全身垂直訓練改善中風患者膝關節過度伸拉和下肢功能的影響：一項隨機對照試驗研究

Whole Body Vibration Training Improves Walking Performance of Stroke Patients with Knee Hyperextension: A Randomized Controlled Pilot Study

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簡述內容：

中風康復期的患者大部分會有走路費力、穩定性差、不對稱的情形，甚至有些無法行走、步態異常容易出現跌倒等問題，亦或是出現患側下肢肌無力、肢體僵硬、平衡障礙，導致患側膝關節出現過度伸展（角度大於5°）的現象，嚴重影響行走能力，若康復期內持續惡化無法改善，對後續復原的狀況會越來越困難。

本研究經八週採用全身垂直律動(頻率6–10Hz,振幅4mm)進行了步行、下肢功能和膝關節過度伸展時間的實驗訓練，證實可以提升中風患者相關肢體功能和後續生活品質的變化有顯著效益，是理想的康復期訓練工具。

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Whole Body Vibration Training Improves Walking Performance of Stroke Patients with Knee Hyperextension: A Randomized Controlled Pilot Study

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Abstract: *Objective*: To investigate the effect of 8-week whole body vibration training on gait performance and lower extremity function in stroke patients with knee hyperextension.

Methods: Total 30 subjects with stroke were randomized into the control group (n=15) or the intervention group (n=15). The patients of intervention group were treated with whole body vibration while the control group was treated with placebo. The walking function, lower limb function and knee hyperextension times were assess in this study. Gait performances were evaluated by 10-meter walk test. The knee hyperextension times was visually observed and counted. The lower limb function was evaluated by Fugl-Meyer motor assessment.

Results: The times of the knee hyperextension of the intervention group was significantly decreased compared with control groups (P=0.000, d=1.749, 95%CI[2.915,7.285]). The walking function assessed by 10-meter test of intervention group was significantly improved compared with control group (P=0.001, d=1.345, 95%CI[1.896,6.704]). The performances of all the three tests were improved after training in both groups (P=0.000/P=0.000, d=1.500/d=1.952, 95%CI[3.309,9.891]/ 95%CI[5.549,12.45]; P=0.000/P=0.000, d=2.015/d=2.952, 95%CI[5.214,11.39]/95%CI[9.423, 15.98]; P=0.000/P=0.000, d=3.537/d=5.108, 95%CI[19.05,12.35]/95%CI[16.52,22.28]).

Conclusion: The results suggest that 8 weeks whole body vibration training can reduce knee hyperextension and increase ambulatory speed in stroke patients.

Keywords: Stroke, knee hyperextension, whole body vibration training, lower extremity function.

INTRODUCTION

The prevalence of knee hyperextension has been reported by a series of studies [1-3]. Knee hyperextension is defined as an increase (more than five degree) in knee extension during standing phase with or without pain, swelling, snapping, slack [1]. It can be caused by many factors in clinic practice such as the amyasthenia of musculi quadriceps femoris, muscle spasm [2, 3], muscle weakness of knee flexion [4-6], the muscle weakness of triceps surae, spasm and contracture of Achilles tendon [7], contracture of hip flexion, muscle weakness of hip extension. The knee joint could be injured by habitual hyperextension which can produce ache, dysbasia [8, 9], synovitisand skeleton distortion [10]. To solve the problem of knee hyperextension, a series of comprehensive assessments such as range of motion, proprioception, muscle spasticity and motor function can be performed and specific rehabilitation exercises can be implemented. The traditional knee extension control training and squat training can help control knee hyperextension. But it is hard to improve the coordination ability of lower limbs and the stability of joint [11, 12]. The effects of routine physical therapy on knee hyperextension were still limited. Therefore, new and advanced rehabilitation techniques are needed to resolve this issue.

There is few evidence supporting the effects of whole body vibration training on knee hyperextension, walking speed and lower extremity function in stroke patients with knee hyperextension [13]. Therefore, the aim of this study was to investigate whether whole body vibration training can improve knee hyperextension, walking speed and lower extremity function of stroke patients.

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MATERIALS AND METHODS

Subjects

This is a randomized controlled trial design. All patients with stroke who had been admitted to the Department of Physical Medicine and Rehabilitation of Jiangsu Province Hospital were included from March 2014 to January 2015.

The Inclusion criteria consisted of the following: a first-time, unilateral stroke due to infarction or hemorrhage, vital signs stable, preserved cognitive and communicative ability (all subjects scored above 24 on the Mini-Mental Status Examination), strong initiative motivation of rehabilitation, standing balance≥2.

The exclusion criteria consisted of the following: serious heart, brain and kidney diseases which can affect the sense and motor ability of the lower limbs. Baseline data was collected for each subject, include gender, age, height, weight, time from stroke onset, stroke type, hemiplegic side and assistive devices (if used). All protocols used in this study were approved by the Medical Ethical Committee of Nanjing Medical University and written informed consents were obtained from all subjects or their family members before study.

Methods

In the treatment group, subjects received whole body vibration (I-VIB5050, Body Green, Taiwan) with a magnitude of 6~10Hz and amplitude of 4.0mm. During the intervention, subjects were positioned on the platform in a semi-squatting position and were kept in an upright position with even weight distribution on both feet. The time course included 60 seconds of vibration with a 10 seconds rest interval,10 rounds per set, eight sets per day. In the control group, subjects followed the same procedures, but the vibration machine was not turned on. Other exercises included single leg standing with knee bending within 0 to 15 degree (treatment group did this on the platform with vibration while control group without vibration, 30 seconds per round with 10 seconds rest, 10 rounds per set, five sets per day), range of motion exercise of lower limb, PNF exercise, climbing stairs, walking with brace and electrical stimulation (see Table **1**).

This study was a randomized controlled trial with blinding of both subjects and assessors. Participants were divided by simple randomization into a whole body vibration group and a control group done by physician-1, who was not involved in the assessment of the patients or the treatments. Patient characteristics and all outcome measures before and after treatment were assessed by an experienced physician-2, who was blinded to the treatment allocations. The treatments were carried out in a separated room for either vibration training or sham treatment by physician-3. All physicians were instructed not to communicate with the subjects about the possible goals or rationale for either treatment. Fugl-Meyer for lower extremity assessment (17 items, total score 34 points) [14], 10-meter walk test [15, 16] and subjective observation of knee hyperextension [1] were evaluated before and after 8-week treatment (Fig. **1**).

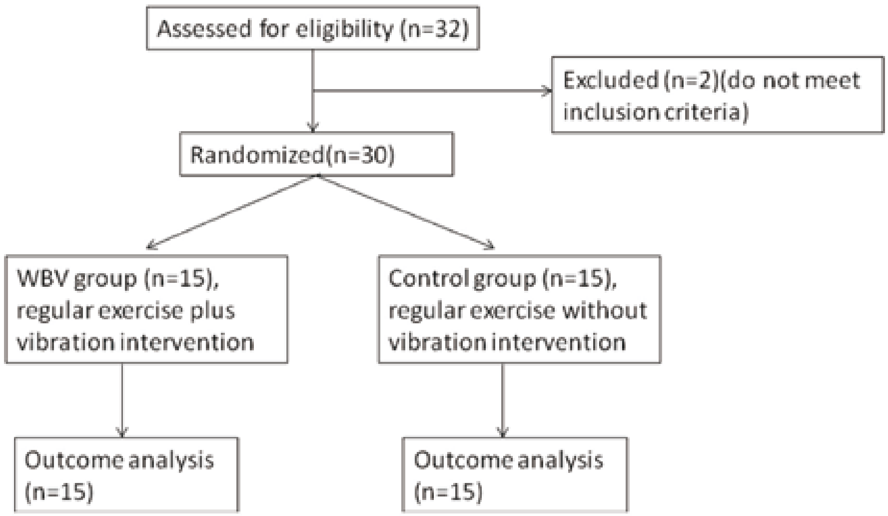


Fig. (1). Flowchart of participants through each stage of study.

Table 1. Progress of whole body vibration training during the eight weeks.

Week	Position	Magnitude	Amplitude	Training Time/ Resting Time	Round	Set
1 to 3	Semi-squatting	6Hz	4.0mm	60s/10s	10	8
	Single leg standing with knee bending within 0 to 15 degree	6Hz	4.0mm	30s/10s	10	5
3-5	Semi-squatting	8Hz	4.0mm	60s/10s	10	8
	Single leg standing with knee bending within 0 to 15 degree	8Hz	4.0mm	30s/10s	10	5
6-8	Semi-squatting	10Hz	4.0mm	60s/10s	10	8
	Single leg standing with knee bending within 0 to 15 degree	10Hz	4.0mm	30s/10s	10	5

Table 2. Participants' anthropometric and physiological characteristics ($\bar{x}$±s).

Group	N	Age (Years)	Height (cm)	Body Mass (Kg)	Course of Disease (Day)	Ischemic Stroke	Hemorrhagic Stroke
Control	15	54.3±6.8	165.1±6.1	72.3±9.5	59.4±61.4	12	3
Treatment	15	53.8±6.0	166.6±7.0	71.6±8.2	66.9±42.9	10	5

Statistical Analysis

All the data were presented as the mean ± standard deviation (SD) and 95% confidence intervals (95% CI). Data analysis was taken by IBM SPSS Statistics 21. Two independent sample t-tests were carried out by the scores of FMA, 10 meter walk test (s) and times of knee hyperextensions in two groups of patients before and after treatment; P<0.05 was considered statistically significant.

RESULTS

There were total 30 patients enrolled in our study. Table **2** outlines the participants' anthropometric and clinical characteristics.

The FMA-L score, the 10m maximum walking speed test and times of knee hyperextensions of two groups had no statistical differences before treatment. However, after treatments, the FMA-L score and 10-meter maximum walking speed test of both groups were improved significantly (*P*=0.000/*P*=0.000, d=1.500/d=1.952, 95%CI[3.309, 9.891]/ 95%CI[5.549,12.45]; *P*=0.000/*P*=0.000, d=2.015/d= 2.952, 95%CI[5.214,11.39]/95%CI[9.423,15.98]), and the times of knee hyperextensions decreased significantly (*P*= 0.000/*P*=0.000, d=3.537/d=5.108, 95%CI[19.05,12.35]/95% CI[16.52,22.28]) (Table **3**); Compared with the control group after treatment, the WBV's 10 meters maximum walking speed and times of knee extension had significant statistical differences (*P*=0.001, d=1.345, 95%CI[1.896,6.704]; *P*= 0.000, d=1.749, 95%CI[2.915,7.285]) (Fig. **2**).

