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WIRTUALNA RZECZYWISTOŚĆ W REHABILITACJI NIEDOWŁADNEJ KOŃCZYNY GÓRNEJ U PACJENTÓW PO UDARZE MÓZGU

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STRESZCZENIE

Wstęp

Udar mózgu jest ważną jednostką chorobową ze względu na liczne zachorowania i dużą śmiertelność wśród pacjentów. Wciąż poszukuje się nowych rozwiązań w procesie leczenia, w tym też nowych sposobów rehabilitacji. Wykazano, że w celu poprawy funkcji sensomotorycznych, utraconych na skutek udaru mózgu, korzystne jest wprowadzenie, do tradycyjnej rehabilitacji, innowacyjnej technologii komputerowej, zwanej terapią wirtualną bądź wirtualną rzeczywistością (VR).

Cel

Celem niniejszej pracy jest ocena efektywności wirtualnej rzeczywistości w leczeniu usprawniającym niedowładnej kończyny górnej u chorych po udarze mózgu.

Materiał i metody

Autorzy dokonali analizy doniesień naukowych, dotyczących rehabilitacji kończyny górnej u chorych po udarze mózgu, opublikowanych w PUBMED od początku 2014 do połowy 2017r.

Wyniki

Po przeanalizowaniu dostępnych prac stwierdzono, że znacząca większość wyników (32 z 35 prac) wykazała pozytywne działanie metod rehabilitacji przy użyciu VR w procesie usprawniania po udarze mózgu.

Wnioski

Możliwości rehabilitacji w oparciu o VR u pacjentów po udarze mózgu nie są jeszcze dostatecznie poznane. Zdaniem autorów istnieje konieczność prowadzenia dalszych badań z wykorzystaniem ustandaryzowanych protokołów tak aby grupy pacjentów były duże, jak najbardziej homogenne a zastosowane technologie umożliwiały porównanie między ośrodkami badawczymi. Pozwoli to na rzetelne potwierdzenie skuteczności klinicznej VR w rehabilitacji.

Słowa kluczowe: wirtualna rzeczywistość, udar mózgu, rehabilitacja, kończyna górna

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VIRTUAL REALITY IN PARETIC UPPER LIMB REHABILITATION OF STROKE PATIENTS

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SUMMARY

Introduction
Due to high incidence and mortality, stroke is a very important medical condition. New therapeutic approaches are sought, including new rehabilitation strategies. An innovative computer-assisted technology known as virtual therapy or virtual reality (VR) has been found to beneficially improve sensorimotor function lost due to stroke.
Aim
The objective of this paper is to evaluate the effectiveness of virtual reality in the rehabilitation of the paretic upper limb in stroke patients.
Material and Methods
Authors reviewed over 150 reports published in PUBMED between early 2014 and mid-2017 and selected only these connected with rehabilitation of upper limb in post- stroke patients.
Results
It was found in the review of available reports that a vast majority of results (in 32 out of 35 papers) showed positive effects of VR-based rehabilitation methods after stroke.
Conclusion
The potential of VR-based rehabilitation is yet to be fully elucidated in stroke patients. Further studies based on standardized protocols are needed to achieve large sizes of possibly homogeneous samples and the technologies used should enable comparison between centers. This will allow to reliably confirm clinical efficacy of VR in rehabilitation.

Keywords:virtual reality, stroke, rehabilitation, upper limb

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INTRODUCTION

Stroke is one of the major causes of central nervous system (CNS) conditions. Due to a high mortality rate as a result of a cerebrovascular event, stroke is the third most frequent cause of death in adults both in Poland and worldwide (Kiper et al. 2013). Between 65,000 and 75,000 new cases of stroke are reported annually in Poland, and the mortality rate is one of the highest (80/100,000/year) without any decreasing trend (Członkowska et al. 2002). The consequences of stroke involve significant impairment or loss of sensory and motor function, which results not only from the injury but also from impaired functional integrity of respective centers in the brain. Studies have shown that intensive neurological rehabilitation (repeated exercises that target precisely the sensorimotor deficits) may be beneficial to restore the functions lost. This is due to the activation of the neuroplasticity mechanism in the affected brain areas.
The term neuroplasticity was coined by Jerzy Konorski, a Polish researcher (Konorski 1948; Konorski 1969). Brain plasticity (neuroplasticity, cortical plasticity) is an ability to undergo permanent structural and functional changes as an effect of information being

