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Original article

Video game-based therapy for the non-dominant hand improves manual skills and grip strength

Effets de la thérapie basée sur les jeux vidéo pour la main non dominante sur les compétences manuelles et la force de préhension

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SUMMARY

The study was designed to investigate the effect of virtual reality-supported training on manual skills and grip strength in the non-dominant hand in healthy participants. Thirty participants were randomized into two groups: ErgoActive group ($n = 15$) and control group ($n = 15$). The ErgoActive study group received 8 weeks of training with leap motion controller-based virtual reality games. The training was done 1 day per week for 30 min. The participants' hand function was evaluated using the Jebsen Taylor Hand Function Test (JTHFT), while grip strength was evaluated with a Jamar Hand Dynamometer and Pinchmeter. After 8 weeks, the ErgoActive and control groups had significantly different JTHFT, Jamar and Pinchmeter results ($P < 0.05$). When leap motion controller-based virtual reality applications are used, healthy subjects have increased manual skills and grip strength in their non-dominant hand. These virtual reality games are an effective and fun way of improving patients' hand functions.

RÉSUMÉ

L'étude était conçue pour étudier l'effet des formations basées sur la réalité virtuelle sur les compétences manuelles et la force de préhension dans le développement de fonctions de la main non dominante chez des participants en bonne santé. Trente participants ont été randomisés en deux groupes : groupe d'entraînement et groupe témoin. L'étude a été réalisée avec des jeux de réalité virtuelle basés sur LMC et le groupe témoin a été évalué à des intervalles de huit semaines. Le groupe de formation a été entraîné un jour par semaine pendant huit semaines et les séances duraient 30 min. Les fonctions des mains des individus ont été évaluées par le test de fonction de la main Jebsen Taylor (JTHFT), la force de poigne avec le dynamomètre et la force de pince avec le pinchmètre Jamar. Après la formation, il y avait une différence significative dans les résultats sur les JTHFT, Jamar et Pinchmeter entre le groupe entraîné et le groupe contrôle ($p < 0,05$). En conséquence, les applications de réalité virtuelle basées sur LMC utilisées pour améliorer les fonctions des mains avaient augmenté la dextérité manuelle et la force de préhension des mains non dominantes de sujets sains. Les jeux de réalité virtuelle basés sur LMC peuvent être considérés comme un moyen efficace et amusant d'améliorer les fonctions manuelles du patient.

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Introduction

Virtual reality (VR) can be defined as a computer-generated environment, real or imaginary, that is experienced and manipulated through a multi-sensory computer interface [1]. VR systems offer benefits such as instant feedback, stimulus-based control, stimulus adjustment from simpler to more complex, easy recording of individuals' progress and a safe learning environment. Another important feature is online feedback, which can improve the effectiveness of learning-based education by detecting and correcting motor errors [2]. The most important characteristic of VR for rehabilitation is its ability to address multiple key features for a variety of different client populations. One of these key features, especially for occupational therapy, is personalized and customized interventions [3].

The virtual image of the upper extremities can be created on a computer screen where individuals will have to make movements according to their intended activities. These methods, which are also used to improve hand and upper extremity function, are called VR-supported rehabilitation.

Overuse, injury and geriatric complications can all contribute to hand dysfunction, total or partial, which directly diminishes the quality of life. In some cases, it requires long-term therapy to fully restore the hand's function, which is sometimes a very intense process for patients. VR games have been shown to be useful in improving upper limb function and activities of daily life when used as an adjunct to normal daily treatment [4]. A Cochrane review concluded that VR was an effective treatment for recovery of upper extremity motor function and activities of daily living after stroke, when compared to conventional rehabilitation therapy [5]. To achieve upper extremity rehabilitation goals, various video games have been created to fulfill the different objectives proposed by health professionals. Video game-based rehabilitation integrates individuals' daily life activities and motivated individuals begin to use these gaming experiences in their daily lives.