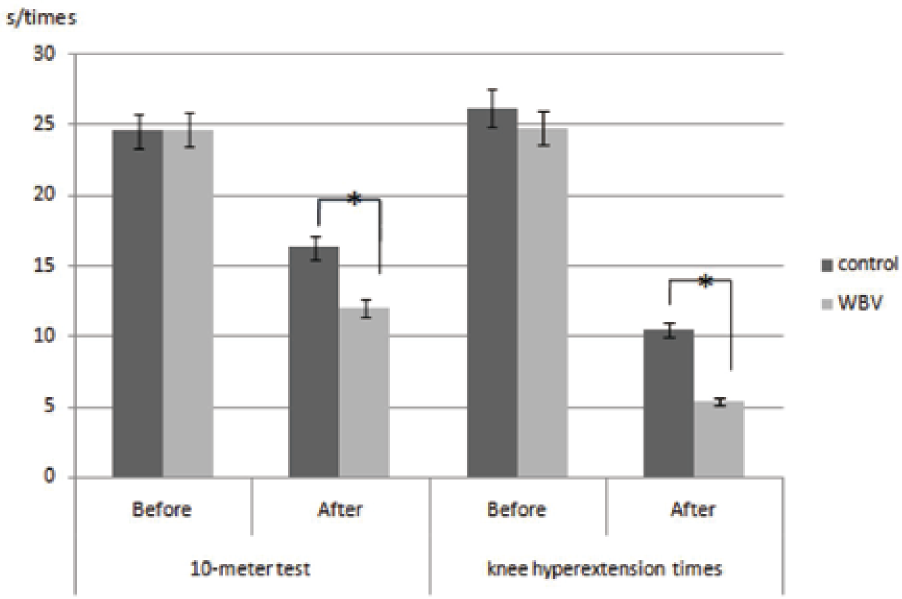
DISCUSSION

This study was conducted to investigate the effect of whole body vibration stimulation on knee hyperextension of stroke patients during walking. In the present study, the times of knee hyperextension were reduced, reflecting better control of the knee joint during walking and standing and probably a reduced risk of injury and reduced energy

Table 3. The comparison of The FMA-L score, 10-meter maximum walking speed test and times of knee extensions ($\bar{x}$±s).

Group	n	FMA-L		10 Meter Walk Test/s		knee Hyperextensions/Times	
		Before the Treatment	After the Treatment	Before the Treatment	After the Treatment	Before the Treatment	After the Treatment
Control	15	16. 7±4. 4	23. 3±4. 4[a]	24. 6±4. 5	16. 3±3. 7[a]	26.2 ±5.4	10.5 ±3.2[a]
Treatment	15	15. 1±4. 3	24. 1±4. 9[a]	24. 7±5. 5	12. 0±2. 6[a]	24.8 ±4.7	5.4 ±2.6[a]

[a]The comparison of results after treatment and before treatment, p<0.05.



[*] The comparison of results after treatment and before treatment, p<0.05

Fig. (2). The comparison of 10-meter test and knee hyperextension times before and after treatment.

exhausting. The 10-meter walk test indicated that gait speed was significantly increased after treatment. Improvement in gait velocity is therefore clinically meaningful in terms of changes in stroke-related function and quality of life, especially for household ambulation [17].

The Knee joint is the biggest and the most complicated joint of the human body. It transfers load, provides a couple for legs, plays a very important role when walking. The skeleton, muscles, meniscus, joint capsule, ligament and proprioception have comprehensive effects on the stability of knee joint. The strength of the muscles around the knee plays an important role in coordination and stability of joint. Relevant researches showed that stroke patients who walked too early would result in knee hyperextension and ankle plantar flexion because that the affected lower limb had not have enough muscle strength to control the knee and ankle joints which lead to increased muscle tone of these muscles during walking [18-20]. When healthy people walk on the ground at the early stage, their knee joints need slight flexion to make the centrifugal contraction of musculi quadriceps femoris to absorb the counterforce from the ground [21]. Patients with stroke who have delayed recovery of musculi quadriceps femoris and eccentric contraction of knee are unable to controll the knee collapse at the range of 0 to 15 degrees knee flexion. Instead, patients will place the knee in the compensatory position of knee hyperextension to prevent the collapse, which lead to the phenomenon of "locked knee", and restrict knee-bent when the swing phase begins [22]. Moreover, it will affect the normal, smooth and fluent walking gait and lead to the pelvic lateral displacement which will form a typical hemiplegic circle gait.

There are many researches about the prevention and treatment of the knee hyperextension of the stroke patients [12, 22-24], including muscle strength training for hip, knee and ankle joints. However, the stability of knee joint is also affected by many other aspects, such as the coordination of extensors and flexors and the proprioception of joint [25]. The proprioception of muscle spindle and tendon is transmitted to the spinal cord by the fast fiber. On one hand, it excites motor neurons of the muscles directly. On the other hand, it inhibits the activity of antagonist muscle which makes the agonist and antagonist muscles to form an interactive coordination and mutually restrict each other by inhibiting interneurons activities [2]. The proprioception of fascia and the deep connective tissue receptors is transmitted by fibers in spinocerebellar tract to cerebellum. Although we feel no subjective perception of body during the process of walking, it has very important significance on the independent control of walking and standing activities [26]. Hemiplegic patients with stroke often face problems of the weakness and loss of proprioception of limbs, so the single factor targeted training in clinic for the key muscle strength of hip, knee and ankle joint may not achieve good results.

In exploring an appropriate adjunct to resistance training in stroke patients, we must select carefully the parameters of mechanical vibration such as frequency, amplitude and duration. Because high frequency (30-40Hz) and small amplitude (1 mm) vibration of muscle can cause fatigue [27, 28]. So we applied whole body vibration at 6Hz to 10Hz and 4mm amplitude. Recent studies using such parameters reported an increase in voluntary force without fatigue [27, 28].

Stroke can impair an individual's leg muscles to different extent. However, instead of vibrating individual leg muscles we exposed our patients to whole body vibration while standing on a vibration platform in a crouched position and in single leg standing with knee bending 0 to 15 degree. The whole body vibration training is completed by the stimulation of mechanical vibration and induces stretch reflex to cause the muscular spindle and α motor neuron to generate muscle contraction and thus enhance the strength of muscles [29, 30]. Furthermore, there are no negative effects on muscle tone [31]. The WBV group in this study combined the squat and single leg standing training with the whole body vibration training in order to facilitate the coordination and control of the flexor and extensor of the lower limb. The angle of knee flexion was adjusted gradually in the training according to the patients' subjective feelings. The body compensations during squatting were strictly controlled. WBV used in its current form actively involves the patient, requires balance and activates several lower extremity muscles, including the quadriceps that is in a mildly stretched position which may have the similar effect of PNF stretch-contraction pattern and steady contraction pattern [32, 33]. And the alternate isometric contraction of agonist and antagonist muscle was conducted, which may lead to the improvement of stability. The crouched posture emphasizes the quadriceps muscle's involvement and dampens the propagation of acceleration waves to the head through the skeletal system.

Because of the impaired proprioception, stroke patients usually depend on the visual function during walking. Whole body vibration is one of the strongest methods for increasing proprioceptive input (mainly through Ia afferents), and it is possible that increased proprioceptive input may induce functional improvement, such as muscle activation and knee control [2]. Many previous studies on whole body vibration trials have reported its effectiveness in improvement in paretic knee extensor muscle strength especially eccentric contraction muscle strength [34], reduced ankle spasticity [35], and postural control [36]. These may be the reason why our patients could benefit from WBV with decreased knee hyperextensions and increased walking speed.

There was no difference between WBV group and control group in Fugl-Meyer lower limb motor assessment after eight weeks. This result could be caused by two reasons. First, Fugl-Meyer motor assessment does not measure proprioceptive, muscle strength and coordination of the knee joint. So it could be less sensitive to the changes of those parameters. Second, whole body vibration training may have effects not only on lower limbs but also on trunk core muscles which could lead to better performance during walking. So there was no significant change in Fugl-Meyer lower limb motor score between two groups.

There are still limitations in this study. First, it is not clear which is the best frequency, amplitude and duration of the WBV training for lower extremity in stroke patients. Second, further investigate is need to see whether pure WBV training can lead to similar benefits as the treatment group in this study. Finally, we had small sample size preventing us from dividing the sample into subgroup on the basis of type of stroke. More participants could have been included to increase the power of the statistical analyses.

CONCLUSION

The whole body vibration training is a more effective approach than traditional physical therapy for stroke patients with knee hyperextension. It can improve gait performance and increase walking speed.

CONTRIBUTORS

Chuan Guo conceived this study. Xun Mi did the randomization. Shouguo Liu did all the assessments. Chen Gong carried out the whole body vibration and the sham procedure. Wenchao Yi and Lan Zhu wrote the paper. Sergio Machado analyzed the data and wrote the results. Ti-Fei Yuan and Chunlei SHAN guided the study design.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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REFERENCES

[1] Bleyenheuft C, Bleyenheuft Y, Hanson P, Deltombe T. Treatment of genu recurvatum in hemiparetic adult patients: A systematic literature review. Ann Phys Rehabil Med 2010; 53: 189-99.

[2] Shiwen L, Fang G, Zheng L, *et al*. Investigation of mechanism of genu recurvatum by the loss of proprioception in cerebrovascular accident patients. Chin Rehabil Med J 2005; 20(1): 30-3.

[3] Bing H, Min G, Zheng L, *et al*. Research progress on mechanism underlying genu recurvatum in hemiplegic patients with stroke. Hebei J Trad Chin Med 2010; 32(6): 944-5.

[4] Fei Z, Shiyi C. The functional instability of joint and reconstruction of proprioception. J China Sports Med 2000; 19(1): 65-8.

[5] Beard DJ, Dodd CA, Trundle HR, Simpson AH. Proprioception enhancement for anterior cruciate ligament deficiency. A prospective randomized trial of two physiotherapy regimes. J Bone Joint Surgery 1994; 76(4): 654-9.

[6] Lephart SM, Pincivero DM, Giraldo JL, *et al*. The role of proprioception in the management and rehabilitation if Athletic injuries. Am J Sports Med 1997; 25(1) : 130-7.

