Influence of Innovative Rehabilitation Technology on Intensity of Training: Preliminary Results

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Abstract The present study compared intensity of training between technology-supported and conventional exercises during a regular therapy session in three brain injured patients with arm/hand limitations. Results showed that intensity was higher during technology-supported exercises. Further research with a larger sample is needed to confirm these outcomes and assess its potential relation to treatment effect.

1 Introduction

Upper limb motor impairment is one of the most common deficits after stroke, which has substantial impact on a person's quality of life. To stimulate upper limb motor function, therapy should consist of several key elements: repetitive, high-intensive, task-specific and functional exercises with active contribution of the patient [1]. A proposed solution to achieve a high intensity of training is the use of rehabilitation technology, such as robotics, which has shown to be as effective as conventional therapy for improving arm/hand function [2].

A common, and compelling, assumption is that using technology for motivation and repetition increases the intensity of training. When expressed as number of movements, intensity of functional upper extremity exercise in clinical practice was reported to be only an average 32 per session, which is much lower than commonly used in studies aiming for (animal and human) motor learning [3]. One could question whether the number of movements is a good representation of intensity of practice,

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as this is not applicable to functional non-repetitive movements, and doesn't take into account the effort of the movement.

A direct comparison of intensity between conventional and technology-supported exercises is yet to be examined. Therefore, the aim of the present study was to get a first insight into intensity of arm/hand movement during gaming exercises of the upper extremity with respect to conventional exercises.

2 Methods

2.1 Study Design and Procedure

A pilot observational study was conducted at Roessingh Centre for Rehabilitation, Enschede, the Netherlands. All participants followed their regular arm-/hand function therapy sessions, consisting of a circuit mixing conventional and technology-supported exercises during 1-h group sessions. During one of those sessions, recordings were made during a set of conventional exercises (CON set) and exercises supported by rehabilitation technology (RT set). The order was determined by randomization.

The therapist chose the most appropriate exercises within each set matching individual treatment goals, as usual, and instructed the participants to perform the exercises as usual. Ten minutes of both sets were recorded, of which five minutes were used for analysis. No approval of the Medical Ethical Committee was needed for this observational study. All participants signed an informed consent prior to the start of the study.

2.2 Participants

Participants of the study involved a small sample of sub-acute stroke or acquired brain injury (ABI) patients with some functional ability of their upper extremity (ARAT > 9).

2.3 Interventions

Technology-supported exercises (RT set)

Therapists could choose from two systems (Fig. 1):

- ArmeoBoom: Participants with minimal arm function were trained with the ArmeoBoom (Hocoma AG, Switserland), a passive device providing weight support of the arm in a 3D work space. It has a webcam and a laptop, on which

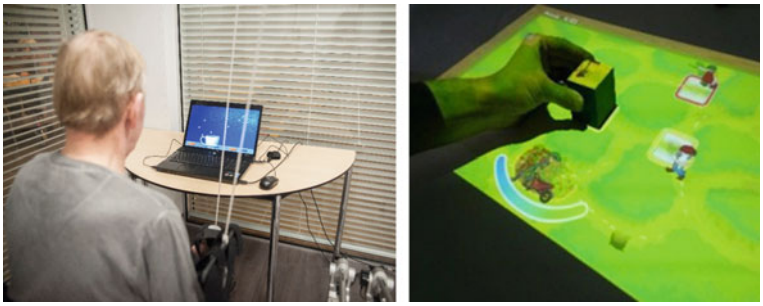

Fig. 1 Devices in RT set: ArmeoBoom (left) and HandsOn game (right)

interactive exercises are played by moving the affected arm in an individually adjusted virtual environment, practicing reaching.

- HandsOn game: Participants who had at least moderate arm function and minimal hand function were trained with the HandsOn game, an applied game, designed inhouse, to train functional movements. The virtual environment is projected on a table by a beamer and the game is controlled by moving physical objects, detected by Kinect camera. The choice of the objects, a variety of different shapes and sizes, determines the grasp, hand and/or wrist movement to be practiced, integrating reaching and grasping/releasing.

Conventional exercises (CON set)

Exercises in CON set were 'analog', without mechanical supports or computerized training environments.

