International Journal of Education and Humanities (IJEH), 5(3) 2025:602-614
http://i-jeh.com/index.php/ijeh/index
E-ISSN: 2798-5768

Effect and Mechanism of VR Exercise Therapy on Improving Physical Function in Elderly Patients with Parkinson's Disease

Xiaodong Liao[1], Jiong Luo[2]

Abstract

Parkinson's disease (PD) is a neurodegenerative disorder primarily affecting the elderly, leading to significant impairments in mobility, limb dysfunction, and an increased risk of falls, while also deteriorating emotional, cognitive, and sleep functions, ultimately reducing the overall quality of life. Despite pharmacological treatments, non-drug interventions are essential to address these multidimensional challenges. Virtual reality (VR) exercise therapy, an interactive approach combining exercise and cognitive stimulation, has emerged as a potential non-pharmacological intervention for PD. This review aims to evaluate the impact of VR exercise therapy on the physical and cognitive functions of PD patients. A systematic search of databases, including PubMed, Web of Science, CNKI, and Google Scholar, was conducted to identify relevant studies examining the effects of VR therapy on PD patients. The review found that the pathogenesis of PD, characterized by the degeneration of dopaminergic neurons in the substantia nigra, can be partially addressed by VR therapy. VR exercise therapy enhances motor function, improves cognitive abilities, and positively affects specific physiological indicators. Furthermore, VR therapy's interactive nature allows for tailored exercise regimens, which help in muscle and nerve function improvement. The results indicate that VR exercise therapy can be an effective intervention for improving motor and cognitive functions in PD patients. However, long-term engagement is essential to maintain its therapeutic benefits. Based on the findings, we recommend that healthcare providers consider integrating VR exercise therapy into PD treatment plans as part of a comprehensive, non-pharmacological approach, while encouraging sustained usage for lasting improvements.

Keywords: *Parkinson's disease, Physical function, VR exercise therapy, Virtual reality technology.*

A. Introduction

Parkinson's disease (PD) is a neurodegenerative disease, which mainly affects the basal ganglia of the brain (Dibble et al., 2004), and is the second most common neurodegenerative disease in the elderly (Alamri et al., 2015). According to statistics, there are about 1.7 million PD patients in China (Wen, 2011), the prevalence rate of people over 65 years old is 1.7% (Chen et al., 2015), and the global prevalence rate is about 1% (Dotchin et al., 2008). The pathogenesis of PD is the loss of dopaminergic neurons in the substantia nigra of the midbrain (Hornykiewicz, 2006). With the development of the disease, the spinal structure, limbic system, forebrain, and neocortex will also be affected (Fereshtehnejad et al., 2019). The onset is manifested by sensory processing disorders (such as proprioception, tactile, and discrimination dysfunction) (Maschke et al., 2006) and movement disorders (including bradykinesia, stiffness, and tremor) (Moustafa et al., 2016), as well as decreased muscle strength (Cano-de-la-Cuerda et al., 2010). These symptoms not only affect the musculoskeletal and balance systems, reduce the activity and

[1]Postgraduate student, research direction: physical fitness and health promotion; email: 1615411320@qq.com.School of Southwest University Physical Education Institute, Beibei District, Chongqing, China，400715.

[2]Professor, doctor, doctoral supervisor, research direction: physical fitness and health promotion, email: 784682301@qq.com , Tel: 13108991439. Research Centre for Exercise Detoxification, College of Physical Education, Southwest University, Chongqing, China，400715

walking ability, but also may lead to upper limb dysfunction (Hashemi et al., 2022) and increase the risk of falls (Bekkers et al., 2020), and also show various non-motor symptoms, such as mood, cognitive, and sleep disorders, which often affect the quality of life more seriously (Pazzaglia et al., 2020).

At present, the treatment of PD is divided into drug treatment and non-drug treatment. The most widely used drug treatment for PD-related motor symptoms is dopamine replacement therapy or dopamine agonists (Obeso et al., 2010). They can improve the quality of life of patients (Manson et al., 2012). However, as neuron death continues, the dose needs to be continuously increased, and the effect is weakened after long-term use and may cause side effects, such as dyskinesia (Ahlskog & Muenter, 2001), so new treatment methods are needed to reduce the impact of these side effects (Heumann et al., 2014).

Non-drug treatment of PD includes physical exercise, deep brain stimulation (DBS), transcranial magnetic stimulation (TMS), cell replacement, or virtual reality therapy (García-López et al., 2021). VR therapy is one of the latest technologies in the field of neural rehabilitation, aging, and disability (Lange et al., 2010). VR rehabilitation training provides a rich training environment and enhances participation through visual, sound, and motion information. In recent years, it has been gradually applied in the field of PD rehabilitation (Canning et al., 2020). VR is a 3D computer-generated environment in which users can experience content (Bohil et al., 2011). According to the degree of immersion, VR can be divided into immersion, semi-immersion, and non-immersion (Mujber et al., 2004). Due to the lack of complete multi-sensory simulation, but still able to obtain part of the real-world information, the latter two are generally referred to as "non-immersive" (Matijević et al., 2013). Sports games are a combination of "Sports" and "games," and they are electronic games that require bulky body movement (Staiano & Calvert, 2011). Unlike sedentary video games that mainly require finger and hand movement, sports games require a lot of physical activity (such as lower limb or whole-body movement) to interact with the game environment, and rely on various sports interfaces (such as dance mats, bicycle dynamometers) or sports tracking technology (Papastergiou, 2009).

