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Research Article

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The Usage of Physiotherapeutic Intervention to Improve the Function Ability of the Upper Limb

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Abstract

Background: *The aim of clinical study was to investigate and compare impact of robotic assisted therapy by using virtual reality to classical kinesiotherapy improving the function abilities of upper limb.*

Patients and Methods: *60 patients were divided randomly into two groups. Main group completed a robotic assisted therapy and comparative group completed classical kinesiotherapy. The patients with impaired upper limb were from 6 to 17 years old and all underwent twenty therapies.*

Results: *Statistically significant results were obtained in the patients who completed a robotic assisted therapy by ArmeoSpring® in all Fugl-Meyer Assessment of Physical Performance, the best improvement ($p = 0.000$) in all tested blocks, apart from block H, where was the statistical significant ($p = 0.002$). Comparative group of the patients achieved statistically significant results only in testing of the Fugl - Meyer in block of sum of motor function A-D ($p = 0.009$). In other blocks were the results without statistically significant $p \geq 0.05$.*

Conclusion: *The patients with cerebral palsy are statistically more effective from robotic assisted therapy by using virtual reality for the improvement of function ability of paretic upper limb, than those who completed the classical kinesiotherapy.*

Keywords: Cerebral Palsy, Robot-Assisted Therapy, Classical Kinesiotherapy, Fugl – Meyer Assessment of Physical Performance

Introduction

Clinical study has tested usage robotic-assisted therapy to improve movements of the upper limb in children and adolescents with cerebral palsy (CP). Cerebral palsy is the commonly used name for a group of conditions characterised by motor dysfunction due to non-progressive brain damage early in life [1]. CP is one of the most common disabilities in childhood and makes heavy demands on families, children, and health, educational, and social services [2]. The range of severity may be from total dependency and immobility to adequate abilities of talking, independent self-care and walking, running and other skills, although with some clumsy actions [1]. The most frequently cited definitions of CP are: a disorder of posture and movement due to a defect or lesion in the immature brain or a group of movement and posture disorders that are associated with progressive alteration of the immature brain during fetal or infant growth. The disorders are permanent but not invariable, and these disorders do place some limitations on daily living. CP is often associated with sensory deficits, cognition impairments, communication and motor disabilities, behavior issues, seizure disorder, pain, and secondary musculoskeletal problems. The main causes and risk factors are: multiple birth, extreme prematurity, birth asphyxia, feeding issues, prolonged hospitalization, or postnatal infection [2]. A number of people with cerebral palsy are now able to benefit from mainstream education and further education. They participate more in various activities in society. These opportunities are assisted by legislation, advances in technology and changing attitudes in their society [1]. A cure for CP, which means repair of the underlying brain damage, is not currently available; therefore, the management of children with CP usually focuses on maintaining and improving quality of life and function and preventing secondary complications. Patients with CP are at a high risk of developing musculoskeletal problems that are mainly related to physical growth, abnormal muscle tone, weakness, a lack of mobility, poor balance, and a loss of selective motor control. Treatments for CP patients depend on the specific patient's pathology and range from physical therapy to medication and surgery [2]. When distinguishing therapeutic approaches by their main emphasis, the following basic principles can be recognized: 1) emphasis on normalization of the quality of movement and 2) emphasis on functional activities, which focuses on the development of skills necessary for the performance of activities of daily living [2]. These activities include playing, self-care activities, such as dressing, grooming, and feeding, and fine motor tasks, such as writing and drawing. Children treated with an emphasis on functional activities have better clinical results than treatments that focus on movement [2]. CP often involves restrictions of participation that change throughout life with the emergence of new needs. Because CP is an umbrella term for a group of motor disorders that limit activity, motor rehabilitation is a central component of any care provision [3]. The aim of the rehabilitation is to improve the patient's independence in daily life activities; it is during the early stages of development that fundamental abilities and skills are developed and therefore it is essential to give infants with CP an opportunity to interact with the environment for integral development (physical and cognitive). Therefore, management of children with CP depends on a multidisciplinary, comprehensive, and coordinated approach, and goals are the child's independence and community engagement [2, 4, 5]. The success rate of rehabilitation increases in accordance with the intensity of therapy, repetition, and the patient's motivation, especially in children [4].