[7] Dongfeng X, Lijun X, Bizhen F, *et al*. The etiological treatment of stroke patients with knee hyperextension. Clin Med Engineer 2011; 18(4): 546-7.

[8] Bleyenheuft C, Bleyenheuft Y, Hanson P, *et al*. Treatment of genu recurvatum in hemiparetic adult patients : a systematic literature review. Ann Phys Rehabil Med 2010; 53(3) : 189-99.

[9] Schenck RC Jr, Kovach IS, Agarwal A, *et al*. Cruciate injury patterns in knee hyperextension : a cadaveric model. Arthroscopy 1999; 15(5) : 489-95.

[10] Fish DJ, Kosta CS. Genu recurvatum: identification of three distinct mechanical profiles. JPO 1998; 10(2) : 26-36.

[11] Qi L, Lei W, Xiaodong F. The study of " slope training" on improving stroke patients with knee hyperextension. China Prac Med 2008; 3(36): 221-2.

[12] Wanlin L, Hui W, Juan H, *et al*. Effect of Half Squat on Knee Hyperextension of Stroke Patients. Chin Rehabil 2011; 26(1): 18-19.

[13] Liao LR, Huang MZ, Lam FMH, *et al*. Efficacy of whole-body vibration training on body function, activity, and participation poststroke: A systematic review. Hong Kong Physiother J 2013; 31(2): 106.

[14] Xiaoping Y, Huazhen G, Wei C. Therapy evaluation of rehabilitation. Beijing: Huaxia Publishing House, 2006.

[15] Bohannon RW. Comfortable and maximum walking speed of adults aged 20-79 years: reference values and determinants. Age Ageing 1997; 26(1): 15-9.

[16] Wolf SL, Catlin PA, Gage K, Gurucharri K, Robertson R, Stephen K. Establishing the reliability and validity of measurements of walking time using the Emory Functional Ambulation Profile. *Phys Ther* 1999; 79(12): 1122-33.

[17] Schmid A, Duncan PW, Studenski S, *et al*. Improvements in speed-based gait classifications are meaningful. Stroke 2007; 38: 2096-100.

[18] Jun Z. The treatment analysis of recurvatum rehabilitation of knee joint with stroke. China Rehabil Theory Practice 2004,10 (5): 319.

[19] Tan YX, Liu JG, Qi XK. Effect of weight-bearing too early in lower limbs on extensor muscle spasm and knee hyperextension of affected limb in acute stroke patients with hemiplegia. Neural Injury Funct Reconstr 2012; 7(6): 433-4.

[20] Appasamy M, De Witt ME, Patel N, *et al*. Treatment Strategies for Genu Recurvatum in Adult Patients With Hemiparesis: A Case Series. PM R 2015; 7(2): 105-12.

[21] Isakov E, Mizrahi J, Onna I, *et al*. The control of genu recurvatum by combining the swedish knee-cage and an ankle-foot brace. Disabil Rehabil 1992; 14(4) : 187-91.

[22] Harris ML. Quadriceps disability after stroke. Clin Rehabil 2001; 15: 274-81.

[23] Xin W. The effects of reinforced trunk training with squat training on the balance and walking ability in hemiplegic patients with stroke. Chin J Phys Med Rehabil 2007; 29: 701-3.

[24] Bleyenheuft C, Bleyenheuft Y, Hanson P, *et al*. Treatment of genu recurvatum in hemiparetic adult patients:A systematic literature review. Ann Phys Rehabil Med 2010; 53(3): 189-99.

[25] Yan W, Qiang T, Lian-Ru K. Effect to Genu Recurvatum of Enhancing Steady Training to Knee Joint of Stroke Patients in Early Course of Diseases. Chin J Rehabil 2006; 21(4): 249-50.

[26] Peter D. Topical Diagnosis in Neurology. Geory: Thieme Publishing Company, 1995.

[27] Cardinale M, Lim J. The acute effects of two different whole body vibration frequencies on vertical jump performance. Med Sport 2003; 56: 287-92.

[28] Torvinen S, Sievanen H, Jarvinen TA, *et al*. Effect of 4-min vertical whole body vibration on muscle performance and body balance: a randomized cross-over study. Int J Sports Med 2002; 23: 374-9.

[29] Abercromby AFJ, Amonette WE, Layne CS, *et al*. Variation in neuromuscular responses during actue whole-body vibration exercise. Med Sci Sports Exerc 2007; 39(9): 1642-50.

[30] Ekaterina Tankisheva, An Bogaerts, Steven Boonen, *et al*. Effects of Intensive Whole-Body Vibration Training on Muscle Strength and Balance in Adults With Chronic Stroke: A Randomized Controlled Pilot Study. Arch Phys Med Rehabil 2014; 95(3): 439-46.

[31] Ahlborg L, Andersson C, Julin P. Whole-body vibration training compared with resistance training : effect on spasticity, muscle strength and motor performance in adults with cerebral palsy. J Rehabil Med 2006; 38 : 302-8.

[32] Hongshi M. Theory and practice of rehabilitation medicine (Part 1). Shanghai, Science and Technology Press, 2000.

[33] Dong-Yun J, Tong-Cai T, Xiang-Ming Y. Proprioceptive Neuromuscular Facilitation Prevent Knee Hyperextension in

Patients with Stroke. Chin J Rehabil Theory Pract 2011; 17(11): 1062-3.

[34] Tekla KT, Monika H, Gabor F, *et al*. One session of whole body vibration increases voluntary muscle strength transiently in patients with stroke. Clin Rehabil 2007; 21:782-93.

[35] Chan KS, Liu CW, Chen TW, *et al*. Effects of a single session of whole body vibration on ankle plantarflexion spasticity and gait performance in patients with chronic stroke: a randomized controlled trial. Clin Rehabil 2012; 26(12):1087-95.

[36] Lee SW, Cho KH, Lee WH. Effect of a local vibration stimulus training programme on postural sway and gait in chronic stroke patients: a randomized control trial. Clin Rehabil 2013; 27(10): 921-31.

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上肢負重振動訓練對
偏癱肩關節半脫位患者上肢功能的影響

發表自：

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簡述內容：

一般的久坐上班族、勞力工作者或職業運動員等通常都會有肩頸痠痛不適的狀況產生，大部分人來說可能會做伸展拉筋的動作來緩解不舒服症狀，但長時間不在意或是無法自主運動者久而久之症狀會越加明顯，導致血液、神經循環無法通暢，可能就會產生肌肉與骨骼的萎縮與退化，而無法自主運動者通常上肢訓練運動又比下肢訓練運動容易受到忽略，因為多半會注重於下肢的步行功能。

而本研究探討腦中風患者採用上肢負重垂直律動進行訓練，分為實驗組(垂直律動訓練)與對照組(一般物理治療)，垂直律動可引起全身或局部的肌肉收縮伸張及神經的適應性改變，提高神經活性與改善上肢關節功能，對於實驗組的患者提高復健的效益，是種有效而非侵入性的改善治療工具。

上肢负重振动训练对偏瘫肩关节半脱位患者上肢功能的影响

龚晨，顾昭华，郭川，王盛，王彤

【摘要】 目的：观察上肢负重振动训练对改善脑卒中患者上肢功能的疗效。方法：脑卒中患者30例随机分为2组各15例，对照组采用患侧上肢负重压手和神经肌肉促进技术；观察组在此基础上进行偏瘫上肢负重振动训练。结果：治疗4周后，观察组伸肘肌肌张力均较治疗前及对照组明显提高（$P<0.05$），对照组治疗前后比较差异无统计学意义；2组屈肘肌肌张力均较治疗前明显下降（$P<0.05$），且观察组更低于对照组（$P<0.05$）；观察组肩半脱位程度较治疗前及对照组明显下降（$P<0.05$），对照组治疗前后差异无统计学意义；2组上肢Brunnstrom分期评分均较治疗前明显提高（$P<0.05$），且观察组更高于对照组（$P<0.05$）。结论：负重振动训练作为一种神经肌肉训练方法，可有效降低患者的肩关节半脱位程度。

【关键词】 脑卒中；肩关节半脱位；振动训练；本体感觉刺激

【中图分类号】 R49；R743.3 【DOI】 10.3870/zgkf.2015.04.012

肩关节半脱位状态长时间会导致肩关节囊及周围韧带的松弛，并有可能进一步牵拉臂丛神经[1]。本研究旨在探讨肩关节负重支撑结合振动训练对脑卒中肩关节半脱位及上肢功能的影响。

1 资料与方法

1.1 一般资料 选取2014年6月～2015年2月在我科住院的脑卒中偏瘫患者30例，均符合全国第四届脑血管疾病学术会议制定的脑卒中诊断标准，并经头颅CT或MRI证实。30例随机分为2组各15例，①观察组，男9例，女6例；年龄(53.8±6.0)岁；病程(43.5±10.4)d。②对照组，男8例，女7例；年龄(54.3±6.8)岁；病程(40.8±8.2)d。2组一般资料比较差异无统计学意义。

1.2 方法 2组均进行上肢常规的作业治疗、物理治疗、物理因子治疗及上肢负重训练：患者端坐位，患侧手置于坐位等高平面，用健手帮助患侧肘关节伸直，患者完成身体重心向患侧转移，15min 1组，上、下午各1组，每周5d。2组上肢负重的唯一区别在于对照组将受压于治疗床上，而观察组将上肢置于垂直振动平台上，采用Body green振动平台，振幅4mm，振动频率2.5～15Hz，根据患者耐受逐渐增加。

1.3 评定标准 ①上肢关键肌肌张力：采用改良的Ashworth分期进行屈肘肌、伸肘肌的肌张力评估。0、1、1＋、2、3、4级分别赋值为0、1、1.5、2、3、4分。②肩关节半脱位程度：采用临床实践中较常用的触诊法：即用横指测量的方法测量肩峰和肱骨头之间的空间，以食指的横指个数计算[2-4]。③上肢运动功能：采用Brunnstrom运动功能分期评估患者的上肢功能，分为I、II、III、IV、V、VI期，分别赋值为1、2、3、4、5、6分。

1.4 统计学方法 采用SPSS 20.0软件进行统计学处理，计量资料用$\bar{x}\pm s$表示，t检验，$P<0.05$为差异有统计学意义。

2 结果

治疗4周后，观察组伸肘肌肌张力均较治疗前及对照组明显提高（$P<0.05$），对照组治疗前后差异无统计学意义；2组屈肘肌肌张力均较治疗前明显下降（$P<0.05$），且观察组更低于对照组（$P<0.05$）。见表1。

