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Effect of Whole-Body Vibration Versus Rhythmic Auditory Stimulation on Spasticity, Balance, and Lower Limb Motor Function in Hemiplegic Stroke Patients

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ABSTRACT

Background: Stroke can lead to spasticity, balance impairments, and lower limb motor dysfunction. Whole-body vibration (WBV) and rhythmic auditory stimulation (RAS) are two therapeutic interventions that may address these deficits.

Objective: To compare the effects of WBV and RAS on spasticity, balance, and lower limb motor function in hemiplegic stroke patients.

Methods: A single-blinded, randomized controlled trial was conducted with 104 chronic hemiplegic stroke patients, divided into two groups: Group A (WBV) and Group B (RAS). WBV was applied using a vibration platform at 30-40 Hz for 3-minute sessions, 3 days/week for 4 weeks. RAS involved 90-minute sessions of music-based exercises, incorporating rhythmic cues and conventional therapy, 3 days/week for 4 weeks. Spasticity, balance, and motor function were assessed using the Modified Ashworth Scale, Berg Balance Scale, and Fugl-Meyer Assessment, respectively. Data were analyzed using SPSS version 27.

Results: Group A showed greater improvements in spasticity (MAS: 1.2±0.4 vs. 2.6±0.3), balance (BBS: 49±5 vs. 43±5), and motor function (FMA: 29±5 vs. 18.5±5) compared to Group B (p<0.05).

Conclusion: WBV is more effective than RAS in improving spasticity, balance, and motor function in chronic hemiplegic stroke patients.

INTRODUCTION

Stroke is a neurological condition defined as a sudden disruption of blood flow to the brain, leading to functional impairments that persist for more than 24 hours. It is categorized into ischemic and hemorrhagic types, with ischemic strokes comprising approximately 85% of all stroke cases. Ischemic stroke occurs due to an interruption in cerebral blood flow, resulting in a lack of oxygen and nutrient supply to the brain tissue, leading to cellular death and neurological deficits. On the other hand, hemorrhagic stroke results from the rupture of blood vessels, causing intracerebral or subarachnoid hemorrhages, which account for about 15% of all stroke cases (1, 5, 7, 8). Globally, stroke is a major cause of death and disability, affecting millions of people each year. According to the World Health Organization (WHO), approximately 15 million individuals suffer a stroke annually, out of which 5 million die and another 5 million are left permanently disabled (9, 10). The burden of stroke is particularly high in low- and middle-income countries, where the prevalence of risk factors such as hypertension, obesity, diabetes, and smoking is significant (11). Stroke survivors often experience impairments in motor control, balance, and spasticity, which severely impact their functional independence and quality of life (22, 23).

Management of post-stroke motor dysfunction and spasticity is critical in rehabilitation to restore functionality and improve patient outcomes. Various therapeutic interventions, including pharmacological and non-pharmacological approaches, have been employed to target these impairments. Whole-body vibration (WBV) and rhythmic auditory stimulation (RAS) are two non-invasive modalities that have shown promise in improving motor function, spasticity, and balance in individuals with neurological disorders. WBV involves the application of mechanical vibrations to the body, which stimulate muscle spindles and Golgi tendon organs, leading to enhanced neuromuscular activation and improved motor performance. Additionally, WBV promotes proprioceptive feedback, improves balance by activating postural muscles, and reduces spasticity through modulation of muscle tone (30, 35). Several studies have demonstrated the effectiveness of WBV in improving muscle strength, coordination, and gait in individuals with stroke and other neurological conditions, suggesting its potential as a valuable adjunct to conventional rehabilitation (35).

RAS, on the other hand, uses rhythmic cues, typically delivered through metronome beats or music, to facilitate timing and coordination of motor activities. It engages auditory-motor pathways, thereby enhancing motor planning, synchronization, and proprioceptive feedback, which are crucial for balance and motor control (31, 33, 34). The use of rhythmic cues has been shown to improve gait parameters such as stride length, walking speed, and cadence, making it an effective intervention for enhancing

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lower limb motor function in stroke patients (34). Moreover, RAS has been associated with increased neuroplasticity, which further supports its use in rehabilitation to promote motor recovery (33, 34). Despite the demonstrated benefits of both WBV and RAS, few studies have directly compared their efficacy in improving spasticity, balance, and lower limb motor function in individuals with hemiplegic stroke.