Robot-assisted therapy ArmeoSpring®

ArmeoSpring® - Self-initiated repetitive arm and hand therapy in an extensive 3D workspace. By providing arm weight support, the ArmeoSpring® enables patients to use any remaining motor function and encourages them to achieve a higher number of reach and grasp movements based on specific therapy goals [6]. The system supports an affected limb and allows the patient to move the arm or hand successfully and to improve his or her functional potential. A spring mechanism and a pressure sensitive handgrip (joystick) provide adjust able gravity support for the affected arm and help to improve its motor function [7]. ArmeoSpring® training is safe and effective for different populations. Training leads to motor improvements of upper limb. Training can be performed under limited supervision and ArmeoSpring Pediatric is safe and effective in children. The ArmeoSpring® is used in the case of: Neurological conditions, such as: Stroke, Multiple sclerosis, Spinal cord injury, Cerebral palsy, Acquired brain injury, Burn victims, Individuals recovering from a humerus fracture. Training reduces motor impairments and leads to improvements in the following domains: Quality of movement, Arm function, Muscle strength, Range of motion, Pain and spasticity, Activities of daily living. Training with ArmeoSpring® in a clinical setting under limited supervision and minimal assistance is safe and feasible and promotes independence. Training with limited supervision gives the therapist the opportunity to provide therapy to more patients at the same time in a safe and efficient environment. ArmeoSpring® training with limited supervision is positively rated by patients and allows extra rehabilitation time. A correlation between the number of extra training sessions and the amount of shoulder force improvement was shown. ArmeoSpring® Pediatric is safe and effective for treating children with acquired brain injury and cerebral palsy. Training increases the movement efficiency and reduces the compensatory shoulder movements in children with acquired brain injury. ArmeoSpring® Pediatric enables children with cerebral palsy to acquire arm and hand skills and transfer them to daily activities. Provides a fun, virtual environment which enhances adherence to treatment and retention of the relearned motor functions in children with cerebral palsy [8-11] [Figure 1].

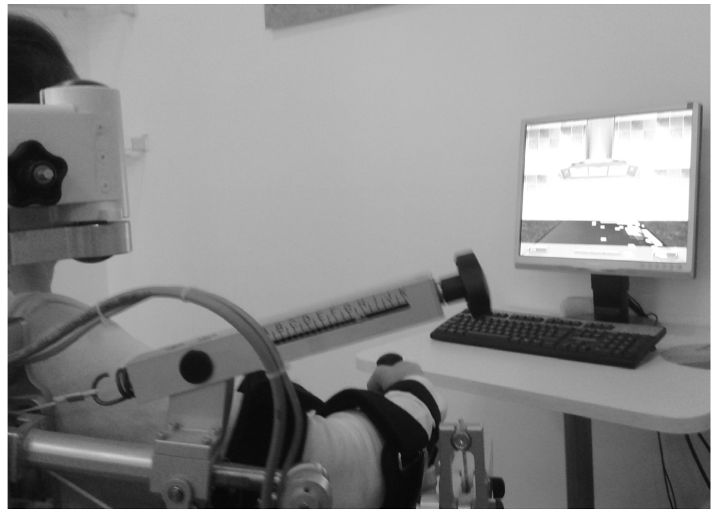

Figure1: ArmeoSpring® device in use

The aim of this study was to determine the effect of therapy in the system ArmeoSpring® by using virtual reality in children and adolescents with cerebral palsy. The study was focused to identify and verify the comparison of the impact of robotic-assisted therapy to classical kinesiotherapy. The aim of the comparation was the functionality effect of self-sufficiency and improvements of paretic upper limb in the group of the patients with CP. As we know, that the complete elimination of paresis is impossible, we believe that paresis of the upper limb can effect to a large extent for children and adolescents and they can improve their independence and quality of life.