治疗后，观察组肩半脱位程度较治疗前及对照组明显下降（$P<0.05$），对照组治疗前后差异无统计学意义；2组上肢Brunnstrom分期评分均较治疗前提高（$P<0.05$），且观察组更高于对照组（$P<0.05$）。见表2。

表1 2组伸、屈肘肌肌张力评分治疗前后比较 分，$\bar{x}\pm s$

组别	n	伸肘肌		屈肘肌	
		治疗前	治疗后	治疗前	治疗后
对照组	15	0.45±0.02	0.63±0.04	1.91±0.34	1.41±0.43^a
观察组	15	0.38±0.10	1.69±0.21^{ab}	1.88±0.43	0.92±0.12^{ab}

与治疗前比较，$^aP<0.05$；与对照组比较，$^bP<0.05$

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表2 2组肩半脱位程度及上肢Brunnstrom分期治疗前后比较 $\bar{x}\pm s$

组别	n	肩半脱位程度(食指的横指个数)		Brunnstrom(分)	
		治疗前	治疗后	治疗前	治疗后
对照组	15	1.24±0.44	0.97±0.48	1.12±0.21	2.10±0.11[a]
观察组	15	1.20±0.43	0.43±0.45[ab]	1.24±0.14	3.45±0.43[ab]

与治疗前比较，[a] $P<0.05$；与对照组比较，[b] $P<0.05$

3 讨论

肩关节在上肢运动中起到非常重要的作用。在脑卒中急性期，往往因过分重视下肢步行功能而忽视上肢的康复，引起继发性上肢功能失用、肩关节半脱位、疼痛、废用手。脑卒中后肩关节半脱位的研究很多，包括各类肩吊带、神经肌肉促进技术、上肢机器人，各类电刺激等。当患者转移能力提高后，上肢作为一个被悬挂在躯干两侧的肢体，会持续性受到地球引力的作用，缺乏支持或支持不充分，会导致半脱位持续存在，并进一步影响患者上肢功能的恢复。而脑卒中患者肩关节周围肌肉力量不足，同时缺乏足够的负重刺激本体感觉，从而导致上肢肩周肌张力低下，半脱位持续存在及上肢功能出现较迟缓。

全身振动是一种利用外源性机械振动和外加抗阻负荷刺激机体，引起局部或全身肌肉振荡及中枢神经系统适应性改变，从而改善神经肌肉功能的训练方法[5]。研究发现全身振动能提高神经肌肉活性[6-8]，提高骨密度[9]，促进软骨下骨重塑和提高心血管系统效应等作用[10]。而近期对脑卒中患者患侧肢体肌力、肢体肌张力及平衡与步态等均有一定的积极意义[11-12]；但研究主要集中在对下肢肌力肌张力的影响，还未发现负重振动对上肢功能的影响。本研究将机械振动施加于患者的上肢，取得了较好的疗效，患者偏瘫侧上肢的伸肘肌肌张力显著提高，而屈肘肌肌张力显著下降；肩关节半脱位及上肢功能均较常规训练显著改善。说明通过机械振动对上肢关节及肌肉的负重刺激及本体感觉输入，能有效地改善患者的上肢功能，可作为改善肩关节半脱位程度及提高上肢运动功能的一种康复方法。

【参考文献】

[1] Kaplan PE, Meridith J, Taft G, et al. Stroke and brachial plexus injury: a difficult problem[J]. Arch Phys Med Rehabil,1997,58(6):415-418.
[2] Hall J, Dudgeon B, Guthrie M. Validity of clinical measuresof shoulder subluxation in adults with poststrokehemiplegia[J]. Am J Occup Ther,1995,49(7):526-533.
[3] Boyd EA, Torrance GM. Clinical measures of shoulder subluxation: their reliability[J]. Can J Public Health, 1992,83(2): 24-28.
[4] Prevost R, Arsenault AB, Dutil E,et al. Shoulder subluxationin hemiplegia: a radiologic correlational study [J]. Arch Phys Med Rehabil,1987,68(9):782-785.
[5] 宋佩成，李玉章. 振动训练法研究进展[J]. 体育科研，2010,16(2):78-82.
[6] 张园园，潘化平，许光旭，等. 不同振动条件下的正常人体下肢肌肉表面肌电分析[J]. 中国康复医学杂志，2013,28(12):1093-1096.
[7] Turbanski S, Haas CT, Schmiedtbleicher D. Effects ofrandom whole body vibration on postural control inParkinson's disease[J]. Research in Sports Medicine, 2005, 13(3):243-256.
[8] Ahlborg L, Andersson C, Julin P. Whole-body vibrationtraining compared with resistance training: effect onspasticity, muscle strength and motor performance in adultswith cerebral palsy[J]. Journal of Rehabilitation Medicine, 2006,38(3):302-308.
[9] 刘洋，叶超群，周军，等. 全身振动对绝经后妇女骨量和骨代谢的影响[J]. 中国康复医学杂志，2008,23(10):875-877.
[10] Wang P, Wei XF, Yang XT, et al. Effects of whole bodyvibration on structural and functional remodeling ofsubchondral bones in rabbits with early osteoarthritis[J]. Journal of Sichuan University(Medical Science Edition), 2014,45(1):111-115.
[11] Chan KS, Liu CW, Chen TW,et al. Effects of a single session of whole body vibrationon ankle plantarflexion spasticity and gait performance inpatients with chronic stroke: a randomized controlled trial[J]. Clinical Rehabilitation, 2012,26(13):1087-1095.
[12] Merkert J, Butz S, Nieczaj R, et al. Combined whole body vibration and balancetraining using Vibrosphere?: improvement of trunkstability, muscle tone, and postural control in strokepatients during early geriatric rehabilitation[J]. Zeitschrift fürGerontologie und Geriatrie, 2011, 44(3):256-261.

全身振動刺激對
腦卒中偏癱患者步行效率的影響

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簡述內容：

能重新站起來走路可能是每位腦中風癱瘓者最想達成的目標之一，但中風的後遺症讓肢體偏癱，嚴重一點的患者可能是連站都站不穩，但及早預防中風併發症、減輕機能損傷通常建議愈早開始執行復健愈好，包括翻身或關節運動，防止關節僵硬及肌肉萎縮，對於患者後續的恢復狀況會越佳。

本實驗採用全身垂直律動進行中風偏癱患者的步行測試分析，發現患者步行的速度加快、週期縮短及步行幅度變大，而垂直律動明顯增加大腿肌肉的收縮伸張，因此長期的全身垂直律動搭配對於患者的復健訓練將是改善的最佳選擇之一，也對於無法自主運動者來說，增加身體活動、減少退化持續的良好方式之一。

全身振动刺激对脑卒中偏瘫患者步行效率的影响

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【摘要】 目的：观察全身振动训练对脑卒中偏瘫患者步行效率的影响。方法：脑卒中患者11例，均进行全身振动刺激，频率10Hz，振幅4mm，时间10min。振动刺激前后进行步态分析。结果：振动刺激10min后，11例患者步频、步速及患侧步长、患侧单支撑相时间、健腿摆动相时间、健侧髋关节最大屈曲角度、健患侧髋关节及膝关节最大屈曲角度、患侧踝关节最大背伸角度均较刺激前明显增加（$P<0.05$）；步行周期、双支撑相时间显著缩短（$P<0.05$）；健侧步长、健侧单支撑相时间、患腿摆动相时间刺激前后比较差异无统计学意义。结论：全身振动刺激可以显著改善脑卒中偏瘫患者步行时空参数，提高患者的步行能力。

【关键词】 全身振动；步态分析；偏瘫

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Effects of whole body vibration on walking efficiency in hemiplegia patients *Zhu Juan, Xu Guangxu, Zhang Wentong, et al.*

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【Abstract】 **Objective**: To investigate the effect of whole body vibration training on walking efficiency of the hemiplegia patients. **Methods**: Eleven patients with cerebral apoplexy accepted the whole body vibration for 10 min with vibration exciting frequency being 10 Hz, amplitude being 4 mm. Gait spatial and temporal parameters containing step length, cadence, walking speed, single support phase time, swing time and double support phase with time and the largest maximum of lower joint angles were collected and calculated by gait analysis system before and after intervention. **Results**: After the whole body vibration stimulation, stride frequency, walking speed, walking cycle, double limb support phase, paretic swing phase, and step length were significantly increased ($P<0.05$). A significant increase in hemiplegia ankle dorsiflexion angle was associated with increased maximum hip flexion and knee flexion ($P<0.05$). **Conclusion**: Whole body vibration stimulation can significantly improve gait parameters and enhance lower limb walking ability of patients with stroke.

【Key words】 whole body vibration; gait analysis; hemiplegia

全身振动（whole body vibration, WBV）训练是一种利用机械振动和外在抗阻负荷刺激机体以引起肌肉振荡及中枢神经系统适应而改善神经肌肉功能的训练方法[1]。本研究拟探讨WBV对脑卒中偏瘫患者步行效率的影响，报道如下。

1 资料与方法

1.1 一般资料 选择2013年11月～2014年3月在江苏省人民医院盛泽分院康复科住院的脑卒中患者11例，均符合全国第四届脑血管病会议制定的诊断标准，并经头颅CT或MRI证实，且患者病情稳定，意识清晰，无明显认知障碍，能够服从指令，患侧下肢Brunnstrom分期Ⅳ～Ⅴ期，能够安全独立步行100m以上。11例患者中男6例，女5例；年龄（64.73±11.82）岁；身高（1.64±0.09）米；体质量（62.55±13.29）kg；病程（188.82±134.29）d；脑梗死9例，脑出血2例；左侧偏瘫3例，右侧8例。

1.2 方法 11例患者均进行WBV训练，采用BodyGreen全身有氧垂直律动机进行振动刺激。振动时要求患者双手扶持振动器前方的保护栏站在振动平台上，两脚分开与肩同宽，双侧膝关节屈曲角度控制在10°～30°。使用垂直上下振动模式，振动频率为10Hz，振幅4mm，振动时间为10min。

1.3 评定标准 振动刺激前及接受振动刺激10min后，分别进行步态分析，采用Gait Watch步态分析系统检测，步态分析：空间参数，步长、步频、步速；时间参数，单支撑相时间、摆动相时间及双支撑相时间；关节角度，髋关节、膝关节最大屈曲角度及踝关节最大背伸角度。

