ORIGINAL PAPER

Arch Phys Glob Res 2019; 23 (2): 7-13
DOI 10.15442/apgr.23.2.1

Innovative technologies in medical rehabilitation of patients with cerebral palsy

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Abstract

Background: Rehabilitation games that combine physical therapy exercises with computer games provide all prerequisites for effective motor learning – repeated practice of the same task with the adjusted difficulty level and motivating feedback in the safe environment.

The aim: The aim of the study was to evaluate the influence of stepping games on walking abilities and balance of children with cerebral palsy. Preliminary assessment was carried outon ten patients with cerebral palsy, aged four to twelve years, GMFCS Level II - III.

Materials: Stepping games using a Dance Mat –a flat electronic game controller with 3×3 matrix of square panels for the player to step on to evoke actions within the game have been used.

Methods: Patients followed a two-week home training program with daily 20-minute gaming sessions. Each session included 3 or 4 different games (from the total number of eight games) with individually adjusted difficulty parameters.

Results: Each patient was assessed before and after the training course by the following tests: Timed Up and Go, Paediatric Balance Scale and Four Square Step Test. After two weeks of daily training, balance and walking improvements were noted. The Paediatric Balance Scale improved on average by 1.5 points, the Timed Up and Go Test by 2.1 seconds, the time in the Four Square Step Test was reduced on average by 1.7 seconds.

Conclusion: Rehabilitation computer stepping games may improve balance and walking skills in patients with cerebral palsy.

Key words: Cerebral Palsy, Rehabilitation, Computer Games

Introduction

Games are relevant for harmonious development of children. The comprehensive child development depends on multifaceted nature of entertainment, which aims at motivating the child to action. For children with cerebral palsy, games are of key importance. All the elements of games (real and virtual) significantly affect the development of children with special needs. The most recent experimental data suggest that virtual reality technologies have great potential for neurological rehabilitation of patients with limited mobility and balance disturbances [1]. The use of video games contributes to the development of mental abilities and motivates the child to lead a more active life.

The restoration of motor functions depends on the plasticity of the nervous system, which is stimulated by multiple repetition of the movements required, intensity of trainings and positive training motivation.

The majority of virtual rehabilitation systems and physical exercises is fairly complex, expensive and can be used only in the hospital settings.

On the other hand, there are many inexpensive game systems available on the market, such as Nintendo Wii and Xbox Kinect, which are widely used at the home setting and have great potential for training movements [2]. These games, however, are designed for healthy children and are too complicated for neurological patients. Moreover, they do not allow the instructor attending the child to monitor remotely home trainings.

In the Kozyavkin International Rehabilitation Clinic, various devices and systems for game rehabilitation have been used for more than 20 years [3].

The major objective of therapy with computer games is to create an interaction between positive emotional background and improvement of motor functions, sensory and cognitive skills as well as increased motivation of disabled children. Practicing a given exercise, the patient simultaneously plays a computer game, which motivates him/her for training movements, favours the acceleration of reactions, coordination and balance.

Web-based rehabilitation gaming system home training system using games

To activate and improve the motor functions of patients with cerebral palsy, a web-based rehabilitation gaming system was developed in the Kozyavkin International Rehabilitation Clinic [4]. It includes a web server of virtual rehabilitation and a client`s software installed on the home computer. The web server is accessible at http://game.reha.lviv.ua/

The essential features of the system include a) possibility of using various game controllers - Nintendo Wii remote, Nintendo WiiFit and Microsoft Kinect; b) rehabilitation games of different levels of difficulty can be applied for trainings with various gaming controllers; c) possible remote control provided by an instructor during home training.

To train at home, a personal computer connected to the Internet and a Nintendo WiiFit balance board is needed. The board is a standard game controller that can be purchased in computer stores or hired. The WiiFit board detect and track the user's center of balance, a feature utilized in the games. The data from the board are sent to the computer using the Bluetooth technology.

The above system can be used in cases of various motor dysfunctions, most often for people with balance problems.