processed (experience). Neuroplasticity is an underlying mechanism of learning and memory, and developmental and compensatory changes following brain injury. Brain structures constantly and smoothly respond to changes in the environment. Centers associated with specific functions may adjust their location as a result of structural rearrangement influenced by normal function or injury. Synaptic plasticity, the neuronal ability to modify mutual communication, is believed to be the most vital cerebral plasticity mechanism. The rearrangement involves processes, such as changes in neuronal structure, axon growth and dendrite branching; in addition, new synapses form, cell secretory profiles are adapted and receptor expression is affected. Changes in the function of specific neurons are the ultimate result of this rearrangement (Kossut 2000; Wieloch et al. 2006; Bonfanti et al. 2011).

It has been shown that combination of conventional rehabilitation with innovative computer-assisted technology known as virtual therapy or virtual reality (VR) beneficially improves sensorimotor function (Kiper et al. 2014; Laver et al. 2015; Luque-Moreno et al. 2015).

Virtual reality is a pattern of artificial reality (objects, living creatures, space and events that exist in computer memory only), created using information technologies. It is interactive in real time and provides 3D movement simulation. Intensive development of research into VR applications in neurorehabilitation has been seen for approx. 15 years. The International Society for Virtual Rehabilitation (ISVR), which aims to provide a platform for understanding and collaboration between engineers, researchers and clinicians interested in new technologies that promotes motor, psychiatric, cognitive and social rehabilitation, was founded in 2009. The principles of VR-assisted rehabilitation are meant to enable selection of specific tasks in an attractive form so that skills and functions learnt in artificial conditions could be used in the real world (Fluet et al. 2013). The current state of knowledge assumes that training must be a challenge, exercises should be repeated and based on specific tasks and should motivate patients; they should be clear with adequate intensity to stimulate self-repair of the nerve tissue as much as possible (Bojan et al. 2002; Saposnik et al. 2011). Virtual reality is the tool that seems to fulfill all these prerequisites.

Rehabilitation based on VR requires modern technologies, such as specialized computer software or video game consoles as well as devices that display images and collect information about the patient's movement.

VR display devices are divided into two groups. The first one includes traditional displays, such as flat screens, computer monitors (Shin et al. 2014; Saposnik et al. 2016) and LCD screens (Colomer et al. 2016). CAVE (cave automatic virtual environment) systems are a variant of this type, with stereoscopic images displayed on the walls and floor of a cuboid room. 3D glasses are needed for anyone in the room to see the images properly (Sveistrup 2004). The other group are head mounted displays (HMD) fitted in special glasses or helmets (Trojan et al. 2014).

Equipment that senses the patient's movement and ensures biofeedback based on visual, tactile and acoustic stimuli is needed for therapy. This includes movement detectors so that the patient can interact with the console or computer through an interface that uses gestures based on the limbs and the whole body. Movements are recorded in 3D in real time through synthesis of data from accelerometers, gyroscopes and 3D cameras. Certain systems also feature sound systems that record and analyze sounds, and thus interpret voice commands. Sometimes, sounds can also be produced, and the patient may be more immersed in virtual reality.

More extended VR systems generate tactile sensations, such that the patient seemingly touches objects of various hardness or textures or else feels mechanic resistance (Ferche et al. 2015).

