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Effect of whole-body vibration versus functional strength training on functional balance and aerobic capacity in children with hemiparetic cerebral palsy: A randomized clinical trial

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Abstract:
Purpose: to compare the effect of whole-body vibration and functional strength exercise on functional balance as well as aerobic capacity in hemiparetic cerebral palsy.
Method: Thirty CP children, aged four to eight were randomly split into two groups, level of spasticity grade I and II on the Modified Ashworth Scale. The physical therapy program was identically planned for both groups for 30 minutes with five-minute rest intervals in between plus group A (n = 15) received a 25-minute whole body vibration session 20 to 30 Hz and an amplitude of 2 mm. Group B (n = 15) functional strength training for 30 minutes to improve function balance and aerobic capacity, over 12 weeks, both groups trained three times a week, up to three sets of ten to fifteen repetitions. Pediatric balance scale and 6-minute walk test measured before and after treatment.
Results: There was an obvious distinction. The pediatric balance scale and the six-minute walk test were in favor of group A between the two groups. value of < 0.001. Regarding six-minute walk test, both groups (A&B) showed a notable variation (P < 0.01) post-treatment as compared with pretreatment in favor of group A with percent of change 182.97% & 31.04% respectively, while regarding pediatric balance scale, both groups (A&B) showed an important distinction (P<0.01) posttreatment as compared with pretreatment in favor of group A with percent of change 105.5% & 21.62% respectively.
Conclusion: functional strength training and whole-body vibration affect the enhancement of balance and aerobic capacity in kids with hemiparetic cerebral palsy with the favor of whole-body vibration
Keywords: Cerebral palsy, Hemiparesis, Whole body vibration, and Functional strength training.
Abbreviations: Cerebral palsy (CP), Whole-body vibration (WBV), Functional strength training (FST), Gross Motor Functional Classification System (GMFCS).

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1.Introduction:

Early-life brain lesions or dysfunctions are the source of a variety of persistent, non-progressive movement and posture problems known as cerebral palsy (CP). CP is predominantly a movement and postural disarray. It is the most frequent reason why children experience serious physical disabilities (1).

Hemiparesis is a weakness affecting one side of the body (2). Hemiplegia is characterized by an affection of the upper and lower ipsilateral limbs, along with the hand's main function impacted. The impact is greater on the upper limb than on the lower limb. Hemiplegia is most likely caused by a localized lesion (3). The most common form of cerebral palsy (about 38% of cases) plus the subsequent greatest frequency in terms of occurrence among premature newborns (around 20% of cases) are the hemiplegic variants, they have unilateral motor and sensory dysfunction as their clinical pattern (4).

Maintaining proper posture and stability requires balance, which is the result of multiple mechanisms cooperating. People who suffer from cerebral palsy frequently struggle with balance because of issues related to their strength, tone, and/or sensory systems. The evolution of children's motor skills fundamentally relies on postural control, especially postural stability (5). Postural control is largely dependent on the intricate fusion of visual, vestibular, and proprioceptive perceptions, central nervous system orders, as well as neuromuscular reactions, in particular, quickness of response and muscle strength (6). A significant barrier to a kid with cerebral palsy's motor development is impairments in postural control. The inability of these kids to do both static and dynamic actions, such as sitting, standing, and walking, results in a variety of impairments (7).

Neuromuscular dysfunctions, like weakness, imbalance between the agonist and antagonist muscles, abnormalities in coordination, alterations in sensory perception, and loss of selective motor control and muscle tone are among the clinical manifestations of cerebral palsy (8). Several different sensory systems interact to enable postural control and the maintenance of both static and dynamic balance. The somatosensory, ocular, and vestibular systems are among these sensory systems. One of the primary systems for preserving balance, according to Woollacott, is the vestibular system, which acts as a benchmark for all other systems, including the somatosensory and visual ones (9). It has been noted that receiving vestibular stimulation in moderation improves balance. The vestibular-spinal reflex produces compensating for body motion, which preserves the stability of the head and posture and reduces the risk of falls (10).

The ability to use aerobic capacity to carry out aerobic activities is known as aerobic performance. CP patients likely have some of the lowest rates of mechanical efficiency because of their co-contraction, reduced selectivity, and spasticity. This results in low maximal aerobic performance and a high energy expenditure when walking, which decreases as motor involvement increases (11,12).

