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WEB-BASED HOME REHABILITATION GAMING SYSTEM FOR BALANCE TRAINING

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***Abstract*:** Currently, most systems for virtual rehabilitation and motor training require quite complex and expensive hardware and can be used only in clinical settings. Now, a low-cost rehabilitation game training system has been developed for patients with movement disorders; it is suitable for home use under the distant supervision of a therapist. It consists of a patient-side application installed on a home computer and the virtual rehabilitation Game Server in the Internet. System can work with different input gaming devices connected through USB or Bluetooth, such as a Nintendo Wii balance board, a Nintendo Wii remote, a MS Kinect sensor, and custom made rehabilitation gaming devices based on a joystick. The same games can be used with all training devices. Assessment of the Home Rehabilitation Gaming System for balance training was performed on six patients with Cerebral Palsy, who went through daily training sessions for two weeks. Preliminary results showed balance improvement in patients with Cerebral Palsy after they had completed home training courses. Further studies are needed to establish medical requirements and evidence length.

Keywords: rehabilitation, game, balance disorders, cerebral palsy.

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Introduction

Recent experimental evidence suggests that virtual reality technologies have great potential in the neurological rehabilitation of patients suffering from movement and balance disorders (Adamovic et al, 2009). Recovery of motor skills depends on neuroplasticity that is driven by repetition, intensity, motivation, and task-oriented training. Currently, there are many different systems designed for virtual rehabilitation and motor training, but most hardware is quite complex and expensive and can be used only in clinical settings. Low-cost, commercially available gaming systems such as Nintendo Wii and Xbox Kinect are widely used at home and have a high potential for movement training (Deutsch et al, 2008). However, such typical games are too difficult for neurological patients, whereas therapists have no means to carry out distant supervision of home training sessions. For more than twelve years, specially developed rehabilitation games with gaming devices have been used at our International Clinic of Rehabilitation in order to stimulate motor training in patients with Cerebral Palsy (CP) (Kachmar et al, 2001). Now, gaming rehabilitation has become one of the components of the multimodal rehabilitation system and is used on a regular, daily basis (Kozyavkin et al, 2004). However, movement training should be continued in home settings after the patient has been discharged from the clinic.

The objective of our work was to develop a low-cost rehabilitation game training system for patients suffering from movement disorders, which would be suitable for home use and under the distant supervision of a therapist. The second aim was to make a preliminary assessment of its benefits for training balance in patients with Cerebral Palsy.

Description of the training system

The Home Rehabilitation Gaming System was developed to provide game training at home under the supervision of a therapist. It consists of two main parts: a) a patient-side application installed on a home computer – the Game Device Controller (GDC), and b) a virtual rehabilitation Game Server in the Internet. The GDC main functions are to connect gaming hardware, convert

data from different hardware to one format, send the game controlling data to the games, and receive feedback.

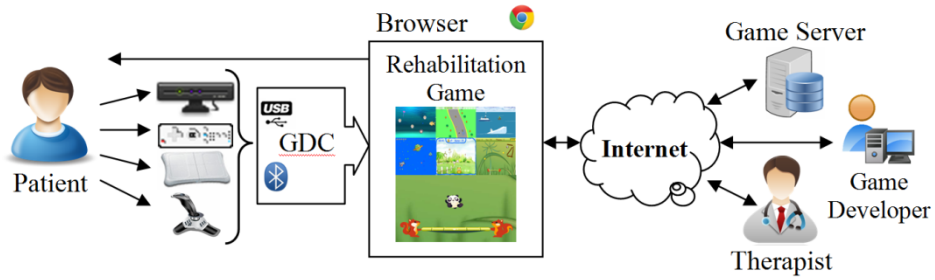
In our system, GDC can work with different input gaming devices connected through USB or Bluetooth: a Nintendo Wii balance board, a Nintendo Wii remote, a MS Kinect sensor, custom-made rehabilitation gaming devices based on a joystick, and several other. Such an approach allows us to use the same games with all training devices and not develop separate games for each device. Of course, there are some restrictions for game scenarios, and games for disabled persons should not be too complicated.

The virtual rehabilitation Game Server performs the following tasks:

- *User management* – there are different types of users: the patient, therapist, game developer, and systems administrator, all of whom have different interfaces and access rights to the system.
- *Repository for rehabilitation games with training guidelines* – there are instruction for each game, including required gaming devices, training positions, and a short game legend.
- *Usage statistics* – stores and presents graphs on data about game scores, the duration and time of each training session.
- *Messaging* – message support exchange between patients and therapists.