Two types of VR are known based on the kinds of display equipment: immersive VR and non-immersive VR. The system used, and first of all the kind of display and the avatar, dictates which type of VR is available. Immersive VR means that the patient has a high-level feeling of being in the virtual world. This is ensured by HMDs in which the patient sees the virtual world only, being isolated from the external environment as much as possible (Nalivaiko et al. 2015). High immersion also means that the patient sees on the display an avatar that recreates the patient's own movement (Garipelli et al. 2016). With non-immersive VR, flat views of 3D images are generated by screens and projectors. Together with virtual reality, the patient also sees the real environment and records signals from both the external and virtual reality (Colomer et al. 2016; Saposnik et al. 2016).

No matter what system is used, the computer memory stores all data on how the patient completes tasks. The results are recorded in the database, available to the therapist both during and after exercises.

AIM

The objective of this paper was to evaluate the effectiveness of virtual reality in the rehabilitation of the paretic upper limb in stroke patients.

PATIENTS AND METHODS

Reports published in PUBMED between early 2014 and mid-2017 were reviewed, that is, after the review of Laver et al. (2015) with a summary of reports on the application of VR technology in neurorehabilitation before late 2013. The following keywords were used in the search: virtual reality, stroke, rehabilitation, upper limb, extremity.

RESULTS

A number of researchers attempted the evaluation of VR effectiveness in neurorehabilitation. A review by Laver et al. was published in 2015 that summarized research reports available in more than ten databases (Cochrane Stroke Group Trials Register, Cochrane Central Register of Controlled Trials, MEDLINE, EMBASE, AMED, CINAHL, PsycINFO, PsycBITE, OTseeker, COMPENDEX, INSPEC) between 1950 and late 2013. Metaanalysis included reports that evaluated VR-based rehabilitation or compared the efficacy of standard methods against VR-based methods. Laver et al. analyzed 37 (with a total of 1019 patients) out of 8244 reports on the use of VR in neurorehabilitation. These reports fulfilled the inclusion criteria of functional assessment of the upper limb and activities of daily living (ADL), and also functional assessment of the lower limb, gait and cognitive functions. The results showed statistically significant effectiveness and superiority of VR-based rehabilitation compared to standard rehabilitation strategies related to upper limb function and ADL, but no effect in terms of increased grip strength, walking pace or balance or cognitive functions was revealed. The highest effectiveness of both standard and VR-based rehabilitation was seen in the first six months after stroke, in particular in patients with mild to moderate disability (Pakaratee et al. 2012; Laver et al. 2015). The limitations of VR discussed in Laver at al. include first of all a small size of study groups and scarcity of studies that would probe into long-term therapeutic effects. In addition, few reports only concerned gait and cognitive functions (Lo et al. 2017).

We evaluated the reports on VR-based rehabilitation published in PUBMED between early 2014 and mid-2017. The review included 150 reports on VR in stroke rehabilitation, and only those were selected that addressed upper limb rehabilitation in stroke patients (a total of 35 reports). The assessment included upper limb function in terms of ADL, muscle strength and manual dexterity.

When the available reports were evaluated, the results in 32 reports showed beneficial effects of VR-based rehabilitation, of which five reports showed comparable effects of VR to traditional rehabilitation methods. Three reports revealed no effect of rehabilitation through VR methods. Table 1 lists the reports.

