Article published online: 2024-07-04

Original Article

Cognitive Outcomes following Virtual Reality Rehabilitation in Patient with Traumatic Brain Injury: A Prospective Randomized Comparative Study

Ankit Sharma[1] Arvind Sharma[1] Surendra Jain[1] Ashok Gupta[1] Virendra Deo Sinha[2]

[1] Department of Neurosurgery, S. M. S. Medical College and Hospital, Jaipur, Rajasthan, India
[2] Department of Neurosurgery, Santokba Durlabhji Memorial Hospital, Jaipur, Rajasthan, India

Address for correspondence Surendra Jain, MBBS, MS, MCh, Department of Neurosurgery, SMS Medical College, Jaipur, Rajasthan 302004, India (e-mail: simplesogani@gmail.com).

Indian J Neurotrauma

Abstract

Introduction Comprehensive rehabilitation is essential to enhance the quality of life and cognitive performance of traumatic brain injury (TBI) survivors. Virtual reality (VR) has emerged as a promising tool for TBI rehabilitation due to its ability to provide an engaging and tailored environment.

Materials and Methods This was a randomized comparative study conducted at tertiary hospital and included individuals aged between 18 and 60 with mild-to-moderate cognitive impairment due to TBI. The participants were divided into a case group receiving intensive VR rehabilitation and a control group receiving standard care. Cognitive assessments were conducted before and after treatment, and during follow-up.

Results VR rehabilitation demonstrated significant improvements in cognitive function. The VR group exhibited remarkable progress in the Montreal Cognitive Assessment (MoCA), Tower of London (TOL), and Trail Making Test (TMT) scores. Baseline MoCA, TOL, and TMT scores (mean value) of case group 16.5, 11.75, and 14.05 and for control group 17, 10, and 13 were respectively. All the parameters of case group improved at the time of discharge (MoCA: 24.3, TOL: 22, TMT: 27.5) and in follow-up (MoCA: 28.5, TOL: 32.5, TMT: 42.07) as compared with control group at discharge (MoCA: 19, TOL: 13, TMT: 17) and in follow-up (MoCA: 21, TOL: 15, TMT: 19), which shows significant improvement in case group ($p < 0.001$) as compared with control group.

Conclusion VR rehabilitation significantly improves cognitive outcomes in TBI patients. It has the potential to be a significant tool in TBI rehabilitation.

Keywords
- traumatic brain injury
- virtual reality
- rehabilitation
- Montreal cognitive assessment
- cognitive function

Introduction

Traumatic brain injury (TBI) is a medical condition that causes brain damage after receiving an external, powerful, and violent head injury (such as a fall from a height, a sports injury, or a car accident) or having an object to penetrate the skull (i.e., bullets). TBI causes the majority of long-term disabilities and fatalities in young adults, and it is a major socioeconomic and healthcare burden.[1,2] Priority should be given to managing TBI patients through an integrated,

DOI https://doi.org/10.1055/s-0044-1778735.
ISSN 0973-0508.

tailored, thorough diagnostic, treatment, and rehabilitation program. Following a TBI, behavioral alterations and aberrant cognitive function are caused by modifications of neurotransmitter and neuroendocrine activity.[3] Executive function, problem-solving, memory, and attention are just a few of the cognitive problems that a TBI can lead to. Impaired daily living activities are regarded as executive function impairment, which is a predictive marker for rehabilitative activities. There is a shortage of comprehensive rehabilitation services in many developing nations, including India, as well as a lack of knowledge about rehabilitation and its solutions. This makes it more difficult for post-TBI survivors to work and stresses out carers. To improve both quality of life and cognitive performance after a TBI, rehabilitation is essential.

Many studies have shown the potential efficiency of cutting-edge methods, such as virtual reality (VR), during the various phases of rehabilitation following a TBI.[4–6] A computer-based solution known as VR produces artificial settings with special sensory stimuli that may be interacted with in real time.[7] VR can be nonimmersive, where virtual content is displayed on a computer screen using conventional interfaces, or immersive, where virtual content is typically displayed by a head-mounted display (giving the user the impression that he or she has entered the computer-generated artificial world). Finding items and performing tasks in VR can mimic the ecological needs of the real world, which can enhance the brain's capacity for plasticity and regeneration processes.[6] VR has been demonstrated to boost cognitive functions in TBI patients as a rehabilitation technique. Moreover, it increases motivation and enjoyment, two crucial elements for effective rehabilitation exercise and adherence.[8] In short, VR offers a fun, interactive environment that can improve patient compliance and the effectiveness of rehabilitation itself. It can also be tailored to the specific needs of the patient.

