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Health effects of whole body vibration | Perspective

Felix Gritschmeier, Klaus W. Lange
Institute of Psychology, University of Regensburg, 93040 Regensburg, Germany
Correspondence: felix.gritschmeier@ur.de; klaus.lange@ur.de

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Abstract: Whole body vibration (WBV) has attracted increasing interest in recent years as an exercise modality with potential to improve neuromuscular performance and to increase bone mass and density. The utility of WBV in the management of various chronic conditions and in the promotion of physical fitness have been examined. Despite many promising findings, the question of whether WBV can play a role in the fostering of physical fitness in elderly people or the treatment of chronic diseases, such as lower back pain, fibromyalgia, osteoporosis, obesity and diabetes is currently unclear. Further research is required to explore the therapeutic potential of WBV as an exercise modality and to investigate whether WBV training could become a viable (add-on) treatment for low back pain, fibromyalgia or osteoporosis in post-menopausal women. Furthermore, potential long-term risks should be investigated.

Keywords: Whole body vibration; exercise; health; back pain; fibromyalgia; osteoporosis; obesity; diabetes.

1. Introduction

Whole body vibration (WBV) exercise uses an oscillating platform as a stimulus, transmitting forced mechanical oscillation through the legs of an individual standing on the platform [1] and stimulating subcutaneous proprioceptors, muscle spindles and Golgi tendon organs [2,3]. It has been suggested that WBV exercise can have beneficial effects on skeletal muscle strength and cardiovascular health, especially in elderly people and individuals with medical conditions [4]. In recent years, the utility of WBV in promoting physical fitness and managing various chronic conditions has been assessed.

2. Physical fitness and motor functions

Research has increasingly explored the potential value of WBV in improving athletic performance not only in elite athletes [5], but also in recreational athletes, untrained adults, children with disabilities and older people [5–13]. The evidence in regard to the effects of WBV on various performance parameters, such as vertical jump height, power, balance and agility is contradictory. While numerous studies have shown improvements in performance following exposure to WBV, others have found no positive effects (see reference 14). The differences in results may be due to the use of different protocols in respect to frequency (with a range of 20–50 Hz), amplitude (2–10 mm) and duration (30 s–10 min) of WBV.

Middle age is associated with physiological decline of, among other parameters, muscle power [15,16]. While physical exercise is known to be effective in improving muscle power and performance [17], adherence to exercise training routines tends to be low [18]. WBV may be a tool capable of overcoming barriers to regular physical exercise [14]. In comparison to a control group, a 5-week progressive WBV training in 45–55-year old women was demonstrated to improve vertical countermovement jump and range of motion performance [19]. These findings suggest that WBV training can reduce age-related performance deterioration in middle age.

WBV training may be a useful exercise modality, especially in elderly people, since it does not require conventional dynamic exercise such as free weight or

dynamic movement. In a randomised controlled trial, for example, short training sessions using WBV three times weekly for 6 weeks improved gait, motor capacity, body balance and quality of life in elderly nursing home residents [20]. Various benefits have been reported following WBV training [21], including increased muscle strength [22] and bone density [23] as well as improved cardiorespiratory fitness [24], body balance [25–27] and quality of life [28]. WBV exercise in older people also appears to produce beneficial effects on walking ability and postural control [29–31]. A systematic review and meta-analysis, combining the evidence from randomised controlled trials of resistance training, endurance training and WBV exercise in older people, examined the comparative effects of these different approaches [32]. WBV appeared to have a small beneficial effect on physical performance. However, resistance training of a minimum 6 weeks duration was found to be the most effective intervention, achieving a substantial increase in muscle strength and a moderate improvement in physical performance when compared with people following their normal routine [32]. Furthermore, WBV provided no additional benefit in regard to muscle strength, balance or mobility when added to a comprehensive exercise programme attended regularly by institutionalised older adults [33].