VR systems are developed based on sensor technologies. Many sensors can be used for VR systems. The most popular of these are Nintendo Wii™ and Microsoft Kinect™. However, these devices focus on all body functions and are inadequate to detect fine hand skills [6]. The leap motion controller (LMC) is a commercially available device that is a low-cost, low-flexibility, optoelectronic system embedded in a semi-immersive VR system capable of tracking hand movements [7]. It can be used to improve one's hand function as it can be easily changed based on the person's needs. It is perceived as entertaining and motivating and provides motor learning.

Considering this information, the aim of this study was to investigate the effect of VR games on manual skills and grip strength in the non-dominant hand. The first goal was to increase our understanding of the availability of VR rehabilitation games for healthy individuals. The second goal was to evaluate the usability of games developed for grip skills in rehabilitation and to obtain preliminary data for expectations and preferences about video game-based training in hand rehabilitation. This study was initiated because VR is easy to apply, provides real-time evaluation during play and provides feedback in hand rehabilitation that is not possible with conventional treatments.

Material and methods

Participants

Participants were recruited between April 2016 and July 2017 to participate in this study at Medipol University. All participants signed informed consent forms. Ethical approval for this study was obtained from the Research Ethics Committee of Istanbul Medipol University (No.: 108400987-275). This project was supported by the Scientific and Technological Research Council of Turkey (project number: 1919B011800515).

Inclusion criteria consisted of being aged between 18–24 and being able to use both upper extremities. Participants were excluded from the study if they had a history of upper extremity surgery or neurological and orthopedic problems affecting the upper extremity's function. Participant demographics are presented in Table 1.

Study design

This study was conducted as a randomized controlled study, with randomization performed by computer program. Participants were randomized into two groups: ErgoActive group ($n = 15$) who received 8 weeks of non-dominant hand training based on VR games designed by the research team, using the LMC system, and a control group ($n = 15$) who received no training, only evaluations. A flow diagram of the study design is presented in Fig. 1.

Outcomes

The participants' non-dominant hand was assessed with the Jebsen Taylor Hand Function Test (JTHFT) while grip and pinch strength were assessed with pinchmeter and Jamar hand dynamometer. All measurements were performed at baseline and after 8 weeks.

Jebsen Taylor Hand Function Test (JTHFT)

Manual skills were the main outcome. The JTHFT was used to evaluate the broad aspects of hand function commonly performed in daily activities and to provide quantitative measurements of standard activities [8]. JTHFT consists of seven timed subtests: writing, card turning, picking up small common objects, simulated feeding, stacking checkers, moving light objects and moving heavy objects [9]. The time to complete each subtest was recorded in seconds. The time for each subtest was determined along with the total time to complete all tasks.

Jamar® hand dynamometer

Handgrip strength was evaluated with a Jamar® hand dynamometer, which measures isometric muscle contraction for dominant and non-dominant hands. Measurements were made as recommended by the American Society for Hand Therapists, with the participant seated, shoulder in adduction, elbow flexed at 90°, forearm in neutral position [10].

Pinchmeter

A pinchmeter was used to measure finger grip strength. Three types of grips were evaluated with a pinchmeter in the non-dominant hand: fingertip grip strength with the end portions of the 1st and 2nd

Table 1
Demographic features of the participants.

Demographic features	ErgoActive group $n = 15$	Control group $n = 15$	P
Sex, n *(%)*			0.550
Female	13 (86.7)	1 (6.7)	
Female	2 (13.3)	14 (93.3)	
Age (years)	19.86 (1.45)	19.73 (1.16)	0.310
Mean (SD)			0.148
Dominant side, n *(%)*			
Right	11 (73.3)	14 (93.3)	
Left	4 (26.7)	1 (6.7)	