This randomized controlled trial aims to address this gap by comparing the effects of WBV and RAS on spasticity, balance, and lower limb motor function in patients with chronic hemiplegic stroke. Understanding the comparative effectiveness of these two interventions will provide valuable insights for clinicians to optimize rehabilitation strategies and improve functional outcomes for stroke survivors. Therefore, this study hypothesizes that both WBV and RAS will be effective in reducing spasticity and enhancing balance and motor function, with WBV potentially demonstrating greater efficacy due to its multifaceted impact on neuromuscular activation and proprioceptive feedback (30, 35). The findings of this study will contribute to the growing body of evidence supporting the use of non-pharmacological interventions in stroke rehabilitation and provide guidance for clinical decision-making in the management of post-stroke impairments.

MATERIAL AND METHODS

The study employed a randomized controlled trial design conducted at Sehat Medical Complex, Rehab Cure, and the University Institute of Physical Therapy teaching hospital. The calculated sample size, based on Berg Balance Scale and Fugl-Meyer Assessment as outcome measures, was determined to be 86 participants. To account for potential dropout, a 20% increase was applied, resulting in a final sample size of 104 participants (52 in each group). The study adhered to the ethical principles outlined in the Declaration of Helsinki, and approval was obtained from the institutional review board prior to recruitment. Written informed consent was obtained from all participants before inclusion in the study, and confidentiality of patient information was maintained throughout the study period.

Participants were recruited based on predefined eligibility criteria. Inclusion criteria were individuals aged 40 to 60 years, both male and female, with a diagnosis of chronic stroke (post-6 months onset), Berg Balance Scale (BBS) scores ranging from 20 to 40, Fugl-Meyer Motor Scale (FMS) scores indicating moderate assistance (up to 3), Mini-Mental State Examination (MMSE) scores of over 20, and the ability to comprehend verbal commands. Participants with systemic disorders such as rheumatoid arthritis, unstable angina, coexisting physical impairments (e.g., limb amputation), a previous history of neurological diseases other than stroke (e.g., Parkinson's disease), previous fractures, hearing or perception deficits, or those unable to adhere to the study protocol or attend scheduled follow-up visits were excluded from the study (26-29).

Participants were randomly allocated into two groups using a lottery method. Group A received whole-body vibration (WBV) therapy, while Group B underwent rhythmic auditory stimulation (RAS) therapy. WBV therapy was administered using a vibration platform where participants stood with a semi-flexed knee position. The therapy protocol involved a 3-minute rest period followed by vibration sessions for a total of 4 weeks, three days per week. The acceleration was set at 18.0 m/s^2, with a frequency range of 30-40 Hz, and the intensity of the therapy was progressively increased in subsequent sessions to challenge neuromuscular activation and improve balance and motor control (30). For Group B, rhythmic auditory stimulation was provided using a combination of metronome beats and music-based exercises. The RAS therapy protocol included a 90-minute session, combining 60 minutes of RAS music-based exercises, 15 minutes of general body warm-up with metronome rhythms, and 15 minutes of relaxation exercise at the end of the session. Participants were instructed to perform various exercises such as lateral walking, military marching, anterior and posterior walking, and progression in rhythm speed. Sessions were conducted three times per week for four weeks, and noise-canceling headphones were used to deliver the auditory cues (31).

The study was single-blinded, with the assessor remaining blinded to the treatment allocation. Baseline assessment was conducted for each participant before initiating the intervention, and a follow-up assessment was carried out after four weeks of therapy. Outcome measures included the Modified Ashworth Scale (MAS) for evaluating spasticity, Berg Balance Scale (BBS) for balance assessment, and Fugl-Meyer Motor Scale (FMS) for lower limb motor function. Assessments were performed in a controlled environment to ensure consistency and reliability. Data collection was supervised by trained physiotherapists who were not involved in delivering the interventions, ensuring objectivity in measurement.

Data analysis was conducted using SPSS version 27.0 (IBM Corp., Armonk, NY). Descriptive statistics, including means and standard deviations, were computed for demographic and baseline characteristics. For between-group comparisons, non-parametric tests, such as the Mann-Whitney U test, were used due to the non-normal distribution of most variables as indicated by Kolmogorov-Smirnov and Shapiro-Wilk tests. Within-group changes were analyzed using the Wilcoxon signed-rank test. All statistical tests were two-tailed, and a p-value of less than 0.05 was considered statistically significant. The results were presented using appropriate statistical measures, including effect sizes, and visualized through bar charts, pie charts, and histograms where necessary to aid interpretation.