The general structure of the system is presented in Figure. 1.

***Figure 1**. Scheme of the Web-based virtual rehabilitation system.*



Rehabilitation games

Rehabilitation games is the most important component of the home training system. They should be rather simple, appropriate for the person with

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movement disorders and, at the same time, entertaining and fun enough so that the training process does not become boring. Widespread tools, such as the Adobe Flash platform and AS3 language have been selected for game development. A special game user interface was implemented to simplify adding new games to the system and testing them with different training devices. Since the system is multilingual, the game messages are not included directly into the games, but are obtained from the server, depending on the language selected during registration.

***Figure 2**. Screenshots of rehabilitation games.*

Typically, patients with motor disorders have a limited range of motion. Therefore, before the training session starts, each game is calibrated according to the patient's individual possibilities. He/she needs to perform one or two movements within maximal range and later, games will require the patient to carry out movements that are appropriate for his/her abilities. Each game has five levels of difficulty. The first level is quite simple so that even patients with significant movement disorders are able to complete it. Each subsequent level requires more accurate and faster responses. The complexity of the last level is appropriate for a healthy child aged seven to eight years.

A unified scoring system is used in the games. A completed first level earns the patient ten points, the second – fifteen, the third, fourth and fifth – twenty-five points each. The maximal game score comes to 100 points. The score, time, and duration of each gaming session are stored in the database. Currently, there are six games in the system and our team continues working on new ones. Several game screenshots are presented in Fig.2.

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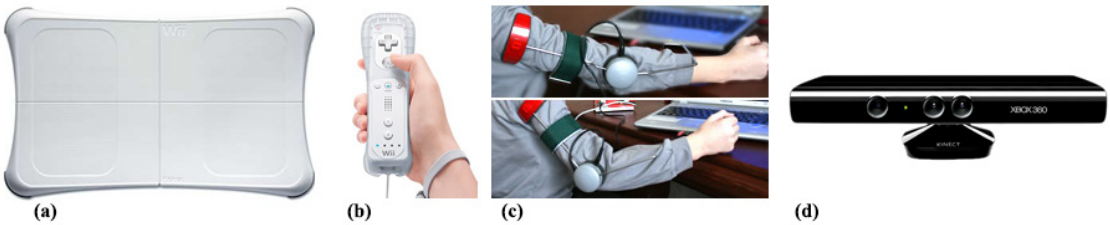
Rehabilitation gaming hardware

The following types of rehabilitation gaming hardware are used in the home training system: a) Nintendo Wii balance board, b) Nintendo Wii remote, c) Universal Gaming Device, d) Microsoft Kinect motion sensor.

Figure 3. Rehabilitation gaming hardware used in the system: a) Nintendo WII balance board b) Nintendo WII remote, c) Universal Gaming Device, d) Microsoft Kinect.



The Nintendo Wii balance board has four pressure sensors located in each corner of the board; information about center of pressure displacement is transmitted to the computer over the wireless Bluetooth connection. Balance training exercises are performed in different positions: standing, sitting, kneeling, etc.

The Nintendo Wii remote has two accelerometers, making it possible to define its inclination in the gravity field. The Wii remote, attached to a patient's body part, transmits information about its position. For example, if the remote is attached to the patient's chest, the games can be played by bending the body sideways.

The Universal Gaming Device is a custom-made simple electrogoniometer developed at the International Clinic of Rehabilitation. It can be used for tracking movements of elbow, wrist, knee, and ankle joints. Two levers of the device, attached above and below the joint, track flexion/extension movements and are used to control the game.

The Microsoft Kinect motion sensor tracks all body movements. However, in our training system, we choose to track only one or two body parts that are aimed for training. These body parts and required movements are defined in exercise setups and are used for game controlling.

