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Impact of virtual reality games as an adjunct treatment tool on upper extremity function of spastic hemiplegic children

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Abstract: Aim: This study was conducted to investigate effect ofvirtual reality games (VRG) as an adjunct treatment tool on upper extremity function in management of spastic hemiplegic children. **Methods and subjects**: the study was conducted on forty spastic hemiplegic cerebral palsied children; ranged in age from 5 to 10 years old. They were divided into two equal groups; the control group that received selected physical therapy program and the study group that received the same program in addition to VRG. Both groups were evaluated with Peabody Developmental motor scale PDMS-2 and Abilhand Kids questionnaire.
Results Object manipulation and visual-motor skills of PDMS-2 and upper limb functions were measured before and four months post treatment. Significant results in both groups were noted in all measuring variables. Object manipulation, visual-motor skills and upper limb functions were significantly improved in study group post treatment compared to control one.
Discussion and Conclusion significant improvement of object manipulation, visual motor skills and upper limb functions in study group post treatment are related to active participation of children in simulating environment, driven their active motivation and enhance their participation through self-competition activities. VRG can enhance active participation of children with motor deficits in majority of upper limb activities through consideration of child personality and changing of environmental factors.
Key words Hemiplegic children; virtual reality games; upper extremity function.

Introduction

Spastic hemiparesis could be a result of; intrauterine growth restriction, preeclampsia, chorioamnionitis , systemic infection, birth asphyxia, prolonged rupture of membranes, cord abnormalities, cardiac and coagulation disorders, middle cerebral artery infarct, hemi-brain atrophy, periventricular lesions which have been reported as risk factors[1,2]. Spastic hemiplegic children have involvement of the arm and leg on one side of the body moreover; the upper extremity is more severely involved than the lower limb[3].

Upper limbs are used in almost every movement and they are therefore extremely important for independent performance. Children with spastic hemiplegia encounter problems in the execution of gross and fine motor skills and participation of daily activities[4]. The motor performance of children with spastic hemiplegic is characterized by slower movements that consist of more sub-movements[5,6,7], a stereotypical shoulder–elbow recruitment order[8], more variable hand trajectories[9], and increased trunk involvement [10].The posture pattern of child with spastic hemiparesis assumes mainly flexion attitude of upper extremity, pronated forearm, fisted hand and thumb adduction [11]

However, the most outlined conservative interventions among children with spastic hemiplegia are often repetitive; they are often of low interest, which affects the child's motivation to continue with the activities. The impact of motivation and engagement are essential components of successful therapy[12].

Virtual reality games (VRG) is a technology that allows individuals to experience and interact with computer-generated environments through their senses, including vision, touch and/or hearing. VRG provides an opportunity to engage in multisensory activities that are similar to daily life such as; hand skills, activities of daily living, manipulation, mobility, balance and cognition [13]. In addition, VRG can motivate, challenge, increase curiosity; control, and promote fantasy for children which assist deeply engagement with the intervention[14].

Previous studies reported that VRG are a motivating and entertaining way to engage children in therapy[15]. In addition, VRG allow the therapist/patient to change mode, dose of exercise, frequency, and intensity of exercises. Furthermore, safety is easily to be gained during using VRG comparing to the same activities in the real world[16]. The primary aim of this study was to examine the effect of VRG on upper extremity functions for children with spastic hemiplegic.

Table 1 - General characteristics of the participating children in both groups.

characteristics	**Control group N=20**	**Study group N=20**
Age (years) (X ±SD)	7.25± 0.96	7.05 ± .0.99
Gender (girls/boys)	9 girls ;11 boys	8 girls; 12 boys
Involved side (right/left)	9 Rt;11 lt	9Rt;11 lt

Materials & methods:-

Forty patients were recruited from outpatient clinic of faculty of physical therapy; Cairo university in a period from 2014-2015. Participated children initially screened and assessed to determine age, diagnosis and meet the inclusion and exclusion criteria. Fig.1.

Inclusion Criteria: All children diagnosed as acquired spastic hemiplegic children. Age between 5-10 years; they all have muscle tone of grade 1+ or 2 (according to Modified Ashworth Scale) in shoulder, elbow and wrist flexors as well as shoulder adductors of the affected upper limb; they are able to understand and follow verbal commands and instructions included in evaluation and training. They have full passive range of motion (ROM) for shoulder joint, while no tightness interfere or obstruct motion.

Subjects were selected with active ROM of shoulder flexion, horizontal abduction, elbow extension &wrist extension that not restricting movement to be able to engage in the selected intervention procedures. All participants were of GMFCS level 1 and 2.

Exclusion criteria: Children with Intelligent Quotient (IQ) level below 70 according to Stanford Binet scale .A visual, cognitive, or auditory disability that would interfere with interactive game playing. Patients underwent surgical intervention for tendon release or tendon transfer in the last year.

