Nutrición Hospitalaria

Nutr Hosp. 2013;28(5):1365-1371
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Revisión

Whole-body vibration training as complement to programs aimed at weight loss

Carlos Cristi-Montero[1], María J. Cuevas[2] y Pilar S. Collado[2]

[1]GICEFYD, Grupo de Investigación en Ciencias de Ejercicio Físico y del Deporte. Universidad Viña del Mar. Chile. [2]Instituto de Biomedicina (IBIOMED). Universidad de León. León. España.

Abstract

Introduction: **Whole-body vibration training (WBVT) has been shown to be an extremely useful tool for increasing muscle mass, bone tissue, muscle power, flexibility, and strength, among others. However, to date, there are few studies on the effects of WBVT on energy metabolism and whether this tool could be able to enhance weight loss in addition to a nutritional plan and/or exercise.**

Objective: **The aim of this review is to analyse the most recent studies on vibration training in order to determine whether this method constitutes a reliable complement to programs aimed at weight loss.**

Methods: **An updated literature search was conducted using PubMed, SciELO and SPORTDiscus. In addition, a detailed search was also performed from references given in selected studies.**

Results: **WBVT appears to be associated with three pathways involved in weight loss: inhibition of adipogenesis and reduction of fat mass, increased energy expenditure, and increase in muscle mass. After analysing the literature, none of the results for the proposed pathways are consistent, and indeed are often contradictory.**

Conclusion: **Further in-depth research is required on this subject. However, WBVT would appear to be a safe method, and may possibly yield benefits, mainly as regards muscle mass, which in turn might promote weight loss when combined with a nutritional plan and a traditional exercise program.**

(*Nutr Hosp.* 2013;28:1365-1371)

DOI:10.3305/nh.2013.28.5.6656

Key words: *Whole-body vibration training. Adipogenesis. Fat mass. Muscle mass. Energy expenditure.*

ENTRENAMIENTO DE VIBRACIONES DE CUERPO COMPLETO COMO COMPLEMENTO A LOS PROGRAMAS ORIENTADOS A LA PÉRDIDA DE PESO

Resumen

Introducción: **El entrenamiento de vibraciones de cuerpo completo (EVCC) ha demostrado ser de gran utilidad para aumentar la masa muscular, el tejido óseo, la potencia muscular, la flexibilidad, y la fuerza, entre otros. No obstante, hasta la fecha es escasa la literatura respecto a sus efectos sobre el metabolismo energético y si esta herramienta podría ser capaz de potenciar la pérdida de peso como complemento a un programa nutricional y/o de ejercicio físico.**

Objetivo: **El objetivo de la presente revisión es analizar los últimos estudios sobre el EVCC con la finalidad de determinar si puede ser un método fiable para complementar los programas orientados a la reducción del peso corporal.**

Métodos: **Se realizó una búsqueda bibliográfica en Pubmed, Scielo y SPORTDiscus, así como una búsqueda manual entre las referencias de los estudios seleccionados.**

Resultados: **El EVCC parece estar vinculado a tres vías relacionadas con la reducción del peso corporal: inhibición de la adipogénesis y reducción de la masa grasa, aumento del gasto energético y aumento de la masa muscular. Tras analizar la literatura, ninguna de las vías propuestas es consistente, y en muchas ocasiones los resultados son contradictorios.**

Conclusión: **Se concluye que es necesario profundizar sobre esta línea de investigación. No obstante, el EVCC parece ser un método seguro y posiblemente tendría beneficios, principalmente sobre la masa muscular, lo que podría promover la pérdida de peso si se combina con un plan nutricional y un programa de ejercicio tradicional.**

(*Nutr Hosp.* 2013;28:1365-1371)

DOI:10.3305/nh.2013.28.5.6656

Palabras clave: *Entrenamiento de vibraciones de cuerpo completo. Adipogénesis. Masa grasa. Masa muscular. Gasto energético.*

Correspondence: Pilar Sánchez Collado.
Instituto de Biomedicina (IBIOMED).
Campus Universitario. Universidad de León.
24071 León. España.
E-mail: p.sanchez.collado@unileon.es

Recibido: 11-IV-2013.
1.ª Revisión: 22-IV-2013.
Aceptado: 8-V-2013.