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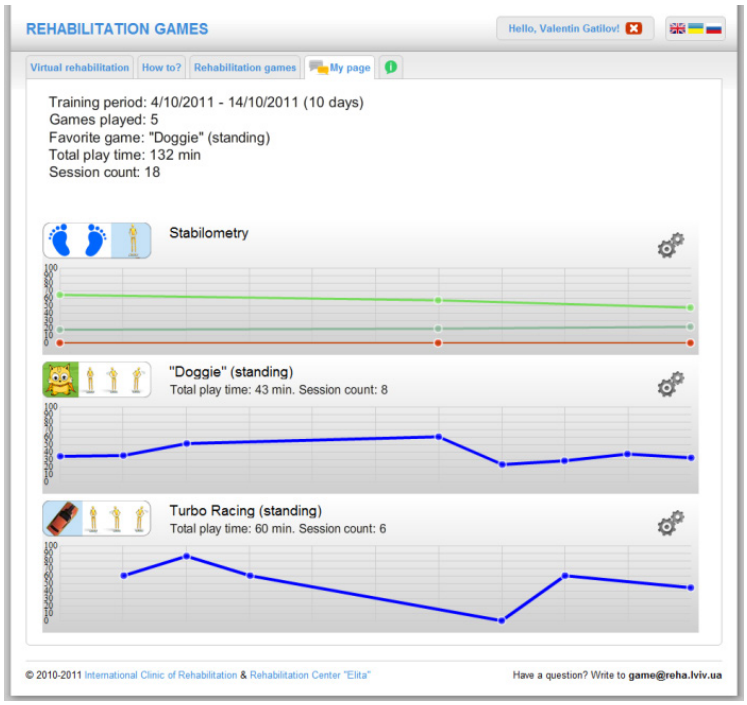
Home training

Before starting home training sessions, the physical therapist evaluates the patient and draws up a relevant training program, indicating recommended games, training positions, and the frequency and duration of sessions. He registers the patient in the system and trains the child and his parents how to use the system.

The patient or his/her parents should ensure that they have all the required hardware at home; they should download and install Game Device Controller software on the computer, and check the connection of gaming hardware to computer. After setting up the home computer, the patient logs in to the system on the Web-page, selects the recommended games and starts his/her training session. Information about the duration and time of the gaming sessions, as well as game scores are stored in the system and can be viewed in the form of graphs. This information is accessible to the therapist so that the program may be adjusted, if necessary.

***Figure 4**. Results and duration of the training sessions are presented as charts.*



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Balance training exercises

The Game Training System can be used as a supplementary treatment option for patients with different motor problems. This article describes its usage for patients with balance problems. Currently the system is available at http://game.reha.lviv.ua/.

A personal computer with an Internet connection and a Bluetooth adapter, a Nintendo Wii balancing board, and a Nintendo Wii remote are required to conduct home balance training exercises. Balance training exercises are aimed at developing coordinated left-right and forward-backward weight-shifting skills and maintaining position. The patient stands or sits on the balance board; while performing specific exercises; at the same time, he/she controls the movements of computer game characters.

Figure 5. Gaming sessions for balance training.

Balance training is performed in the following positions: a) standing on the board and shifting body weight left-right, b) standing and shifting body weight forward-backward, standing with support, d) sitting on the board, e) standing with one foot in front of the other, e) kneeling.

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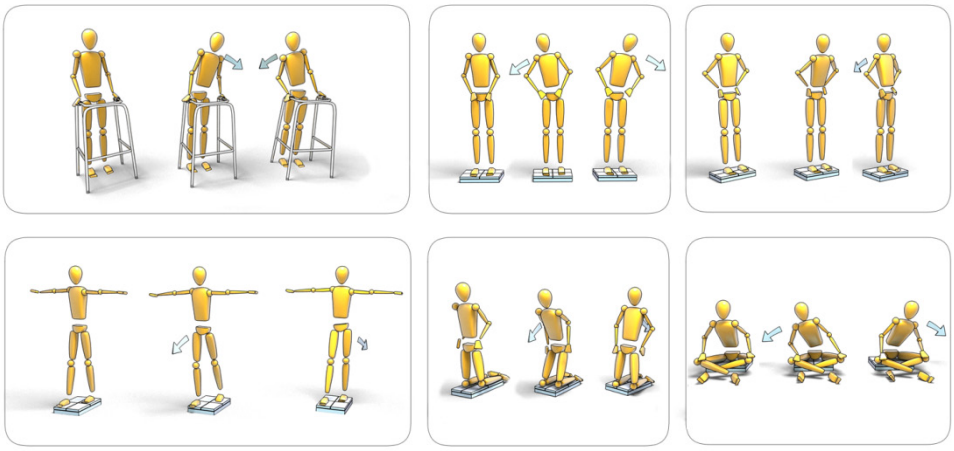
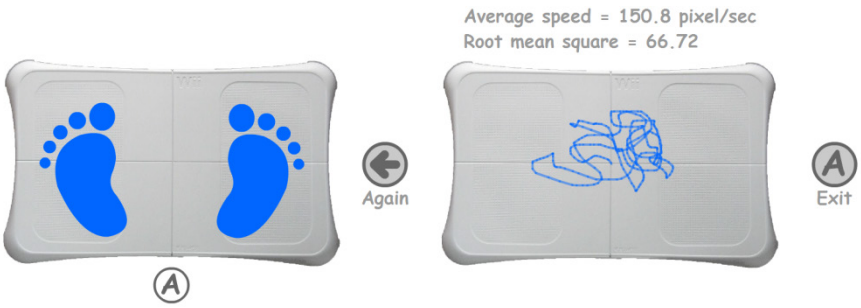
Figure 6. Training positions for balance exercises.