3. WBV in the management of chronic conditions

WBV has been proposed to be of potential use in a variety of chronic medical conditions, such as lower back pain, fibromyalgia, osteoporosis, obesity and diabetes.

Exercise treatment is widely recommended and used in people with non-specific lower back pain [34]. Vibration has been suggested to be of value when used as an exercise modality rather than in an occupational context, and to be able to alleviate rather than aggravate chronic back pain [35,36]. WBV has also been used as a complementary treatment to relieve pain intensity and improve back function [37–41]. It has been further hypothesised that WBV exercise may be more helpful than general exercise, since vibratory stimulation may increase muscle strength and joint stability by improving neuromuscular activation [42,43]. A systematic literature review concluded that there is no clear evidence of therapeutic efficacy of WBV exercise in individuals with nonspecific chronic lower back pain [44]. However, this conclusion was based on randomised controlled trials with small sample sizes. A recent randomised controlled trial comprising 89 participants with non-specific chronic low back pain showed that WBV exercise was more effective than general exercise in relieving pain and improving functional disability [45]. Further studies should include different subgroups exposed to different WBV frequencies.

Fibromyalgia is a chronic disorder of unknown aetiology, which is characterised by chronic, widespread, non-inflammatory body pain, fatigue, insomnia, and poor physical fitness [46,47]. Exercise training is commonly recommended for adults with fibromyalgia. WBV may be helpful in the management of this disorder, since it could offer benefits in regard to balance, fatigue, pain, disability and health-related quality of life. A systematic literature review surmised that WBV could be an effective treatment for fibromyalgia as a main therapy or in addition to physical exercise programmes [48]. However, the comparison of the small number of available trials was limited by significant differences in intervention, protocol and assessment. A Cochrane study analysed whether WBV alone or in addition to mixed exercise is superior to a control condition or another intervention in women with fibromyalgia [49]. The findings of this study indicated that the small number of participants and wide confidence intervals yielded very low quality evidence. Furthermore, the few studies included in the Cochrane analysis failed to measure major outcomes such as pain intensity, stiffness, fatigue or physical function.

Low bone mineral density and associated osteoporosis are major risk factors for fragility fractures [50,51]. Mechanical stimulation is necessary for the maintenance of bone health [52], and physical exercise is an effective treatment for osteoporosis [53]. WBV training has been employed as an alternative exercise intervention and has been demonstrated to increase bone density via mechanical load [54]. A recent systematic review and meta-analysis evaluated the results of published randomised controlled trials assessing the effects of WBV on bone mineral density in postmenopausal women [55]. Statistically significant differences in lumbar spine and femoral neck bone mineral density between WBV intervention and control groups were found [55]. However, the number of published studies was small and the WBV protocols used were highly heterogeneous.

Two major health risk factors today are high body mass index and high fasting plasma glucose, both of which are increasing in prevalence at an alarming rate [56]. The majority of obese people maintain a sedentary lifestyle and show little inclination to enroll and persist in conventional exercise programs due to physical limitations, musculoskeletal discomfort or lack of self-motivation. WBV may therefore offer a low-threshold

training option. Factors that may contribute to a reduction in fat mass after WBV exercise include: (1) triggering of lipolysis through activation of the central sympathetic nervous system innervating white adipose tissue, (2) improved insulin action and glucose regulation leading to enhanced glycaemic control, and (3) an increase in the release of growth hormone, which stimulates metabolism and is usually decreased in obese people [57].

The findings of a systematic review of the scientific literature showed that WBV training is a promising adjuvant intervention in the treatment of obese women [57]. WBV training may be particularly useful in de-conditioned obese individuals with poor motivation [58]. When WBV exercise is combined with dietary intervention or used as an alternative to traditional exercise training, it may be as effective as aerobic and resistance exercise in reducing fat mass [59,60]. Improved cardiac autonomic function [61,62] and a decrease in central and peripheral arterial stiffness [63,64] have been observed following at least 6 weeks of WBV exercise, and a significant reduction in body weight and an improvement in muscle strength have been seen after 10 or more weeks of training [62,64–66]. Further long-term studies, with male as well as female participants, are needed to further evaluate the health benefits of WBV exercise in obese people.