One standardized, self-paced walking test that is frequently accessed to evaluate functional abilities in cerebral palsy (CP) is the 6-minute walk test (6MWT). According to reports, the exam measures functional capacity for daily tasks (13). A horizontal vibrating platform with a frequency range of 10 to 25 Hz is used to perform whole-body vibration (WBV) exercises on subjects. This acts similarly to the tonic vibration reflex, stimulating the main ends of muscle spindles and actuating motor neurons to cause muscular contraction. Training at low frequencies reduces muscle tone while training at high frequencies (40 Hz) increases muscular tone. Consequently, WBV improves muscular function. When undergoing WBV instruction, an individual is positioned on a platform that vibrates vertically, stimulating the muscle spindles and causing reflexive contractions (14).

Functional strength training (FST) is a type of exercise that focuses on enhancing the strength and function of muscles used in everyday activities. It is often used to help people with cerebral palsy improve their mobility and independence. More and more research points to the possibility that FST can help children with CP. A recent systematic review and meta-analysis found that FST can lead to significant improvements in muscle strength, function, and quality of life for kids with cerebral palsy (15).

Within this study, we investigate the impact of WBV and functional strength training on functional balance and aerobic capacity in children with hemiparetic cerebral palsy and detect the most effective methods.

2.Patients and Methods:

Sample size calculation:

To determine the sample size, the G*POWER statistical tool (version 3.1.9.2; Franz Faul, University at Kiel, Kiel, Germany) This sample was calculated according to the previous study (16). A minimum of thirty kids would be a suitable sample size for this investigation (17). The ethical committee of the Faculty of Physical Therapy in Kafr Elsheikh, Egypt, gave its approval to the study.t NO: P.T.PED/2/2023/51.

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The Pan African Clinical Trial Registry: PACTR202403663291917.

Study design

The study was a randomized clinical trial. The study took place at the Kafr Elsheikh University Faculty of Physical Therapy Outpatient Clinics. from May 2024 to July 2024, The Modified Ashworth Scale Spasticity Grade I and II classification and according to the Gross Motor Function Classification System (GMFCS) level I or II were the criteria used to classify the participants into two groups, the participants aged from four to eight years, and they had to be capable of understanding basic verbal guidelines and following orders. Participants weren't allowed to participate if they had experienced any of the following: uncontrolled shaking, fixed contractures, and deformities, surgery within the preceding year, BOTOX injections into the calf muscle during the previous year, or a history of epileptic seizures (**figure 1: flow chart**). Randomization was carried out using an Excel sheet, where patients' names were listed in one column, and random numbers were generated in a second column using the RAND formula. Each patient was then assigned to either Study Group I or II in a third column. Patients were ultimately sorted into their respective groups based on the ascending order of the random numbers.

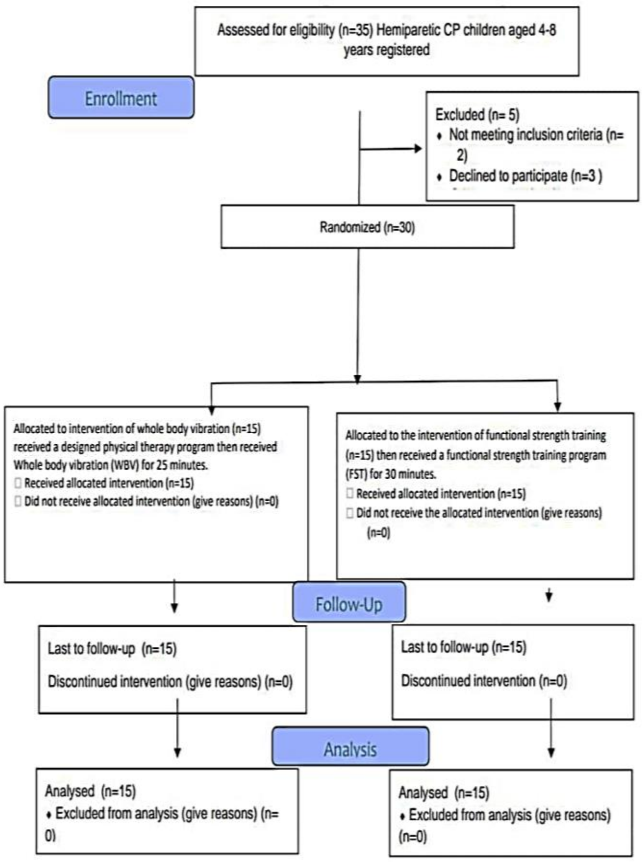

Figure1: flow chart

A. For Evaluation

1) Modified Ashworth scale:

The modified Ashworth scale, developed by Bohannon and Smith, is used to assess the degree of spasticity in adults and children who exhibit upper motor neuron diseases (17).

2) Gross Motor Function Classification System Expanded and Revised (GMFCS-ER).

An objective way to track the evolution of gross motor function in children with cerebral palsy is to use the Gross Motor Function Measure (GMFM), a standardized observational tool. The GMFM assessed a child's motor function, or the amount of work they could accomplish, as opposed to their motor performance, which measures how well the child performed the activity. Rasch Analysis invented it, and GMFM-88 is the more recent version (18).

3) Pediatric balance scale:

The pediatric balance scale (PBS) was developed by modifying the Berg balance scale (BBS). The 14-item PBS test examines functional balance within the framework of daily tasks and is criterion-referenced. These exercises involve balancing while sitting and standing, transferring from one position to another, standing and sitting, reaching forward and down to the floor, turning, and stepping on and off of an elevated surface. Every item receives a 4-point rating. With equipment frequently accessible in clinics and schools, it may be administered and scored in less than 20 minutes (19). Test-retest and interrater reliability are demonstrated to be good when administering this exam to school-age children with mild to moderate motor disability. We employed the PBS in Korean, which has a high interrater reliability among kids with motor impairments (20). Participants fulfilled the minimal requirements for enrollment. Each child's height (in centimeters) and weight (in kilograms) were measured and documented. Each item received one of five possible scores (0, 1, 2, 3, or 4), where zero represented the inability to do the assignment without help and four the capacity to do so completely alone. The distance an upper limb could reach in front of the torso, the amount of time it took to do the activity, and the amount of time it took to maintain a position where the factors that determined the score. A score of 56 points was the maximum.

4) 6-minute walk test (6MWT):

To evaluate functional exercise capacity and the capacity to carry out daily physical activities, functional walking capacity—a submaximal quantitative assessment—must be evaluated. As per the guidelines set forth by the American Thoracic Society (2002), the child strolled along a rectangular path free of obstacles. The therapist accompanied the child at a safe distance, keeping them safe without interfering, and recorded the actual distance covered

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in six minutes using a stopwatch. The 6MWT was employed to evaluate the participants' walking speed. The young patient got to the starting line, stood there, and started the timer as soon as she could walk. During the intermission, patients moved as much back and forth as possible. During this time, the monitor may offer verbal counsel and support. Following the test, the patients' 6-minute walking lengths were noted (20).

Interventions:

Thirty participants were divided randomly into two groups after providing their parents' informed consent. a physical therapy program with a specific design was given to group A (n=15) It included kneeling exercises, standing and gait training as a warm-up for thirty minutes, and stretching activities for the muscles of the lower limb, including the hamstrings, calf, and hip flexors and adductors. To concentrate the vibration's energy on the lower extremities, the youngster stands on the WBV platform in a semi-squat posture (30 degrees of knee flexion). With a frequency of 20–30 Hz and a vertical displacement of 2-4 mm, the WBV application protocol consists of 25 minutes of vibration and 5 minutes of rest intervals (21). The objective of the WBV device is to raise the frequency of vibration from 28 to 30 Hz and the peak-to-peak displacement to 2 mm (as determined for the middle toe of each foot) by increasing 0.8 or 1 Hz every three treatment sessions until the target frequency of 30 Hz is reached. The rate of rise in WBV frequency is contingent upon the child's tolerance to vibration and their comfort with the setting. The WBV device's user was likely to experience increased musculoskeletal force in response to higher frequency and amplitude (22).