Stabilometry as a diagnostic tool measuring equilibrium

Patients with balance disorders can use our system, which includes a special diagnostic tool – a game called "Stabilometry", aimed at evaluating balance disorders. The child should stand still on the balance board for fifteen seconds. Two parameters are calculated: the mean velocity of center of pressure (CoP) displacement and area of CoP displacement.

Figure 7. The Stabilometry game is a tool for testing equilibrium.



The mean velocity of CoP displacements indicates how briskly the patient's sway movements are, whereas the area of CoP shows the range of these movements. Higher velocities and larger areas indicate poor balance. The Stabilometry game has not been validated or certified as a clinical diagnostic tool; it is just an additional tool for patients and parents.

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Preliminary system assessment

Preliminary assessment of the Home Rehabilitation Gaming System for balance training was performed on six patients with Cerebral Palsy, who went through daily training sessions for two weeks.

Patients with spastic forms of Cerebral Palsy, aged five to eleven years, cooperative with normal mental development, were selected for the study. All parents and patients were informed and gave their consent for participation. The therapist evaluated each child and drew up relevant training program, indicating recommended games, training positions, and timing. The first two treatment sessions were performed at the rehabilitation center together with the therapist. He registered the patient in the system and trained the child and his parents how to use the system and carry out gaming exercises at home.

For a period of two weeks (twelve sessions), patients conducted daily home training sessions, each lasting thirty minutes. The patients then returned to the rehabilitation center for the second evaluation. They were assessed according to standard evaluation systems, whereas their motor development was classified according to the Gross Motor Function Classification System (GMFCS), the Pediatric Balance Scale, and Stabilometry testing.

The Gross Motor Function Classification System (GMFCS) is a five level classification system that describes the gross motor function of children with Cerebral Palsy. Children at Level I can generally walk without restrictions, but tend to be limited in some of the more advanced motor skills. Children at Level V are generally very limited in their ability to move around even with the use of assistive technology (Palisano et al, 1997).

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Table 1. Distribution of patients according to diagnosis, age and GMFCS level.

Patient	Age (years)	Gender (M/F)	Diagnosis	GMFCS level
A	5	M	CP, spastic right-sided hemiplegia	I
B	5	F	CP, spastic right-sided hemiplegia	II
C	7	F	CP, spastic right diplegia	I
D	7	M	CP, spastic right-sided hemiplegia	I
E	11	M	CP, spastic left-sided hemiplegia	I
F	8	F	CP, spastic tetraplegia	III

The Pediatric Balance Scale (PBS) is an instrument with proven reliability and validity, designed to evaluate the child's balance function, including his/her ability to move around in the surrounding environment (Franjoine et al, 2003). It is a modification of Berg's Balance Scale, developed as a balance measure for school-age children with mild to moderate motor impairments. The scale consists of fourteen tasks; each has a scoring scale from 0 to 4 points; the maximum score is 56. The distribution of patients according to age, gender, diagnosis, and GMFCS level is presented in Table 1. The majority of patients were in the five-to-eight-year-old group, predominantly with hemiplegic Cerebral Palsy. Four of them were classified at Level I of motor development; one walked with limitation (Level II), and one girl with spastic tetraplegia was able to walk only with assistance (Level III).

Results and discussion

Assessment results of six patients before and after a two-week home gaming training course are presented in Table 2. The same information is presented as charts in Fig. 8.

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Table 2. Balance testing results of six patients with Cerebral Palsy before and after home game training.