Introduction

Recent decades have witnessed a variety of economic, urban and especially technological changes which have transformed the habits and lifestyle of our society.[1] This social transition has led to a drastic reduction in people's levels of physical activity, which has been associated with a steady increase in the incidence of overweight and obesity.[2]

Various methods and programs have been proposed to help prevent, control and reverse excess weight gain.[3] Although the implementation of a low calorie diet without exercise may reduce body weight rapidly, this occurs at the expense of loss of muscle mass. In contrast, a weight loss program consisting solely of physical exercise may be effective. It has been shown that exercise can help maintain or increase muscle mass and stimulate metabolism, etc. However, the effects of exercise on body composition tend to develop slowly if not accompanied by a proper diet. For this reason, the combination of diet and exercise is proposed as the ideal and most reliable weight loss method.[3-5] A nutritional plan combined with aerobic exercise or resistance training, or combination of both, has proved useful in improving the body composition of people who engage in a weight loss program, producing favourable changes in fat and muscle mass.[4]

Recently, the use of whole-body vibration training (WBVT) has become increasingly popular as a useful tool in both sports and rehabilitation centres.[6,7] The main advantage of WBVT is that in a short period of time (~10 minutes per session) it has the capacity to stimulate a large number of muscle fibers and produce a great many contractions, which helps to increase strength, balance and muscle power,[8,9] enhance mobility,[10] reduce chronic pain,[11] stimulate blood circulation in the extremities[12] and improve bone mineral density,[9] among other effects.

In addition to inducing significant benefits in variables related to physical condition, WBVT has also been shown to be an extremely useful tool for reducing arterial stiffness, blood pressure and sympathovagal balance in a population of overweight or obese women.[13] In recent years, several authors have suggested that WBVT could contribute to weight loss, indicating that it generates an increase in energy metabolism and a reduction in body fat percentage. However, no clear consensus exists on this issue to date. Therefore, the aim of this review was to analyse the most recent studies on vibration training in order to determine whether this method constitutes a reliable complement to programs aimed at weight loss.

To this end, an updated literature search was conducted using various metasearch engines such as PubMed, SciELO and SPORTDiscus, and employing keywords such as “Body vibration”, “Whole body vibration”, “Vibration training”, “Vibration exercise”, “Whole-body vibration”, “Body vibration training”, “Fat”, “Low weight program”, “Hypertrophy” and “Body composition”. In addition to the computer search, a manual literature search was also performed based on the references given in the selected studies.

An analysis of the literature indicated that there are three main pathways through which WBVT could act to reduce body weight (fig. 1), although the results of the studies appear to be rather contradictory, mainly depending on the study population, exercise intensity and the amplitude (mm), frequency (Hz) and duration of the program.

Table I lists the main studies which have been conducted on the inhibition of adipogenesis, reduction in fat mass, increase in energy expenditure and increase in muscle mass as a result of vibration training.

Inhibition of adipogenesis and reduction in fat mass

In studies conducted on rats, it was concluded that WBVT reduced the accumulation of body fat and decreased serum leptin levels, but did not affect bone density or mineral content, or lean mass.[14]

Furthermore, Rubin et al. (2007) published a study based on molecular techniques in which the authors indicated that if their results on rats were extrapolated to humans, vibration training could contribute as a non-pharmacological approach to the prevention of obesity and its sequelae. They found that after 15 weeks of short daily exposure to high-frequency vibrations, adipogenesis in rats was inhibited by 27%, esterifica-

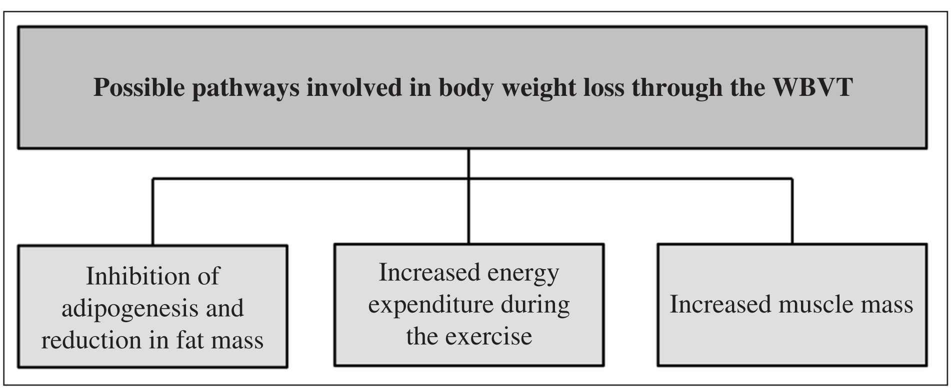

Fig. 1.—Possible pathways through which WBVT could act as complement to programs aimed at weight loss.