WBV exercise has been shown to reduce blood glucose levels [67] but not to affect insulin or glucagon concentrations. The most likely explanation for this is elevated glucose uptake into contracting skeletal muscles. A pilot study examined the effect of WBV on blood glucose levels in elderly people and found a significant decrease following a single 10-minute WBV session [68]. These benefical effects on glucose levels need to be confirmed in studies using larger samples and control groups. An acute session of WBV training has been shown to reduce glucose levels in elderly women with diabetes [69]. The findings of a systematic review and meta-analysis of randomised controlled trials suggest that a 12-week progressive intervention with WBV combined with exercise has a slight, statistically significant effect on glycaemic control in patients with type 2 diabetes [70]. High-quality trials need to establish the efficacy of WBV in diabetes and to clarify whether the effects are due to vibration, exercise or a combination of both. WBV training in addition to a hypocaloric diet may further enhance insulin sensitivity and glucose regulation [71].

WBV has often been promoted in recent years as a useful intervention and has shown favourable outcomes in the rehabilitation of various populations with chronic conditions that normally diminish quality of life. A systematic review of the available literature attempted to identify the effects of WBV on health-related quality of life in individuals with chronic conditions, such as respiratory, musculoskeletal and neurological diseases [72]. Based on the findings of randomised controlled trials comparing WBV with non-intervention or alternative intervention groups, it was found that WBV may improve health-related quality of life in patients with chronic conditions. However, the evidence provided is insufficient to warrant the recommendation of WBV as an intervention [72].

4. Conclusion and future perspectives

Despite many promising findings, it is currently far from clear whether WBV can play a role in the promotion of physical fitness and the management of chronic medical conditions. While many studies have shown improvements after exposure to WBV, others found no positive effects on performance. Major problems hampering the evaluation of the available evidence involve a wide range of methodological issues, including a lack of standardised procedures. The value of comparisons between the available studies is limited by varying interventions, vibration protocols and measurements. In order to ensure the reproducibility of WBV interventions, the information provided in research reports should include the type of vibration, frequency, amplitude, peak acceleration and duration of vibration, assessment of accuracy of vibration parameters, type of footwear, potential slipping of the feet and use of support devices during vibration exposure (e.g. in frail people) [73].

Future well-designed randomised controlled trials using larger sample sizes and different exercise intensities and intervention durations should be performed. Optimal settings regarding frequency, amplitude and duration of WBV exercise need to be determined in order to establish causal relationships between these parameters and WBV training outcomes and to develop WBV training guidelines. The question of whether the response to WBV is affected by age or sex also needs to be examined. Moreover, a comparison of the effects of WBV training on muscle strength and physical performance with effects of other types of exercise, such as resistance and endurance training would be of interest. A question meriting particular attention is whether the positive effects of WBV on body balance and postural control can reduce the risk of falls in elderly individuals. Any additional benefits of WBV when combined with other exercise programmes should also be assessed.

In summary, whether WBV training is a viable treatment for lower back pain, fibromyalgia or osteoporosis in

post-menopausal women is, at present, unclear. More research is required to explore more specifically the therapeutic potential of WBV as an exercise modality. In addition, potential long-term risks should be investigated.

Conflict of interest

The authors declare no conflict of interest.