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1.4 统计学方法 采用SPSS 19.0统计软件进行统计分析，计量资料以 $\bar{x}\pm s$ 表示，t检验，$P<0.05$ 为差异有统计学意义。

2 结果

振动刺激10min后，11例患者步频、步速及患侧步长、患侧单支撑相时间、健腿摆动相时间、健侧髋关节最大屈曲角度、健患侧髋关节及膝关节最大屈曲角度、患侧踝关节最大背伸角度均较刺激前明显增加（$P<0.05$）；步行周期、双支撑相时间显著缩短（$P<0.05$）；健侧步长、健侧单支撑相时间、患腿摆动相时间刺激前后比较差异无统计学意义。见表1～4。

表1 11例患者刺激前后步态空间参数比较 $\bar{x}\pm s$

时间	步频(步/min)	步速(cm/s)	健侧步长(cm)	患侧步长(cm)
刺激前	90.64±32.99	60.03±36.22	38.82±16.68	38.33±14.09
刺激后	106.24±31.17ª	76.67±43.12ª	41.15±17.32	42.00±16.47ª

与刺激前比较，ª$P<0.05$

表2 11例患者步态时间参数刺激前后比较 $\bar{x}\pm s$

项目	刺激前	刺激后
步行周期(s)	1.62±0.97	1.32±0.79ª
双支撑相时间(%)	32.82±17.34	27.39±15.81ª
健侧单支撑时间(%)	31.55±9.47	34.33±9.95
患侧单支撑时间(%)	35.52±14.85	38.27±15.95ª
健侧摆动相时间(%)	35.64±14.82	38.27±15.71ª
患侧摆动相时间(%)	31.67±9.46	34.33±10.24

与刺激前比较，ª$P<0.05$

表3 11例患者刺激前后健侧关节角度比较 °，$\bar{x}\pm s$

时间	髋关节屈曲	膝关节屈曲	踝关节背伸
刺激前	26.48±11.28	49.09±24.35	20.94±8.28
刺激后	32.42±10.37ª	60.70±24.51ª	22.61±8.09

与刺激前比较，ª$P<0.05$

表4 11例患者刺激前后患侧关节角度比较 °，$\bar{x}\pm s$

时间	髋关节屈曲	膝关节屈曲	踝关节背伸
刺激前	20.15±8.90	31.24±21.52	14.12±6.81
刺激后	24.45±8.37ª	41.88±18.98ª	17.67±5.17ª

与刺激前比较，ª$P<0.05$

3 讨论

WBV是指利用振动平台使人体足部或臀部接触振动，通过下肢或躯干作用于全身，使人体整体发生振动，从而训练各种骨骼肌并触发其他生理效应的一种方法。Mason等[2]研究显示WBV训练能明显提高多发性硬化患者的10m步行速度。Ness[3]研究发现WBV训练能明显改善不完性脊髓损伤患者的步速、步频及步长。Lee等[4]研究发现WBV训练后，脑瘫患儿步行速度加快、步行周期缩短及步幅变大。WBV对脑卒中患者的运动功能的作用目前仍存在争议。Miyara[5]在一项前瞻性研究中对25名脑卒中患者进行WBV训练后，发现腘绳肌、腓肠肌及比目鱼肌痉挛程度下降，踝关节背屈主动及被动活动度增加，步行速度和节奏性改善。Chan等[6]发现恢复期脑卒中患者经过1次WBV训练后，患侧踝关节跖屈痉挛明显改善，步行速度加快，步态稳定性增加，步行能力提高。Marin等[7]对恢复期脑卒中患者进行WBV训练，发现治疗前后患者平衡、肌力等评定指标均无显著改善，Pang[8]与Brogardh[9]也报道了类似的研究结果。其治疗作用不明显的原因可能与这些研究对象均为恢复期脑卒中患者有关。目前国内外的研究报道都是关于WBV如何改善亚急性及急性期脑卒中患者的肌力、痉挛程度、平衡及姿势控制能力，而WBV对患侧肢体步行时间—空间参数的变化及髋、膝、踝关节屈伸角度的变化关注较少。本研究主要通过利用简易三维步态分析系统测量步行的时间—空间参数及关节角度变化，探讨WBV对脑卒中患者步行能力的影响。

本研究结果显示脑卒中患者在接受WBV后步行能力得到全面改善。WBV的这种治疗作用可能与其能够改善脑卒中患者的姿势控制能力、增加肌力、缓解痉挛有关。Van等[10]发现WBV训练可在短期内显著改善亚急性脑卒中患者的姿势控制能力和本体感觉，并能在一段时间内(12周)维持这种效果；Tihanyi等[11]对20例急性脑卒中患者进行WBV训练后，发现股四头肌等长和等张收缩的肌力分别增加36.6%和22.2%，表面肌电幅度增加44.9%，而在对照组则改变不明显。

目前普遍认为WBV能够引起大量肌梭兴奋，其产生的动作电位经Ia类神经纤维传至脊髓，经单突触和多突触途径影响脊髓前角运动神经元活动[12]，在阻力相同的情况下动员更多的运动单位参与收缩。根据上述理论推论，在脑卒中患者中，WBV激活了屈髋肌、屈膝肌与踝背伸肌肌梭的Ia传入神经纤维的兴奋性，最大限度地募集运动单位参与运动，同时通过交互抑制的原理缓解了拮抗肌(股四头肌及小腿三头肌)的高张力能使其能够及时而充分地放松，从而使患侧髋、膝关节屈曲及踝关节背屈角度较WBV前增加明显。但患者在接受WBV时，下肢伸肌屈肌均同时接受振动刺激，其产生的兴奋或抑制作用应该是相同的，上述理论不能够很好的解释患者步态改善的原因。我们推测这可能与患者处于半蹲位，下肢伸肌处于抗阻收缩状态有关。

另外振动还能够改变运动皮层的兴奋性，功能磁共振的研究发现，在健康人手施加20min振动刺激，刺激后受试者在执行对指任务时，M1区、S1区、SMA区激活面积增加，且这种作用持续了1小时以上[13]，

另外一项采用运动诱发电位的研究证实桡侧腕屈肌局部振动提高正常人运动皮层的兴奋性[14]。这些结果提示振动可能通过促进脑功能重塑来改善脑卒中患者的运动功能,有可能达到生物谐振状态。

本研究振动训练实施时仍需要考虑性别、年龄、关节角度、频率、时间等因素的影响。需要根据情况适时调整,建立适合个人训练和治疗目标的最佳振动刺激方案,即能量利用效率最高的生物谐振方案[15]。同时临床样本量较少,希望扩大样本,深入研究 WBV 对脑卒中偏瘫患者步行规律的影响。

总之本研究显示 WBV 可以即刻明显改善脑卒中患者下肢的步行效率,提高患者的步行能力。后续将研究 WBV 对脑卒中患者下肢步行效率的长期影响。

【参考文献】

[1] 王兴泽. 振动负荷训练研究进展[J]. 中国运动医学杂志, 2012,31(7):648-653.

[2] Mason RR, Cochrane DJ, Denny GJ, et al. Is 8 weeks of side-alternating whole-body vibration a safe and acceptable modality to improve functional performance in multiple sclerosis[J]. Disabil Rehabil, 2012,34(8):647-654.

[3] Ness LL, Field-Fote EC. Effect of whole-body vibration on quadriceps spasticity in individuals with spastic hypertonia due to spinal cord injury[J]. Restor Neurol Neurosci, 2009,27(6):621-631.

[4] Lee BK, Chon SC. Effect of whole body vibration training on mobility in children with cerebral palsy: a randomized controlled experimenter-blinded study[J]. Clin Rehabil, 2013,27(7):599-607.

[5] Miyara K, Matsumoto S, Uema T, et al. Feasibility of using whole body vibration as a means for controlling spasticity in post-stroke patients: a pilot study[J]. Complement Ther Clin Pract, 2014,20(1):70-73.

[6] Chan KS, Liu CW, Chen TW, et al. Effects of a single session of whole body vibration on ankle plantarflexion spasticity and gait performance in patients with chronic stroke: a randomized controlled trial[J]. Clin Rehabil, 2012,26(12):1087-1095.

[7] Marin PJ, Ferrero CM, Menendez H, et al. Effects of whole-body vibration on muscle architecture, muscle strength, and balance in stroke patients: a randomized controlled trial[J]. Am J Phys Med Rehabil, 2013,92(10):881-888.

[8] Pang MY, Lau RW, Yip SP. The effects of whole-body vibration therapy on bone turnover, muscle strength, motor function, and spasticity in chronic stroke: a randomized controlled trial[J]. Eur J Phys Rehabil Med, 2013,49(4):439-450.

[9] Brogardh C, Flansbjer UB, Lexell J. No specific effect of whole-body vibration training in chronic stroke: a double-blind randomized controlled study[J]. Arch Phys Med Rehabil, 2012,93(2):253-258.

[10] Nes IJ, Geurts AC, Hendricks HT, et al. Short-term effects of whole-body vibration on postural control in unilateral chronic stroke patients: preliminary evidence[J]. Am J Phys Med Rehabil, 2004,83(11):867-873.

[11] Tihanyi TK, Horvath M, Fazekas G, et al. One session of whole body vibration increases voluntary muscle strength transiently in patients with stroke[J]. Clin Rehabil, 2007,21(9):782-793.

[12] Perchthaler D, Horstmann T, Grau S. Variations in neuromuscular activity of thigh muscles during whole-body vibration in consideration of different biomechanical variables[J]. J Sports Sci Med, 2013,12(3):439-446.

[13] Christova M, Golaszewski S, Ischebeck A, et al. Mechanical flutter stimulation induces a lasting response in the sensorimotor cortex as revealed with BOLD fMRI[J]. Hum Brain Mapp, 2012,19(2):284-293.

[14] Marconi B, Filippi GM, Koch G, et al. Long-term effects on motor cortical excitability induced by repeated muscle vibration during contraction in healthy subjects[J]. J Neurol Sci, 2008,275(1):51-59.

[15] 许光旭,顾绍钦,孟殿怀,等. 生物谐振规律对步行效率影响的前驱研究[J]. 中国康复医学杂志, 2008,23(12):1092-1094.

一回合的全身律動對於慢性中風患者踝關節蹠屈痙攣以及步態表現的影響：隨機對照試驗

Effects of a single session of whole body vibration on ankle plantarflexion spasticity and gait performance in patients with chronic stroke: a randomized controlled trial.