This study was conducted to evaluate the role of VR rehabilitation in cognitive assessment and rehabilitation in individuals affected by TBI and to observe whether the benefits of in-patient VR rehabilitation are sustainable by assessing the patients in follow-up examination a minimum after 1 month of discharge.

Materials and Methods

After obtaining institutional ethical committee approval, this randomized prospective comparative study was conducted from July 1, 2021, to December 31, 2022. The patients were enrolled in the study after obtaining informed and written consent. No extra financial burden would be incurred for the patient.

A total 80 patients with TBI after obtaining written and informed consent were enrolled in study. Patients with following characteristics were included: Aged between 18 and 60 years, ability to sit for at least 15 minutes (Including at least 1 minute without support), presence of mild-to-moderate cognitive impairment (Montreal Cognitive Assessment [MOCA] from 10 to 26). Patients with global aphasia, poor comprehension, and comorbidities interfering with rehabilitation, known case of psychiatric or central nervous system pathology or medical and surgical disease that interfere with the study and patient with multiple injuries that interfere with the uses of VR user interface were excluded from the study.

Methodology

The rehabilitation program was started on patients with a history of TBI after completing the initial clinical assessment within 48 hours of admission. After obtaining their written informed consent, all patients were evaluated with detailed clinical examination, and sociodemographic, educational, current neurological and radiological and biochemical data were recorded. Assessment of motor, cognitive and functional outcomes was done at three points: prior training, after 15 days, and after 1 month (follow-up).

All patients were divided into case and control groups randomly; the control group received standard care that includes antiepileptics, analgesics, and physiotherapy focused to improve locomotion, spasticity reduction, balance improvement, positioning, resistive, and stretching exercises and graded gait training and for tic-tac-toe, matchmaking and Sudoku like exercises for cognitive rehabilitation. At the time of discharge, these patients were advised home-based program and asked to report for follow-up after 15 and 30 days from the date of TBI.

All patients in the case group received standard care similar to the control group along with intensive VR training sessions once a day for 6 days a week; first session was conducted after 2 days of admission. Each VR session was a one-on-one session, using the patient-centered approach with the level of individual task difficulty varied according to the participant's level of performance; each session was conducted with a registered clinician

There were three different VR exercises and each exercise had 10 difficulty levels and it scores were according to patient performance ranging from 1 to 3 stars. If the patient got 2 or more than 2 stars, then only he proceeded to the next level; otherwise he shifted to another exercise for that particular VR session.

Outcome Measures

Each participant was assessed using neuropsychological evaluation before the training, at the time of discharge and during the follow-up by using the MOCA and a group of tests that include the Tower of London (TOL) test, trail-making test, and go and no go test to assess cognitive function.

1) **Montreal Cognitive Assessment:** MOCA was a screening tool for cognition and is found to be more sensitive and specific for the detection of mild cognitive deficits compared with Folstein mini–mental state examination.[9] MOCA tests visuospatial executive, naming, memory, attention, language, abstraction,

delayed recall and orientation aspects of cognition. The total MOCA score was calculated by summing the score of all domains from 0 to 30. Scores less than 10 indicate severe, 10 to 17 moderate, and scores between 18 and 26 suggestive of mild impairment. A score more than 26 is interpreted as normal cognition.

Patient with MOCA score ranging from 10 to 26 was included in the study and was further assessed by a group of quantitative cognitive and functional assessment tests that include the TOL test and trail-making test; these group of tests will be done by another clinician to reduce the bias.

2) Tower of London test: The TOL was a test used for the assessment of executive functioning specifically to detect deficits in planning.[10,11] The TOL test includes transferring three-colored disks between three vertical rods, from an initial position to a prespecified goal arrangement. Solving the TOL problem within a limited number of moves requires planning the sequence of action before starting to move the discs. It is, therefore, considered a planning test.

3) Trail-making test: This test can provide information about visual search speed, scanning, speed of processing, mental flexibility, as well as executive functioning.[12] Trail-making requires a subject to connect a sequence of 25 consecutive targets on a sheet of paper or computer screen.