References

1 Rittweger J. Vibration as an exercise modality: how it may work, and what its potential might be. Eur J Appl Physiol 2010; 108: 877–904.
2 Rogan S, Hilfiker R, Herren K, Radlinger L, de Bruin ED. Effects of whole-body vibration on postural control in elderly: a systematic review and meta-analysis. BMC Geriatrics 2011; 11: 72.
3 Sonza A, Maurer C, Achaval M, Zaro MA, Nigg BM. Human cutaneous sensors on the sole of the foot: altered sensitivity and recovery time after whole body vibration. Neurosci Lett 2013; 533: 81–85.
4 Park SY, Son WM, Kwon OS. Effects of whole body vibration training on body composition, skeletal muscle strength, and cardiovascular health. J Exerc Rehabil 2015; 11: 289–295.
5 Bullock N, Martin DT, Ross A, Rosemond CD, Jordan MJ, Marino FE. Acute effect of whole-body vibration on sprint and jumping performance in elite skeleton athletes. J Strength Cond Res 2008; 22: 1371–1374.
6 Cochrane DJ, Legg SJ, Hooker MJ. The short-term effect of whole-body vibration training on vertical jump, sprint, and agility performance. J Strength Cond Res 2004; 18: 828–832.
7 Merriman H, Jackson K. The effects of whole-body vibration training in aging adults: a systematic review. J Geriatr Phys Ther 2009; 32: 134–145.
8 Colson SS, Pensini M, Espinosa J, et al. Whole-body vibration training effects on the physical performance of basketball players. J Strength Cond Res 2010; 24: 999–1006.
9 Ebben WP, Petushek EJ, Nelp AS. The effect of whole body vibration on the dynamic stability of women basketball players. Proceedings of the 28th Conference of the International Society of Biomechanics in Sports, 2010; 28: 537–540.
10 Fernandez-Rio J, Terrados N, Fernandez-Garcia B, et al. Effects of vibration training on force production in female basketball players. J Strength Cond Res 2010; 24: 1373–1380.
11 Wyon M, Guinan D, Hawkey A. Whole-body vibration training increases vertical jump height in a dance population. J Strength Cond Res 2010; 24: 866–870.
12 Matute-Llorente A, González-Agüero A, Gómez-Cabello A, Vicente-Rodríguez G, Casajús Mallén JA. Effect of whole-body vibration therapy on health-related physical fitness in children and adolescents with disabilities: a systematic review. J Adolesc Health 2014; 54: 385–396.
13 Ritzmann R, Kramer A, Bernhardt S, et al. Whole body vibration training–improving balance control and muscle endurance. PloS ONE 2014; 9: e89905.
14 Wallmann HW, Bell DL, Evans BL, Hyman AA, Goss GK, Paicely AM. The effects of whole body vibration on vertical jump, power, balance, and agility in untrained adults. Int J Sports Phys Ther 2019; 14: 55–64.
15 Metter EJ, Conwit R, Tobin J, Fozard J. Age-associated loss of power and strength in the upper extremities in women and men. J Gerontol A Biol Sci Med Sci 1997; 52: B267–B276.
16 Reid KF, Fielding RA. Skeletal muscle power: a critical determinant of physical functioning in older adults. Exerc Sports Sci Rev 2012; 40: 4–12.
17 Booth FW, Laye MJ, Roberts MD. Lifetime sedentary living accelerates some aspects of secondary aging. J Appl Physiol 1985; 111: 1497–1504.
18 Kowal J, Fortier MS. Physical activity behaviour change in middle aged and older women: the role of barriers and of environmental characteristics. J Behav Med 2007; 30: 233–242.
19 Hawkey A, Griffiths K, Babraj J, Cobley JN. Whole-body vibration training and its application to age-related performance decrements: an exploratory analysis. J Strength Cond Res 2016; 30: 555–560.
20 Bruyere O, Wuidart MA, Di Palma E, et al. Controlled whole body vibration to decrease fall risk and improve health-related quality of life of nursing home residents. Arch Phys Med Rehabil 2005; 86: 303–307.
21 Sitjà-Rabert M, Rigau D, Vanmeerghaeghe AF, Romero-Rodriguez D, Subirana MB, Bonfill X. Efficacy of whole-body vibration exercise in older people: a systematic review. Disabil Rehabil 2012; 34: 883–893.
22 Bogaerts AN, Delecluse C, Claessens AL, Coudyzer W, Boonen S, Verschueren SMP. Impact of whole-body vibration training versus fitness training on muscle strength and muscle mass in older men: a 1-year randomized controlled trial. J Gerontol Med Sci 2007; 62: 630–635.
23 Verschueren SMP, Roelants M, Delecluse C, Swinnen S, Vanderschueren D, Boonen S. Effect of 6-month whole body vibration training on hip density, muscle strength, and postural control in postmenopausal women: a randomized controlled pilot study. J Bone Miner Res 2004; 19: 352–359.
24 Bogaerts AC, Delecluse C, Claessens AL, Troosters T, Boonen S, Verschueren SM. Effects of whole-body vibration training on cardiorespiratory fitness and muscle strength in older individuals (a 1-year randomised controlled trial). Age Ageing 2009; 38: 448–454.
25 Torvinen S, Kannus P, Sievanen H, et al. Effect of a vibration exposure on muscular performance and body balance. Randomized cross-over study. Clin Physiol Funct Imaging 2002; 22: 145–152.
26 Bautmans I, Van Hees E, Lemper J-C, Mets T. The feasibility of whole body vibration in institutionalised elderly persons and its influence on muscle performance, balance and