Patients and Methods

There were two groups in this investigation. The patients of the main group completed a robot-assisted therapy and the patients of the comparative group completed a classical kinesiotherapy (for example passive movements, active-assisted exercises, Bobath concept, Kabat method). The patients were from 6 years up to 17 years old with impaired upper limb. In the main group: 30 children (average of the age 12.73, SD ± 3.18), the comparative group: 30 children (average of the age 11.33, SD ± 2.85). Twenty therapies were delivered to all of the patients from both groups. Main group by ArmeoSpring® device and the comparison group by classical kinesiotherapy. The estimated time for one therapy was 45 minutes and consisted of the active exercise. Attendance to those therapies was at least twice a week. The tests on the patients were provided before and after completion of the therapy using Fugl - Meyer Assessment of Physical Performance as an investigation of function ability of paretic upper limb [12].

Inclusion criteria of the patients: patient age was 6 - 17 years, diagnosis of CP, possibility of autonomous sitting on a chair or wheelchair, possibility of patient cooperation. Exclusion criteria of the patients: inability to properly set up and adapt the ArmeoSpring® device to the patient's functional condition, non-collaborative therapy from the patient, premature termination of therapy. The study was conducted in accordance with ethical principles, based on the Declaration of Helsinki [13].

Results

In the group of patients who were completed therapy by ArmeoSpring® device was achieved statistically significant score in all conducted tests, compared to the group of patients who were completed classic kinesiotherapy.

Fugl - Meyer Assessment of Physical Performance of the upper limb

After rehabilitation by device ArmeoSpring®, the patients with cerebral palsy achieved improvements in all blocks of testing Fugl - Meyer Assessment of Physical Performance of the upper limb. After the testing of obtained input and output data, we used tests of normality (Kolmogorov - Smirnov and Shapiro - Wilk). The tests have confirmed homogeneous and inhomogeneous distribution of the data in the study; we used parametric statistical test - Student's paired dependent t-test and nonparametric statistical test - Wilcoxon Signed Ranks Test. The study also shows the effect size. Effect size is used to obtain the size of standard rates of our observations. Effect size with significance, gives us information about the size and significance of the effect. Data were processed by using the software Microsoft Office Word 2007, Microsoft Office Excel, 2007. For mathematical - statistical evaluation was used descriptive statistical methods SPSS 16.0.

After the treatment has occurred in children and adolescent patients to statistically significant improvements in function abilities of the upper limb which resulted in a higher average output score in block A (M = 23.87, SD ± 5.50) than the input score (M = 18.53, SD ± 6.81), t (30) = -8.731, p = 0.000, r = 0.851, a higher average output score in block B (M = 4.03, SD ± 2.75) than the input score (M = 2.27, SD ± 2.20), Z (30) = -4.252, p = 0.000, r = -0.549, a higher average output score in block C (M = 8.70, SD ± 2.93) than the input score (M = 5.63, SD ± 3.39), t (30) = -10.822, p = 0.000, r = 0.895, a higher average output score in block D (M = 3.93, SD ± 1.11) than the input score (M = 2.77, SD ± 1.50), Z (30) = -4.218, p = 0.000, r = -0.545, a higher average output score in total A-D (M = 40.53, SD ± 10.12) than the input score (M = 29.20, SD ± 12.29), t (30) = -11.627, p = 0.000, r = 0.907, a higher average output score in block H (M = 11.40, SD ± 1.22) than the input score (M = 10.67, SD ± 1.97), Z (30) = -3.108, p = 0.002, r = -0.401, a higher average output score in block J1 (M = 18.50, SD ± 3.29) than the input score (M = 13.83, SD ± 4.20), Z (30) = -4.800, p = 0.000, r = -0.620, a higher average output score in block J2 (M = 21.00, SD ± 3.57) than the input score (M = 18.93, SD ± 5.78), Z (30) = -3.532, p = 0.000, r = -0.456. The results are summarized in [Table 1].

Table 1. Descriptive statistics of the testing Fugl – Meyer in patients, of the upper limb in the main group of patients, who completed robot-assisted therapy.