Virtual reality sports games are a new type of video game. It breaks through the traditional operation mode of external devices such as game consoles and keyboards, and realizes the interaction between players and the game system and environment through physical actions of the body (Ju-Ling & Yu-Jen, 2016). It allows players to use full-body activity as the controller of game input and enjoy the unique somatosensory interaction experience with the game system. After 2011, virtual reality sports games can run in simulated three-dimensional scenes. At present, there are three most popular and low-cost commercial virtual reality sports game devices in the world: Nintendo's Wii (released in 2006), Microsoft's Kinect (released in 2010), and Sony's PlayStation Move (released in 2010) (Scheer et al., 2014). To sum up, this paper refers to the sports game based on virtual reality technology as VR exercise therapy, which will be used later.

In conclusion, PD is the second most common neurodegenerative disease in the elderly. It will lead to sensory processing disorders and movement disorders, increase the risk of falls, and seriously affect the quality of life of elderly patients with PD. VR exercise therapy is a new type of virtual reality sports game, which realizes the interaction between players and the game system and environment through body movement, and has a significant effect on the treatment of elderly patients with PD. This article will more systematically summarize and explain the efficacy of VR exercise therapy in improving the physical function of PD patients. Excluding the interference effect of interventions other than VR, this study only focused on the independent effect of VR training on physical activity function of PD patients, avoiding the effect of combined intervention superimposed interference. It provides a new perspective for the clinical rehabilitation of PD and the application of VR therapy.

B. Methods

We searched PubMed, web of science, CNKI, Google Scholar and other databases for the selected years from 2020 to 2024, and obtained and sorted out the relevant literature on the effect of VR exercise therapy on the physical function of elderly patients with PD, in order to explore the research on the improvement of physical function of PD patients with VR exercise therapy. Chinese search formula: (Parkinson's disease or Parkinson's syndrome) and (virtual reality or game) and (physical function) and randomized controlled trials. English retrieval formula: (Parkinson disease or Parkinson) and (virtual reality or gaming) and (physical function) and (randomized controlled trial or RCT). The search process is conducted according to PRISMA guidelines, as shown in Figure 1.

Randomized controlled clinical trials published in domestic and international journals as of December 31, 2024 were included, in which the effectiveness of VR treatment and conventional treatment was compared for PD patients. In addition, the study must measure the improvement of at least one of the following variables: gait and displacement distance, static and dynamic balance, fall risk, cognitive function, upper limb motor skills and quality of life, which are the focus of this review. ① Subjects complicated with other major diseases; ② Incomplete data; ③ Overview; ④ Repeated publication; ⑤ VR combined with other therapies; ⑥ The control group was not intervened.

Two researchers extracted the data independently, and the third evaluator then verified all extracted variables. The Picos strategy is used for this extraction, allowing the identification of the basic data needed to develop the entire study. In addition, we also extracted the data about participants' characteristics (gender, sample size, age), intervention characteristics (frequency, intensity, duration), and variables related to physical function indicators:

The study focuses on a population of adults aged 55 and older diagnosed with Parkinson's disease. The intervention being tested is Virtual Reality (VR) therapy, which is compared to conventional physical therapy. The outcomes measured in the study include various scales and tests such as the Berg Balance Scale, Six-Minute Walk Test, Unified Parkinson's Disease Rating Scale (UPDRS-III), Dynamic Gait Index (DGI), Disabilities of the Arm, Shoulder, and Hand (DASH) scale, Timed Up and Go (TUG) test, Hospital Anxiety and Stress Test (HAST), Montreal Cognitive Assessment (MoCA), and other relevant measures. These assessments aim to evaluate the effectiveness of VR therapy in improving motor function, balance, and cognitive abilities in patients with Parkinson's disease.