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簡述內容：

即使是輕度中風的患者，都可能產生肢體行動的障礙或造成永久性的損傷，而肢體半癱或全癱患者通常無法自由行動且行動困難，多數需要協助復健或被動式運動協助，若沒有復健或運動，受傷的肢體會慢慢因神經肌肉萎縮而變將僵硬或攣縮，本實驗研究慢性中風患者採用全身垂直律動方式，對踝關節蹠屈痙攣及行動力獲得大幅改善，包含提升步行速度、促進起身與行走平衡能力，此外藉由垂直律動刺激增加血氧循環、降低血壓及加強血管內纖維溶解作用，將對預防中風、血栓或梗塞的再度形成有預防之作用。

Article

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Effects of a single session of whole body vibration on ankle plantarflexion spasticity and gait performance in patients with chronic stroke: a randomized controlled trial

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Abstract

Objective: To investigate the effects of a single session of whole body vibration training on ankle plantarflexion spasticity and gait performance in chronic stroke patients.

Design: Randomized controlled trial.

Setting: Rehabilitation unit in university hospital.

Participants: Thirty subjects with chronic stroke were randomized into either a control group (n = 15) or a group receiving a single session of whole body vibration (n = 15).

Intervention: The intervention group was actually treated with whole body vibration while the control group was treated with placebo treatment.

Main measures: The spastic changes were measured clinically and neurophysiologically. Subjective evaluation of ankle spasticity was performed via a visual analogue scale. Gait performances were evaluated by the timed up and go test, 10-meter walk test and cadence. A forceplate was used for measuring foot pressure.

Results: The changes between whole body vibration and control groups were significantly different in Modified Ashworth Scale (1.33, 95% confidence interval (CI) = 1.06~1.60). The H_{max}/M_{max} ratio (0.14, 95% CI = 0.01~0.26) and visual analogue scale (1.87, 95% CI = 1.15~2.58) were significantly decreased. Whole body vibration could significantly improve gait velocity, timed up and go test (6.03, 95% CI = 3.17~8.89) and 10-meter walk test (1.99, 95% CI = 0.11~3.87). The uneven body weight posture on bilateral feet was also improved after vibration.

Conclusion: These results suggest that a single session of whole body vibration training can reduce ankle plantarflexion spasticity in chronic stroke patients, thereby potentially increasing ambulatory capacity.

Keywords

Whole body vibration, spasticity, gait, stroke

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Introduction

The prevalence of post-stroke spasticity has been reported to be as high as 39%.[1] Spasticity is defined as a velocity-dependent increase in tonic stretch reflexes with exaggerated tendon jerks due to hyperexcitability of the stretch reflex.[2] Excessive spasticity can limit functional recovery and cause pain or contracture in stroke patients.[3] In addition, a spastic limb can also negatively impact walking ability, physical activities and gait, including a reduction in step length and cadence.[4]

A spastic ankle joint is a major concern since ankle plantarflexors contribute as much as 50% of positive mechanical work in a single stride to walk forward.[5] Decreased ankle dorsiflexion might cause increased swing time and double-leg supporting time in gait cycles.[4,6] Therefore, spastic ankles might decrease walking velocity and mobility.

The primary approaches to antispasticity management are conservative treatments and surgical intervention. Conservative treatments commonly include positioning, passive stretching, physiotherapy with active movement, splinting, medication and botulinum toxin injection.[7] Although surgical treatment for spasticity is another therapeutic option, potential for complications might be found.

Few studies have investigated the effects of whole body vibration training on spasticity. Whole body vibration training could reduce spasticity in the knee extensors of adults with cerebral palsy[8] and chronic spinal cord injuries.[9] Whole body vibration can stimulate the muscle spindles and alpha motoneurons,[10] and initiate a muscle voluntary contraction as a result of the tonic vibration reflex.[11,12] Whole body vibration has been used to increase muscle strength and improve proprioceptive control. Although it can modulate motoneural excitability,[13] its benefit for spasticity is still not fully known. The purpose of this study was to determine the ability of whole body vibration to reduce spasticity in stroke patients.

Methods

All patients with stable, chronic stroke (as confirmed by computed tomography or magnetic resonance imaging scans) who had been admitted to the Department of Physical Medicine and Rehabilitation of the University Hospital were included. The inclusion criteria consisted of the following: a first-time, unilateral stroke due to infarction or haemorrhage with an interval of at least six months since stroke onset, spasticity of the ankle with a Modified Ashworth Scale ≧2,[14] the ability to ambulate with or without assistive devices for at least 100 m, preserved cognitive and communicative ability (all subjects scored above 24 on the Mini-Mental Status Examination),[15] no joint contractures and sufficient motor control to perform the functional walking tests. The exclusion criteria consisted of the following: gallbladder or kidney stones, recent leg fractures, internal fixation implants, a cardiac pacemaker, intractable hypertension, recent thromboembolism and infectious diseases.

Baseline data were collected for each subject, including gender, age, time from stroke onset, stroke type, hemiplegic side and any use of antihypertonia medications or ambulatory devices. The subjects included in the study had not changed their existing physical exercise programmes or medical treatments within the month prior to participation. A schematic outline of the study is shown in Figure 1.

Although high-frequency low-amplitude vibration is commonly used to muscle performance training, these parameters can cause muscle fatigue.[16–18] The effects in our study were contraindicated for patients with impaired standing balance because of the increase in the risk of falling and subsequent influence on the ambulatory results.

In the whole body vibration group, subjects received a single session of vertical whole body vibration (AV-001, Bodygreen, Taiwan) with a magnitude of 12 Hz and an amplitude of 4 mm. During the intervention, subjects were positioned on the platform in a semi-squatting position with buttock support and were kept in an upright position with even weight distribution on both feet. The time course included two 10-minute periods of vibration with a 1-minute rest interval. In the control group, subjects followed the same procedures, but the vibration machine was not turned on.

In the preliminary study, the semi-squatting posture without buttock support was not suitable

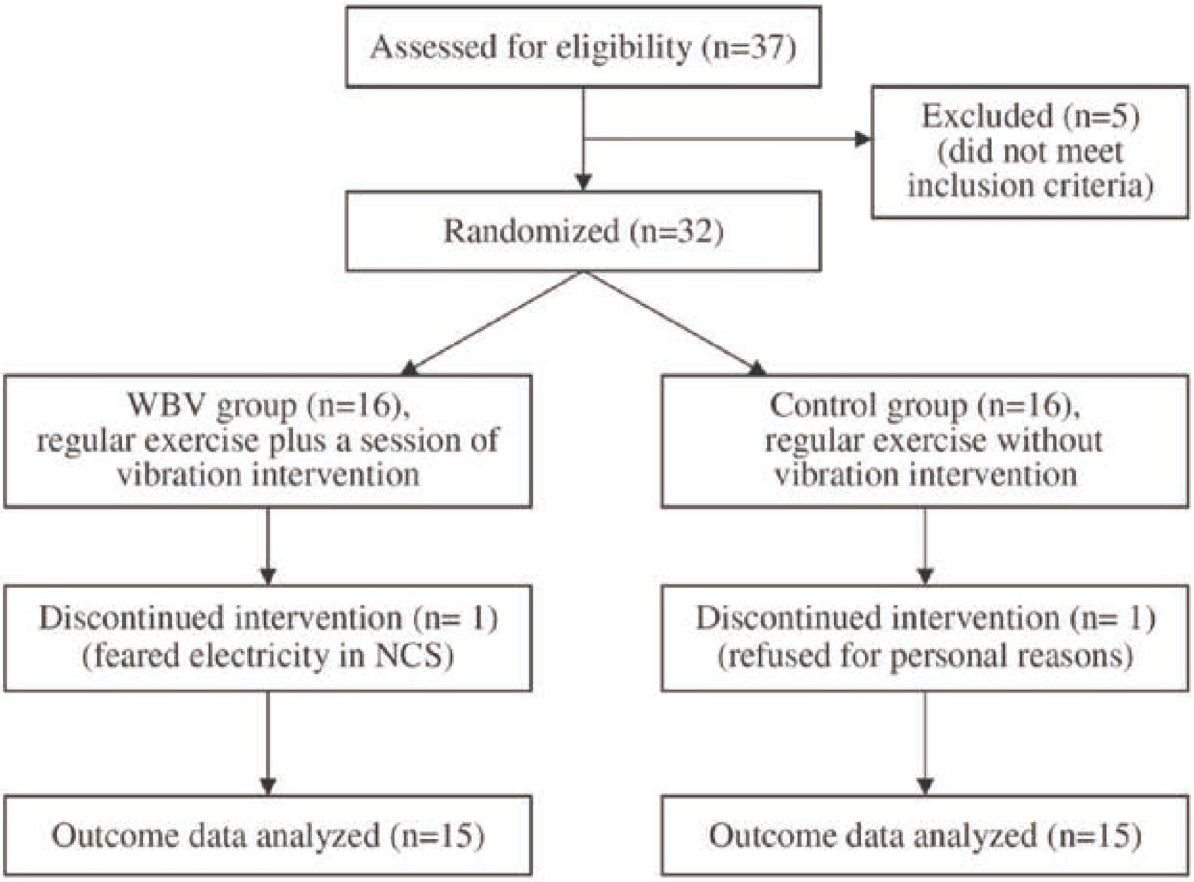

Figure 1. CONSORT flowchart of the study. WBV, whole body vibration; NCS, nerve conduction study.

because some patients could not tolerate the vibration in standing postures without support. It was also not suitable for patients in sitting postures. During the vibration, subjects were asked to distribute most of their body weight on their feet as evenly as possible. All of the subjects could walk independently with or without their original assistive devices.