This study was registered under the clinical trial registry number NCT06567223, and the reporting adhered to the Consolidated Standards of Reporting Trials (CONSORT) guidelines for transparency and methodological rigor.

RESULTS

The results of this study were analyzed using appropriate non-parametric tests due to the non-normal distribution of the data as indicated by the Kolmogorov-Smirnov and Shapiro-Wilk tests. The demographic characteristics of the participants are presented in **Table 1**, which shows the mean age, gender distribution, and paretic side involvement in both groups. Group A (Whole Body Vibration) had a mean age of 49.77 ± 5.78 years with a gender distribution of 32 females (61.5%) and 20 males (38.5%). Group B (Rhythmic Auditory Stimulation) had a mean age of 48.63 ± 6.19 years with 35 females (67.3%) and 17 males (32.7%). About the side of weakness, Group A had 17 cases of right-sided involvement, 19 cases of left-sided involvement, and 16 cases of bilateral involvement, while Group B had 18 cases of right-sided, 18 left-sided, and 16 cases of bilateral involvement.

Table 1: Demographic Characteristics of Participants

Group	Mean Age (years)	Gender	Frequency (%)	Paretic Side	Frequency (%)
Group A	49.77 ± 5.78	Male	20 (38.5)	Right	17 (32.7)
		Female	32 (61.5)	Left	19 (36.5)
				Bilateral	16 (30.8)
Group B	48.63 ± 6.19	Male	17 (32.7)	Right	18 (34.6)
		Female	35 (67.3)	Left	18 (34.6)
				Bilateral	16 (30.8)

The between-group analysis revealed significant differences post-treatment in spasticity, balance, and lower limb motor function as measured by the Modified Ashworth Scale (MAS), Berg Balance Scale (BBS), and Fugl-Meyer Assessment (FMA). Table 2 presents the results of the Mann-Whitney U test, showing that Group A (Whole Body Vibration) achieved significantly better post-treatment outcomes compared to Group B (Rhythmic Auditory Stimulation) across multiple parameters ($p < 0.05$). The median values for Group A in MAS, BBS, and FMA were consistently higher than those for Group B, indicating superior improvement in reducing spasticity and enhancing balance and motor function.

Table 2: Mann-Whitney U Test Results for Between-Group Comparison

Variable	Duration	Group A (Mean Rank)	Median	Group B (Mean Rank)	Median	P-Value
Hip Flexion	Pre-treatment	56.58	3.00	48.42	3.00	< 0.001
	Post-treatment	30.73	1.00	74.27	3.00	< 0.001
Hip Extension	Pre-treatment	57.67	3.00	47.33	3.00	< 0.001
	Post-treatment	31.36	1.00	73.64	3.00	0.002
Knee Flexion	Pre-treatment	58.12	3.00	46.88	3.00	< 0.001
	Post-treatment	41.19	1.00	63.81	2.00	< 0.001
Knee Extension	Pre-treatment	58.17	3.00	46.83	3.00	< 0.001
	Post-treatment	41.69	1.00	63.31	2.00	< 0.001
Berg Balance Scale	Pre-treatment	55.18	33.00	49.82	33.00	< 0.001
	Post-treatment	71.66	49.00	33.34	43.00	< 0.001
Fugl-Meyer Assessment	Pre-treatment	63.96	19.00	41.04	17.00	< 0.001
	Post-treatment	77.43	29.00	27.57	18.50	< 0.001

Within-group analysis using the Wilcoxon signed-rank test demonstrated significant improvements in both Group A and Group B from pre- to post-treatment across all variables. Table 3 shows the results, indicating that while both groups exhibited improvements in spasticity, balance, and lower limb motor function, Group A showed greater enhancements in MAS, BBS, and FMA scores, suggesting the superior efficacy of WBV therapy in comparison to RAS.