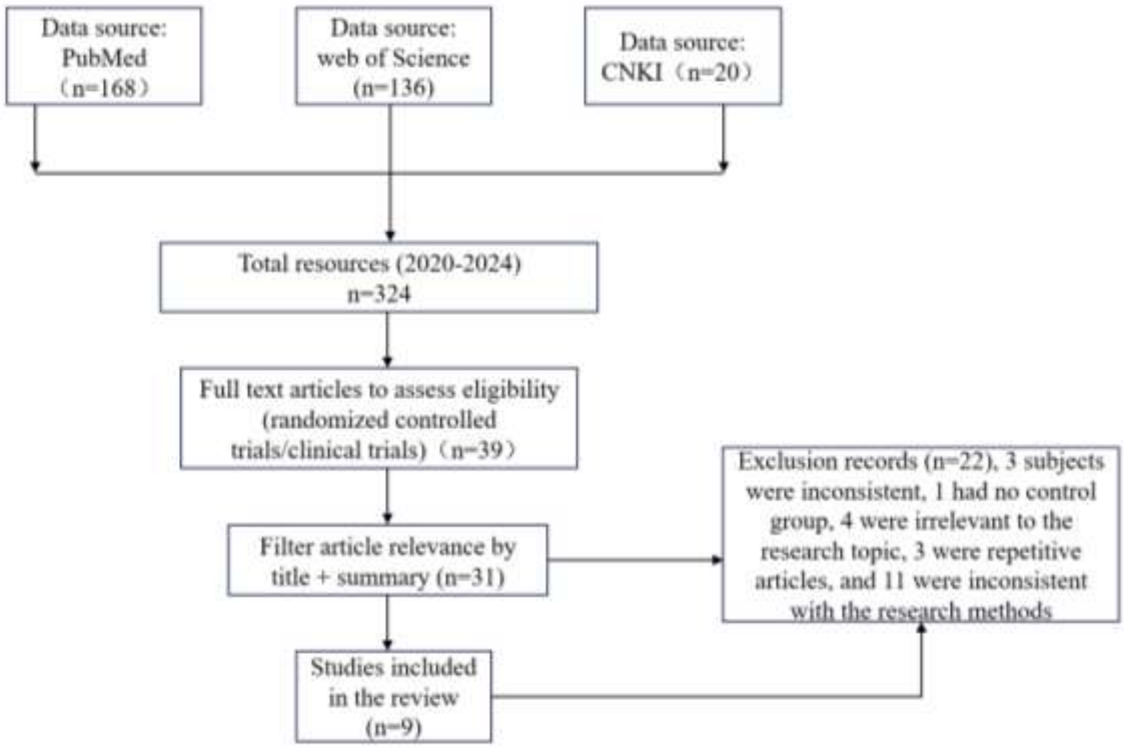

Figure 1. Preferred Reporting Items for The System Assessment (PRISMA) Flowchart Selected for The Study

C. Results and Discussion

It is reported that VR system can promote sports learning in sports training through strong audio-visual clues and feedback mechanism (Gulcan, Guciu-Gunduz, Yasar, et al., 2022). In particular, VR exercise therapy shows great potential in helping PD patients solve gait and balance problems. This therapy allows users to immerse themselves in personalized scenes, exercise cognitive and motor functions at the same time, and adjust stimulation and task difficulty according to individual needs. Research shows that patients receiving VR exercise therapy have improved gait stability, posture control and cognitive performance, especially in balance (Berg Balance score, standing on one leg, functional extension test), motor function (from sitting to standing, getting up and walking time), PD motor symptom severity (UPDRS III) and activities of daily living.

In addition, VR exercise therapy can also improve the daily life skills of PD patients, and may enhance nerve connection and signal transduction, and optimize functional circuits. This treatment method usually includes goal-oriented movement training to activate key cognitive circuits, and the therapist encourages the patient to surpass the ability of self-perception by giving guidance and feedback (Maranesi, Casoni, Baldoni, et al., 2022). These are the reliable basis for VR exercise therapy to improve PD patients, and the specific benefits are as follows:

Table 1. Statistics of physical function benefits of VR exercise therapy on elderly patients with PD in clinical trials

Author	Subject Country	Experimental subjects	Experimental design	Test indicators	Main results
Hajebrahimi Farzin Error! Reference source not found. (**2022**)	Turkey	24PD patients (VRG=11, Aa=66.36±8.04; CG=13; 65.5±9.93)	VRG: Nintendo balance board uses NW Fit Plus games that cover gait, static and dynamic balance. CG: balance and gait training, mainly focusing on lower limb movement. 3 times/week, 60min/session, 12 courses, 4 weeks in total	Disease level: UPDRS-III; Balance: BBS, ABSC; Activity ability: TUG; Functional capability: 6MWT. Collected during motor and cognitive assessment: rs-fMRI	Both VRG and CG improved disease level, movement, balance and gait. Only VRG significantly improved the quality of life and cognitive status of patients. RS fMRI analysis showed increased activity in the precuneus region of VRG
Pazzaglia C Error! Reference source not found. (**2020**)	Italy	51PD patients (CG=26, Aa=70±10, VRG=25, Aa=72±7)	CG: warm up + activity (motor coordination, balance, start and stop, walking exercises of upper and lower limbs)+relaxation. VRG: multiple VR training. Each exercise was started by the patient in the center of the room and asked to perform a task. 4 min/time, rest for 1 min. 3 times/week, 40min/time, 6 weeks in total	BBS; DGI; DASH	Compared with CG, VRG shows more significant progress in balance, walking and arm function. Specifically, the BBS score of VRG increased to 49.2, the DGI score increased to 20.2, and the DASH scale score decreased to 21.6. In contrast, only DASH score of CG decreased to 25.1
Bekkers Esther M. J Error! Reference source not found. (**2020**)	Israel, Belgium, Britain, Italy and the Netherlands	77FOG+PD patients, 44FOG-PD patients (VRG=62, Aa=71.06± 6.3; CG=59, Aa=70.86± 6.0)	VRG: VR treadmill training; CG: treadmill walking training. 6 weeks in total, 3 times/week, about 45min/time	Mini-BEST assessed postural stability, number of falls; NFOG-Q; SPPB、FSST, FES-I; PASE; MoCA; H&Y; MDS-UPDRS-III	After training, the balance and double arm activity ability of VRG group were significantly improved, the number of falls was significantly reduced, and the SPPB score was higher than that of CG group. Fog + patients have higher fear of falling