mobility: a randomised controlled trial. BMC Geriatr 2005; 5: 17.
27 Cheung WH, Mok HW, Qin L, Sze PC, Lee KM, Leung KS. High-frequency whole-body vibration improves balancing ability in elderly women. Arch Phys Med Rehabil 2007; 88: 852–857.
28 Runge M, Rehfeld G, Resnicek E. Balance training and exercise in geriatric patients. J Musculoskelet Neuronal Interact 2000; 1: 61– 65.
29 Silva PZ, Schneider RH. Effects of a whole-body vibration platform on postural balance in elderly persons. Acta Fisiatr 2011; 18: 21–26.
30 Chen CH, Liu C, Chuang L, Chung P, Shian T. Chronic effects of whole-body vibration on jumping performance and body balance using different frequencies and amplitudes with identical acceleration load. J Sci Med Sport 2014; 17: 10712.
31 Osugi T, Iwamoto J, Yamazaki M, Takakuwa M. Effect of a combination of whole-body vibration exercise and squat training on body balance, muscle power, and walking ability in the elderly. Ther Clin Risk Manag 2014; 10: 131–138.
32 Lai CC, Tu YK, Wang TG, Huang YT, Chien KL. Effects of resistance training, endurance training and whole-body vibration on lean body mass, muscle strength and physical performance in older people: a systematic review and network meta-analysis. Age Ageing 2018; 47: 367–373.
33 Lam FM, Chan PF, Liao LR, et al. Effects of whole-body vibration on balance and mobility in institutionalized older adults: a randomized controlled trial. Clin Rehabil 2018; 32: 462–472.
34 Searle A, Spink M, Ho A, et al. Exercise interventions for the treatment of chronic low back pain: a systematic review and meta-analysis of randomised controlled trials. Clin Rehabil 2015; 29: 1155–1167.
35 Rittweger J, Just K, Kautzsch K, Reeg P, Felsenberg D. Treatment of chronic lower back pain with lumbar extension and whole-body vibration exercise: a randomized controlled trial. Spine 2002; 27: 1829–1834.
36 Iwamoto J, Takeda T, Sato Y, Uzawa M. Effect of whole-body vibration exercise on lumbar bone mineral density, bone turnover, and chronic back pain in post-menopausal osteoporotic women treated with alendronate. Aging Clin Exp Res 2005; 17: 157–163.
37 Del Pozo-Cruz B, Hernandez Mocholi MA, Adsuar JC, et al. Effects of whole body vibration therapy on main outcome measures for chronic non-specific low back pain: a single-blind randomized controlled trial. J Rehabil Med 2011; 43: 689–694.
38 Boucher JA, Abboud J, Dubois JD, et al. Trunk neuromuscular responses to a single whole-body vibration session in patients with chronic low back pain: a cross-sectional study. J Manipulative Physiol Ther 2013; 36: 564–571.
