THE EFFECT OF TWO-HANDED EXERCISES WITH THE BIMEO PRO SYSTEM ON THE UPPER LIMB MOTOR FUNCTIONS OF STROKE PATIENTS

VPLIV DVOROČNE VADBE S SISTEMOM BIMEO NA MOTORIČNE FUNKCIJE ZGORNJIH OKONČIN PRI BOLNIKIH PO MOŽGANSKI KAPI

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ABSTRACT

Introduction: A robotic or sensory-supported workout in conjunction with virtual reality enables improvements in the patient's motor functions. A clinical study demonstrated the impact of two-handed exercises with the Bimeo PRO rehabilitation system on the motor functions of the upper limbs in a selected test group of stroke patients. The study sample consisted of 6 stroke patients, undergoing rehabilitation at the University Rehabilitation Institute (URI – Soča). The two inclusion criteria were an indicated stiff grip of the weaker upper limb and a score of 25 points in the Mini Mental State Examination (MMSE). **Methods**: The patients performed two-handed exercises on a Bimeo PRO system in virtual reality. The exercises were composed of: reaching, tracking and labyrinth. The exercises of each patient spanned over a period of one month, 5 days a week, 15 - 20 minutes per day. The quality of movement during the exercises was monitored with physical parameters of the systems sensors. In the analysis of the quality of movement, the parameters of efficiency and deviation were used, while the clinical evaluation of the function of the upper limb was performed with the Fugl-Meyer scale (FMA) and the Wolf motor functions test (WMFT) prior to and after one-month exercise. **Results**: The results of clinical trials improved after the end of the therapy, with the average estimates of WMFT time improving from 45.55 to 39.91; WMFT functional ratings from 2.29 to 2.63; WMFT power from 6.53 to 9.35 and the ability to lift a load rose from 1.25 to 1.58. The FMA rating rose from 33.6 to 40.5. In the process of exercising with Bimeo PRO, all the patients improved the accuracy of performing all tasks, which indicates improvement of coordination of movement. The efficiency of the performance was also increased. **Conclusion:** The Bimeo system provides a safe and effective exercise that, in conjunction with standard therapy, improves the motor function of stroke patients.

Key words: stroke, motor functions, virtual reality, Bimeo PRO

IZVLEČEK

Izhodišča: Robotsko ali senzorno-podprta vadba v povezavi z navidezno resničnostjo omogoča izboljšanje motoričnih funkcij bolnikov. S klinično študijo je bil na izbrani populaciji bolnikov po možganski kapi preverjen vpliv dvoročne vadbe z rehabilitacijskim sistemom Bimeo PRO na motorične funkcije zgornjih okončin. **Preiskovanci:** V študijo je bilo vključenih 6 bolnikov po možganski kapi, ki so bili na rehabilitaciji na Univerzitetnem rehabilitacijskem inštitutu - Soča (URI - Soča). Kriterija za vključitev sta bila nakazan vsaj grob prijem v slabšem zgornjem udu in najmanj 25 točk pri Kratkem preskusu spoznavnih sposobnosti (KPSS). **Metode:** Bolniki so vadili z napravo Bimeo PRO v navidezni resničnosti dvoročno. Izvajali so tri naloge: seganje, sledenje in labirint. Vadba posameznega bolnika je trajala 1 mesec, 5 dni v tednu, 15 – 20 minut na dan. Kakovost gibanja med izvajanjem nalog smo spremljali s fizikalnimi parametri preko senzorjev sistema. Za analizo kakovosti gibanja smo uporabili parametra učinkovitost in odklon, za klinično ocenjevanje funkcije zgornjega uda pa Fugl-Meyerjevo lestvico (FMA) in Wolfov test motoričnih funkcij (WMFT) pred začetkom in po 1 mesecu vadbe. **Rezultati:** Rezultati kliničnih testov so se po zaključku vadbe izboljšali in sicer so se povprečne ocene WMFT časa izboljšale iz 45,55 na 39,91; WMFT funkcijske ocene iz 2,29 na 2,63; WMFT moč iz 6,53 na 9,35 in sposobnost dviga bremena se je iz 1,25 zvečala na 1,58. Ocena FMA se je iz 33,6 zvišala na 40,5. Vsi bolniki so v procesu vadbe z Bimeo PRO izboljšali natančnost izvedbe vseh vrst nalog, kar kaže na izboljšanje koordinacije gibanja. Prav tako se je povečala učinkovitost izvedbe. **Ugotovitve:** Sistem Bimeo PRO omogoča varno in učinkovito vadbo, ki v povezavi s standardno terapijo omogoča izboljšanje motoričnih funkcij bolnikov po možganski kapi.