Table 1. A list of the evaluated reports

No.	Author	Date	Group size	Time after stroke (phase)	Statistical significance ($p < 0.05$)	Effect of VR
1	Hoermannet al.	2017	17	subacute	yes	positive
2	Stockleyet al.	2017	12	chronic	yes	positive
3	Maris et al.	2017	14	chronic	yes	negative
4	Grimm et al.	2016	5	chronic	yes	positive
5	Brunner et al.	2016	50	subacute	yes	positive
6	Patel et al.	2016	5	acute	yes	positive
7	Lledó et al.	2016	9	chronic	yes	positive
8	Wittmannet al.	2016	11	chronic	yes	positive
9	Lee et al.	2016	10	subacute	yes	positive
10	Grimm et al.	2016	18	chronic	yes	positive
11	Lee et al.	2016	18	chronic	yes	positive
12	Taveggiaet al.	2016	54	chronic	yes	positive, comparable to standard rehabilitation
13	Saposniket al.	2016	141	chronic	yes	positive, comparable to standard rehabilitation
14	Choi et al.	2016	24	chronic	yes	positive
15	Kong et al.	2016	105	subacute	yes	negative
16	Kutlu et al.	2016	6	chronic	yes	positive
17	Shin et al.	2016	46	chronic	yes	positive
18	Paquin et al.	2016	10	chronic	yes	positive
19	da Silva et al.	2015	30	chronic	yes	positive
20	Kottink et al.	2015	20	chronic	yes	positive, comparable to standard rehabilitation
21	Mousavi et al.	2015	18	chronic	yes	positive
22	Fluet et al.	2015	21	chronic	yes	positive, comparable to

						standard rehabilitation
23	Levin et al.	2015	12	chronic	yes	positive
24	Paquin et al.	2015	16	chronic	yes	positive
25	Tsoupikova et al.	2015	6	chronic	yes	positive
26	Thielbar et al.	2014	14	chronic	yes	positive
27	Tsekleves et al.	2014	3	chronic	yes	positive
28	Choi et al.	2014	20	subacute	yes	positive, comparable to standard rehabilitation
29	Standen et al.	2014	17	chronic	yes	negative
30	Bao et al.	2014	5	subacute	yes	positive
31	Kiper et al.	2014	44	chronic	yes	positive
32	Jordan et al.	2014	13	chronic	yes	positive
33	Shin et al.	2014	6+16	chronic + acute and subacute	yes	positive
34	Rand et al.	2014	29	chronic	yes	positive
35	Lee et al.	2014	24	chronic	yes	positive

DISCUSSION

Upper limb function is an important aspect of overall skills, which affects the quality of life. Therefore, impaired upper limb function in stroke patients should be one of the key objectives of comprehensive rehabilitation (Saposnik et al. 2011). This is all the more important as clinical practice and literature reports show that upper limb dysfunction persists for much longer than lower limb dysfunction in this group (Kiper et al. 2014). Therefore, this is the focus of the potential related to new types of targeted therapies, in particular based on VR (Laver et al. 2015).

It is quite interesting that 35 reports only published recently and retrieved from the database address the improvement of paretic upper limb function owing to VR. This may result from the low availability of such methodologies in clinical practice or rather insufficient knowledge of medical practitioners (PMR doctors) and physiotherapists about their potential.

The review of the reports clearly shows that VR-based therapy is indeed effective in stroke patients with a paretic upper limb. However, most studies included a relatively short period of rehabilitation assessment, and the study groups were rather small (three reports only included more than 50 subjects).

The 35 papers evaluated various aspects of upper limb performance, range of movement, grip strength, various grip types, movement precision and coordination and ADL score. As the study groups were small, with the multitude of functions evaluated and varied inclusion and exclusion criteria, it is difficult to estimate the potential applicability of VR in clinical practice and what long-term effects should be expected. Therefore, study protocols and patient management during rehabilitation should be standardized.

In our opinion, upper limb performance evaluation should be based first of all on limb usability in activities of daily living, because this seems to be the crucial objective of rehabilitation, no matter what technology is used.

CONCLUSIONS

The potential of VR-based rehabilitation is yet to be fully elucidated in stroke patients. We believe that further studies based on standardized protocols are needed to achieve large sizes of possibly homogeneous samples and the technologies used should enable comparison between centers. In addition, the inclusion period, duration and intensity of VR-based rehabilitation should be normalized. Furthermore, follow-up needs to be scheduled to evaluate the durability of effects after a longer period, such as 6, 12 and 24 months, after the end of treatment. This will increase the credibility and reliability of research as much as possible so that the ultimate results are widely applicable and could be used in stroke therapy worldwide.

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