Standing or sitting on th eWiiFit board, the patient exercises to develop balance; simultaneously leaning forward or backward, he/she controls the action of the special computer game.

Fig. 1. Playing the game by transferring the body weight forward-backward (picture by Oleh Kachmar)

Six special games have been developed for training balance, each game has 4-5 levels of difficulty. The first levels are quite simple and even patients with severe balance disorders can practice them. Each further level requires more accurate and quicker response as well as more coordinated transfer of the body mass centre. The highest level is tailored to the abilities of a 7-8-year-old healthy child.

Before the session, the game is calibrated, i.e. the range of movements is determined. In the future,

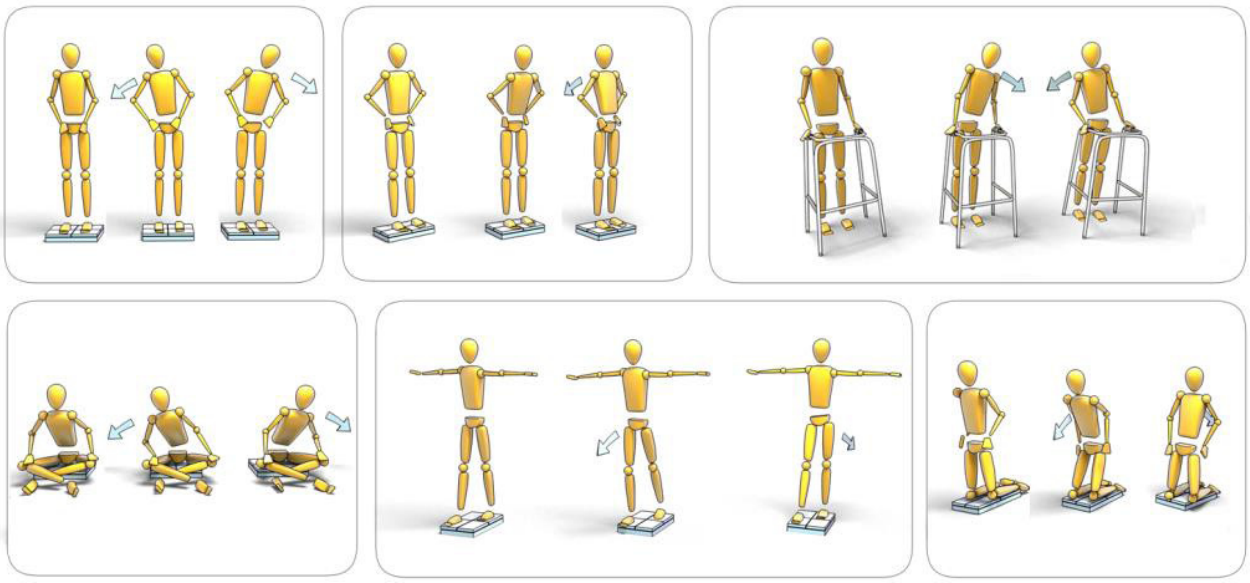

Fig. 3. Positions for balance training (picture by Oleh Kachmar)

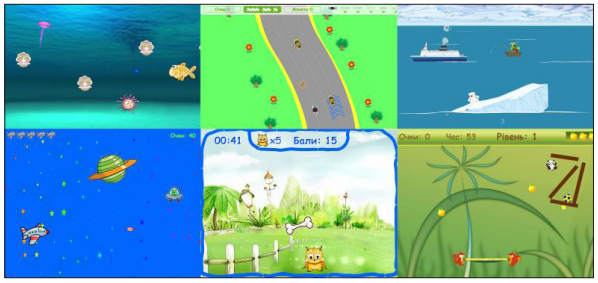

Fig. 2. Screens of rehabilitation games developed in the Kozyavkin International Rehabilitation Clinic (picture by Oleh Kachmar)

the patient will have to make such movements unaided during the game.

Balance training using games is to develop the ability to transfer the body weight to the left and right, forward- backward and to hold the position. Therefore, various initial baseline positions are used: a) standing on the board and shifting the body weight left-right; b) standing and moving the body weight forward-backward, c) standing with support, d) sitting on the board, e) standing with one foot in front of the other one, f) kneeling.