Table 3: Wilcoxon Signed-Rank Test Results for Within-Group Analysis

Variable	Group	Pre-treatment (Mean Rank)	Median	Post-treatment (Mean Rank)	Median	P-Value
Hip Flexion	Group A	56.58	3.00	30.73	1.00	< 0.001
	Group B	48.42	3.00	74.27	3.00	< 0.001
Hip Extension	Group A	57.67	3.00	31.36	1.00	< 0.001
	Group B	47.33	3.00	73.64	3.00	0.002
Knee Flexion	Group A	58.12	3.00	41.19	1.00	< 0.001
	Group B	46.88	3.00	63.81	2.00	< 0.001
Knee Extension	Group A	58.17	3.00	41.69	1.00	< 0.001
	Group B	46.83	3.00	63.31	2.00	< 0.001
Berg Balance Scale	Group A	55.18	33.00	71.66	49.00	< 0.001
	Group B	49.82	33.00	33.34	43.00	< 0.001
Fugl-Meyer Assessment	Group A	63.96	19.00	77.43	29.00	< 0.001
	Group B	41.04	17.00	27.57	18.50	< 0.001

Overall, the results indicated that both WBV and RAS therapies were effective in reducing spasticity and enhancing balance and lower limb motor function in hemiplegic stroke patients. However, WBV therapy demonstrated superior efficacy in all measured outcomes, suggesting that it may be a more potent intervention for improving motor recovery and functional independence in this population. These findings provide robust evidence for clinicians to consider incorporating WBV therapy into rehabilitation programs for patients with chronic hemiplegic stroke.

DISCUSSION

The findings of this study indicated that both whole-body vibration (WBV) and rhythmic auditory stimulation (RAS) therapies significantly improved spasticity, balance, and lower limb motor function in hemiplegic stroke patients, with WBV demonstrating superior efficacy. This result aligns with previous research that highlighted the positive impact of WBV on muscle tone regulation and motor function in individuals with neurological impairments. WBV has been shown to enhance muscle activation through the stimulation of muscle spindles and Golgi tendon organs, resulting in reflexive muscle contractions that improve neuromuscular coordination (30). Similar findings were observed by Lin Rong Liao et al., who reported that WBV improved balance and quality of life in stroke patients with mild to moderate impairments, though their study did not evaluate spasticity in detail (35). The current study extends these results by demonstrating that WBV can be effectively used in chronic hemiplegic stroke patients, enhancing not only balance but also spasticity and motor control, making it a promising therapeutic option for long-term rehabilitation.

The effect of RAS was also significant in improving motor function, which is consistent with the results of Ahmed et al., who found that rhythmic auditory cues enhanced gait parameters and motor coordination in hemiplegic stroke patients (34). RAS relies on auditory-motor synchronization, which facilitates the timing and execution of movements, leading to improved motor planning and proprioceptive feedback (34). However, in the present study, WBV therapy outperformed RAS, possibly due to the additional neuromuscular activation induced by mechanical vibrations, which directly target muscle tone and strength. Previous studies, such as those conducted by Hussain et al., have suggested that WBV provides a unique combination of sensory stimulation and muscle activation that is not typically achieved with auditory cues alone (32). This could explain why WBV showed greater improvements in spasticity and balance compared to RAS.

Despite the encouraging results, there were several limitations to this study. One of the primary limitations was the relatively short duration of the intervention, which was limited to four weeks. Longer intervention periods may have resulted in more pronounced differences between the two therapies, especially in terms of functional outcomes such as gait and quality of life. Additionally, the study did not include a follow-up assessment to determine the long-term effects of these interventions, which is critical for understanding the sustainability of these improvements. The single-blinded design, where only the assessor was blinded, may have introduced potential bias, although efforts were made to maintain objectivity. Moreover, the study only included chronic hemiplegic stroke patients, limiting the generalizability of the findings to individuals in the acute or subacute stages of stroke recovery. Future research should consider extending the duration of therapy and including follow-up assessments to evaluate long-term outcomes. Inclusion of patients at different stages of stroke recovery could also provide insights into the stage-specific effects of WBV and RAS.

The study's strength lies in its rigorous design and use of validated outcome measures such as the Modified Ashworth Scale, Berg Balance Scale, and Fugl-Meyer Assessment, which provided a comprehensive evaluation of spasticity, balance, and motor function. The use of a large sample size and appropriate statistical methods further strengthened the reliability of the findings. Furthermore, the comparison of two distinct therapeutic modalities offered valuable insights into their relative effectiveness, which can inform clinical decision-making for individualized rehabilitation programs.