All subjects and their parents were asked to sign a formal consent for the participation in the study. Only those that fulfilled the above outlined criteria were included in the study**.** **Study Design:** The research design used in this study is a randomized control design.

Forty children participating in this study were randomly assigned into two groups using closed envelops procedure. **Group A**: **The study** group included 20 children. This group received 3 sessions /week including VRG by X-BOX system; for 30 minutes, in addition to upper extremity therapeutic program for 60 min. **Group B**: **The control** group included 20 children. They received upper extremity therapeutic program for 60 min.

The period of therapy for both groups was four successive months.

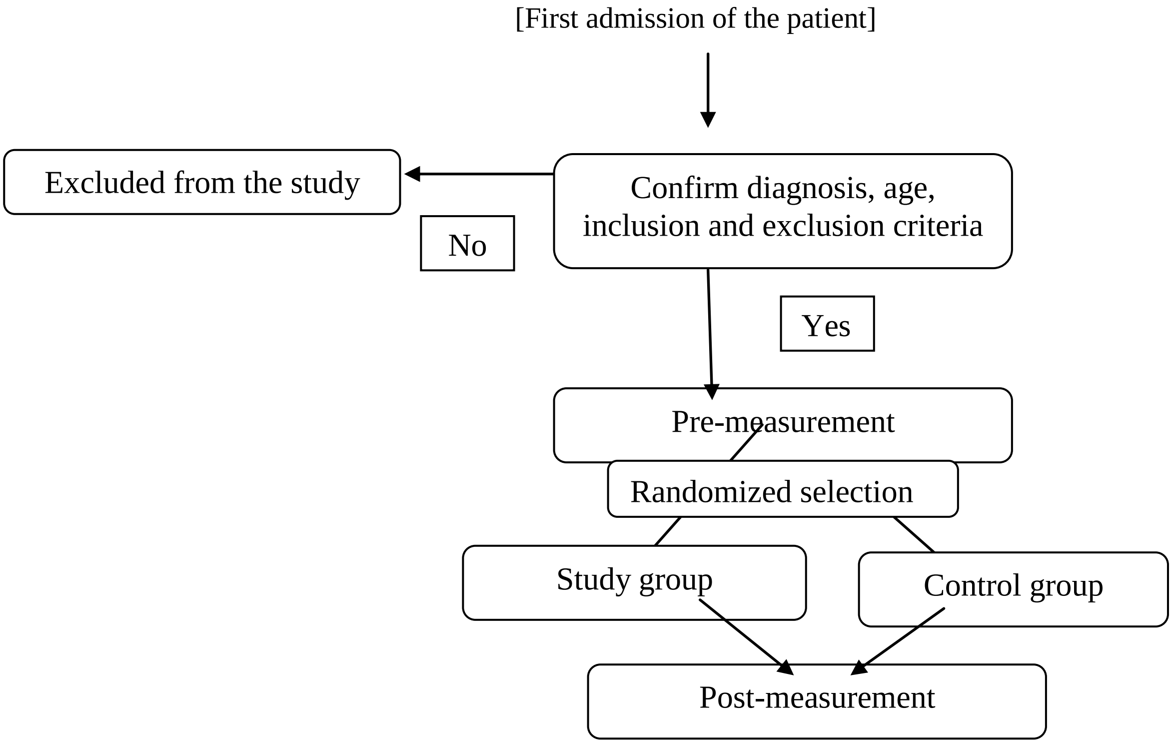

Figure 1: flow chart of patient admission and enroll in the study

Instrumentation:

Abilhand kids Questionnaire consists of 21 items, administered on an interview basis, the child asked to estimate the ease or difficulty of performing each activity. The activities were presented in a random order to avoid any systematic effect. During the evaluation, the 3-point ordinal scale is presented to the child. The child asked to rate his/her activity on scale as "Impossible", "Difficult" or "Easy". The activities that the patient does not perform because they are too difficult must be scored as "Impossible".

Peabody Developmental scale-2: Two subtests of PDMS-2 were only measured; the object manipulation and visual-motor integration

X-Box presenting Virtual reality games

The X- Box system consists of Kinect infrared camera sensor which positioned in front of the subject with distance about 2-4 meters. The Kinect camera can capture and track movement and immerse the subject inside the VR scene. Each subject was asked to stand straight in front of The LCD screen and Kinect camera to allow the subject to engage in the activities. Fig.2 .

Group A: **(Study group**) received selected PT exercises in addition to VRG.