Data Analysis

Numerical variables were summarized as mean and standard deviation and were analyzed by using various parametric tests. Nominal/categorical variables were presented as proportions and were analyzed using the chi-squared test and other suitable nonsuitable, nonparametric tests.

p-Value less than 0.05 would be considered statistically significant.

Table 1 Sociodemographic characteristics of study population

Characteristic	Case	Control	*p*-Value
Total n	40	40	–
Age, years (mean)	49.73 (9.05)	56.5 (7.13)	0.43
Male (%)	28	27	0.9
Female	22	23	
Education			
Up to primary (1–5th)	12	14	0.71
Up to Sr. secondary (6–12th)	9	7	
Graduation	8	5	
Professional	5	5	
Home maker	6	9	

Table 2 Clinical characteristics of study population

Characteristic	Case	Control	*p*-Value
Total, *n*	40	40	–
Injury Severity			0.37
Mild (%)	25	13	
Moderate (%)	10	25	
Severe (%)	5	2	
Mode of injury			0.61
Falls	19	18	
Motor vehicle accident	21	22	
Time since trauma (in hours)	7.1 ± 6.7	7.25 ± 6.8	0.917
Lesion site			0.84
Right	11	13	
Left	29	27	

Results

Sociodemographic characteristics of study population: In ►**Table 1**, the mean age of cases was 49.73 years, and the mean age of control was 56.17 years. Both in cases and control, there was male preponderance. Their education level shows no significant difference.

Clinical characteristics of study population: As described in ►**Table 2**, our study showed maximum prevalence of mild injury, followed by moderate and then severe. Among cases, the major reason behind TBI was a fall in 21 patients, while among controls, the reason was motor vehicle accidents in 22 cases. Time since trauma in both cases and control had no significant difference; mean time since trauma was approximately 7 hours. In both groups, the lesion was more common on the left side of cerebral hemisphere.

Cognitive and functional score (MOCA, TOL and TMT) in patient with TBI: In ►**Table 3**, it is observed that variables MoCA, TOL, and TMT represented significant differences after VR sessions, while in the control group, there is no significant difference.

Cognitive domain score using MOCA scale: ►**Table 4** describes therapeutic use of VR had positive and significant effects on cognitive function in individuals; there was a significant improvement in the subcategories such as global cognition, executive function, language, abstraction, recall, orientation, and attention when compared with the control group.

Discussion

Current literature demonstrates that VR could be useful as a rehabilitation tool in cognitive recovery post-TBI. However, the evaluation protocols with VR have been mainly applied in mild TBI, which is difficult to evaluate with traditional tools. Instead, VR treatment protocols for cognitive rehabilitation

Table 3 Cognitive and functional score (MOCA, TOL, and TMT) in patient with traumatic brain injury

Variables	Groups	Mean value on admission	Mean value at discharge	Mean values at follow-up	Degree of freedom	*p*-Value
MoCA	Case	16.5	24.3	28.5	1	< 0.001
	Control	17	19	21	1	0.081
TOL	Case	11.75	22	32.5	1	< 0.001
	Control	10	13	15	1	0.061
TMT	Case	14.05 s	27.5 s	42.07 s	1	< 0.001
	Control	13 s	17 s	19 s	1	0.068

Abbreviations: MoCA, Montreal Cognitive Assessment; TMT, Trail Making Test; TOL, Tower of London.

Table 4 Cognitive domain score using MoCA scale

Cognitive subdomains	Descriptive statistics	Admission	Discharge	Follow-up	*p*-Value
Visuospatial/Executive	Case	0.5 ± 0.23	0.81 ± 0.15	0.96 ± 0.08	0.041
	Control	0.48 ± 0.18	0.51 ± 0.09	0.59 ± 0.08	0.82
Naming	Case	0.64 ± 0.14	0.7 ± 0.16	0.84 ± 0.08	0.002
	Control	0.63 ± 0.09	0.64 ± 0.12	0.65 ± 0.01	0.72
Attention	Case	0.76 ± 0.19	0.77 ± 0.15	0.99 ± 0.03	0.004
	Control	0.75 ± 0.18	0.75 ± 0.12	0.78 ± 0.15	0.91
Language	Case	0.65 ± 0.13	0.68 ± 0.15	0.84 ± 0.05	0.048
	Control	0.62 ± 0.14	0.64 ± 0.14	0.71 ± 0.16	0.062
Abstraction	Case	0.68 ± 0.18	0.71 ± 0.19	0.82 ± 0.21	0.001
	Control	0.67 ± 0.14	0.64 ± 0.12	0.68 ± 0.16	0.92
Delayed recall	Case	0.71 ± 0.21	0.75 ± 0.24	0.81 ± 0.26	0.037
	Control	0.69 ± 0.14	0.71 ± 0.14	0.71 ± 0.16	0.91
Orientation	Case	0.72 ± 0.19	0.75 ± 0.21	0.81 ± 0.23	0.048
	Control	0.70 ± 0.18	0.71 ± 0.18	0.73 ± 0.20	0.82