2.4 Equipment

Hand movements were recorded with 5 inertial measurement units (IMUs, Xsens Technologies, NL) at a frequency of 40 Hz. IMUs were positioned on the hand, lower arm and upper arm of the affected limb, on the sternum and pelvis. All sensors were fixated by straps, except the sternum marker, which was attached by a small unobtrusive harness. Custom-made software was used for calibration protocols, performed each time sensors were (re-) applied, collection of all movement data and estimation of horizontal hand position relative to the center of intervertebral body L5/S1.

2.5 Data Analysis

Of the 10-min recordings, 5 min were used for analysis. The cumulative length of the 3D trajectories of the hand (distance travelled) represented dosage. Movement

Table 1 Participant characteristics

Participant	Gender	Age (years)	Diagnosis	Affected side
1	Male	74	Stroke	Left
2	Female	42	Stroke	Left
3	Male	49	Cerebral toxoplasmosis	Left

effort was assessed by measuring the maximal work area of the hand covered during exercises, considering that effort is increasing with increasing RoM due to reduced independent joint control [4]. Data was analysed using IBM SPSS Statistics (v23.0). Descriptive statistics were used to compare the 3D hand trajectories between sets. No statistical tests were done due to the small sample size.

3 Results

3.1 Participants

Table 1 shows the characteristics of the three included participants. The mean time after injury was 14.3 weeks (SD = 4.2). Participants one only had minimal arm function, while participant two and three already had some hand function.

3.2 Intensity of Practice

Figure 2 shows typical hand position data for two participants (P2 and P3) in a transverse plane. The maximal area covered by the affected hand was larger during RT set compared to CON. Remarkably, the work area during the RT set covered a different section than during CON set; movements were performed further away from the body in RT exercises. The mean distance traveled by the hand was substantially larger during RT exercises (31 m) compared to CON (21.1 m).

4 Discussion

The present findings showed that three patients with neurological motor impairments performed larger hand trajectories during 5 min of technology-supported exercises compared to conventional exercises. In addition, the difference in work area suggests that technology-supported exercises might stimulate making movements towards the edges of the reachable workspace, more so than conventional exercises.

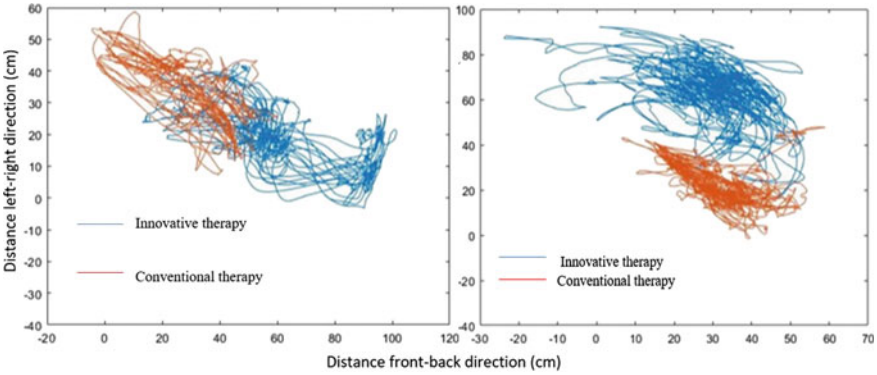

Fig. 2 Hand position traces of affected hand with respect to pelvis in transverse plane (left figure: P2; right figure: P3)

Increased intensity of practice is often used to convey potential benefit of a technology-supported approach, such as robotic training, but this is usually defined as number of repetitions (dosage). When considering number of movements, post-stroke patients receiving different doses of functional exercises didn't show differences in treatment effects [3]. In this study, regarding intensity as a concept that represents both the dosage and effort during movement, we observed a positive influence of technology-supported approaches (gaming and/or arm support) on intensity in a single session. This underlines the importance for defining intensity of treatment explicitly and considering other aspects of intensity, beyond simply dose. Whether differences in intensity of practice as represented in this study would contribute to different treatment effects has yet to be investigated.

Although seemingly confirming the hypothesis, these initial results need to be interpreted with utmost care due to the small sample size and descriptive nature of the analysis, and further research is needed to support current findings and relate them to clinical relevance.

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