Six virtual environments were interfaced; the tennis, bowling, golf, space pop, bubbles and boat driving games. Fig. 3&4. Each game was played 3 times and, depending on the game, within each game there were three levels of difficulties. The selected games are the most games to enhance eye tracking, coordinated reaching in different directions, regulating coordinated force and arm swing movements. The selected games are variable in activating bilateral as well as unilateral arm activities. Starting &posture, game guidelines and instructions to avoid substitutions were illustrated to each child before each session. Each game took place for 10 minutes. This part of the therapy started after the upper extremity exercises, the session of using X-Box lasts for 30 minutes.

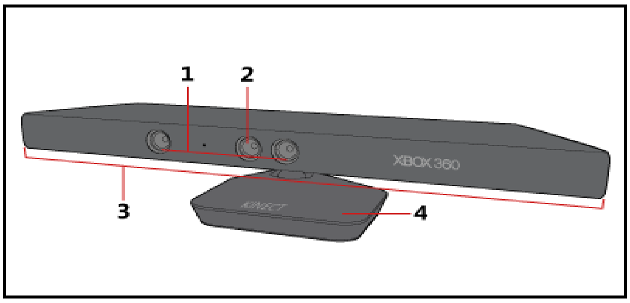

Figure 2 Microsoft Kinect description: 1. Depth Sensor, 2. RGB Camera, 3. Microphone Array, 4. Motorized Base

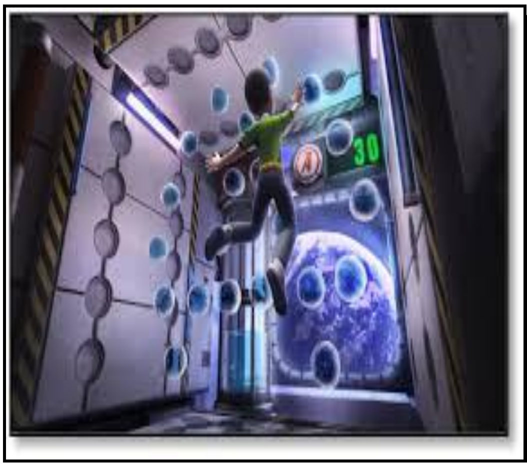

Fig. 3- Space pop game

Fig. 4- Bowling game

Group B: The control group received **the upper extremity therapeutic program which include;** passive stretching, weight bearing exercises, global strengthening exercises and functional training activities. Each task took place 20 minutes.

Results

The ordinal total scores obtained on the Abilhand-Kids questionnaire were subsequently transformed into linear measures according to the Rasch model. The manual ability measures were expressed in “logits”. The linear measures obtained by the Rasch model can be used to compare manual ability between both groups. The mean ± SD values of Abilhand-Kids questionnaire in the "pre" and "post" tests were -0.451±1.06 and 0.65±0.866 logits respectively in the control group with a percent of change 244.12%. "Paired t test" revealed that there was a significant increase of manual ability (t-value= -6.077, p-value =0.000*). The mean ± SD values of Abilhand-Kids questionnaire in the "pre" and "post" tests were -0.594±0.95 and 1.546±1.13 logits respectively in the study group with a percent of change 360.26%. "Paired t test" revealed that there was a significant increase of manual ability (t-value= -12.82, p-value =0.000*).

The mean ± SD values of Abilhand-Kids questionnaire in the "study group" and "control group" were 1.546±1.13 and 0.65±0.866 logits respectively at post treatment. "Unpaired t test" revealed that the mean values of the "post" test between both groups displayed a significantly higher manual ability (t-value= -2.787, p=0.008*) in favor of study group.

Regarding visual-motor integration of PDMS-2, the mean ± SD values in the "pre" and "post" tests were 79.3±14.4 and 93.65±15.52respectively in the control group with a percent of change 18.09%. "Paired t test" revealed that there was a significant increase of Peabody V/M (t-value= -9.15, P-value =0.000*). The mean ± SD values in the "pre" and "post" tests were 88.7±17.87 and112.35±16.81respectively in the study group with a percent of change 26.66%. "Paired t test" revealed that there was a significant increase of Peabody V/M (t-value= -10.939, p-value =0.000*). The mean ± SD values of Peabody V/M in the "study group" and "control group" were 112.35±16.81 and 93.65±15.52 respectively at post treatment. "Unpaired t test" revealed that the mean values of the "post" test between both groups showed there was significant differences (t-value= -3.654, P=0.001*) and this significant increase in favor of study group.

The mean ± SD values of Peabody object manipulation in the "pre" and "post" tests were 19.38±4.28 and 28.75±7.23 respectively in the control group with a percent of change 48.34%. "Paired t test" revealed that there was a significant increase of object manipulation (t-value= -8.156, P-value =0.000*).

The mean ± SD values of Peabody object manipulation in the "pre" and "post" tests were 22.23±4.39 and 33.7±6.77 respectively in the study group with a percent of change 51.6%.. "Paired t test" revealed that there was a significant increase of Peabody object manipulation (t-value= -10.689, P-value =0.000*).