Author	Subject Country	Experimental subjects	Experimental design	Test indicators	Main results
Duarte Gabriel Pereira Error! Reference source not found. **(2023)**	Brazil	58PD patients（CG1=18，Aa=71±5；CG2=20，Aa=68±5；VRG=20，Aa=68±4）	Participants were randomly divided into three groups. CG1: functional training; CG2: bicycle exercise, VRG : Kinect adventures exercises training. 3 times/week, 50min/time, 8 weeks in total	The main result was forced expiratory volume in the first second; Secondary outcomes were forced vital capacity, maximal expiratory flow, and maximal inspiratory and expiratory pressures	All intervention measures failed to improve the forced expiratory volume in the first second, forced vital capacity and maximum expiratory flow. However, the maximum expiratory pressure in group 2 increased from 65.5 cmH2O to 73.1 cmH2O, and the maximum inspiratory pressure in group 3 increased from 61.3 cmH2O to 71.6 cmH2O. RF slightly improved
Hashemi Yazdan Error! Reference source not found.（**2022**）	Iran	45PD patients（CG=15，Aa=61.07±7.01；VRG1=15，Aa=54.80±10.51；VRG2=15，Aa=60.07±7.29）	They were randomly divided into 3 groups. CG: routine rehabilitation exercise (3 times/week, 90min/time, 24 times); Vrg1: supervised Kinect VR training; Vrg2: unsupervised Kinect VR training (24 VR exercises (3 times/week, 75min/time, warm-up for about 5min, main exercises for 50-60min, rest and level assessment for about 10min)	HAST；WPST；BBT；NHPT；Grip strength, pinch strength	The sensory function, wrist proprioception, hand flexibility and grip strength of the three groups of patients with idiopathic PD were significantly improved. Upper limb VR training using Kinect device effectively improves the upper limb function of PD patients
Maggio Maria Grazia Error! Reference source not found. （**2024**）	Italy	34 PD patients（CG=10，Aa=66.8±6.5；VRG1=12，Aa=59.7 ± 9.7；VRG2=12，Aa=63.8 ± 8.3）	They were randomly divided into 3 groups. Vrg1: two VR cognitive rehabilitation applications on mobile phones (neuron brain training; training your brain); Vrg2: one VR cognitive rehabilitation application (neuron brain training) and one VR social cognitive rehabilitation application (SIMS) on the mobile phone; CG: use pen and paper exercises (non-VR) for routine training. 3 times/week for 6 weeks. A complete neuropsychological	MMSE；MoCA；FAB；RAVLT；Stroop Color word test; Speech fluency alphabet test-COWAT；RCPM；CDT；Digital copy；MAC-Q；HRS-D；VRT；EQ-short；Disrespectful test - Adult；TAS	Research shows that vrg1 and vrg2 can improve the cognitive and social cognitive abilities of PD patients, and cooperate with relevant training can improve cognitive and emotional functions, and promote the lasting maintenance of cognitive achievements

Author	Subject Country	Experimental subjects	Experimental design	Test indicators	Main results
			assessment was performed after 6 weeks (T1, the end of the rehabilitation program) and 3 months after the end of rehabilitation training (T2, follow-up)		
Droby Amgad Error! Reference source not found.（**2020**）	Israel	37 PD patients（VRG=18，Aa=72.8 ± 6.7；CG=19，Aa=73.6 ± 6.5）	CG: treadmill training; VRG: VR treadmill training. Both groups received 18 courses of treatment (3 courses/week × 6 weeks)	Mini best assessed posture and balance; The functional magnetic resonance imaging (fMRI) data at baseline and 6 weeks later were compared to analyze the changes of brain functional network.	Both kinds of training changed the connectivity of basal ganglia, executive control network and frontal striatal network. VRG was more effective in supplementing the connectivity changes of motor area and right middle frontal area, which was helpful to improve the gait and balance ability of patients
Liu Jing Error! Reference source not found. **(2020)**	China	42 PD patients（VRG=21，Aa=60.9 ±7.20；CG=21，Aa=63.90±5.82）	CG: balance board training + center of gravity transfer training + Bobath ball training, 30min/day, 5 days/week, 4 weeks in a row, 20 times in total. VRG: VR treadmill training, 30min/day, 5 days/week, 4 weeks in a row, 20 times in total	BBS；Activities of daily living：MBI; LS；PS；TS。	Both CG and VRG can improve the balance function of PD patients, and the latter is better
Lou Feng Qi Error! Reference source not found. **(2021)**	China	113 PD patients (VRG=57, AA=64. 1 ± 2. 3; AA=64; Cg=56, aa=63.8 ± 2.1)	CG: routine balance training. Joint training each joint activity lasted for 1 min; Muscle stretch lasted for 10min; Resistance training lasted for 20 min; The transfer training lasted for 15 min; Gait training lasted for 10 minutes. The whole training process is once a day. VRG: three VR treadmills, 10min each, with an interval of 5min. Both groups lasted for 3 months	LS；Brunnstrom；FMA-UE；FMA-LE	VR balance training can significantly improve the autonomy and balance ability of PD patients, which is suitable for clinical promotion