Ključne besede: možganska kap, motorične funkcije, navidezna resničnost, Bimeo PRO

BACKGROUND

People who experience a stroke are the largest group of patients in need of rehabilitation (Hopman et al., 2003). To improve motor functions, intensive therapy is required (Langhorne et al., 2011; Lo et al., 2010) and specific approaches are necessary for each patient. A stroke may cause partial or complete paralysis of one of the upper limbs. Most of the activities of daily living are bimanual. It has been proven that bimanual training improves the activities on the affected side (Waller et al., 2008) in the subacute and chronic recovery phase (Stewart et al., 2006).

In recent years, various new technologies have been introduced into the rehabilitation of the upper limbs, such as robots and virtual reality. Robots are used as a help while training and to evaluate motor functions. Different methods of robot control enable the recognition of the intent of the patient's movement, motor abilities and psychophysiological condition of the patient, and adjust the robotic support to the patient's activity (Marchal-Crespo et al., 2009; Novak et al., 2011). Robotic devices allow unimanual (Nef et al., 2007) and bimanual training (Trlep et al., 2011; Lewis et al., 2009).

Motivation of patients is an important aspect of motor rehabilitation. Motivation can be increased by virtual reality. It encourages the patient by playing computer games (Mihelj et al., 2012). Training takes place in a controlled environment, which increases the patient's confidence and training can be easily adapted to individual needs in terms of direction and extent of movement, speed, difficulty and number of repetitions. At the same time, the display can be used to present deviations from the optimum movement. This information is also useful for a therapist who encourages the patient to develop the appropriate spatial and temporal framework in the required movement pattern (Sisto et al., 2002). It has been found that the use of virtual reality and interactive games is useful in improving the function of the upper limb in everyday life (Laver et al., 2015).

Frequent limitations in rehabilitation of stroke patients are the availability of therapists, the duration and intensity of the training, the methods of assessing the patient's condition and progress, the complexity of new technologies and related costs. The Bimeo PRO (Kinestica d.o.o.) device (Perčič et al., 2013) is easy to use in a clinical and home environment, allows intensive workout with prolonged duration, provides an objective measurement of motion quality and includes many functions that are common to robotic rehabilitation.

The paper presents a pilot study with the Bimeo PRO system (Kinestica d.o.o.) aimed at determining the impact of bimanual training with the Bimeo PRO rehabilitation system on motor function of affected upper limb in stroke patients.

METHODS

Subjects: The study involved 6 patients after a cerebral stroke that were first time involved in rehabilitation programs at the University Rehabilitation Institute of the Republic of Slovenia (URI - Soča). The inclusion criteria were the evaluation of the Mini Mental State Examination (MMSE) (Granda et al. 2003) of more than 25 points out of 30 points and, after a clinical assessment, at least a coarse grip in the affected upper arm was indicated. All patients had given consent to participate in the study.

Clinical evaluation: For the clinical evaluation of neurological impairment and functional abilities of the upper limb, the Fugl-Meyer scale (FMA) (Fugl-Meyer AR and sod. 1975) and Wolf motor function test (WMFT) (Wolf SL et al 2001) were used. On the Fugl-Meyer scale we used only an estimate of the motor abilities of the upper limb (maximum score of 66 points). WMFT contains 15 different motor-functional tasks, which are timed, one of the tasks is the grip strength, one ability to raise the load, and the performance quality shows the estimates of functional abilities (Ocepek et al., 2017).

The assessment was carried out before the start of the training on the Bimeo PRO device and after four weeks of training.

Device: Bimeo PRO is a rehabilitation system that allows the therapy of the upper limbs in stroke patients and other central nervous system disorders, peripheral nerve defects and upper limb injuries. Bimeo PRO is a passive sensory system that is associated with virtual reality. It exploits the preserved motor functions of the affected or unaffected limb of the patient and does not use other active drives. The patient performs tasks in virtual reality by moving his or her arms. Using a variety of therapeutic attachments unimanual or bimanual therapy, surface therapy or free-space therapy, or therapy of the individual upper limb joint is possible. An unaffected limb can help in the movement of the affected limb while measuring and evaluating the movement of the affected limb. In this way it is possible to carry out a therapy that encourages the maximum use of the affected limb and minimum use of the unaffected limb.

Figure 1: System Bimeo PRO

The physical part of the system is divided into three main parts. In the first part, the handle is held by the patient in the affected arm. The handle housing is ergonomically designed and coated with rubber, allowing for reliable and comfortable grip. The three-axis force sensor with a measuring range of ± 100 N and a resolution of 0,1 N in all directions is mounted in the housing. In addition, an inertial sensor that measures orientation is also present in the housing.