SD: standard deviation

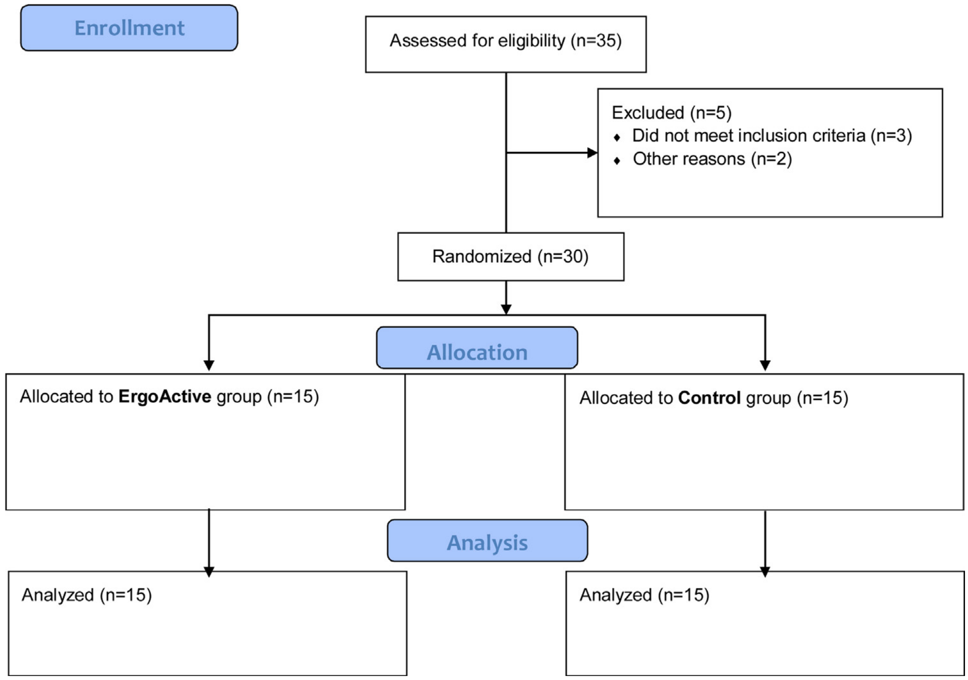


Fig. 1. Flow diagram summarizing the study design.

fingers, key grip strength with the tip of the 1st finger and the lateral aspect of the 2nd finger, triple grip strength with the tip portions of the 1st, 2nd and 3rd fingers. The test was repeated three times. The average value in these three grip types was recorded as a kilogram force [11].

Intervention

The training program for the ErgoActive group consisted of one 30-minute session once a week for 8 weeks with the non-dominant hand. Researchers developed two rehabilitation games: "Masterchef" and "Hold-and-Put" using LMC as part of a research project (Fig. 2). The games were developed on a single platform called ErgoActive. The aim of these games was to develop manual skills and fine motor skills (supported by the Scientific and Technological Research Council of Turkey with project number: 1919B011800515). Manual skills are trained during these games, which include many types of grip, such as light circumferential flexion grip and standard grip. The participants trained on these games during each session. The way to play the games and the performance criteria were explained in detail to the participants.

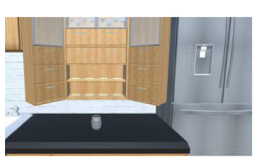
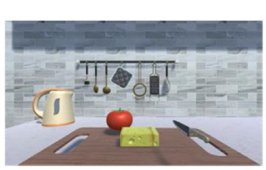
Game	Grip type	Success criteria
Hold-and-Put 	Standard	• Hand opens to grasp the cup • Cup is held diagonally in the palm of the hand, with the fingers wrapped around the cup • Participant brings the cup to the shelf • Fingers extend and release the cup
MasterChef 	Light circumferential flexion	• Participant grasps the egg. DIP and PIP joints are flexed approximately 30° and thumb is abducted. Force is generated by the thumb and other fingers. • Participant extends his/her fingers and places the egg in a pan

Fig. 2. Games designed for LMC-based VR training.

Table 2
JTHFT scores before and after VR training.