This study was a two-armed, randomized controlled trial with blinding of both subjects and assessors. Participants were divided by simple randomization into a whole body vibration group and a control group done by physician-1, who was not involved in the assessment of the patients or the treatments. Patient characteristics and all outcome measures before and after treatment were assessed by an experienced physician-2, who was blinded to the treatment allocations. The treatments were carried out in a closed room for either vibration training or sham treatment by physician-3. All physicians were instructed not to communicate with the subjects about the possible goals or rationale for either treatment. After whole body vibration training for around 30 minutes, the subjects were moved to the experimental area in wheelchairs to avoid any physical activity on their feet that might influence the vibration results. Clinical assessments, neurophysiological tests and subjective improvement of the soleus spasticity were evaluated before and after the vibration. The Modified Ashworth Scale and deep tendon reflex of Achilles tendon were used for clinical assessments.[19,20] Affected ankle spasticity was estimated according to the Modified Ashworth Scale, which has six degrees (0, 1, 2, 3, 4 and 5). The deep tendon reflex of the Achilles tendon was measured on the affected side and scored on a 5-point scale (range 0–4). The maximal amplitude of H-reflex and the H_{max}/M_{max} ratio were measured to assess ankle spasticity. Subjective experience of the influence of ankle spasticity on ambulation was scored by participants using a visual analogue scale (VAS). The VAS ranged from 0 to 10, with 0 representing a spasticity-free status and 10 representing a maximal spastic intensity that interferes with ambulation.[21]

The timed up and go test evaluates balance and is commonly used to examine functional mobility in community-dwelling, frail, older adults.[22] In the present study, the participants sat on a standard chair and were instructed to get up and walk at a comfortable and safe pace to a line on the floor 3 meters away, then turn around and return to the chair to sit down again. The 10-meter walk test examines gait speed.[23] A 10-meter course was measured, and the start and finish lines were marked with tape on the floor. Each subject was positioned approximately a meter behind the start line and instructed to walk at a maximal pace until approximately a meter past the finish line.

The subjects were asked to stand statically with a natural posture on the forceplate (Physical Gait Software, version 2.65), and the percentage of total body weight on each foot was recorded. The static pressure on each foot was divided among six areas (Figure 2 on-line), and the pressure change for each area was individually recorded before and after standing on each foot. No devices were allowed while the participants were standing on the forceplate.

Statistics

All outcome measures were performed three times, and the average was used for statistical analysis. The data were presented as the mean ± standard deviation (SD) and 95% confidence intervals (95% CI). Statistical procedures were performed by using SPSS version 14.0 (SPSS Inc., Chicago, IL, USA). Paired *t*-tests were used to compare the differences between results before and after interventions in the same group. The differences between the groups were compared with two-sample *t*-tests and Fisher's exact test. A value of $P < 0.05$ was regarded as statistically significant.

Results

The flow of subjects through the study is shown in Figure 1. The demographics of the study participants are shown in Table 1. The baseline

Table 1. General characteristics of the subjects

Characteristics	WBV group (*n* =15)	Control group (*n* =15)	*P*-value
Age, years	56.07 (11.04)	54.93 (7.45)	0.744
Gender, *n*			>0.999[a]
Men	10	11	
Women	5	4	
Location of stroke, *n*			0.128[a]
Left	12	7	
Right	3	8	
Type of stroke, *n*			0.143[a]
Ischaemic	10	5	
Haemorrhagic	5	10	
Time post stroke, months	30.40 (25.80)	38.87 (38.22)	0.483
Min–max	6–93	6–122	
Antispastic drug use, *n*	7	6	>0.999
Ambulatory device use, *n*			0.884[a]
Regular cane	3	3	
Quadricane	5	3	

Values are mean (± SD).
WBV, whole body vibration; min-max, minimal–maximum.
[a]*P*-value was computed by Fisher's exact.

characteristics were similar between groups. After the intervention, for the unaffected side the H_{max}/M_{max} ratio was significantly decreased in the whole body vibration group (score change = –0.14 ± 0.21, $P < 0.05$), but not in the control group (score change = –0.00 ± 0.07, $P > 0.05$) (Table 2). The scores changes were significantly different between whole body vibration and control groups (0.14, 95% CI = 0.01~0.26, $P = 0.031$). On the affected side, however, the score changes were significantly different after the intervention, but not in the control group. In addition, the scores changes were not statistically different between the whole body vibration and control groups ($P = 0.066$).

Modified Ashworth Scale scores were significantly different in the whole body vibration and control groups (1.33, 95% CI = 1.06~1.60, $P < 0.0001$). The subjective assessment by VAS also showed a significant difference between the whole body vibration and control groups (1.87, 95% CI = 1.15~2.58, $P < 0.0001$). Deep tendon reflex or H-reflex on both sides was not significantly different between groups.

The performances of the timed up and go test were significantly improved in the whole body vibration group (6.03, 95% CI = 3.17~8.89, $P < 0.003$) (Table 3). In addition, 10-meter walk test scores were also significantly improved in the whole body vibration group (1.99, 95% CI = 0.11~3.87, $P = 0.039$). However, the score changes in the cadence performances were not statistically significant after whole body vibration training ($P = 0.277$).

The change in body weight loading on each foot showed a significant difference in the whole body vibration group (Table 4). Before the intervention, a higher proportion of body weight loading on the affected side was recorded. After the vibration training, the percentage of total body weight loading on the affected side showed a significant increase (–3.27, 95% CI = –6.02~–0.51, $P = 0.022$), whereas it showed a significant decrease on the unaffected side (3.27, 95% CI = 0.51~6.02, $P = 0.022$).

The score changes of pressure loading of area E on the affected sides were significantly different after the intervention, but not in the control group.

Table 2. Change in the H-reflex, H_{max}/M_{max} ratio, Modified Ashworth Scale, VAS and Achilles deep tendon reflex from pretest to posttest for the whole body vibration group and control group

Outcome measures	WBV group			Control group			*P*-value	Diff (95% CI)
	Pretest	Posttest	Change score	Pretest	Posttest	Change score		
H-reflex (affected side) (mV)	4.17 (1.68)	3.88 (2.14)	–0.27 (1.13)	5.10 (3.40)	5.11 (3.47)	0.01 (0.60)	0.396	0.29 (–0.40, 0.97)
H_{max}/M_{max} ratio (affected side)	0.63 (0.43)	0.34 (0.16)	–0.27 (0.41)[c]	0.35 (0.26)	0.30 (0.17)	–0.05 (0.17)	0.066	0.22 (–0.02, 0.46)
H-reflex (unaffected) (mV)	2.31 (0.93)	2.61 (1.03)	–0.14 (1.21)	2.77 (1.22)	2.95 (1.34)	0.17 (0.51)	0.348	0.31 (–0.36, 0.97)
H_{max}/M_{max} (unaffected side)	0.36 (0.27)	0.21 (0.13)	–0.14 (0.21)[c]	0.22 (0.17)	0.22 (0.14)	–0.00 (0.07)	0.031[a]	0.14 (0.01, 0.26)
Modified Ashworth Scale	2.60 (0.63)	1.27 (0.46)	–1.33 (0.49)	2.20 (0.41)	2.20 (0.41)	0.00 (0.00)	<0.0001[b]	1.33 (1.06, 1.60)
VAS	6.33 (2.35)	4.40 (1.99)	–1.93 (1.28)	5.33 (1.04)	5.27 (0.96)	–0.07 (0.26)	<0.0001[b]	1.87 (1.15, 2.58)
Achilles deep tendon reflex	2.87 (0.52)	2.53 (0.52)	–0.33 (0.62)	2.47 (0.52)	2.47 (0.52)	0.00 (0.00)	0.055	0.33 (–0.01, 0.68)

Values are mean (± SD).
WBV, whole body vibration; H-reflex, Hoffmann reflex; H_{max}/M_{max} ratio, maximum Hoffmann reflex/maximum M response ratio; VAS, visual analogue scale.
[a]$P < 0.05$ by 2-sample *t*-test between WBV and control groups.
[b]$P < 0.001$ by 2-sample *t*-test between WBV and control groups.
[c]$P < 0.05$ by paired *t*-test within the groups.

Table 3. Change in timed up to go test, 10-meter walk test and cadence from pretest to posttest for WBV group and control group

Outcome measures	WBV group			Control group			*P*-value	Diff (95% CI)
	Pretest	Posttest	Change score	Pretest	Posttest	Change score		
Time up to go test (seconds)	53.95 (30.38)	47.47 (26.72)	–6.48 (4.89)	32.41 (14.65)	31.95 (14.74)	–0.45 (2.00)	0.0003[a]	6.03 (3.17, 8.89)
10-meter walk test (seconds)	31.60 (18.88)	29.51 (17.10)	–2.09 (3.17)	24.67 (14.37)	24.57 (14.50)	–0.10 (1.43)	0.039[b]	1.99 (0.11, 3.87)
Cadence (steps/min)	64.99 (23.79)	62.78 (21.71)	–2.21 (5.76)	42.62 (30.04)	43.08 (30.42)	0.46 (1.69)	0.104	2.67 (–0.61, 5.95)

Values are mean (± SD).
WBV, Whole body vibration.
[a]$P < 0.001$ by 2-sample *t*-test between WBV and control groups.
[b]$P < 0.05$ by 2-sample *t*-test between WBV and control groups.

Table 4. Change in distribution of total body weight loading on each foot from pretest to posttest for WBV group and control group

Outcome measures	WBV group			Control group			*P*-value	Diff (95% CI)
	Pretest	Posttest	Change score	Pretest	Posttest	Change score		
TBW% on affected side (%)	43.15 (5.81)	46.62 (6.64)	3.47 (4.30)	46.13 (5.95)	46.33 (4.59)	0.2 (2.88)	0.022[a]	–3.27 (–6.02, –0.51)
TBW% on unaffected side (%)	56.85 (5.82)	53.38 (6.64)	–3.47 (4.30)	53.87 (5.95)	53.67 (4.59)	–0.2 (2.88)	0.022[a]	3.27 (0.51, 6.02)

Values are mean (± SD).
TBW%, percentage of total body weight; WBV, whole body vibration.
[a]$P < 0.05$ by 2-sample *t*-test between WBV and control groups.

In addition, those were not statistically different between the whole body vibration and control groups ($P = 0.177$) (Table 5 on-line). Similarly, after whole body vibration training, the changes of pressure loading of area F on the unaffected sides were significantly different, but not in the control group. These were not statistically different between the whole body vibration and control groups. After whole body vibration training, the pressure loads of area E on the unaffected sides were significantly decreased in the whole body vibration group (score changes = -22.71 ± 26.32, $P = 0.002$), but not in the control group (score changes = 4.33 ± 10.59, $P > 0.05$). The scores changes were significantly different between the whole body vibration and control groups (27.04, 95% CI = 11.67~42.41, $P = 0.002$).

Discussion

This is a randomized controlled trial in which we are interested in investigating the effects of a single session of whole body vibration training on ankle spasticity in subjects with chronic stroke. Our results showed that after whole body vibration training, ankle spasticity was significantly decreased and gait performance was significantly improved.