Author	Subject Country	Experimental subjects	Experimental design	Test indicators	Main results
Note: CG: Control Group; VRG: Virtual Reality Group; Aa: Average age; Min: minutes; UPDRS-III: Unified Parkinson's Disease Rating Scale-motor; BBS: Berg Balance Scale; ABSC: Activities-specific Balance Confidence; TUG: Timed Up and Go Test; 6MWT: Six Minute Walk Test; rs-fMRI: resting state-functional Magnetic Resonance Imaging; DGI: The Dynamic Gait Index; DASH: The Disabilities of the Arm, Shoulder and Hand scale; Fog+: PD and freezing of gait; Fog-: without FOG; Mini-BEST: the Mini Balance Evaluation System Test; NFOG-Q: the New Freezing of Gait Questionnaire; SPPB: Short Physical Performance Battery; FSST: Four Square Step Test; FES-I: Falls Efficacy Scale–International; PASE: Physical Activity Scale for the Elderly; MOCA: Montreal Cognitive Assessment; H&Y: Hoehn & Yahr staging to assess disease severity; MDS-UPDRS-III: Disease Rating Scale motor part (III); HAST: Hand Active Sensation Test; WPST: Wrist Position Sense Test; BBT: Box-Block Test; NHPT: Nine Hole Pile Test; MMSE: Mini-Mental State Examination; FAB: Frontal Assessment Battery; RAVLT: Rey Auditory Verbal Learning test; RCPM: Raven's Colored Progressive Matrices; CDT: Clock drawing test; MAC-Q: Memory Assessment Clinics-questionnaire; HRS-D: Hamilton Rating Scale for Depression/Anxiety; VRT: Verbal Reasoning Assessment Test; EQ-short: The Short Empathy Quotient Scale; TAS: Toronto Alexithymia Scale; MBI: modified Barthel index; Ls: limits of stability; PS: postural stability; TS: time to stability; Brunnstrom: hemiplegic motor function scale; FMA-UE: upper limb motor function scale; FMA-LE: lower limb motor function scale.					

The statistical results are based on the statistical data of PubMed, web of science and CNKI (2020-2024)

According to the comments of Matta Mello et al. (2013), regular exercise improves blood circulation, oxygen supply and brain metabolism, affects the production of neurotransmitters and regulatory molecules, and enhances neural adaptability and regeneration ability, such as promoting neuron growth, synapse formation and vascular development. In addition, exercise can also reduce inflammation and reduce the risk of chronic diseases (Matta Mello, Cevada, & Sobral Monteiro-Júnior, 2013).

Physical exercise seems to be effective in improving muscle function. The physical training program of multifactor exercise (muscle strength, posture balance, etc.) can increase strength and muscle volume, and comprehensively improve physical fitness (Binder et al., 2005). The changes of muscle fibers may be caused by mechanical and metabolic stress caused by physical exercise. The tension exerted on muscle fibers can produce some cell adaptation signals, increase protein synthesis and reduce cell apoptosis. In addition, the injury of muscle cells will rapidly release interleukin-6 (IL-6), which will stimulate satellite cells to differentiate into new muscle nuclei. Muscle nuclei can enhance protein synthesis, resulting in an increase in muscle tissue volume (Spiering et al., 2008).

Physical exercise seems to strengthen the nervous system. Maguire et al. (2022) proved that the work efficiency was improved by stimulating the hippocampus, caudate nucleus, frontal and parietal cortex and cerebellum. The hippocampus is mainly responsible for episodic memory and spatial orientation. The inferior parietal cortex is related to self-centered displacement, the activity of the caudate nucleus is related to displacement speed, and the activity of the left frontal cortex is related to the adjustment of displacement direction, execution and decision-making related to virtual tasks (Maguire et al., 2022).

These nutritional factors can then spread to the brain and stimulate the differentiation and proliferation of neurons (Matta Mello et al., 2013). Thus, increasing nerve activation, long-term nerve activation will stimulate neural plasticity (Maguire et al., 2022). To sum up, VR exercise therapy, with its unique dual characteristics of combining physical activity and cognitive stimulation, can not only optimize the functional structure of muscles, but also promote the improvement and remodeling of brain activity and neural function. As shown in Figure 2, the effect of VR exercise therapy on muscle and brain circuits.