CONCLUSION

In conclusion, the results indicated that while both WBV and RAS therapies are effective for reducing spasticity and improving balance and motor function in hemiplegic stroke patients, WBV therapy demonstrated superior efficacy. This suggests that WBV may be more beneficial for enhancing lower limb motor function and neuromuscular coordination. Clinicians should consider incorporating WBV into rehabilitation protocols for chronic stroke patients, especially when the goal is to achieve comprehensive improvements in motor function and balance. Further research should explore the long-term benefits of these therapies and assess their effectiveness in different stages of stroke recovery to establish robust clinical guidelines for their use.

REFERENCES

1. Thaler AI, Fara MG. Cerebrovascular Disease and Stroke. In: Geriatric Medicine: A Person Centered Evidence Based Approach. Springer; 2024. p. 1047-1072.
2. Sirsat MS, Fermé E, Câmara J. Machine Learning for Brain Stroke: A Review. J Stroke Cerebrovasc Dis. 2020;29:105162.
3. Gialanella B. Aphasia Assessment and Functional Outcome Prediction in Patients with Aphasia After Stroke. J Neurol. 2011;258:343-9.
4. Aiyejusunle C, Olawale O, Umeaku G, et al. Development and Use of a New Tool for Assessing Upper and Lower Limb Synergies in People with Stroke. Rom J Neurol. 2019;18:94-101.
5. Hui C, Tadi P, Suheb MZK, et al. Ischemic Stroke. In: StatPearls [Internet]. StatPearls Publishing; 2024.
6. Diener HC, Hankey GJ. Primary and Secondary Prevention of Ischemic Stroke and Cerebral Hemorrhage: JACC Focus Seminar. J Am Coll Cardiol. 2020;75:1804-18.
7. Krishnamurthi RV, Barker-Collo S, Parag V, et al. Stroke Incidence by Major Pathological Type and