	ErgoActive group $n = 15$			Control group $n = 15$			P^b
	Before	After	P^a	Before	After	P^a	
JTHFT, total	74.99 (12.68)	61.93 (7.59)	0.001	67.44 (9.0)	65.87 (7.91)	0.733	0.003
Writing	31.69 (8.92)	24.17 (6.36)	0.002	28.87 (7.89)	27.41 (6.65)	0.427	0.012
SPT	5.71 (1.34)	4.70 (0.72)	0.017	4.81 (0.85)	4.99 (0.92)	0.348	0.17
PO	8.20 (1.57)	8.06 (1.03)	0.733	7.39 (1.12)	8.0 (1.51)	0.173	0.254
SF	15.92 (5.76)	14.27 (2.91)	0.496	15.22 (2.62)	14.38 (1.94)	0.281	0.983
SC	3.72 (1.10)	3.29 (1.32)	0.222	3.09 (0.56)	3.02 (0.65)	0.394	0.372
MLO	4.93 (0.73)	3.745 (0.46)	0.001	4.01 (0.43)	3.98 (1.0)	0.427	0.001
MHO	4.80 (0.61)	3.66 (0.490)	0.001	4.06 (0.43)	4.05 (0.42)	0.426	0.000

JTHFT: Jebsen Taylor Hand Function Test total score; SPT: simulated page turning; PO: picking up small common objects; SF: simulated feeding; SC: stacking checkers; MLO: moving light objects; MHO: moving heavy objects.
[a] Intragroup comparison (Wilcoxon test).
[b] Intergroup comparison (Mann Whitney U test).

Statistical analysis

The SPSS statistical package (version 21; SPSS Inc, Chicago, IL) was used for data analysis. The data normality was determined using the Shapiro-Wilks test ($P < 0.05$). The Wilcoxon test was used to compare the score change between baseline and the 8-week visit in both groups. The Mann Whitney U test was used compare the outcomes between the groups after 8 weeks.

Results

The ErgoActive group had significantly better results on the JTHFT tasks of writing, card turning, light object lifting and heavy object lifting after 8 weeks of VR training than at baseline ($P < 0.05$). The ErgoActive group was faster in the writing, moving light objects and moving heavy objects tasks after VR training than the control group ($P < 0.05$). When the changes in total score were examined, there was a significant difference between groups after 8 weeks ($P < 0.005$). JTHFT scores before and after training are presented in Table 2.

Handgrip strength was significant better in the ErgoActive group after their 8 weeks of training ($P < 0.05$). The ErgoActive group also had statistically better grip strength after VR training than the control group ($P < 0.01$).

After VR training, the tip grip and triple grip were statistically improved in the ErgoActive group ($P < 0.05$). The tip grip and triple grip evaluations were significantly better in the ErgoActive group than the control group ($P < 0.05$). However, there was no significant difference between groups in the key grip ($P > 0.05$). Grip strength scores before and after training were presented in Table 3.

Discussion

The aim of this study was to determine whether training performed on VR games would be effective at improving non-dominant hand skills and grip strength in healthy individuals. In particular, the first objective was to prove the effectiveness of VR games on hand function in healthy individuals and to increase our understanding of the usability of this type of training to guide future clinical use. The second objective was to evaluate the usability of games developed for grip skills in rehabilitation and to obtain preliminary data for expectations and preferences about VR games in hand rehabilitation.

Chiu et al. compared groups at 6 weeks and 12 weeks to determine the short- and long-term effects of VR games on hand function. No significant difference was found between groups after 6 weeks and 12 weeks [12]. Hence, the 8-week training period in our study is consistent with this time frame.

Tarakci et al. conducted a randomized controlled trial evaluating the effectiveness of the 8-week LMC-based therapy (LMCBT) upper extremity rehabilitation program, comparing conventional rehabilitation to VR-based training in children with physical disabilities. They found significant improvement in upper extremity functions in all LMCBT and conventional rehabilitation groups [13]. The methods and sensors used in our study were similar to that study. Also, games aimed at manual skills used in the two training methods are similar. In both studies, JTHFT was found to be significantly faster than the total time at baseline for the ErgoActive group, and individuals were able to complete activities in less time.

Gonzalez et al. designed a randomized controlled trial involving 23 Parkinson's patients that compared LMC-based VR training with conventional therapy. While there were no improvements in grip strength, significant improvements in functional abilities with the Box and Blocks Test and the Purdue Pegboard Test were observed after VR training [14]. These findings and ours suggest that LMC-based VR training has a positive effect on hand grip strength.