Table I
Main studies conducted on the inhibition of adipogenesis, reduction in fat mass, increase in energy expenditure and increase in muscle mass as a result of vibration training

Reference	*Sample*	*Protocol*	*Results*
	Inhibition of adipogenesis and reduction in fat mass		
Maddalozzo et al., 2008	Fischer Rats n = 344 Females 7 months old	30-50 Hz 6 mm 30 min/day 5 times/week 12 weeks	Vib. group: 10%, 2% and 46% less weight, fat and leptin, respectively.
Rubin et al., 2007	Male mice n = 40 7 weeks old	15 weeks High frequency 0.2-g peak acceleration displacement of ≈12 μm	Inhibited adipogenesis by 27% more than the control group.
Yoo et al., 2009	112 students men and women	10 min 3 times/week 3 months	Women vib., slight increase of 0.8 kg weight and 1.1 kg fat.
Roelants et al., 2004	48 untrained women ~21 years old	24 weeks 3 times/week 35-40 Hz 2.5 to 5.0 mm plus cardiovascular exercise and strength training	Vibration group reduced fat mass by 2.2% compared to controls.
Song et al., 2011	15 healthy, obese, postmenopausal women > 50 years old	10 min 2 times/week 8 weeks	Weight -1.18 kg BMI -0.49 Waist circ. -2.34 cm
Wilms et al., 2012	14 obese women ~43.1 years old	6 weeks 2 mm 30 s/30 s 30 Hz	Weight: no difference Waist circ.: -1.7 cm Fat mass: -0.2%
Vissers et al., 2010	79 overweight/obese participants ~44.5 years old Diet group Exercise group Vibration training group Control group	6-month intervention 6-month follow-up 30-40 Hz 2-4 mm 30-60 s/exercise 10-22 exercises	Vibr. group at 6 months: Weight: -10.3 kg BMI: -3.4 kg/m^2 Visceral fat: -47.8 cm^2 Adipose tissue: -154.4 cm^2 Fat bioimpedance: -7.0% Waist-hip circ. ratio -0.05
Von Stengel et al., 2012	151 postmenopausal women ~68 years old	2 times/week 60 min/session 18 months 25-30 Hz 1.7-2.0 mm	Weight: no difference Fat: -0.8% Abdominal fat: -0.4 kg Lean mass: +0.4 kg Abdominal and body fat: significant differences compared to the control group.
Fjeldstad et al., 2009	55 sedentary, postmenopausal women ~63.2 years old	3 times/week 8 months 15-40 Hz 3 mm	Fat: -1.3% Fat: 0.7 kg Lean mass without bone: +1 kg Fat decreased significantly in the region of the arms and trunk, but not in the legs.

Table I *(cont.)*
Main studies conducted on the inhibition of adipogenesis, reduction in fat mass, increase in energy expenditure and increase in muscle mass as a result of vibration training