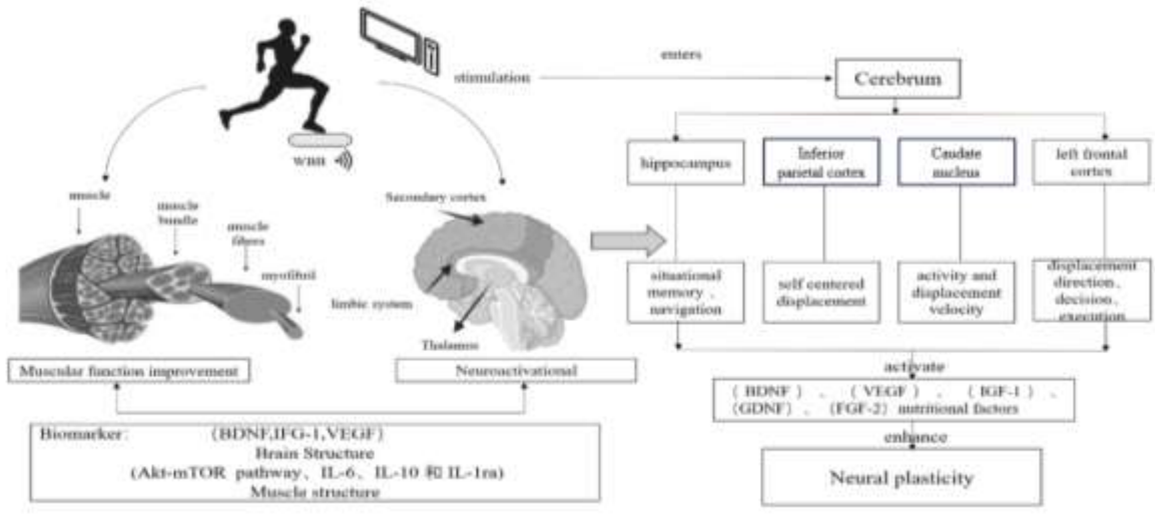

Figure 2. Effect of VR exercise therapy on muscle and brain circuits

As early as 1990, Whitcomb (1990) pointed out that well-designed computer games can improve the reaction speed, coordination, and flexibility of the elderly, but due to the characteristics of the game, the lower interest of the elderly may be because the sound, rhythm, and visual elements of the game are not suitable for them. With the development of VR technology, it shows great potential in rehabilitation medicine with its immersive experience and interactivity. This study deeply analyzed the analysis of 9 cases about VR intervention in PD treatment, and discussed the intervention methods, curative effect evaluation, and development trend, aiming to promote the application and optimization of VR rehabilitation technology, as follows:

1. **Diversity of Research Design and Intervention Programs**

Intervention Type and Control Group Setting

Diversified forms of VR technology: the intervention program covers VR games (Hashemi Yazdan et al., 2022), immersive VR training (Maggio, 2024), combination of VR and devices (Hashemi Yazdan et al., 2022; Maggio, 2024; Duarte Gabriel Pereira, 2023), and mobile VR applications (Maggio, 2024). Among them, Maggio (2024) further subdivided the VR application combination of cognitive rehabilitation and social cognitive rehabilitation, highlighting the trend of technology customization. The control group was dominated by traditional rehabilitation: the design of the control group included balance/gait training (Hashemi Yazdan et al., 2022), conventional rehabilitation training (Maggio, 2024), paper and pen exercise (Maggio, 2024), and a few studies set up double control groups (Maggio, 2024) (comparing functional training with bicycle exercise), reflecting the exploration of the efficacy differences of different rehabilitation methods.

Disease and Rehabilitation Goal-Oriented Intervention Stratification Motor function rehabilitation is dominant: 80% of the studies focus on balance, gait, and limb motor function (Hashemi Yazdan et al., 2022; Duarte Gabriel Pereira, 2023). Among them, VR treadmill training has been proved to have a positive impact on posture stability, fall risk (Maggio, 2024; Hashemi Yazdan et al., 2022) and activities of daily living (Duarte Gabriel Pereira, 2023). Extended application of cognition and cardiopulmonary function: Maggio (2024) applied VR to cognitive and social cognitive training for the first time and found its effect on memory and mental state; Duarte Gabriel Pereira (2023) focused on lung function indicators (such as forced expiratory volume in the first second), showing the potential of VR training in respiratory rehabilitation.

Exploration of autonomous training mode: Hashemi Yazdan (2022) compared supervised and unsupervised VR training to provide the basis for the feasibility of home-based rehabilitation and highlight the practical design of technology landing.

2. Core Dimensions and Heterogeneity of Efficacy Evaluation

Motor function: balance and gait as the common focus Disease level, dynamic gait index (Maggio, 2024) and postural stability (Hashemi Yazdan et al., 2022; Duarte Gabriel Pereira, 2023) are high-frequency indicators, suggesting that VR can effectively activate the vestibular cerebellar system and motor cortex through visual feedback and task-oriented training, and improve proprioception and coordination ability (Hashemi Yazdan et al., 2022) (involving the analysis of brain function network, supporting the mechanism of neural plasticity).

Cognitive function: application of multidimensional cognitive scale Maggio (2024) confirmed the specific effect of VR cognitive training by using listening/visual speech learning, memory, and other scales; Hajebrahimi Farzin (2022) and Bekkers (2020) included in the cognitive assessment, showing the improvement potential of VR on motor cognitive dual tasks, supporting the hypothesis of "neurocognitive motor integration."

Physiological and functional indicators: from gross movement to fine ability Hashemi Yazdan (2022) focused on hand function (grip strength, pinch strength, fine flexibility), which made up for the limitations of traditional rehabilitation in distal limb training; Duarte Gabriel Pereira's (2023) lung function index expands the research boundary of VR in the rehabilitation of respiratory diseases.

Heterogeneity and potential influencing factors Difference in intervention intensity and duration: the study did not have a unified course of treatment (for example, Lou Feng Qi, 2021 adopted three VR treadmill training programs, while Pazzaglia et al., 2020 was "multiple VR training"), which may lead to deviation in efficacy comparison. Lack of disease-specific adaptation: most studies have not made clear the diagnosis of the target population (such as nervous system diseases, cardiopulmonary diseases, or orthopedic rehabilitation), which affects the extrapolation of conclusions; Only Maggio (2024) designed hierarchical intervention for cognitive impairment, reflecting the concept of precision medicine.