Luna-Oliva et al. conducted a study of hemiplegic and diplegic cerebral palsy patients between the ages of 4 and 11 who were given two 30-minute VR sessions per week for 8 weeks. In their study using the Xbox One Kinect, JTHFT decreased in all subtests except for moving heavy objects [15]. Considering this significant difference, the positive change in JTHFT supports using LMC-based VR games to improve manual skills.

Table 3
Grip strength before and after VR training.

	ErgoActive group			Control group			P^b
	Before	After	P^a	Before	After	P^a	
Hand grip	24.60 (6.38)	28.26 (7.36)	0.001	20.26 (6.54)	20.93 (6.49)	0.025	0.001
Tip grip	2.26 (0.72)	3.13 (1.17)	0.001	2.76 (0.65)	2.63 (0.78)	0.339	0.000
Key grip	5.10 (1.32)	5.70 (1.29)	0.10	4.86 (0.97)	5.23 (0.82)	0.19	0.451
Triple grip	3.73 (1.26)	4.56 (1.38)	0.003	3.66 (0.83)	3.40 (0.82)	0.33	0.000

[a] Intragroup comparison (Wilcoxon test).
[b] Intergroup comparison (Mann Whitney U test).

Studies have reported a relatively high accuracy of LMC for determining finger and hand positions and movements [16]. Thanks to this sensitivity, participants reported that finger and hand movements could be transferred into daily living activities that require different types of grip.

It is highly restrictive to purchase various materials needed for these VR environments in clinical settings. However, an LMC-based VR system is cost-effective and portable. It also offers individuals an environment where they can perform safe activities during their training sessions. It is important that participants who are successful in VR activities can transfer these performances to a real environment such as home. Good occupational therapy training can be achieved by transferring the learned activities to daily life.

It is assumed that the VR-based training protocol on the Rehabilitation Gaming System (RGS) creates conditions that help recovery through the human mirror neuron system. In their RGS study, Prochnow et al. sought to test this hypothesis by identifying the areas of the brain involved in controlling the capture of the approaching colored balls in the virtual RGS environment. In agreement with their working hypothesis, these findings showed the engagement of brain areas believed to represent the human mirror neuron system [17].

In their study, Moseley et al. sought to test whether the mirrors for treating pain can be used to induce increased neck or other spine movements, and whether this illusion can be achieved using VR. They showed that VR could produce movements similar to the body illusion underlying mirror therapy for imaginary limb pain and chronic pain. The statistical significance also confirmed this [18]. In our study, we suggest that these perceived movements could be used in hand rehabilitation.

We observed good motivation, which is one of the biggest advantages of the VR system used, as evidenced by the high percentage of adhesion to the training. One participant stated that after she started the VR-supported practice, she frequently used her non-dominant hand while applying makeup and started to do so without realizing it.

The results of the VR training support our hypothesis. We believe that LMC technology will be useful because of its compact size, high performance and precision, and because it offers the opportunity to implement human-machine interaction training into daily living activities. In accordance with our philosophy, this system will continue to be designed to train essential movements for rehabilitation and provide performance feedback to users and clinicians.

Based on our findings, it can be said that LMC-based VR games can be used as an effective and fun training method for improving non-dominant hand function that can be integrated in the rehabilitation protocol.

Some limitations of the study are the small sample size and the low intensity of the training sessions. Follow-up evaluations should be made after the training and user opinions should be recorded. Further studies should also investigate whether the results obtained with VR games can be maintained over a long period of time. A larger sample group should be used in future studies to confirm the preliminary results of this study.

Conclusion

This study quantitatively demonstrated that VR games could be effective at improving non-dominant hand function. These VR games provided a stimulating and fun environment, using the interests and motivations of the participant and working with task and activity-based techniques. LMC-based VR is easy to use, portable and inexpensive for occupational therapy sessions.

Disclosure of interest

The authors declare that they have no competing interest.

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