39 Wang XQ, Pi YL, Chen PJ, et al. Whole body vibration exercise for chronic low back pain: study protocol for a single-blind randomized controlled trial. Trials 2014; 15: 104.
40 Chen B, Dong Y, Guo J, et al. Effects of whole-body vibration on lumbar-abdominal muscles activation in healthy young adults: a pilot study. Med Sci Monit 2019; 25: 1945–1951.
41 Zheng YL, Wang XF, Chen BL, et al. Effect of 12-week whole-body vibration exercise on lumbopelvic proprioception and pain control in young adults with nonspecific low back pain. Med Sci Monit 2019; 25: 443–452.
42 Ye J, Ng G, Yuen K. Acute effects of whole-body vibration on trunk muscle functioning in young healthy adults. J Strength Cond Res 2014; 28: 2872–2879.
43 Maeda N, Urabe Y, Sasadai J, et al. Effect of whole-body vibration training on trunk-muscle strength and physical performance in healthy adults: preliminary results of a randomized controlled trial. J Sport Rehabil 2016; 25: 357–363.
44 Perraton L, Machotka Z, Kumar S. Whole-body vibration to treat low back pain: fact or fad? Physiother Can 2011; 63: 88–93.
45 Wang XQ, Gu W, Chen BL, et al. Effects of whole-body vibration exercise for non-specific chronic low back pain: an assessor-blind, randomized controlled trial. Clin Rehabil 2019; 33: 1445 –1457.
46 Bennett RM. Clinical manifestations and diagnosis of fibromyalgia. Rheum Dis Clin North Am 2009; 35: 215–232.
47 Bennett RM, Jones J, Turk DC, Russell IJ, Matallana L. An internet survey of 2,596 people with fibromyalgia. BMC Musculoskelet Disord 2007; 8: 27.
48 Collado-Mateo D, Adsuar JC, Olivares, PR, et al. Effects of whole-body vibration therapy in patients with fibromyalgia: a systematic literature review. Evid Based Complement Alternat Med 2015; 2015: 719082.
49 Bidonde J, Busch AJ, van der Spuy I, Tupper S, Kim SY, Boden C. Whole body vibration exercise training for fibromyalgia (Review). Cochrane Database Syst. Rev. 2017: CD011755.
50 Gregg EW, Kriska AM, Salamone LM, et al. The epidemiology of quantitative ultrasound: a review of the relationships with bone mass, osteoporosis and fracture risk. Osteoporos Int 1997; 7: 89–99.
51 Kanis JA, Johnell O, Oden A, et al. Long-term risk of osteoporotic fracture in Malmo. Osteoporos Int 2000; 11: 669–674.
52 Frost HM. Wolff's law and bone's structural adaptations to mechanical usage: an overview for clinicians. Angle Orthod 1994; 64: 175–188.
53 American College of Sports Medicine Position Stand. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. Med Sci Sports Exerc 1998; 30: 975–991.
54 Prioreschi A, Oosthuyse T, Avidon I, et al. Whole body vibration increases hip bone mineral density in road cyclists. Int J Sports Med 2012; 33: 593–599.