Reference	*Sample*	*Protocol*	*Results*
		Increase in energy expenditure during vibration training	
Da Silva et al., 2007	17 active university students Men ~18.3 years old	Acute effect 5 sets/10 rep 2 min/rest/set	Energy during and after exercise was significantly higher in the vibration training group. ~7.8 kcal.
Wilms et al., 2012	14 obese women ~43.1 years old	Long-term effect 6 weeks 2 mm 30 s/30 s 30 Hz	Resting energy: +9 kcal
Rittweger et al., 2000	16 women 21 men ~23.5 years old	Acute amplitude effect a0 = 1.05 cm Frequency: 26 Hz Additional load 40% weight in men and 35% in women	Vibration training: ~21.9 ml/kg/min approx. ~ 48.8% of VO2max.
Cochrane et al., 2008	12 young adults ~21.5 years old (6M and 6W) and 12 healthy older adults ~69.2 years (6M and 6W)	Acute effect 30 Hz 0%, 20% and 40% body weight	MET increased by 0%, 20% and 40% at 0.35, 0.8 and 1.2, respectively. Corresponding to 19.7%, 26.7% and 62.9% of VO2max. VO2 was increased in both groups.
Garatachea et al., 2007	9 recreationally active men ~24.2 years old	Squats (90º) in cycles of 6, 4 and 2 seconds. 30 Hz 4 mm 30% extra body weight	6-second vibration cycles increased VO2, total energy expenditure and fatty acid utilisation compared to cycles of 4 and 2 seconds.
		Increase in muscle mass	
Ceccarelli et al., 2012	Cells *in vivo* and *in vitro* (CD1 mice muscle tissue)	Low amplitude 30 Hz	The vibratory stimulus promoted satellite cell fusion. 30 Hz was sufficient to suppress atrophy both *in vivo* and *in vitro*.
Martínez-Pardo et al., 2012	38 physically active people Two groups, high and low frequency	Group: 2 mm Group: 4 mm Group: control 2 times/week 6 weeks 50 Hz 60 s exercise 60 s rest Static exercise or half-squat	Both groups increased isokinetic strength. Lean mass was significantly increased in the high-frequency group (4 mm), fat mass did not differ between groups.
Osawa and Oguma, 2013	32 untrained, healthy subjects (22-49 years old)	Vibration training plus strength training 13 weeks Group with and without vibration training	Group with vibration training: significant increase in the cross section of the psoas muscle (+6.9%) and erector spinae (+3.8%) compared to strength training without vibration.
Fjeldstad et al., 2009	55 sedentary, postmenopausal women ~63.2 years old	8 months Strength training group and vibration plus strength training group Strength: 3 sets 10 reps at 80% maximum force. 15-40 Hz 3 mm	The vibration plus strength training group presented a significant increase in lean mass (~1 kg) compared to the control group. Mainly on the trunk and arms.

Table I *(cont.)*
Main studies conducted on the inhibition of adipogenesis, reduction in fat mass, increase in energy expenditure and increase in muscle mass as a result of vibration training

Reference	*Sample*	*Protocol*	*Results*
Bogaerts et al., 2007	97 subjects ~67.3 years old	1 year Fitness training group Vibration training group Control group	Strength and muscle mass increased significantly in the vibration training group (9.8% and 3.4%, respectively). But also in the fitness group. No significant differences were found between the groups.
Yoo et al., 2009	112 students Men and women	Vibration training 10 min 3 times/week 3 months	No significant differences in the increase in lean mass.
Song et al., 2011	15 healthy, obese postmenopausal women > 50 years old	Vibration training 10 min 2 times/week 8 weeks	Increase in muscle mass ~0.54 kg
Osawa et al., 2011	Young, healthy, untrained adults (21-39 years old)	Strength plus vibration training Non-vibration training group 8 exercises per 40-minute session Vibration training group: 30-40 Hz, 2 mm) 2 times/week 12 weeks	At 12 weeks, no differences in body composition were found between the two groups.

tion of fatty acids decreased by 43% and triglyceride content in the liver was reduced by 39%.[15]

The study by Yoo et al. (2009) focused on the effect of 10 minutes exposure three times a week in a group of 112 students. After three months of training, the group exposed to vibration training did not present significantly different changes in weight, fat mass or visceral fat compared to the control group.[16] These results are similar to those found by Roelants et al. (2004), who concluded that 24 weeks of WBVT did not reduce body weight or total and subcutaneous body fat in untrained women.[17]

In a more recent study involving overweight, postmenopausal women, it was found that the use of WBVT produced significant benefits, including a significant reduction in weight (-1.18 ± 1.61 kg), BMI (-0.49 ± 0.66 kg/m^2), and waist circumference (-2.34 ± 2.48 cm). Nevertheless, body fat percentage and mass did not change significantly.[18]

Moreover, in a research on obese women, it was reported that despite presenting no change in body weight with the use of WBVT, waist circumference, bioelectrical impedance and resting energy expenditure increased slightly compared to the group that did not use vibration training.[19]

Other studies have obtained favourable results for WBVT when used as a complement to low calorie diets. Vissers et al. (2010) concluded that combining aerobic exercise or WBVT with a low calorie diet can help achieve significant weight loss (5-10%) in the long term.[20] It is worth highlighting that this was one of few studies employing a randomised, controlled design which analysed a group of people throughout a 6-month intervention and a 6-month follow-up period. Furthermore, it should also be noted that a significant reduction in visceral fat was achieved in the group that used WBVT.