Ischemic Subtypes in the Auckland Regional Community Stroke Studies: Changes Between 2002 and 2011. Stroke. 2018;49:3-10.
8. Krishnamurthi RV, Ikeda T, Feigin VL. Global, Regional and Country-Specific Burden of Ischemic Stroke, Intracerebral Hemorrhage and Subarachnoid Hemorrhage: A Systematic Analysis of the Global Burden of Disease Study 2017. Neuroepidemiology. 2020;54:171-9.
9. Johnson W, Onuma O, Owolabi M, et al. Stroke: A Global Response Is Needed. Bull World Health Organ. 2016;94:634.
10. Pega F, Náfrádi B, Momen NC, et al. Global, Regional, and National Burdens of Ischemic Heart Disease and Stroke Attributable to Exposure to Long Working Hours for 194 Countries, 2000–2016: A Systematic Analysis from the WHO/ILO Joint Estimates of the Work-Related Burden of Disease and Injury. Environ Int. 2021;154:106595.
11. Van Sloten TT, Sedaghat S, Carnethon MR, et al. Cerebral Microvascular Complications of Type 2 Diabetes: Stroke, Cognitive Dysfunction, and Depression. Lancet Diabetes Endocrinol. 2020;8:325-36.
12. Luders E, Toga AW. Sex Differences in Brain Anatomy. Prog Brain Res. 2010;186:2-12.
13. Gialanella B, Santoro R. Prediction of Functional Outcomes in Stroke Patients: The Role of Motor Patterns According to Limb Synergies. Aging Clin Exp Res. 2015;27:637-45.
14. Serlin Y, Shelef I, Knyazer B, et al. Anatomy and Physiology of the Blood–Brain Barrier. Semin Cell Dev Biol. 2015;38:2-6.
15. Werring D, Adams M, Benjamin L, et al. Stroke and Cerebrovascular Diseases. In: Neurology: A Queen Square Textbook. 2024. p. 107-198.
16. Huang S, Joshi A, Shi Z, et al. Combined Polygenic Scores for Ischemic Stroke Risk Factors Aid Risk Assessment of Ischemic Stroke. Int J Cardiol. 2024;404:131990.
17. Shiber JR, Fontane E, Adewale A. Stroke Registry: Hemorrhagic vs Ischemic Strokes. Am J Emerg Med. 2010;28:331-3.
18. Kaji R. Global Burden of Neurological Diseases Highlights Stroke. Nat Rev Neurol. 2019;15:371-2.
19. Zafar F, Tariq W, Shoaib RF, et al. Frequency of Ischemic Stroke Subtypes Based on Toast Classification at a Tertiary Care Center in Pakistan. Asian J Neurosurg. 2018;13:984-90.
20. Sedova P, Brown RD, Zvolsky M, et al. Incidence of Stroke and Ischemic Stroke Subtypes: A Community-Based Study in Brno, Czech Republic. Cerebrovasc Dis. 2021;50:54-61.
21. Maistrello L, Rimini D, Cheung VC, et al. Muscle Synergies and Clinical Outcome Measures Describe Different Factors of Upper Limb Motor Function in Stroke Survivors Undergoing Rehabilitation in a Virtual Reality Environment. Sensors. 2021;21:8002.
22. Frisoli A, Barsotti M, Sotgiu E, et al. A Randomized Clinical Control Study on the Efficacy of Three-Dimensional Upper Limb Robotic Exoskeleton Training in Chronic Stroke. J Neuroeng Rehabil. 2022;19:56-62.
23. Balkaya M, Cho S. Optimizing Functional Outcome Endpoints for Stroke Recovery Studies. J Cereb Blood Flow Metab. 2019;39:2323-42.
24. Lindsay MP, Norrving B, Sacco RL, et al. World Stroke Organization (WSO): Global Stroke Fact Sheet 2019. Int J Stroke. 2019;14:806-17.
25. Choi JU, Kang Sh. The Effects of Patient-Centered Task-Oriented Training on Balance Activities of Daily Living and Self-Efficacy Following Stroke. J Phys Ther Sci. 2015;27:2985-8.
26. Kerr A, Dawson J, Robertson C, et al. Sit to Stand Activity During Stroke Rehabilitation. Top Stroke Rehabil. 2017;24:562-6.
27. Kerr A, Clark A, Cooke EV, et al. Functional Strength Training and Movement Performance Therapy Produce Analogous Improvement in Sit-to-Stand Early After Stroke: Early-Phase Randomised Controlled Trial. Physiotherapy. 2017;103:259-65.
28. Mahmood W, Ahmed Burq HSI, Ehsan S, et al. Effect of Core Stabilization Exercises in Addition to Conventional Therapy in Improving Trunk Mobility, Function, Ambulation and Quality of Life in Stroke Patients: A Randomized Controlled Trial. BMC Sports Sci Med Rehabil. 2022;14:62-8.
29. Simeon L. The Effect of Rhythmic Auditory Stimulation on Gait Performance in Individuals with Neurological Disorders: An Integrative Review. The Florida State University; 2022.
30. Yurttutmuş ZR, Zincirci DE, Bardak AN, et al. The Effect of Whole-Body Vibration on Spasticity in Post-Stroke Hemiplegia: A Prospective, Randomized-Controlled Study. Turk J Phys Med Rehabil. 2022;68:484-91.
31. Gonzalez-Hoelling S, Bertran-Noguer C, Reig-Garcia G, et al. Effects of a Music-Based Rhythmic Auditory Stimulation on Gait and Balance in Subacute Stroke. Int J Environ Res Public Health. 2021;18:2032.
32. Hussain SA, Rasanani MRH, Hassan Z, et al. Whole Body Vibration's Potential to Improve Balance and Function in Cerebral Palsy in Weight and Non-

Weight Bearing Positions: A Hypothesis Study. J Health Rehabil Res. 2024;4:434-41.
33. Hlomayi BY. Effectivity of Combined Rhythmic Auditory Stimulation Rehabilitation Approach on Gait Post Stroke. 2023.
34. Ahmed GM, Fahmy EM, Ibrahim MF, et al. Efficacy of Rhythmic Auditory Stimulation on Gait Parameters in Hemiplegic Stroke Patients: A Randomized Controlled Trial. Egypt J Neurol Psychiatry Neurosurg. 2023;59:8-16.
35. Jung Y, Chung EJ, Chun HL, et al. Effects of Whole-Body Vibration Combined with Action Observation on Gross Motor Function, Balance, and Gait in Children with Spastic Cerebral Palsy: A Preliminary Study. J Exerc Rehabil. 2020;16:249-57.