The system of home training with games was supplemented with stepping games using a Dance Matas a game controller. Those games are available of the separate gaming server accessible at http://rehagame.com/.

Fig. 4. Dance Mat (picture by Oleh Kachmar)

During the game, the player should follow the screen picture and step into the appropriate squares on the Dance Mat. The Dance Mat is widely used in dance games; however, those available on the market are too complicated for patients with motor disorders. Therefore, several special rehabilitation games were designed for disabled individuals.

„Happy Farmer". The gaming screen presents 8 holes, which correspond to the structure of the dance mat. A marmot randomly jumps from each hole. The player has to catch the marmot,

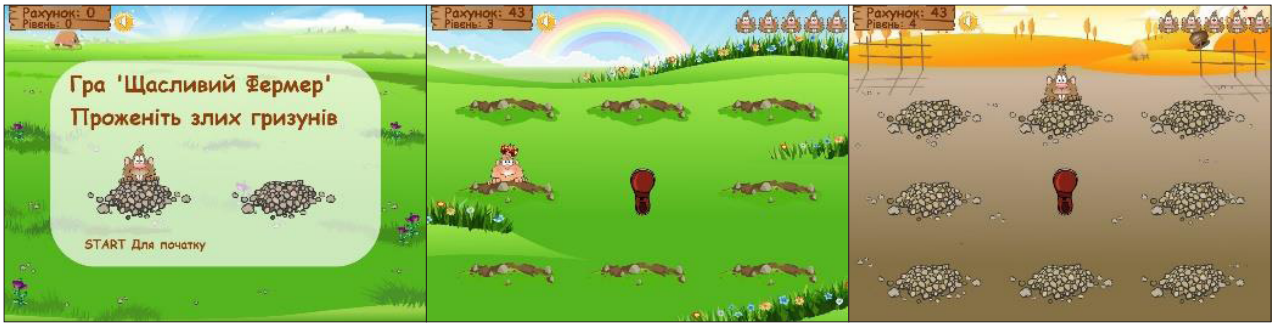

Fig. 6. Some levels of „Happy Farmer" (picture by Oleh Kachmar)

Fig. 7. Some levels of „Catch a butterfly"(picture by Oleh Kachmar)

stepping into a suitable square. The game has 5 levels of difficulty with different graphics; each of them requires quick responses. The first levels are simpler as the speed that the marmot appears with facilitates catching it. The third levelis complicated by the appearance of a marmot-girl, which has not be caught.

Fig. 5. A child with cerebral palsy playing on the dance mat(picture by Oleh Kachmar)

A similar gameis called „Catch a butterfly". A butterfly is sitting on one of 8 flowers and the player is trying to catch it by stepping on an appropriate square. This game also has 5 levels of difficulty. At the third level, a bee is introduced, which the player does not have to catch. Each level is accompanied by a change in graphics and a shorter time of butterfly`s stay on the flower.

There are also several other games for training stepping movements.

Before the training, the instructor assesses motor capacities of the patient, records them in the system and carries out one or two training sessions. Subsequently, the instructor designs the training program, which includes the recommended games, training setups, the frequency and duration of the training. The optimal training time is 20-30 minutes a day.

At home, the patient alone or assisted by his/her parents set ups the computer for home training according to the detailed instructions available onthe website. The patient enters the training system using his password, chooses the recommended games and starts exercising.

The information concerning game sessions, their duration and results are stored in the system and displayed on the website in the form

of graphs. The instructor remotely controls the training, adjusts the home program and provides instructions.

To assess the impact of stepping games on walking skills and balance of children with cerebral palsy a study was conducted. Stepping games for balance training were initially assessed in 10 patients with cerebral palsy aged 4-12 years. All the patients gave their informed consent for participation.

Main inclusion criteria:

- Diagnosis of cerebral palsy;
- age> 4 years;
- mild or moderate motor disorders (GMFCS level II-III);
- normal or slightly delayed mental development;
- communication abilities.