Another study investigated the long-term (18 months) effect of WBVT on older adult women, and found that an exercise program which included aerobic exercise, coordination and upper and lower body strength training did not benefit from the addition of vibration training. However, both groups —normal training and training plus vibration— presented significantly modified fat mass and visceral fat mass compared to the control group.[21] These results are very similar to those found in another study on postmenopausal women using resistance training exercises.[22]

Increased energy expenditure

To date, few authors have investigated whether WBVT has the capacity to increase oxygen consumption, energy expenditure and fat oxidation. Furthermore, no consensus appears to exist regarding the frequency, duration and amplitude required in order to increase energy expenditure.[23]

In male university students, performing half-squat exercises on a vibration platform generated greater energy expenditure than the same exercise performed without the platform. Researchers concluded that combining WBVT with regular training programs aimed at muscle hypertrophy could, in the long term, achieve a reduction in body fat.[24]

The aforementioned effect has also been reported by Wilms et al. (2012), who observed that resting energy expenditure in obese women increased slightly when aerobic exercise was combined with vibration training, compared to the group that did not use vibration. However, it should be noted that the increase was very slight (vibration training group: 77 ± 33 kcal/24 h; non-vibration training group: +68 ± 34 kcal/24 h).[19]

Although there is clear evidence that use of WBVT induces an increase in muscle activation,[25,26] this increase does not appear to be proportional to that which occurs in oxygen consumption and energy costs, but rather, is much lower.[27]

Increasing the workload with additional weight on the platform has been shown to increase oxygen consumption. Cochrane et al. (2008) found that WBVT (frequency: 30 Hz and amplitude: 1 mm) generated an increase of 0.35 metabolic equivalents (METs) when the load was increased by 20% and 40% up to values of 0.8 and 1.2 METs, respectively.[28]

In addition to the proportional increase in oxygen consumption, when the frequency, amplitude of vibration and load (40%) was increased, Rittweger et al. (2002) observed that the rate on the platform (rise time vs fall time of the exercise) also influenced energy expenditure,[27] this latter being greater the more rapid the rate —1 s: 1 s than 2 s: 2 s and 3 s: 3 s—, although the latter was found to oxidise more fat than the faster rates.[29] Despite the above evidence, authors concluded that the increase in oxygen consumption was small and unlikely to be of help in reducing body weight. In fact, it has been reported that 15 minutes training on the vibrating platform produces a difference of about 14.2 kcal.[23]

Considering the current recommendations for weight control,[4] which suggest training at an intensity of between 3 and 5.9 METs and completing between 150-200 minutes of aerobic exercise a week, it appears that the use of WBVT is not an appropriate means to achieve the objective indicated, although if it is combined with a low calorie diet it might generate certain benefits.[23]

Increased muscle mass

Muscle mass is the active tissue mainly responsible for the body's energy consumption. A healthy male adult can have between 35 and 50 kg of muscle mass.[30]

An increase in muscle volume raises resting energy expenditure, which could help in reducing body weight and in fatty acid oxidation. A report by Wolfe (2006) indicated that each kg of lean mass generates an energy difference of about 10 kcal/day, which would imply almost half a kilologram of fat a year.[31]

In an interesting study by Ceccarelli et al. (2012), low amplitude and high frequency vibrations were stimulated in animals in order to analyse their effect on muscle hypertrophy/atrophy pathways, and the authors concluded that a frequency of 30 Hz was effective in suppressing the pathway associated with muscular atrophy and in enhancing the fusion of satellite cells,[32] thus promoting muscle hypertrophy.[33]

In recreationally active subjects who trained twice a week for six weeks at a frequency of 50 Hz, 60 s of exercise and 60 s rest, it was shown that the use of greater amplitudes (4 mm instead of 2 mm) was much more effective in increasing strength and lean mass (0.9 ± 1.0 kg).[34]

In a recent article, it has also been shown that 13 weeks of a combination of WBVT plus resistance training is much more effective in generating muscle hypertrophy (cross-sectional area of the psoas major) than resistance training alone (+10.7% and +3.8% compared to baseline and the group who did not use WBVT, respectively).[35]

The effects also appeared to be pronounced in the older adult population. For both men and women, it has been shown that WBVT is effective in increasing lean and muscle mass, and it has also been suggested that this type of training has the potential to prevent or reverse the effects on muscle mass that occur with aging.[22,36]

However, it should also be noted that several studies have been published in which no differences were found after using WBVT. Furthermore, Song et al. (2011), Yoo et al. (2009) and Osawa et al. (2011) observed a reduction in muscle mass in overweight postmenopausal women, in students (27.4 years old) and young, healthy adults (21-39 years old), respectively.[16,18,37] Therefore, the question of the effects of WBVT on muscle mass remains open.