Most of the existing research uses VR combined with other intervention methods (such as Gulcan Kubilay, 2022 using augmented reality technology + VR gait training + conventional training; Kashif Muhammad et al., 2022 used physical therapy + VR + sports image training; Sun Li Chun, 2020 used conventional medicine + rehabilitation training + VR + to strengthen muscle strength training; Hong Zhen Mei, 2022 used conventional treatment + VR + Jiao's scalp acupuncture; Zhang Li Ming, 2023 used VR + repetitive transcranial magnetic stimulation) to intervene the physical activity function of PD patients. Although combination therapy is a trend in recent years, in order to eliminate the interference effect of intervention methods other than VR, this study only focuses on the independent effect of VR training on physical activity function of PD patients, and avoids the superposition interference of the effect of combined intervention.

D. Conclusion

This study highlights the effectiveness of VR exercise therapy in improving the physical function of elderly Parkinson's disease (PD) patients, focusing on its mechanism and training effects. The pathogenesis of PD, characterized by the loss of dopaminergic neurons in the substantia nigra of the midbrain, leads to significant motor and cognitive dysfunction. VR exercise therapy, combining cognitive stimulation with physical exercise, has proven to enhance motor function, cognitive abilities, and specific physiological indicators. The therapy has shown significant improvements in gait, balance, stability, functional activity, and respiration, and it also alleviates PD-related symptoms, contributing to better overall quality of life. These findings support VR exercise therapy as a viable non-pharmacological intervention for PD patients.

Looking ahead, there are several areas for further exploration and improvement in the application of VR therapy. Current research points to the core advantages of VR, including its immersive experience that enhances patient engagement and dynamic feedback that allows for real-time adjustments in training difficulty, offering a potential advantage over traditional passive training methods. The synergy of VR with other equipment, such as treadmills and balance boards, can enhance neuromuscular control through multimodal sensory input. However, most studies have been short-term, with a lack of follow-up data and limited neuroimaging evidence to explain the underlying mechanisms of VR training. To address these gaps, future research should focus on long-term efficacy, the development of standardized evaluation systems, and a more comprehensive multidimensional framework to assess exercise, cognition, and physiology. Additionally, while high-end VR devices remain limited in availability, mobile-based VR applications show promise for wider accessibility, and further cost-effectiveness studies are needed to guide clinical implementation.

References

Ahlskog, J. E., & Muenter, M. D. (2001). Frequency of levodopa-related dyskinesias and motor fluctuations as estimated from the cumulative literature. *Movement Disorders, 16*(3), 448-458. https://doi.org/10.1002/mds.1090

Alamri, Y., Macaskill, M., Anderson, T., et al. (2015). Parkinson's disease in the Gulf countries: An updated review. *European Neurology, 74*(3-4), 222-225. https://doi.org/10.1159/000442283

Bekkers, E. M. J., Mirelman, A., Alcock, L., et al. (2020). Do patients with Parkinson's disease with freezing of gait respond differently than those without to treadmill training augmented by virtual reality? *Neurorehabilitation and Neural Repair, 34*(5), 440-449. https://doi.org/10.1177/1545968320912756

Bohil, C. J., Alicea, B., & Biocca, F. A. (2011). Virtual reality in neuroscience research and therapy. *Nature Reviews Neuroscience, 12*(12), 752-762. https://doi.org/10.1038/nrn3122

Canning, C. G., Allen, N. E., Nackaerts, E., et al. (2020). Virtual reality in research and rehabilitation of gait and balance in Parkinson disease. *Nature Reviews Neurology, 16*(8), 409-425. https://doi.org/10.1038/s41582-020-0370-2

Cano-de-la-Cuerda, R., Pérez-de-Heredia, M., Miangolarra-Page, J. C., et al. (2010). Is there muscular weakness in Parkinson's disease? *American Journal of Physical Medicine & Rehabilitation, 89*(1), 70. https://doi.org/10.1097/PHM.0b013e3181a9ed9b

Chen, H., Ding, D., Wang, J., et al. (2015). Parkinson's disease research in a prospective cohort in China. *Parkinsonism & Related Disorders, 21*(10), 1200-1204. https://doi.org/10.1016/j.parkreldis.2015.08.020

Dibble, L. E., Nicholson, D. E., Shultz, B., et al. (2004). Sensory cueing effects on maximal speed gait initiation in persons with Parkinson's disease and healthy elders. *Gait & Posture, 19*(3), 215-225. https://doi.org/10.1016/S0966-6362(03)00065-1

Dotchin, C., Msuya, O., Kissima, J., et al. (2008). The prevalence of Parkinson's disease in rural Tanzania. *Movement Disorders, 23*(11), 1567-1672. https://doi.org/10.1002/mds.21898

Fereshtehnejad, S. M., Yao, C., Pelletier, A., et al. (2019). Evolution of prodromal Parkinson's disease and dementia with Lewy bodies: A prospective study. *Brain, 142*(7), 2051-2067. https://doi.org/10.1093/brain/awz111

García-López, H., Obrero-Gaitán, E., Castro-Sánchez, A. M., et al. (2021). Non-immersive virtual reality to improve balance and reduce risk of falls in people diagnosed with Parkinson's disease: A systematic review. *Brain Sciences, 11*(11), 1435. https://doi.org/10.3390/brainsci11111435

Gulcan, K., Guclu-Gunduz, A., Yasar, E., et al. (2022). The effects of augmented and virtual reality gait training on balance and gait in patients with Parkinson's disease. *Acta Neurologica Belgica, 1-9.* https://doi.org/10.1007/s13760-022-02147-0