	Count	Mean	Maximum	Minimum	Median	Standard Error of Mean	Standard Deviation	Student t-test/Wilcoxon Signed Ranks Test	Sig. (2-tailed)	Effect size
block A Input	30	18.53	30	5	18.53	1.244	6.811	t = -8.731	0.000	r = 0.851
block A Output	30	23.87	31	11	23.87	1.004	5.501			
block B Input	30	2.27	8	0	2.27	0.401	2.196	Z = -4.252	0.000	r = -0.549
block B Output	30	4.03	10	0	4.03	0.502	2.748			
block C Input	30	5.63	14	0	5.63	0.619	3.388	t = -10.822	0.000	r = 0.895
block C Output	30	8.70	14	3	8.7	0.534	2.926			
block D Input	30	2.77	6	0	2.77	0.274	1.501	Z = -4.218	0.000	r = -0.545
block D Output	30	3.93	6	1	3.93	0.203	1.112			
total A-D Input	30	29.20	55	7	29.2	2.244	12.294	t = -11.627	0.000	r = 0.907
total A-D Output	30	40.53	57	16	40.53	1.848	10.122			
block H Input	30	10.67	12	6	10.67	0.360	1.971	Z = - 3.108	0.002	r = -0.401
block H Output	30	11.40	12	7	11.4	0.223	1.221			
block J1 Input	30	13.83	21	6	13.83	0.767	4.202	Z = -4.800	0.000	r = -0.620
block J1 Output	30	18.50	22	9	18.5	0.600	3.288			
block J2 Input	30	18.93	24	4	18.93	1.055	5.777	Z = -3.532	0.000	r = -0.456
block J2 Output	30	21.00	24	14	21	0.652	3.572			

total A-D- total of motor function

In the group of patients who completed a classical kinesiotherapy wasn't noticed any improvement. In testing of the Fugl - Meyer in block of sum of motor function A-D, the score was higher for the output test (M = 43.93, SD = 13.55) than the input test (M = 43.57, SD = 13.65), t(29) = -2.796, p = 0.009, r = 0.461. In other blocks testing of the Fugl - Meyer, were values not statistically significant p ≥ 0.05. The results are summarized in [Table 2].

Table 2. Descriptive statistics of the testing Fugl – Meyer of the upper limb in the comparison group of patients, who completed classical kinesiotherapy.

	Count	Mean	Maximum	Minimum	Median	Standard Error of Mean	Standard Deviation	Student t-test/Wilcoxon Signed Ranks Test	Sig. (2-tailed)	Effect size
block A Input	30	24.57	36	9	25.00	1.333	7.300	t = -1.980	0.057	*
block A Output	30	24.73	36	9	25.50	1.331	7.292			
block B Input	30	5.63	10	0	6.00	0.598	3.275	t = -1.000	0.326	*
block B Output	30	5.67	10	0	6.00	0.596	3.262			
block C Input	30	9.00	14	2	9.00	0.636	3.484	t = -1.795	0.083	*
block C Output	30	9.10	14	2	9.00	0.629	3.448			
block D Input	30	4.37	6	2	4.00	0.212	1.159	Z = -1.000	0.317	*
block D Output	30	4.43	6	2	4.50	0.207	1.135			
total A-D Input	30	43.57	66	14	45.00	2.492	13.647	t = -2.796	0.009	r = 0.461
total A-D Output	30	43.93	66	14	46.00	2.475	13.554			
block H Input	30	9.57	12	4	11.50	0.550	3.014	Z = - 1.414	0.157	*
block H Output	30	9.63	12	4	11.50	0.541	2.965			
block J1 Input	30	18.50	24	9	19.50	0.881	4.826	t = -1.000	0.326	*
block J1 Output	30	18.53	24	9	19.50	0.884	4.840			
block J2 Input	30	22.53	24	15	24.00	0.502	2.751	Z = -1.000	0.317	*
block J2 Output	30	22.57	24	15	24.00	0.502	2.750			

total A-D- total of motor function, * not-statistically significant $p \geq 0.05$

Discussion

The aim of the research was to determine and evaluate the effect of robotic-assisted therapy in ArmeoSpring® on the re-education of paretic upper limb movement in pediatric and adolescent patients diagnosed with cerebral palsy compared to classical kinesiotherapy.