Abbreviation: MoCA, Montreal Cognitive Assessment.

are most widely used (i.e., from mild-to-severe conditions), although the efficacy of these interventions should be further explored indeed, although studies suggest that VR training can provide innovative treatment options for TBI. Hence, the study[13] was conducted to evaluate the role of VR rehabilitation in cognitive assessment and rehabilitation in individuals affected by TBI.

In our study, the mean age of cases was 49.73 years, and the mean age of control was 56.17 years. Both in cases and control, there was male preponderance. Their education level shows no significant difference. Similarly, a study by Lui et al showed more males were admitted acutely for TBI, which was consistent with other demographic studies, as male sex has been established as a risk factor for TBI.[14,15] The suggested reasons for higher TBI risk in males were related to males often participating in more risk-taking behavior, contact sports, and alcohol consumption.[16]

Similarly, a study by Liew et al[17] showed a peak incidence of TBI in elderly patients, especially those aged between 45 and 60 years, with falls being the predominant mechanism of TBI in the elderly, whereas road traffic accident was the leading cause in younger patients. This was also the case in a recent study by Liew et al that reported a shift in local TBI demographics toward an older population, with an increased incidence of falls.

The severity of injury in our study showed maximum prevalence of mild injury, followed by moderate and then severe. Among cases, the major reason behind TBI was motor vehicle accidents in 21 patients, while among controls, the reason was motor vehicle accidents in 22 cases. Time since trauma in both cases and control had no significant difference; mean time since trauma was approximately 7 hours. In both groups, the lesion was more common on the left side.

Similar results were observed in articles of Hanson et al[18], Ponsky et al,[19] and Macpherson et al[20] where motor vehicle collision are common mechanisms of TBI.

Similar data of severity were stated by McMahon et al,[21] where the majority of patients selected for VR were older patients with mild TBI. Functional impairment is prevalent in mild TBI, and studies have shown that mild TBI can result in cognitive and psychosocial impairment. Older patients with mild TBI have an increased risk of poor cognitive performance, which could explain their need for inpatient rehabilitation, despite the mild severity.

In our study, all patients in the case group received standard care similar to the control group along with intensive VR training sessions once a day for 6 days a week; first session was conducted after 2 days of admission. Each VR session had a one-on-one session, using a patient-centered approach with the level of individual task difficulty varied according to the participant's level of performance each session was conducted with a registered clinician. Virtual rehabilitation will be conducted in a private room at the hospital, free of distraction using handheld objects, the participant engaged in a virtual environment presented on an LCD screen with a built CPU by using a Tyro motion machine. The patient will interact with virtual scenarios and audiovisual stimuli, creating a multiple sensory involvement that facilitates attention, visual–spatial, memory, and executive skills. There were three different VR exercises and each exercise had 10 difficulty levels and it scored according to the patient, ranging from 1 to 3 stars.

There were several tools for VR in other studies that can be used with different costs and complexity. Currently, studies with VR use advanced and complex instruments. An example in the CAREN used by Onakomaiya et al.[22] In a study of Levy et al,[23] a VR grocery store was used as an assessment and intervention tool. However, in the study of Besnard et al[24], a nonimmersive virtual coffee task—a virtual kitchen to assess daily-life activities, was used. In a study of Canty et al,[25] prospective memory task (i.e., the VR shopping task) was used, whereas Larson et al used VR[26] and robotics technology.

In our study, it is observed that variables MoCA, TOL, and TMT represented significant differences after VR sessions, while in the control group, there is no significant difference. Therapeutic use of VR had positive and significant effects on cognitive function in individuals;, there was a significant improvement in the subcategories such as global cognition, executive function, language, abstraction, recall, orientation, and attention when compared with the control group.