As training advanced on WBV, more exercises were added, like tossing and catching balls, climbing and descending with a stick in both hands, and pulling small things with force, like balls or pens (23). Group B (n=15) underwent a 30-minute functional strength training session, consisting of one to three sets of 12 repetitions maximum, to improve lower extremity muscle strength. Training frequency was split between two groups three times a week for 12 weeks (24). Weights, higher steps, a lower bench, a slower pace, lessening the child's support, and/or performing more customized sets one-on-one are examples of progression; however, these options are typically modified after two weeks (25). The purpose of the functional strength training program is to strengthen the weak muscles in the affected leg so they can produce the required force in graded tasks or activity sequences (26).

Pediatric balance scale which examines functional balance, and 6-minute walk test evaluates functional exercise capacity, both assessed before and after treatment.

Results:

Data analysis:

The chi chi-squared test was used to compare genders between groups. The Mann-Whitney test was used to compare pretreatment age, weight, height, six-minute walk test, and pediatric balance scale. The posttreatment six-minute walk test and pediatric balance scale were compared between the two groups using an independent t-test. A paired t-test was used to compare the pediatric balance scale measurements taken before and after therapy, and a Wilcoxon test was used to compare the minute walk test measurements taken before and after treatment. All statistical tests were conducted with a significance level of P. value < 0.05.

Between-group comparison:

Before the treatment, Age, weight, height, the six-minute walk test, and the pediatric b, 0.463ale did not significantly differ between the two groups with P. values of (0.443, 219, 0.589, 0.463, and 0.95) respectively (**Table, 1&2**) (**Figure 2**), while after treatment, there was a significant difference in six-minute walk test and pediatric balance scale between the two groups in favor of group A with P. value of < 0.001 (**Table 2**) (**Figure 3**).

Within-group comparison:

Regarding six-minute walk test, both groups (A&B) showed a significant difference (P < 0.01) post-treatment as compared with pretreatment in favor of group A with percent of change 182.97% & 31.04% respectively, while regarding the pediatric balance scale, both groups (A&B) showed a significant difference (P<0.01) posttreatment as compared with pretreatment in favor of group A with percent of change 105.5% & 21.62% respectively (**Table 2**).

Table (1). To compare the gender distributions of groups A and B, use the frequency distribution and the chi-squared test.

Gender	Group A	Group B	χ^2 value	P. value	Sig
Female	7 (46.7) %	9 (60) %	0.54	0.464	NS
Male	8 (53.3) %	6 (40) %			

χ^2: Chi squared value **P. value: Probability value**
NS: Nonsignificant

Table (2): Comparison of outcome variables between groups at various measuring intervals and descriptive statistics.

Dependent variables		Group (A) (n = 15)	Group (B) (n = 15)	Group A Vs. B P. value*
Age		4.93 ±1.16	5.2 ±1.08	0.443^{NS}
Weight		21.33 ±2.61	23 ±4.16	0.219^{NS}
Height		119 ±10.45	117.53 ±10.18	0.589^{NS}
Six minute walk	**Pre-treatment**	1.77 ±0.37	1.67 ±0.41	0.463^{NS}
	Post-treatment	5 ±0.85	2.19 ±0.41	< 0.001^{S}
	% of change	182.97 %	31.04%	
	P. value**	< 0.001^{S}	0.001^{S}	
Pediatric balance scale	**Pre-treatment**	19.33 ±2.29	19.96 ±0.04	0.95^{NS}
	Post-treatment	39.73 ±2.28	24.27 ±4.59	< 0.001^{S}
	% of change	105.5%	21.62%	
	P. value**	< 0.001^{S}	0.003^{S}	

*** Comparisons across groups; ** Comparisons within groups between pre- and post-treatment outcomes. Data presented as mean ± SD, with p representing probability and NS, p > 0.05, and S, p < 0.05, denoting non-significant results.**

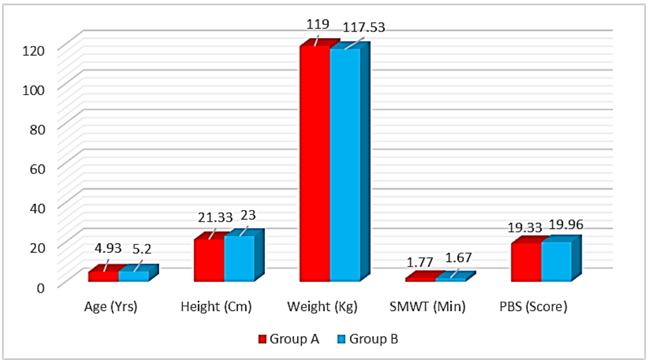

Fig. (2): Prior to treatment group A and group B mean values.