The second part consists of two orientation sensors, which are placed on the upper arm and the forearm of the affected limb with elastic straps. In the third part, there are attachments that allow different therapy modes. In this study, an attachment for bimanual therapy in free-space, which the patient holds with an unaffected arm, was mounted on the handle. The movements were carried out in the frontal plane.

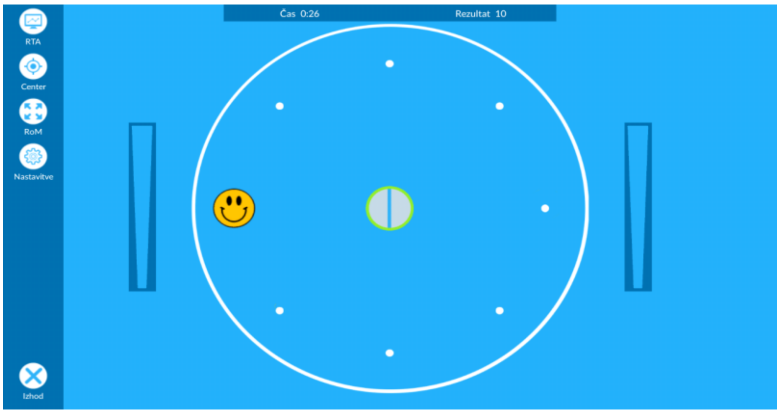
Tasks:

Patients performed training on the Bimeo PRO device 5 days a week, 15-20 minutes per day, 1 month. In addition, everyone was included in the standard occupational therapy rehabilitation treatment.

The study included three tasks in a virtual environment that were designed to evaluate the quality of the individual patient's movement and are designed so that the patient performs relatively simple and repeatable movements.

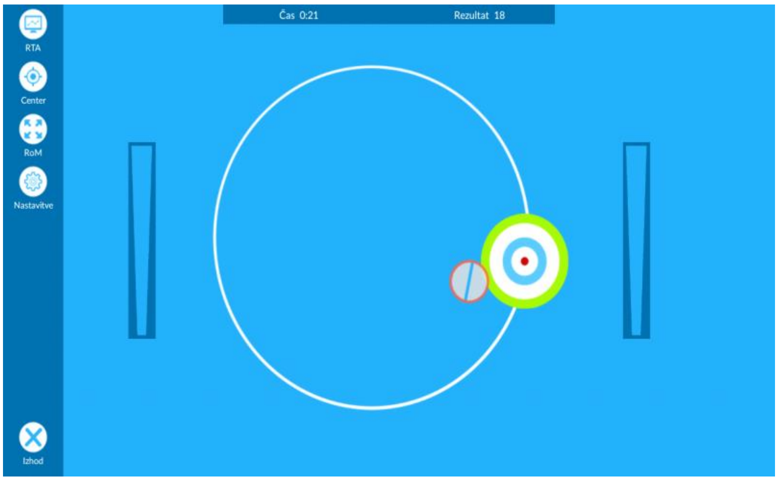
The first virtual task was Reaching. In this task, objects appear randomly on the circle. Each movement begins at the center of the circle marked by a smaller circle. A training person must perform a straight movement from the center to the object on the circle. After a successful move, the movement back to the center is required and a new object appears on the circle.

Figure 2: Reaching task



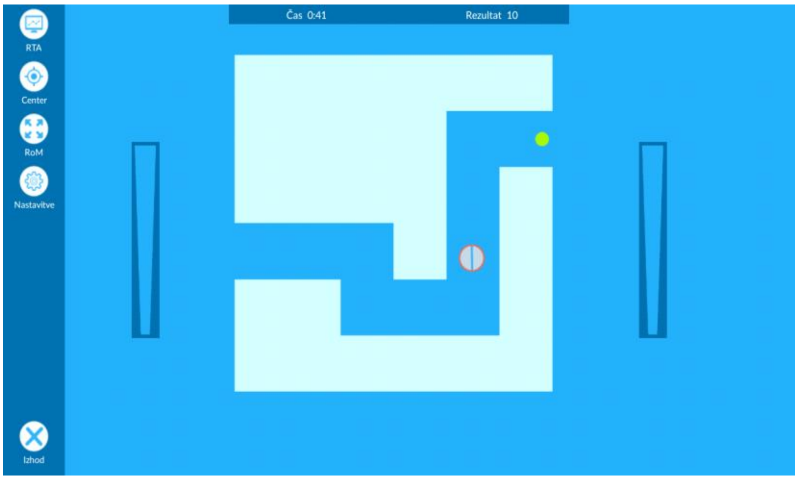
The second task was Tracking. The cursor should follow the center of the target that circulates. The goal of the task is to follow the target as closely as possible.