Similarly, in study of Kim et al,[27] there was significant improvement in the subcategories such as global cognition (mean difference [MD] = −1.15, 95% confidence interval [CI]: −2.83 to 0.53), executive function (MD = −2.56, 95% CI: −8.94 to 3.82), working memory (MD = 0.08, 95% CI: −0.93 to 1.10), memory function (MD = −0.26, 95% CI: −0.73 to 0.22), and attention (MD = −0.61, 95% CI: −1.26 to 0.05) when compared with the control group. Our results are also similar to the results, reported in previous meta-analyses of Kim et al and Yu et al[28], which showed significant improvements in global cognition after VR. A previous meta-analysis by Zhu et al[29] showed significant improvements in executive function and memory function. However, another meta-analysis by Wu et al[30] and Zhong et al[31] reported no positive effects on memory function, execution function, and attention after VR.

Similar results were observed in the systemic review of Shin and Kim[32] where the types of VR programs that have been used in cognitive evaluations of patients with brain injury were identified and studies of cognitive interventions were reviewed according to PICO methods. In the included studies, the VR programs could distinguish the cognitive disability of patients in comparison with healthy subjects. Thus, VR could be used as a new assessment method of the cognitive function of patients with brain injury.

Hence, in this study, the therapeutic application of VR in individuals with TBI was more effective in improving cognitive function when compared with the control group; subcategories of cognitive function also showed significant improvement.

Conclusion

Therefore, by seeing the results from the following charts and tables as depicted above, we can say that in this study, the therapeutic application of VR in individuals with TBI was more effective in improving cognitive function when compared with the control group.

Limitations

Assessment of cognitive and functional outcomes was done at three points: prior training; after 15 days, and after 1 month (follow-up). However, we were not able to analyze the efficacy of a particular program in improving cognition. Study with larger sample size and with longer follow up is necessary.

Funding
None.

Conflict of Interest
None declared.

Acknowledgment
The facilities, resources, and academic environment provided by my institution were essential to the successful completion of this study. I am grateful for their unwavering support of academic pursuits. My family and friends deserve special recognition for their patience, understanding, and encouragement during the ups and downs of this research journey. Their belief in my abilities sustained my motivation. I would also like to thank the anonymous peer reviewers for their valuable feedback, which significantly improved the rigor and clarity of this paper. The work of previous scholars and researchers in this field has been a constant source of inspiration and a foundation for my research. I appreciate their contributions.

References

1 Hackenberg K, Unterberg A. [Traumatic brain injury]. Nervenarzt 2016;87(02):203–214, quiz 215–216
2 Saatian M, Ahmadpoor J, Mohammadi Y, Mazloumi E. Epidemiology and pattern of traumatic brain injury in a