Hashemi, Y., Taghizadeh, G., Azad, A., et al. (2022). The effects of supervised and non-supervised upper limb virtual reality exercises on upper limb sensory-motor functions in patients with idiopathic Parkinson's disease. *Human Movement Science, 85*, 102977. https://doi.org/10.1016/j.humov.2022.102977

Heumann, R., Moratalla, R., Herrero, M. T., et al. (2014). Dyskinesia in Parkinson's disease: Mechanisms and current non-pharmacological interventions. *Journal of Neurochemistry, 130*(4), 472-489. https://doi.org/10.1111/jnc.12751

Hong, Z. M., Qiu, J. F., Zhang, S. Q., et al. (2022). Jiao's scalp acupuncture combined with virtual reality technology rehabilitation training in the treatment of motor dysfunction in Parkinson's disease: A randomized controlled trial. *China Acupuncture, 42*(07), 726-730. https://doi.org/10.13703/j.0255-2930.20210804-0005

Hornykiewicz, O. (2006). The discovery of dopamine deficiency in the parkinsonian brain. In P. Riederer, H. Reichmann, M. B. H. Youdim, et al. (Eds.), *Parkinson's Disease and Related Disorders* (pp. 9-15). Springer Vienna. https://doi.org/10.1007/978-3-211-45295-0_3

Ju-Ling, S., & Yu-Jen, H. (2016). Advancing adventure education using digital motion-sensing games. *Journal of Educational Technology & Society, 19*(4), 178-189.

Kashif, M., Ahmad, A., Bandpei, M. A. M., et al. (2022). Combined effects of virtual reality techniques and motor imagery on balance, motor function, and activities of daily living in patients with Parkinson's disease: A randomized controlled trial. *BMC Geriatrics, 22*, 381. https://doi.org/10.1186/s12877-022-03035-1

Lange, B. S., Requejo, P., Flynn, S. M., et al. (2010). The potential of virtual reality and gaming to assist successful aging with disability. *Physical Medicine and Rehabilitation Clinics of North America, 21*(2), 339-356. https://doi.org/10.1016/j.pmr.2009.12.007

Manson, A., Stirpe, P., & Schrag, A. (2012). Levodopa-induced-dyskinesias: Clinical features, incidence, risk factors, management and impact on quality of life. *Journal of Parkinson's Disease, 2*(3), 189-198. https://doi.org/10.3233/JPD-2012-120103

Maschke, M., Tuite, P. J., Krawczewski, K., et al. (2006). Perception of heaviness in Parkinson's disease. *Movement Disorders, 21*(7), 1013-1018. https://doi.org/10.1002/mds.20876

Matijević, V., Šečić, A., & Mašić, V. (2013). Virtual reality in rehabilitation and therapy. *Acta Clin Croat, 52*(4).

Moustafa, A. A., Chakravarthy, S., Phillips, J. R., et al. (2016). Motor symptoms in Parkinson's disease: A unified framework. *Neuroscience & Biobehavioral Reviews, 68*, 727-740. https://doi.org/10.1016/j.neubiorev.2016.07.010

Mujber, T. S., SzeCSI, T., & Hashmi, M. S. J. (2004). Virtual reality applications in manufacturing process simulation. *Journal of Materials Processing Technology, 155-156*, 1834-1838. https://doi.org/10.1016/j.jmatprotec.2004.04.401

Obeso, J. A., Rodriguez-Oroz, M. C., Goetz, C. G., et al. (2010). Missing pieces in the Parkinson's disease puzzle. *Nature Medicine, 16*(6), 653-661. https://doi.org/10.1038/nm.2165

Papastergiou, M. (2009). Exploring the potential of computer and video games for health and physical education: A literature review. *Computers & Education, 53*(3), 603-622. https://doi.org/10.1016/j.compedu.2009.04.001

Pazzaglia, C., Imbimbo, I., Tranchita, E., et al. (2020). Comparison of virtual reality rehabilitation and conventional rehabilitation in Parkinson's disease: A randomised controlled trial. *Physiotherapy, 106*, 36-42. https://doi.org/10.1016/j.physio.2019.12.007

Scheer, K. S., Siebrant, S. M., Brown, G. A., et al. (2014). Wii, Kinect, and Move. Heart rate, oxygen consumption, energy expenditure, and ventilation due to different physically active video game systems in college students. *International Journal of Exercise Science, 7*(1), 22-32. https://doi.org/10.70252/XHTR7649

Staiano, A. E., & Calvert, S. L. (2011). Exergames for physical education courses: Physical, social, and cognitive benefits. *Child Development Perspectives, 5*(2), 93-98. https://doi.org/10.1111/j.1750-8606.2011.00162.x

Sun, L. C., & Chen, R. (2020). Effect of virtual reality balance game combined with intensive muscle strength training on balance function and motor ability of patients with Parkinson's disease. *Journal of Hainan Medical College, 26*(09), 655-658+663. https://doi.org/10.13210/j.cnki.jhmu.20200304.007

Wen, X. D. (2011). Research progress in clinical drug treatment of Parkinson's disease. *China Contemporary Medicine, 18*(25), 18-20.

Zhang, L. M., Gao, L., et al. (2023). Clinical efficacy of virtual reality technology combined with repetitive transcranial magnetic stimulation in the treatment of mild cognitive impairment in Parkinson's disease. *China Rehabilitation, 38*(03), 148-152.