Figure 3: Tracking task



The last virtual task was to move through the labyrinth. A subject must guide the cursor with as little touch of the labyrinth walls as possible from the beginning to the end of the labyrinth.

Figure 4: Labyrinth task



The quality of the movement was assessed on the basis of the measured physical parameters that were obtained through the sensors of the system. In the study we observed the parameters of efficiency and deviation. The parameters were normalized between 0 and 10, where the value of 10 was approximately the value of a healthy person.

The efficiency parameter represented the Fitts law index (Fitts, 1954), which defined the quality of the movement according to the accuracy of achieving the goal and the speed of the task. In the labyrinth, this parameter contained data on the number of hits with the labyrinth wall.

The deviation parameter was defined in terms of deviations from the ideal path of motion. In the Reaching task this was straight path, and in the Tracking task it was the movement at the center of the target. In the Labyrinth task, the deviation parameter also contained information about the proportion of the path that was performed inside the walls of the labyrinth.

RESULTS

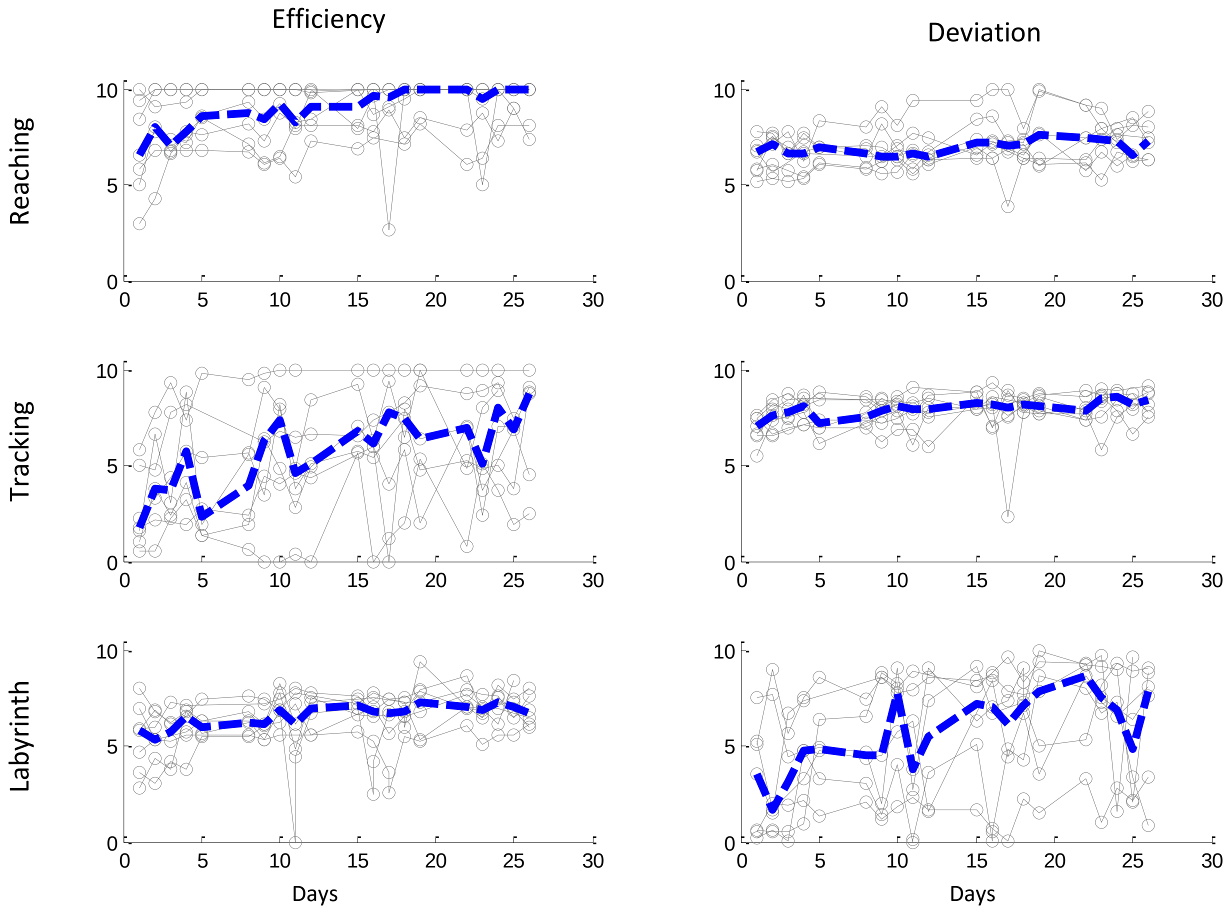
The study involved five men and one woman, four with right-handed disability and two with left-handed disability. The average age of patients was 61.5 years. Table 1 shows the results of clinical assessments before the start of training and after four weeks of training.