developing country regional trauma center. Bull Emerg Trauma 2018;6(01):45–53
3 Rose F, Johnson D. Virtual reality in brain damage rehabilitation. Med Sci Res 1994;22:82
4 Aida J, Chau B, Dunn J. Immersive virtual reality in traumatic brain injury rehabilitation: a literature review. NeuroRehabilitation 2018;42(04):441–448
5 Zanier ER, Zoerle T, Di Lernia D, Riva G. Virtual reality for traumatic brain injury. Front Neurol 2018;9:345
6 Maggio MG, De Cola MC, Latella D, et al. What about the role of virtual reality in Parkinson disease's cognitive rehabilitation? Preliminary findings from a randomized clinical trial. J Geriatr Psychiatry Neurol 2018;31(06):312–318
7 Knight R, Titov N. Use of virtual reality tasks to assess prospective memory: applicability and evidence. Brain Impair 2009;10:3–13
8 Pietrzak E, Pullman S, McGuire A. Using virtual reality and videogames for traumatic brain injury rehabilitation: a structured literature review. Games Health J 2014;3(04):202–214
9 Trzepacz PT, Hochstetler H, Wang S, Walker B, Saykin AJAlzheimer's Disease Neuroimaging Initiative. Relationship between the Montreal Cognitive Assessment and Mini-mental State Examination for assessment of mild cognitive impairment in older adults. BMC Geriatr 2015;15:107
10 Shallice T. Specific impairments of planning. Philosophical transactions of the Royal Society of London. Series B Biol Sci 1982;298(1089):199–209
11 Phillips LH, Wynn VE, McPherson S, Gilhooly KJ. Mental planning and the Tower of London task. Q J Exp Psychol A 2001;54(02): 579–597
12 Arnett JA, Seth SL. Effect of physical layout in performance of the Trail Making Test. Psychol Assess 1995;7(02):220–221
13 Wright WG, McDevitt J, Tierney R, Haran FJ, Appiah-Kubi KO, Dumont A. Assessing subacute mild traumatic brain injury with a portable virtual reality balance device. Disabil Rehabil 2017;39 (15):1564–1572
14 Lui SK, Fook-Chong SMC, Teo QQ. Demographics of traumatic brain injury and outcomes of continuous chain of early rehabilitation in Singapore. Proceedings Singapore Healthcare 2020;29(01):33–41
15 Langlois JA, Rutland-Brown W, Thomas KE. Traumatic brain injury in the United States; emergency department visits, hospitalizations, and deaths. Atlanta: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2004
16 Frost RB, Farrer TJ, Primosch M, Hedges DW. Prevalence of traumatic brain injury in the general adult population: a meta-analysis. Neuroepidemiology 2013;40(03):154–159
17 Liew TYS, Ng JX, Jayne CHZ, Ragupathi T, Teo CKA, Yeo TT. Changing demographic profiles of patients with traumatic brain injury: an aging concern. Front Surg 2019;6:37
18 Hanson HR, Pomerantz WJ, Gittelman M. ED utilization trends in sports-related traumatic brain injury. Pediatrics 2013;132(04): e859–e864
19 Ponsky TA, Eichelberger MR, Cardozo E, et al. Analysis of head injury admission trends in an urban American pediatric trauma center. J Trauma 2005;59(06):1292–1297
20 Macpherson A, Fridman L, Scolnik M, Corallo A, Guttmann A. A population-based study of paediatric emergency department and office visits for concussions from 2003 to 2010. Paediatr Child Health 2014;19(10):543–546
21 McMahon P, Hricik A, Yue JK, et al;TRACK-TBI Investigators. Symptomatology and functional outcome in mild traumatic brain injury: results from the prospective TRACK-TBI study. J Neurotrauma 2014;31(01):26–33
22 Onakomaiya MM, Kruger SE, Highland KB, Kodosky PN, Pape MM, Roy MJ. Expanding clinical assessment for traumatic brain injury and comorbid post-traumatic stress disorder: a retrospective analysis of virtual environment tasks in the computer-assisted rehabilitation environment. Mil Med 2017;182(S1):128–136
23 Levy CE, Miller MD, Akande CA, Lok B, Marsiske M, Halan S. V-Mart, a virtual reality grocery store: a focus group study of a promising intervention for mild traumatic brain injury and posttraumatic stress disorder. Am J Phys Med Rehabil 2019;98 (03):191–198
24 Besnard J, Richard P, Banville F, et al. Virtual reality and neuropsychological assessment: the reliability of a virtual kitchen to assess daily-life activities in victims of traumatic brain injury. Appl Neuropsychol Adult 2016;23(03):223–235
25 Canty AL, Fleming J, Patterson F, Green HJ, Man D, Shum DH. Evaluation of a virtual reality prospective memory task for use with individuals with severe traumatic brain injury. Neuropsychol Rehabil 2014;24(02):238–265
26 Larson EB, Ramaiya M, Zollman FS, et al. Tolerance of a virtual reality intervention for attention remediation in persons with severe TBI. Brain Inj 2011;25(03):274–281
27 Kim O, Pang Y, Kim J-H. The effectiveness of virtual reality for people with mild cognitive impairment or dementia: a meta-analysis. BMC Psychiatry 2019;19(01):219[CrossRef] [PubMed]
28 Yu D, Li X, Lai FH. The effect of virtual reality on executive function in older adults with mild cognitive impairment: a systematic review and meta-analysis. Aging Ment Health 2023;27(04): 663–673
29 Zhu S, Sui Y, Shen Y, et al. Effects of virtual reality intervention on cognition and motor function in older adults with mild cognitive impairment or dementia: a systematic review and meta-analysis. Front Aging Neurosci 2021;13:586999
30 Wu J, Ma Y, Ren Z. Rehabilitative effects of virtual reality technology for mild cognitive impairment: a systematic review with meta-analysis. Front Psychol 2020;11:1811
31 Zhong D, Chen L, Feng Y, et al. Effects of virtual reality cognitive training in individuals with mild cognitive impairment: a systematic review and meta-analysis. Int J Geriatr Psychiatry 2021;36(12):1829–1847
32 Shin H, Kim K. Virtual reality for cognitive rehabilitation after brain injury: a systematic review. J Phys Ther Sci 2015;27(09): 2999–3002