Main exclusion criteria:

- convulsive status epilepticus;
- significant joint contractures;
- severe mental retardation;
- non-cooperative behaviour.

Methods

The patients included in the study underwent the rehabilitation program according to the Kozyavkin method in the Kozyavkin International Rehabilitation Clinic (Truskavets, Ukraine) or the ElitaRehabilitation Centre (Lviv, Ukraine). After the discharge a two-week game program was tailored for each patient; daily duration of a training was 20-30 minutes.

The rehabilitation exercises were conducted at home; all the participants played special computer games on the dance mat. The rehabilitation sessions included initial detailed instructions for parents, regarding proper baseline positions, game requirements and safety during trainings.

All the patients were evaluated two times: before and after the two weeks home training using rehabilitation games. The outcomes were assessed using the Paediatric Balance Scale, Timed Up and Go Test and Four Square Step Test. All the patients were classified into appropriate levels of motor development according to the Gross Motor Function Classification System (GMFCS) [5].

Paediatric Balance Scale

The Paediatric Balance Scale (PBS)is a diagnostic tool of proven reliability and validity for assessment of balance in children, including possibilities of moving around their environment [6]. The PBS is a modification of the Berg Balance Scale and is designed for children aged 5-15 years with slight to moderate balance disorders. The scale consists of 14 questions, each scored 0-4 points. The maximum score is 56.

Timed Up and Go Test

The Timed Up and Go Test (TUG) is used to determine the lower limb functions and coordination in motion (with mobility aids or otherwise) during sit-to-stand movements [7]. After the command „rush", the patient is to rise from the chair, walk 3 metres, turn around, walk back to the chair and sit down.

Four Square Step Test

The Four Square Step Test (FSST)aims at comprehensive assessment of dynamic balance [8]. The motor tasks are performed in the following sequence: the initial standing position in the first square- the left lower, one step forward to the second square, then to the right – in the third square, back in the fourth square, and to the left to the first square; subsequently walking back to the 4-3-2-1 squares. The player should be as quick as possible, preferably looking straight forward. Both lower limbs should contact the floor in each square. At first, the instructor demonstrates each task and allows the patient

Table. 1. Outcomes before and after the two weeks home training with computer games

Tests	Baseline		After two week training		Difference		
	Mean	SD	Mean	SD	Mean difference	95% CI	P value
PBS	40.40	9.77	41.90	8.84	1.5	0.02 to 2.29	0.048
TUG	12.7	3.56	10.6	3.44	-2.1	-4.27 to 0.07	0.056
4SST	17.6	7.14	15.9	6.70	-1.7	-3.35 to -0.046	0.045

to have two trials without measuring time. The number of trials can be higher if the player fails to complete the sequence, loses balance or crosses the line.

Results

After two weeks of everyday home sessions, balance improvements were observed most of the patients. The Pediatric Balance Scale results improved by 1.5 points on average ($p<0.05$).The time of "Timed Up and Go" decreased by 2.1 sec. on average. Likewise, the indices of „Four Square Step Test" decreased by 1.7 sec. on average ($p<0.05$).

The results of assessment are presented in Table 1.

Discussion

It should be stressed that it is a pilot study, has some drawbacks and its results can be considered preliminary. The study was conducted with a small sample of patients without a control group. The balance functions were assessed by the instructor working with children; therefore, his/her estimates can be biased. In further studies, it is essential to determine to what extent the balance skills developed during trainings can be transposed and used in everyday life. The outcomes of our study were published in the Ukrainian Journal of Social Paediatrics and Rehabilitation [9]. The Internet training system using computer games is available free of charge for patients with motor impairments who completed the rehabilitation program according to the Professor Kozyavkin Method, on http://rehagame.com/[10].

Conclusions

Computer stepping games are a useful element of rehabilitation for individuals with motor disorders. The preliminary results indicate possibility that their use improves balance of patients with cerebral palsy. Further studies are required to assess the effectiveness of this rehabilitation approach according to the evidence-based medicine requirements.

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