Patient, age	GMFCS level diagnosis,	Before training Balance Scale	Before training CoP Velocity	Before training CoP Area	After training Balance Scale	After training CoP Velocity	After training CoP Area
A, 5 years	Level I, hemiplegia	52	25	8	53	23	8
B, 5 years	Level II, hemiplegia	45	50	8	46	46	7
C, 7 years	Level I, diplegia	47	29	14	48	25	9
D, 7 years	Level I, hemiplegia	48	22	3	50	26	4
E, 11 years	Level I, hemiplegia	49	31	8	51	24	7
F, 8 years	Level III, tetraplegia	7	48 with support	7 with support	7	44 with support	5 with support

Both the table and graphs show data related to Pediatric Balance Scale (A), mean CoP velocity (B), and CoP areas (C) before and after training sessions. An improvement of one or two points on the Pediatric Balance Scale was noted in five cases. Only one eight-year-old girl (F), with low motor development (GMFCS Level III) showed no changes on the scale after the training course.

In most cases, Stabilometry data indicates marked reduction in both average CoP velocity and CoP areas. This is considered positive and indicates that children can maintain a more stable position, whereas their swaying movements become slower and smaller. One patient (girl F) was not able to stand without support, so she was held by one arm during Stabilometry testing. In her case, both CoP velocity and CoP area improved. Only in one case, (a seven-year-old boy (D) with spastic right-sided hemiplegia) was a slight decline in Stabilometry parameters noted, but balance scale performance improved from 48 to 50 points.

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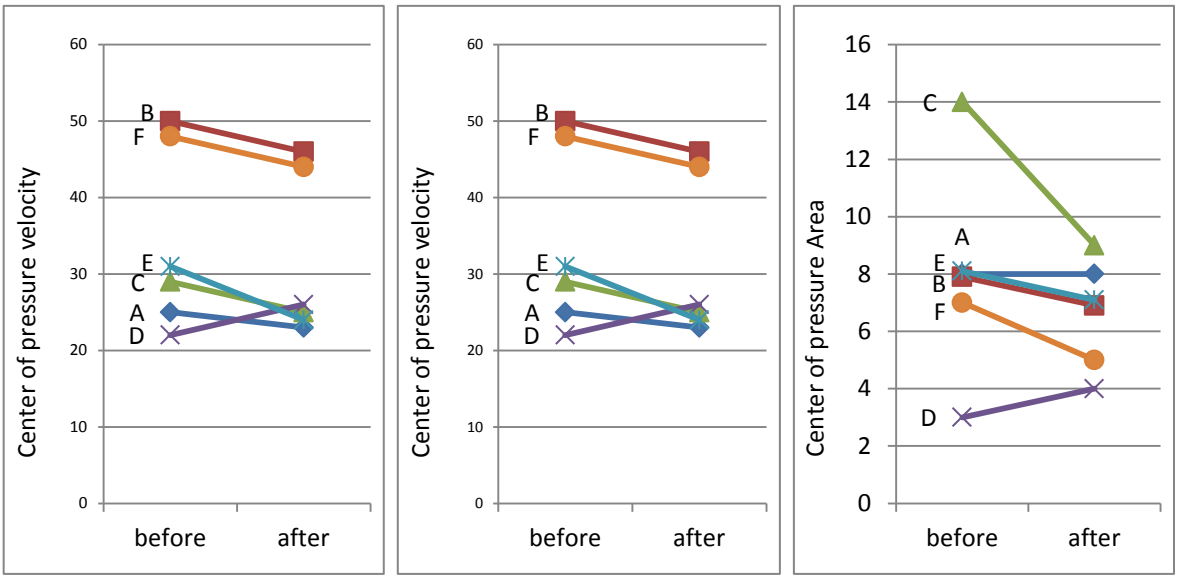
***Figure 8**. Graphical representation of balance testing data of six patients with Cerebral Palsy before and after game training courses.*



Study results suggest that home gaming training is beneficial for improving balance function. After the treatment course, the therapist discussed home gaming training with the patients and parents. All the parents and children were satisfied and interested in continuing home training courses.

This is a pilot study; it presents certain shortcomings, and its results can be interpreted only as preliminary. The study was conducted on a small number of patients without referring to a control group or conducting proper statistical analyses. The evaluation of patients was performed by a therapist working together with them, so his assessments may have been biased. Moreover, it is important to determine how balancing skills, obtained during these training sessions, can be adapted to everyday life.

Conclusions

A Home Rehabilitation Gaming System was developed in order to transfer the virtual rehabilitation of patients with motor disorders from clinical to home settings.

Studies indicate the feasibility of this Home Rehabilitation Gaming System to train the patients' balance function. Preliminary results show balance

improvement in patients with Cerebral Palsy after home training courses. Further studies are needed to establish medical requirements and evidence.

Acknowledgements

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