55 Marín-Cascales E, Alcaraz PE, Ramos-Campo DJ, Martinez-Rodriguez A, Chung LH, Rubio-Arias JA. Whole-body vibration training and bone health in postmenopausal women – a systematic review and meta-analysis. Medicine 2018; 97: 34.

56 Lange KW. Movement and nutrition in health and disease. Mov Nutr Health Dis 2017; 1: 1–2.

57 Zago M, Capodaglio P, Ferrario C, Tarabini M, Galli M. Whole-body vibration training in obese subjects: a systematic review. PLoS ONE 2018; 13: e0202866.

58 Figueroa A, GIl R, Wong A, et al. Whole-body vibration training reduces arterial stiffness, blood pressure and sympathovagal balance in young overweight/obese women. Hypertens Res 2012; 35: 667–672.

59 Vissers D, Verrijken A, Mertens I, et al. Effect of long-term whole body vibration training on visceral adipose tissue: a preliminary report. Obes Facts 2010; 3: 93–100.

60 Nam SS, Sunoo S, Park HY, Moon HW. The effects of long-term whole-body vibration and aerobic exercise on body composition and bone mineral density in obese middle-aged women. J Exerc Nutr Biochem 2016; 20: 19–27.

61 Wong A, Alvarez-Alvarado S, Kinsey AW, Figueroa A. Whole-body vibration exercise therapy improves cardiac autonomic function and blood pressure in obese pre- and stage 1 hypertensive postmenopausal women. J Altern Complement Med 2016; 22: 970–976.

62 Severino G, Sanchez-Gonzalez M, Walters-Edwards M, et al. Whole-body vibration training improves heart rate variability and body fat percentage in obese hispanic postmenopausal women. J Aging Phys Act 2017; 25: 395–401.

63 Wong A, Alvarez-Alvarado S, Jaime SJ, et al. Combined whole-body vibration training and l-citrulline supplementation improves pressure wave reflection in obese postmenopausal women. Appl Physiol Nutr Metab 2016; 41: 292–297.

64 Alvarez-Alvarado S, Jaime SJ, Ormsbee MJ, et al. Benefits of whole-body vibration training on arterial function and muscle strength in young overweight/obese women. Hypertens Res 2017; 40: 487–492.

65 Milanese C, Piscitelli F, Zenti MG, Moghetti P, Sandri M, Zancanaro C. Ten-week whole-body vibration training improves body composition and muscle strength in obese women. Int J Med Sci 2013; 10: 307–311.

66 Figueroa A, Kalfon R, Madzima TA, Wong A. Effects of whole-body vibration exercise training on aortic wave reflection and muscle strength in postmenopausal women with prehypertension and hypertension. J Hum Hypertens 2014; 28: 118–122.

67 Di Loreto C, Ranchelli A, Lucidi P, et al. Effects of whole-body vibration exercise on the endocrine system of healthy men. J Endocrinol Invest 2004; 27: 323–327.

68 Das Graças Bastos Licurci M, de Almeida Fagundes A, Lo Schiavo Arisawa EA. Whole body vibration and blood glucose levels in elderly people: a pilot study. Sci Med 2017; 27: ID27604.

69 Pessoa MF, Souza HC, Silva AP, Clemente RDS, Brandão DC, Dornelas de Andrade A. Acute whole body vibration decreases the glucose levels in elderly diabetic women. Rehabil Res Pract 2018; 2018: 3820615.

70 Robinson CC, Barreto RPG, Sbruzzi G, Plentz RDM. The effects of whole body vibration in patients with type 2 diabetes: a systematic review and meta-analysis of randomized controlled trials. Braz J Phys Ther 2016; 20: 4–14.

71 Bellia A, Sallì M, Lombardo M, et al. Effects of whole body vibration plus diet on insulin resistance in middle-aged obese subjects. Int J Sports Med 2014; 35: 511–516.

72 Li G, Zhang G, Wang Y, et al. The effect of whole body vibration on health-related quality of life in patients with chronic conditions: a systematic review. Qual Life Res 2019; 28: 2859–2870.

73 Rauch F, Sievanen H, Boonen S, et al. Reporting whole-body vibration intervention studies: recommendations of the International Society of Musculoskeletal and Neuronal Interactions. J Musculoskelet Neuronal Interact 2010; 10: 193–198.