Table 1: Patients group, results of WMFT test (time, function score, power, weight) and Fugl-Meyer test

Patient assessment	WMFT time		WMFT Function score		WMFT power		WMFT weight		Fugl Meyer test	
	start	end	Start	end	start	end	start	end	start	end
1	120	120	0	0	0	0	0	0	13	13
2	68,7	37,5	1,4	2,7	0,6	4,5	0	1	28	42
3	3,98	2,61	3,5	3,6	2,3	5,6	1,5	2	34	46
4	4,02	3,47	3,6	3,8	3	6	1	1,5	48	57
5	2,74	2,28	4,26	4,53	31,3	38	5	5	61	65
6	73,9	73,6	1	1,2	2	2	0	0	18	20
Average	45,55	39,91	2,29	2,63	6,53	9,35	1,25	1,58	33,6	40,5

The results of clinical assessments show in five patients progress in WMFT both in time measurement and in functional evaluation; in WMFT power measurement, the assessment is unchanged in two patients; in WMFT the ability to lift the load (weight) is the same in three patients. In only one patient, the results of all assessments are unchanged. FMA progress has also been observed in five patients, with only one patient evaluating remained unchanged.

Graph 1 shows the measured values of the parameters of efficiency and deviation. The top two graphs show the results for the Reaching task, the middle two graphs for the Tracking task and the graphs below show the results for the Labyrinth task. The gray color indicates the values of individual patients, and the dashed line (thickened) shows the median of all patients for each day of exercise.



Graph 1: The measured values of the efficiency and deviation parameters

On all graphs we see a positive trend of both efficiency and deviation through the duration of the training. In the Reaching task the efficiency increases noticeably and, at the end of the training, the values are close to healthy people. In the Tracking task, the measured values are more spread, but the trend shown by the median is significantly positive. The deviation parameter in the Reaching task shows the greatest constancy. In the Tracking task the values are higher and the trend is more positive. In the Labyrinth task, the values of the parameter of efficiency are smaller, and the deviation values are very scattered.

DISCUSSION

The results of an objective measurement of motion quality with the Bimeo PRO system in our pilot study show that the training was successful and effective. Improvement of the motor function of the upper limb is also reflected in the results of clinical assessment instruments.

In the Reaching task the efficiency significantly increased and, at the end of the training, the values were close to healthy people. The greatest improvement was evident at the beginning, which is more likely to be the result of learning and adaptation on the task itself. But even after two weeks, the trend was positive. However, at that time, the patients were in most cases already adapted to the task. This indicates that the actual accuracy of movements has improved. In the Tracking task there was a larger spread of measured values, but the trend was significantly positive. The larger scattering compared to the Reaching task can be explained by the fact that the precision move is required only to the point, while in the Tracking task it is necessary to constantly follow the ideal point - target.

The deviation parameter indicated the highest constant in the Reaching task. The deviations in the Tracking task were greater, but the trend was even more positive. This can be explained by the fact that in the Tracking task the ideal trajectory of the movement is always visible - the position of the target. In the Reaching task, only the end point of the straight movement was seen and the actual trajectory therefore deviated more from the straight trajectory.

In the Labyrinth task, the efficiency parameter values were lower, and the deviation values were very scattered. In the difficulty of the performance, this task was the most difficult and it was necessary to perform more complex movements to the final point of the labyrinth.

Our findings are difficult to compare with the results of other studies due to the variety of therapeutic devices. We are also aware of the limitedness of our study, which was only pilot, carried out on a small number of subjects and without a control group. Virtual training systems have been tested so far most often in patients with stroke (Viñas-Diz and Sobrido-Prietob, 2016) and are promising therapeutic procedures due to evidence of an increase in corticospinal irradiation through a defective cerebral hemisphere, which is associated with an improvement in motor function (Bellester BR et al., 2017). Of course, further research is needed on the most appropriate forms of virtual reality, the frequency and the intensity of training.

CONCLUSION

In the rehabilitation of stroke patients, the Bimeo PRO device proved to be an effective device for improving the function of affected upper limb and could become a useful additional procedure in the occupational therapy clinical practice.

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