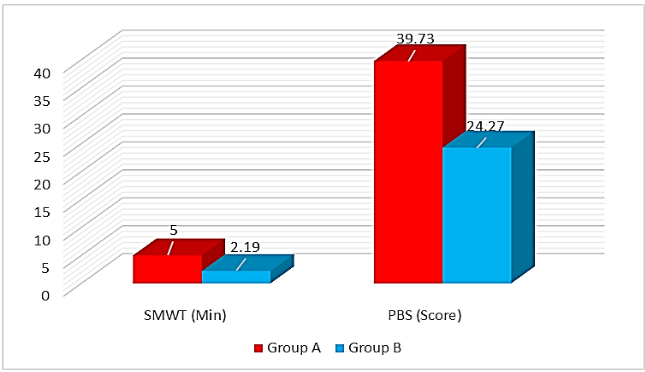

Fig. (3): Following treatment averages for the A and B groups.

Discussion:

This randomized controlled study examined the consequences of WBV and functional strength workouts on functional balance plus aerobic capacity on hemiparetic cerebral palsy. There was an obvious variation in the six-minute walk test and pediatric balance scale in favor of group A between the two groups with a P value of < 0.001. Regarding six-minute walk test, both groups (A&B) revealed a noteworthy variation (P < 0.01) post-treatment as compared with pretreatment in favor of group A with percent of change 182.97% & 31.04% respectively, while regarding pediatric balance scale, both groups (A&B) indicated a remarkable variance (P<0.01) posttreatment as compared with pretreatment in favor of group A with percent of change 105.5% & 21.62% respectively.

Our study's results on the 6-meter walk test are consistent with those of other studies that found that WBVT significantly improved mobility, as seen by improvements in functional tasks (such as getting out of a chair) and a rise distantly traveled throughout the 6-minute walk test. (27). A review was conducted on the impacts on gross motor function, walking speed, additionally walking balance. In contrast to the other intervention groups, the WBV group demonstrated a significant raise in walking distance (6 minutes), although rotation and balance did not change. This aligns with research that found that patients receiving vibration therapy enhanced their average pace at which one walks in the 10-minute walking test, whereas the control group did not exhibit any improvement (28). Enhancement of the 6MWT range after WBVT is in line with other studies (29).

In the WBV group, walking a 6-minute distance was substantially higher. According to research, CP patients who got vibration therapy saw an increase in their mean walking speed during the 10-minute walking test. (30)

Rittweger et al. (31) determined that the study group's improvement was a coincidental finding. In contrast to traditional resistance training, which uses only 40–50% of the muscles and directly stimulates the nervous system, he noted that WBV exercise utilizes the stretch reflex, 90% of the body's muscles are activated by the stretch reflex, which makes muscle contraction easier. These are the training's stated benefits. This highlights the fact that WBV training enhances brain-muscle connection. As a result, it causes muscles to contract more quickly, expertly, and precisely, which develops muscle power and strength. Additionally, by enhancing the ability of the contracted muscles to transmit oxygen, WBV exercise enhances the circulatory system.

Moreover, Wallmann et al. (32) revealed that vibration training lowers cortisone even when human growth hormone levels rise. Together with other things, these two hormones participate in the breakdown additionally synthesis of tissue of the muscle, which is known as anabolism and catabolism. Strong and healthy muscles are kept up when these two hormones are in better balance.

According to the meta-analysis, WBV training enhanced stroke patients' balance, gait, and dynamic stability. Vibration has the potential to impact the spinal anterior horn neurons' rhythmic activity, stimulate excitability in the cerebral motor cortex, help stroke patients' ability to maintain their posture, and promote the remodeling of brain function in injured areas (33).