As a result, we hypothesized that both the H-reflex and the H_{max}/M_{max} ratio on the affected side would decrease after vibration training. The results show that although the H_{max}/M_{max} ratio on both the affected ($P < 0.02$) and unaffected ($P < 0.03$) sides decreased significantly within the whole body vibration group, only the H_{max}/M_{max} ratio on the unaffected side decreased significantly in the whole body vibration group while compared to the control group. We suggest that there is a trend toward a reduction in the H_{max}/M_{max} ratio after vibration training. The H-reflex on the affected and unaffected sides did not decrease in either group. It is possible that the mechanism of spasticity cannot be fully explained by a simple monosynaptic reflex or a single pathway[24] such as that between a type Ia afferent sensory neuron and an alpha efferent motoneuron. The study of their recovery should be further investigated. Armstrong et al.[25] reported that all subjects displayed significant suppression of the H-reflex during the first minute after whole body vibration, whereas only some of the subjects showed such suppression at 30 minutes. In that study, it was noted that some level of potentiation occurred during this period and that not all of the subjects were fully recovered within 30 minutes. As there was a limit to determining the recovery time, it is difficult to conclude how much recovery time is required. In our study, the effects could be maintained for 48 hours with VAS assessments.

Objective scores of spasticity (Modified Ashworth Scale) decreased significantly in the whole body vibration group. The finding of spasticity reduction after vibration was similar to that in previous studies,[8,9] demonstrating the possible benefits of vibration training for ankle spasticity in patients with stroke. Furthermore, the subjective experience of the therapeutic effect as evaluated by the VAS[21] also revealed a significant decrease, suggesting subject satisfaction following whole body vibration training.

Other vibration effects on spasticity, including presynatic inhibition and postactivation depression, should be considered.[24] Presynaptic inhibition of Ia-afferents reduces the release of neurotransmitters to the motoneurons and thereby weakens the effects of Ia-afferents on motoneurons, resulting in inhibition of the H-reflex amplitudes. In our study, the H-reflex amplitudes did not change significantly after vibration; however, significant changes in Modified Ashworth Scale were found. From the results, correlations between presynaptic inhibition and spasticity should be further studied.[24]

Based on past studies,[16,17,26] many researchers have shown the beneficial effects of whole body vibration training on balance and walking ability. In the present study, the timed up and go test results in the whole body vibration group showing significant improvement after treatment, reflecting better functional mobility in stroke patients after vibration training and probably a reduced risk of falling.[27] The 10-meter walk test indicated that gait speed significantly increased after treatment. Improvement in gait velocity is therefore clinically meaningful in terms of changes in stroke-related function and quality of life, especially for household ambulation.[28]

Although the cadence values in the study group demonstrated a beneficial effect on vibration training, the results were not statistically significant. It may be that the subjects lacked sufficient time to develop a new gait pattern and that more time might be needed to adjust muscular adaptation or neuromuscular coordination after vibration treatment. Thus, long-term follow-up might be needed to show a difference in the 10-meter walk test after whole body vibration training.

Gait performance was improved after whole body vibration training. Decreased ankle spasticity might affect the gait performances, especially in terms of mobility and speed. The improvement in ankle joint control could increase gait velocity.[4,6] This finding might indicate that whole body vibration is effective in enhancing neuromuscular rehabilitation.

The forceplate data showed that the percentage of body weight loading distributed on the affected side increased ($P = 0.022$) after vibration training, indicating that the participants shifted their body weight from the unaffected side toward the affected side during static standing. These effects might be due to less plantar flexion and ankle inversion of the affected ankle. Mecagni et al.[29] reported that ankle range of motion may be associated with balance during ambulation and also indicated that all ankle motions contribute to the maintenance of balance during gait.

This study demonstrated a beneficial effect of whole body vibration training in stroke patients, but it had some limitations. First, more participants could have been included to increase the power of the statistical analyses. It also may have been beneficial to follow the progress of the participants to investigate the impact of whole body vibration training on stroke patients over a longer period of time.

In summary, a single session of whole body vibration training appears to successfully reduce ankle spasticity in stroke patients, thereby improving gait performance, particularly with regard to walking mobility and gait speed. This training was well tolerated and appreciated by most patients and could be used as a valuable adjunctive therapy in the management of stroke patients with spasticity.

Clinical messages

- Whole body vibration could reduce ankle plantarflexor spasticity in patient with chronic stroke.
- With decreased ankle spasticity gait performance, especially in gait speed, improved significantly.

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Conflict of interest

No commercial party provides financial support or has financial interest in the results of this study. The authors declare that there is no conflict of interest.

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References

1. Mayer NH. Clinicophysiologic concepts of spasticity and motor dysfunction in adults with an upper motoneuron lesion. *Muscle Nerve Suppl* 1997; 6: S1–13.
2. Neurology AAo. Assessment: the clinical usefulness of botulinum toxin-A in treating neurologic disorders. Report of the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology. *Neurology* 1990; 40: 1332–1336.
3. Young RR. Physiologic and pharmacologic approaches to spasticity. *Neurol Clin* 1987; 5: 529–539.
4. Goldie PA, Matyas TA and Evans OM. Gait after stroke: initial deficit and changes in temporal patterns for each gait phase. *Arch Phys Med Rehabil* 2001; 82: 1057–1065.
5. Eng JJ and Winter DA. Kinetic analysis of the lower limbs during walking: what information can be gained from a three-dimensional model? *J Biomech* 1995; 28: 753–758.
6. Lamontagne A, Malouin F, Richards CL and Dumas F. Mechanisms of disturbed motor control in ankle weakness during gait after stroke. *Gait Posture* 2002; 15: 244–255.
7. Ivanhoe CB, Francisco GE, McGuire JR, Subramanian T and Grissom SP. Intrathecal baclofen management of post-stroke spastic hypertonia: implications for function and quality of life. *Arch Phys Med Rehabil* 2006; 87: 1509–1515.

8. Ahlborg L, Andersson C and Julin P. Whole-body vibration training compared with resistance training: effect on spasticity, muscle strength and motor performance in adults with cerebral palsy. *J Rehabil Med* 2006; 38: 302–308.
9. Ness LL and Field-Fote EC. Effect of whole-body vibration on quadriceps spasticity in individuals with spastic hypertonia due to spinal cord injury. *Restor Neurol Neurosci* 2009; 27: 621–631.
10. Issurin VB. Vibrations and their applications in sport. A review. *J Sports Med Phys Fitness* 2005; 45: 324–336.
11. Cardinale M and Bosco C. The use of vibration as an exercise intervention. *Exerc Sport Sci Rev* 2003; 31: 3–7.
12. Roelants M, Delecluse C, Goris M and Verschueren S. Effects of 24 weeks of whole body vibration training on body composition and muscle strength in untrained females. *Int J Sports Med* 2004; 25: 1–5.
13. van Nes IJ, Latour H, Schils F, Meijer R, van Kuijk A and Geurts AC. Long-term effects of 6-week whole-body vibration on balance recovery and activities of daily living in the postacute phase of stroke: a randomized, controlled trial. *Stroke* 2006; 37: 2331–2335.
14. Byun SD, Jung TD, Kim CH and Lee YS. Effects of the sliding rehabilitation machine on balance and gait in chronic stroke patients – a controlled clinical trial. *Clin Rehabil* 2011; 25: 408–415.
15. Baetens T, De Kegel A, Calders P, Vanderstraeten G and Cambier D. Prediction of falling among stroke patients in rehabilitation. *J Rehabil Med* 2011; 43: 876–883.
16. Torvinen S, Kannus P, Sievanen H, et al. Effect of four-month vertical whole body vibration on performance and balance. *Med Sci Sports Exerc* 2002; 34: 1523–1528.
17. van Nes IJ, Geurts AC, Hendricks HT and Duysens J. Short-term effects of whole-body vibration on postural control in unilateral chronic stroke patients: preliminary evidence. *Am J Phys Med Rehabil* 2004; 83: 867–873.
18. Cardinale M and Wakeling J. Whole body vibration exercise: are vibrations good for you? *Br J Sports Med* 2005; 39: 585–589; discussion 9.
19. Bohannon RW and Smith MB. Interrater reliability of a modified Ashworth Scale of muscle spasticity. *Phys Ther* 1987; 67: 206–207.
20. Chung SG, van Rey E, Bai Z, Rymer WZ, Roth EJ and Zhang LQ. Separate quantification of reflex and nonreflex components of spastic hypertonia in chronic hemiparesis. *Arch Phys Med Rehabil* 2008; 89: 700–710.
21. Wu CL, Huang MH, Lee CL, Liu CW, Lin LJ and Chen CH. Effect on spasticity after performance of dynamic-repeated-passive ankle joint motion exercise in chronic stroke patients. *Kaohsiung J Med Sci* 2006; 22: 610–617.
22. Podsiadlo D, Richardson S. The timed 'Up & Go': a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 1991; 39: 142–148.
23. Holden MK, Gill KM, Magliozzi MR, Nathan J and Piehl-Baker L. Clinical gait assessment in the neurologically impaired. Reliability and meaningfulness. *Phys Ther* 1984; 64: 35–40.
24. Voerman GE, Gregoric M and Hermens HJ. Neurophysiological methods for the assessment of spasticity: the Hoffmann reflex, the tendon reflex, and the stretch reflex. *Disabil Rehabil* 2005; 27: 33–68.
25. Armstrong WJ, Nestle HN, Grinnell DC, et al. The acute effect of whole-body vibration on the hoffmann reflex. *J Strength Cond Res* 2008; 22: 471–476.
26. Cheung WH, Mok HW, Qin L, Sze PC, Lee KM and Leung KS. High-frequency whole-body vibration improves balancing ability in elderly women. *Arch Phys Med Rehabil* 2007; 88: 852–857.
27. Shumway-Cook A, Brauer S and Woollacott M. Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go Test. *Phys Ther* 2000; 80: 896–903.
28. Schmid A, Duncan PW, Studenski S, et al. Improvements in speed-based gait classifications are meaningful. *Stroke* 2007; 38: 2096–2100.
29. Mecagni C, Smith JP, Roberts KE and O'Sullivan SB. Balance and ankle range of motion in community-dwelling women aged 64 to 87 years: a correlational study. *Phys Ther* 2000; 80: 1004–1011.