Conclusions

WBVT appears to be associated with three pathways involved in weight loss: inhibition of adipogenesis and reduction of fat mass, increased energy expenditure, and an increase in muscle mass. After analysing the literature, none of the results for the proposed pathways are consistent, and indeed are often contradictory. We conclude that further in-depth research is required on this subject. However, WBVT would appear to be a safe method, and may possibly yield benefits, mainly as regards muscle mass, which in turn might promote weight loss when combined with a nutritional plan and a traditional exercise program.

References

1. Rodríguez-Rodríguez E, López-Plaza B. López-Sobaler Mª, Ortega RMª. Prevalencia de sobrepeso y obesidad en adultos españoles. *Nutr Hosp* 2011; 26: 355-63.

2. Oviedo G, Marcano M, Moron de Salim A, Solano L. Exceso de peso y patologías asociadas en mujeres adultas. *Nutr Hosp* 2007; 22: 358-62.
3. Lara M, Amigo H. ¿Qué tipo de intervención tiene mejores resultados en la disminución de peso en adultos con sobrepeso u obesidad? Revisión Sistemática y Metaanálisis. *Archivos Latinoamericanos de Nutrición* 2011; 61: 45-54.
4. Donnelly JE, Blair SN, Jakicic JM, Manore MM, Rankin JW, Smith BK. American College of Sports Medicine Position Stand. Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. *Med Sci Sports Exerc* 2009; 41 (2): 459-71.
5. Wu T, Gao X, Chen M, Van Dam RM. Long-term effectiveness of diet-plus-exercise interventions *vs.* diet-only interventions for weight loss: a meta-analysis. *Obes Rev* 2009; 10 (3): 313-23.
6. 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 Min Res* 2004; 19: 352-9.
7. Bogaerts ACG, Delecluse C, Claessens AL, Troosters T, Boonen S, Verschueren SMP. 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: 448-54.
8. Machado A, García-López D, González-Gallego J, Garatachea N. Whole-body vibration training increases muscle strength and mass in older women". *Scand J Med Sci Sports* 2010; 20: 200-7.
9. Sitjà-Rabert M, Rigau D, Fort Vanmeerghaeghe A, Romero-Rodríguez D, Bonastre Subirana M, Bonfill X. Efficacy of whole body vibration exercise in older people: a systematic review. *Disabil Rehabil* 2012; 34 (11): 883-93.
10. Torvinen S, Kannus P, Sievanen H. Effect of four-month vertical whole body vibration on performance and balance. *Med Sci Sports Exerc* 2002; 34: 1523-8.
11. 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: 1829-34.
12. Cochrane DJ. Vibration exercise: the potential benefits. *Int J Sports Med* 2011; 32: 75-99.
13. Figueroa A, Gil R, Wong A, Hooshmand S, Park SY, Vicil F, Sánchez-González MA. Whole-body vibration training reduces arterial stiffness, blood pressure and sympathovagal balance in young overweight/obese women. *Hypertens Res* 2012; 35 (6): 667-72.
14. Maddalozzo GF, Iwaniec UT, Turner RT, Rosen CJ, Widrick JJ. Whole-body vibration slows the acquisition of fat in mature female rats. *Int J Obes* 2008; 32 (9): 1348-54.
15. Rubin CT, Capilla E, Luu YK, Busa B, Crawford H, Nolan DJ et al. Adipogenesis is inhibited by brief, daily exposure to high-frequency, extremely low-magnitude mechanical signals. *Proc Natl Acad Sci USA* 2007; 104 (45): 17879-84.
16. Yoo JH, Joh HK, Do HJ, Oh SW, Lym YL, Choi JK. Effects of whole body vibration exercise on body weight and body composition in young adults. *Korean J Fam Med* 2009; 30 (2): 112-9.
17. Roelants M, Delecluse C, Goris M, 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): 1-5.
18. Song G-E, Kim K, Lee D-J, Joo N-S. Whole body vibration effects on body composition in the postmenopausal korean obese women: pilot study. *Korean J Fam Med* 2011; 32 (7): 399-405.