In the last decade, computerized robotic and (electro) mechanical devices have been introduced to provide autonomous, high-intensive training for the upper limb. Such devices could hold promise for complementing traditional therapy, as therapy time dedicated to arm and hand function training is often limited, principally being indicated in highly disabled patients who have a multiplicity of symptoms requiring treatment. On the other hand, training duration and training intensity are known to be key factors for a successful neurological rehabilitation. In particular, this emerging technology enables independent and repetitive movement practice, and this in a motivating, enriched and interactive virtual learning environment in which complex motor tasks, involving central neural pathways related to proprioceptive and visual feedback processing, need to be accomplished. That way, massed exercise according to principles of motor learning, something that is aimed for in rehabilitation, can be established, also by more severely affected individuals who are unable to sufficiently lift their arm against gravity or lacking minimal fine motor capacity to manipulate objects in daily life setting [14]. Rehabilitation robots have become an important tool in neurorehabilitation. They are used to study and treat patients with neurological impairments. These devices are either end-effector-based, exoskeletons, or of a hybrid type [15]. The patients, who were undergoing robotic-assisted therapy have performed the upper limb movements more easily, even those that were difficult to perform without assistance or could not be performed at all.

Pilot studies by Gilliaux have evoked interest in robot-assisted therapy in children with cerebral palsy [16]. The aim of the study was to assess the effectiveness of robot-assisted therapy in children with CP through a single-blind randomized controlled trial. Sixteen children with CP were randomized into 2 groups. Eight children performed 5 conventional therapy sessions per week over 8 weeks (control group) and eight children completed 3 conventional therapy sessions and 2 robot-assisted sessions per week over 8 weeks (robotic group). For both groups, each therapy session lasted 45 minutes. Throughout each robot-assisted therapy session, the patient attempted to reach several targets consecutively with the REAPlan. The REAPlan is a distal effector robot that allows for displacements of the upper limb in the horizontal plane. A blinded assessment was performed before and after the intervention with respect to the International Classification of Functioning framework: body structure and function (upper limb kinematics, Box and Block test, Quality of Upper Extremity Skills Test, strength, and spasticity), activities (Abilhand-Kids, Pediatric Evaluation of Disability Inventory), and participation (Life Habits). During each robot-assisted therapy session, patients performed 744 movements on average with the REAPlan. Among the variables assessed, the smoothness of movement ($P < .01$) and manual dexterity assessed by the Box and Block test ($P = .04$) improved significantly more in the robotic group than in the control group. This single-blind randomized controlled trial provides the first evidence that robot-assisted therapy is effective in children with CP. Future studies should investigate the long-term effects of this therapy. Our randomized study has also confirmed a positive outcome of direct robotic-assisted therapy, including ArmeoSpring® device.

Fasoli has also examined the effect of robotic-assisted therapy in his study involving 12 children with CP (hemiplegia) from 5 to 12 years old and they were receiving treatment twice a week for 8 weeks [17]. There was a significant overall improvement in children in the QUEST test as well as in the Gilliaux where was also an improvement, which can be compared to our study, as it also can be confirmed as significant improvements in robotic-assisted therapy for the patients [16].

Armeo® system provides motivated engaging rehabilitation of the arm and hand by simulating movements involved in daily activities. A positive result of Armeo® rehabilitation after reconstructive surgery of the upper limbs was demonstrated for children with neurological disorders (including CP). The time it took to achieve a 100% success rate during exercise grew lower, the bilateral handgrip function improved, and the amplitudes of movements in the wrist and elbow joints increased [7]. We agree with the author, in our study have also been made the positive improvements, such as improved ranges of the movement, hand grips, and entire improvement in the functional ability of the paretic upper limb.

Conclusion

In the main group of the patients with cerebral palsy were achieved statistically significant results in this study. For all of the patients who completed robotic-assisted therapy by ArmeoSpring® compared to the comparative group of the patients who have completed classical kinesiotherapy. The patients in the main group have improved using ArmeoSpring® device according to Fugl - Meyer Assessment of Physical Performance. There was a good co-operation with patients during the robotic-assisted therapy. The therapy was taken regularly and the patients were really looking forward to it. We can say based on the analysis results, that robotic-assisted therapy of ArmeoSpring® positively effects the rehabilitation of the children and adolescents with cerebral palsy. We have also registered not only the positive effect of therapy, but also the patient's successfulness of motivation in the adolescent age. We can not completely get a patient with cerebral palsy back to full health, but we can help him to improve the function abilities of paretic upper limb with interesting robotic-assisted therapy with ArmeoSpring® device. The Aim of the study was to point out the justification of using medical-technical devices affecting the function of the upper limb in physiotherapy.

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