The mean ± SD values of object manipulation in the "study group" and "control group" were 33.7±6.77 and 28.75±7.23 respectively at post treatment. "Unpaired t test" revealed that the mean values of the "post" test between both groups showed there was significant differences (t-value= -2.233, P=0.032*) and this significant increase in favor of study group.

Table 2- Comparison of the pre and post treatment values in each group

Groups and measured variables	Pre-test M± SD	Post-test M± SD	P-value	Significance	Percent of improvement
Control group					
1-Abilhand kids questionnaire	**-0.451±1.06**	**0.65±0.866**	0.000	Significant	244.12%.
2-Visual/ motor	79.3±14.4	93.65±15.52	0.000	Significant	18.09%.
3-Object manipulation	19.38±4.28	28.75±7.23	0.000	significant	48.34
Study group					
1-Abilhand kids questionnaire	**-0.594±0.95**	**1.546±1.13**	0.000	Significant	360.26%.
2-Visual/ motor	88.7±17.8	112.35±16.8	0.000	Significant	26.66%.
3-Object manipulation	22.23±4.39	33.7±6.77	0.000	significant	51.6%

M=mean SD=Standard Deviation P-value=Probability Value

Table3- Comparison between the post treatment mean values of both groups

Groups and measured variables	Control group M± SD	Study group M± SD	P-value	Significance
1-Abilhand kids questionnaire	0.65±0.866	1.546±1.13	0.008	Significant
2-Visual/ motor	93.65±15.52	112.35±16.81	0.001	Significant
3-Object manipulation	28.75±7.23	33.7±6.77	0.032	significant

M=Mean difference SD= Standard Deviation P-value= Probability Value

Discussion

The primary outcome of rehabilitation for children with spastic hemiplegia is to develop motor skills, results in refining of child's performance in daily activities. The main rationale to acquire new motor skills following brain injury is regular practice and repetition of meaningful movements.

Outcome measures of hand function were measured by Abilhand Kids questionnaire. Both study and control groups showed significant improvement post treatment. Significant differences in improvement were found between groups post-treatment in terms of hand function of the study group. Traditional exercises for control group include functional training which may explain significant improvement. Functional approach has been introduced in the field of pediatric physical therapy that promotes the use of functional skills instead of isolated movements[17,18,19] showed that internalization of the motor process in target motor behavior is facilitated during visual sensory feedback and VRG. This internalization leads to the formation of new motor pathways especially around the sensorimotor cortices. They demonstrated that VRG stimulates neural motor pathways that were not previously used and might develop neuroplasticity. Thus, motor skills of the affected extremity of the child have developed and cortical reorganization was similar to that of a normally developing child after VR application.

The selected tasks used in VRG were further meaningful for children 20 reported in his study that, if a task is functionally more relevant or meaningful then motor performance will be more precise and less variable.

Rationale of therapy between both groups, enhance bimanual exercises through moving both arms which activate the dominant control centers in the brain. [21]Interact of both hemispheres improve inter-limb coupling activities

Object manipulation was measured in this thesis by PDMS II showed significant improvement post treatment in both study and control groups. Significant differences in improvement were found between groups post-treatment in term of object manipulation of the study group.

The rationales for improvement of object manipulation resulting from using convention therapy as well as VRG are related to improvement of proximal shoulder stability. Shoulder stability is prime contributing factor to enhance hand function based on concept of proper proximal stability. VRG showed significant improvement post treatment compared to traditional therapy, as tasks of interactive games were task directed exercises rather than global strengthening. Training of children through simulating environment enhance accuracy resulting from enhancing feed-forward mechanism as serial of repetitions of specific tasks. However, X-Box games were used in current study didn't use any hand held, improvement were significant which confirm that it's not necessary to train children with hand equipment to utilize object manipulation during therapy.

Visual-motor skills were measured by PDMS II. Both study and control groups showed significant improvement of total scores of this section of PDMS II. Significant differences in improvement were found between groups post-treatment in terms of visual motor skills of the study group. All selected interactive games used in this study, motivated children to perceive the appearance of the target in various locations of the screen and then move their arms quickly to reach toward the targets. Repeated practicing these activities guided children to improve their performance in eye-hand coordination. The selected games were considered to facilitate both eye focusing and eye tracking with different level of difficulties. The selected games also considered quite colors and more contrast between background and field colors to avoid visual confusion. The current results are consistent with [22] who used the virtual reality therapy on upper extremities of children with spastic quadriplegics and hemiplegics. Improvements on the visual-motor skills were recorded among 75% of participated children have been reported.

Conclusion:

Virtual reality games (VRG) is a modern technology provides patient an opportunity to engage in multi-activities that are similar to daily life. Results of this thesis reported improvement of hand skills, and visual-motor skills of the upper extremity.

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