despite this, the amount of intervention that occurs during formal treatment time in a rehabilitation gym is minimal compared with normal activity, and as such may not optimise cortical re-organisation post-stroke

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[7]. Indeed, physiotherapy treatment has been considered to be homeopathic in terms of dosage [8].

Thus, evidence to date suggests that for a therapeutic intervention to be effective, it needs to be exercise based, delivered at an appropriate intensity and involve repetition; robotic technology is ideally placed to deliver this form of intervention. A robot is simply a programmable machine that physically manipulates an object [9]. Isokinetic dynamometers are examples of this technology and are used routinely in many physiotherapy departments.

In neurological rehabilitation, particularly following stroke, the focus of the application of this technology has been on the upper extremity. The proportion of functional recovery of the upper extremity is considerably less than that of the lower extremity [10,11], and even in the presence of what could be deemed to be adequate arm function, a significant sense of personal loss is evident in people with stroke [12]. There are a number of contributory reasons why less recovery occurs in the arm, including issues of complex functioning and the fact that it is exposed to considerably less treatment time [13].

Emerging evidence from studies in the USA supports the therapeutic benefits of RMT. The MIME [14] and MIT-Manus [15] projects demonstrated improvements in arm abilities following RMT in both chronic and acute subjects, respectively. The MIT-Manus project compared the effect of 4–5 hours/week of RMT ($n = 20$) with a control group ($n = 36$) who had exposure to the robot and 1 hour of reaching exercises per week with the unaffected arm [15]. Differences in the motor section of the Functional Independence Measure (FIM), in muscle strength and in motor status were found between the groups. The MIME group [14] demonstrated significant changes in functional ability, measured by the FIM, and motor abilities in the shoulder and elbow, measured by the Fugl-Meyer Assessment. The improvements for the robot-trained group were significantly higher than those of the control group who had equal duration of neurodevelopmental-therapy-based treatment.

The aim of this study was to evaluate the effect of a period of RMT delivered by the GENTLE/s system on the function of the hemiplegic upper extremity in a single case study.

Methodology

Case description

Mrs R is a 79-year-old female who had a right cerebrovascular accident 22 months prior to the start of the study. Her computerised tomographic scan showed a right internal capsule infarct, classified as a partial anterior circulation infarct [16].

At the time of the study, she was living alone and was not receiving any treatment from a physiotherapist. She had a history of depression and atrial fibrillation. Her medications included anticoagulant and antidepressant therapy.

On initial assessment, she had no hemianopia and did not report any pain in her affected arm. She scored maximally on the Star Cancellation Test, indicating no visual inattention, and scored 24/28 on the Short Orientation Memory Concentration Test [17]. Sensation was measured by the Nottingham Sensory Assessment [18]. The sections on light touch, pressure, bilateral simultaneous touch and kinaesthesia were used, yielding a maximum possible score of 36. Mrs R scored 5/36, indicating very poor sensation. Her initial Short-Form-36 (SF-36) score for the physical health subsection was 37.8% of normal for her age group, indicating a significant deficit in health-related quality of life.

The GENTLE/s system

In the GENTLE/s system, the subject sits at a workstation with a table and a computer monitor (Fig. 1). The arm is supported in a deweighting system that allows for the effects of gravity to be counterbalanced. The subject is attached to the robot through a mechanism comprising a gimbal and a wrist orthosis. This incorporates a magnetic safety device that disconnects the patient from the system should any unwanted forces be generated.

GENTLE/s software supports the creation of individually tailored exercises, with the appropriate level of assistance or resistance being provided through three exercise modes. In the passive mode, the robot moves the subject's arm through the prescribed movement patterns. The subject is encouraged to assist with as much of the movement as possible. In the active-assisted mode, once the subject initiates the movement in the required direction, the robot assists with completion of the movement. The active mode enables a subject with some volitional activity to complete the movement pattern, with a degree of resistance. In all of the modes outlined, the haptic interface provides feedback on the direction of movement required. Visual feedback of the movement is presented in the virtual environments on screen. The participant in this study used the passive mode for the initial 10% of the time to introduce the concept, and the active-assisted mode thereafter.

Procedures

Mrs R attended three times per week for 9 weeks. For the first 3 weeks, the rate of recovery without intervention was measured (Phase A). For the next 3 weeks, measurement continued and she also received RMT (Phase B). For the final 3 weeks, she received sling suspension treatment (Phase C). This allowed comparison of the rate of recovery during the RMT phase with improvement due to natural recovery and to the same duration of another intervention. Sling suspension was included to allow a comparison with a different intervention but with similar dosage to the RMT phase. This yielded a total of 27 data points, nine in each phase, for each outcome measure. Backman and Harris [19] and Sunderland et al. [20] suggested that 10 data points per phase is optimal to allow