19. Wilms B, Frick J, Ernst B, Mueller R, Wirth B, Schultes B. Whole body vibration added to endurance training in obese women - a pilot study. *Int J Sports Med* 2012; 33 (9): 740-3.
20. Vissers D, Verrijken A, Mertens I, Van Gils C, Van de Sompel A, Truijen S, van Gaal L. Effect of long-term whole body vibration training on visceral adipose tissue: a preliminary report. *Obes Facts* 2010; 3 (2): 93-100.
21. Von Stengel S, Kemmler W, Engelke K, Kalender WA. Effect of whole-body vibration on neuromuscular performance and body composition for females 65 years and older: a randomized-controlled trial. *Scand J Med Sci Sports* 2012; 22 (1): 119-27.
22. Fjeldstad C, Palmer IJ, Bemben MG, Bemben DA. Whole-body vibration augments resistance training effects on body composition in postmenopausal women. *Maturitas* 2009; 63 (1): 79-83.
23. Cochrane DJ. Is vibration exercise a useful addition to a weight management program? Scand J Med Sci Sports 2012; 22 (6): 705-13.
24. Da Silva ME, Fernandez JM, Castillo E, Nuñez VM, Vaamonde DM, Poblador MS et al. Influence of vibration training on energy expenditure in active men. *J Strength Cond Res* 2007; 21 (2): 470-5.
25. Issurin VB, Tenenbaum G. Acute and residual effects of vibratory stimulation on explosive strength in elite and amateur athletes. *J Sports Sci* 1999; 17 (3): 177-82.
26. Bosco C, Colli R, Introini E, Cardinale M, Tsarpela O, Madella A, Tihanyi J, Viru A. Adaptive responses of human skeletal muscle to vibration exposure. *Clin Physiol* 1999; 19 (2): 183-7.
27. Rittweger J, Beller G, Felsenberg D. Acute physiological effects of exhaustive whole-body vibration exercise in man. *Clin Physiol* 2000; 20 (2): 134-42.
28. Cochrane DJ, Sartor F, Winwood K, Stannard SR, Narici MV, Rittweger J. A comparison of the physiologic effects of acute whole-body vibration exercise in young and older people. *Arch Phys Med Rehabil* 2008; 89 (5): 815-21.
29. Garatachea N, Jiménez A, Bresciani G, Mariño NA, González-Gallego J, De Paz JA. The effects of movement velocity during squatting on energy expenditure and substrate utilization in whole-body vibration. *J Strength Cond Res* 2007; 21 (2): 594-8.
30. Tipton KD, Borsheim E, Wolf SE, Stanford AP, Wolfe RR. Acute response of net muscle protein balance reflects 24 h balance after exercise and amino acid ingestion. *Am J Physiol Endocrinol Metab* 2002; 284: E76-79.
31. Wolfe RR. The underappreciated role of muscle in health and disease. *Am J Clin Nutr* 2006; 84 (3): 475-82.
32. Ceccarelli G, Benedetti L, Galli D, Prè D, Silvani G, Crosetto N, Magenes G, Cusella De Angelis MG. Low-amplitude high frequency vibration down-regulates myostatin and atrogin-1 expression, two components of the atrophy pathway in muscle cells. *J Tissue Eng Regen Med* 2012 doi: 10.1002/term.1533.
33. Schoenfeld BJ. The mechanisms of muscle hypertrophy and their application to resistance training. *J Strength Cond Res* 2010; 24 (10): 2857-72.
34. Martínez-Pardo E, Romero-Arenas S, Alcaraz PE. Effects of different amplitudes (High *vs.* Low) of whole-body vibration (WBV) training in active adults. *J Strength Cond Res* 2012.
35. Osawa Y, Oguma Y. Effects of resistance training with whole-body vibration on muscle fitness in untrained adults. *Scand J Med Sci Sports* 2013; 23 (1): 84-95.
36. Bogaerts A, 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 A Biol Sci Med Sci* 2007; 62 (6): 630-5.
37. Osawa Y, Oguma Y, Onishi S. Effects of whole-body vibration training on bonefree lean body mass and muscle strength in young adults. *J Sports Sci Med* 2011; 10: 97-104.