The WBV triggers the tonic vibration reflex, which involves the contraction of muscle spindles, the action of Ia afferent neural signals, and the final activation of muscle fibers by massive motoneurons. Furthermore, by stimulating muscle spindles and polysynaptic pathways, this reflex raises the recruitment of motor units (34). This aligned with the results of Song et al. (35), who discovered that walking balance, walking speed, stride length, and deviation angle were all improved by WBV training. It also shortened the time that a child with spastic cerebral palsy needed single- and double-limb support. Furthermore, they concluded that since horizontal WBV training can improve a child's physical performance without having a negative effect, it needs to be part of rehabilitation protocols for children with CP.

Patients recovering from strokes may potentially benefit from whole-body vibration. (36,37). Leg muscular strength may have improved along with this increase in physical balance following total body vibration (38). Upright standing on a vibration platform can trigger the activation of proprioceptive spinal networks. Because reflexes are connected to the spindles in muscles and tendons activating at various times (39, 40), Following vibration training, there may be a favorable correlation between improved balance and increased muscular strength and proprioception. Children and teenagers with cerebral palsy may walk more successfully and with better balance thanks to whole-body vibration. Consistent with our findings, other studies have demonstrated that full body vibration enhances kids suffering from cerebral palsy muscular tone, strength, balance, additionally movement (41).

In children with cerebral palsy, low muscle strength is a more significant limiting factor than stiffness. As a result, strengthening muscles has become more important than controlling spasticity. Children with cerebral palsy must have sufficient strength in particular muscle groups to navigate and control their steps when walking. The significance of FST was demonstrated by a prior study that found that six weeks of FST combined with bilateral heel raises, half squats, and loaded step-ups significantly increased the force of the ankle plantar flexors and quadriceps, which also showed up in the walking ability of children with cerebral palsy (42).

The review's meta-analysis revealed that FST had a substantial, significant impact on the quadriceps group but a marginally significant, modest effect size on the hamstring and ankle plantar flexor strength. Overall, this analysis shows that FST helps children with cerebral palsy strengthen their major tonic muscle groups in their lower limbs. This improvement is sustained across two to eight weeks of follow-up (43). These results are consistent with several other studies that showed a positive correlation between functional outcomes and lower extremity strength in children with cerebral palsy (44,45,46).

A significant displacement of the center of pressure is seen in children with spastic cerebral palsy before they recover from the instability disruption. A more gradual and disorganized recovery of balance results from altered timing and sequencing of muscle response and co-contraction of agonist and antagonist muscles at the hip, knee, and ankle joints (47).

A 2014 study involving 30 children with cerebral palsy revealed a significant relationship between balance and movement. Saquetto et al. (48) supported this idea by pointing out that dynamic balance is also increased when lower extremity strength increases.

Targeted strength training significantly improved upright biomechanical alignment and stability during walking, according to research by Unger et al. (49) that did not seek to evaluate balance. Increased strength may have a direct impact on balance and mobility, which are positively connected. Given that FST increases strength and mobility, and that balance and mobility are positively correlated, it may be concluded that strength training could comprehensively help children with CP provided it is conducted in a customized, task-specific, and functional way.

Functional strength training may help children with cerebral palsy (CP) walk more easily and with less aerobic load by improving their coordination. The idea of specificity of training explains that combining functional strengthening exercises with an aerobic training program may increase functional capacity and endurance (50)

Strength training can enhance muscle strength, balance, gait speed, or gross motor function in children and adolescents with cerebral palsy at levels I, II, and III of the Gross Motor Function Classification System, according to a systematic review and meta-analysis (51) Functional strength training has a moderate-to-large, statistically significant, positive impact on muscle strength and mobility in children with spastic cerebral palsy, according to Shilesh et al. (52), who also reported that FST helps these children with the condition. The child's engagement and activities may show these gains clearly. Furthermore, high-quality, consistent evidence across multiple motor domains is required to offer a more comprehensive and definitive view of FST in clinical practice. Lastly, WBV should be used by clinicians to help children with hemiparetic cerebral palsy with their balance and aerobic ability.

Limitation:

The fact that the participants in this study ranged in age from four to eight years old and that it only examined one form of CP are some of its limitations. This sample only contained level 1 or level 2 GMFS.

Conclusion:

The study's findings demonstrated that 12 weeks of function strength training and whole-body vibration could increase function balance as well as aerobic capacity in kids with cerebral palsy that is hemiparetic with the favor of whole-body vibration.

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