REVIEW ARTICLE

The effect of whole-body vibration training on lean mass in postmenopausal women: a systematic review and meta-analysis

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Abstract

Objective: The purpose of the present systematic review and meta-analysis was to evaluate published, randomized controlled trials that investigated the effects of whole-body vibration training (WBVT) on lean mass in postmenopausal women.

Methods: The following electronic databases were searched from September to October 2015: PubMed, Web of Science, and Cochrane. Two different authors tabulated, independently, the selected indices in identical predetermined forms. The methodological quality of all randomized trial studies was evaluated according to the modified PEDro scale. In each trial, the effect size of the intervention was calculated by the difference between pre- and postintervention lean mass in WBVT postmenopausal women. For controlled trials, the effect size of the WBVT was also calculated by the difference in lean mass after the WBVT and in control participants.

Results: Of the 189 articles found from the database search and all duplicates removed, 5 articles were analyzed. The lean mass of 112 postmenopausal women who performed either WBVT or a control protocol was evaluated. The methodological quality of the trials was high, where the mean score was 8 out of a possible 10 points. No significant improvements in lean mass with WBVT were found in postmenopausal women. In addition, there was no significant difference in lean mass between WBVT and control postmenopausal women.

Conclusions: This meta-analysis demonstrated that WBVT alone may not be a sufficient stimulus to increase lean mass in postmenopausal women. Thus, additional complimentary training methods with WBVT are needed to increase muscle size in women with lower hormonal responses.

Key Words: Muscle mass – WBV – Women.

As life expectancy has shown to increase over the years in both developed and less developed countries,[1] there is also a concurrent increase in health-related problems, such as sarcopenia and bone health. Sarcopenia is a multifactorial condition associated with decreased muscle mass, physical inactivity, loss of neuromuscular function, altered endocrine function, and genetic factors among others. Cross-sectional studies have observed an accelerated loss of muscle strength[2] at a time when menopause generally occurs.[3] The decrement in strength and muscle mass is particularly evident in older, postmenopausal women,[4] and it has been shown that decreases in power

(force × velocity) are associated with declines in physical performance.[5,6] Furthermore, age-related sarcopenia may be a risk factor for osteoporosis and may consequently increase the risk of bone fractures.[7,8] Osteoporosis is characterized by a decrease in bone mass due to a higher rate of bone resorption and lower rate of bone formation.[9] There is a higher prevalence of osteoporosis and increasing number of osteoporotic fractures with age,[10] particularly in postmenopausal women.[11] Low bone mass is correlated with the level of osteoporosis, fracture risk, and body composition.[12]

As muscle mass is positively correlated with osteoporosis in women,[7,8] resistance training studies have shown improvement in muscle mass, strength, and physical function in older adults.[13] Interestingly, whole-body vibration training (WBVT) on a vibrating platform may be an alternative approach to increase strength and power,[14] and it could provide improvements in neuromuscular function and musculoskeletal properties, which are similar adaptations observed from traditional training.[15-18] Vibration training exercise is thought to use proprioceptive spinal reflexes to increase muscle function by enhancing muscle spindle excitatory signalling and lowering the inhibitory response of the

Golgi Tendon Organ to the motorneuron pool.[19] Increased activation of propriospinal pathways and increased strength of lower limbs have been observed with WBVT in untrained females.[14] Changes in musculoskeletal properties and bone mineral density[20] may be partially explained by the oscillatory action of the vibration, as it places more demand on the biological tissues (ie, muscle and bone) to absorb and dampen the energy that is being transferred from the actuator (the vibratory source). Thus, WBVT may slow down age-related changes and improve muscle function and bone health.

In postmenopausal women[21] and older women,[22] WBVT has beneficial effects on muscle strength and muscle mass. Roelants et al[23] showed that, after 24 weeks of WBVT, previously untrained females increased fat-free mass, but did not have any change in body mass, total body fat, or subcutaneous fat. In addition, Verschueren et al[24] did not observe an increase in muscle mass after 6 months of WBVT in postmenopausal women (60-70 y). Therefore, these findings indicate that WBVT is an effective method for improving muscle mass and reducing the risk factors associated with sarcopenia in postmenopausal women. Therefore, it remains unclear if WBVT has a beneficial effect on lean mass in postmenopausal women. Thus, the purpose of this systematic review and meta-analysis was to evaluate published, randomized controlled trials (RCTs) that investigated the effects of WBVT on lean mass in postmenopausal women.

METHODS

Study design

The present research followed the Preferred Reporting Items for Systematic Reviews and Meta Analyses guidelines.[25] Eligibility criteria were predetermined by the authors. Only RCTs studies were considered for inclusion in the present review. Two different authors (J.A.R.-A. and E.M.-C.) tabulated, independently, the selected indices in identical predetermined forms. Any discrepancies in methodology, retrieval of articles, and statistical analysis were resolved by the consensus of all authors.

Literature search and data collection

The following electronic databases were searched from September to October 2015: PubMed, Web of Science, and Cochrane. The following keyword combinations were used: ''postmenopausal women'' OR ''women'' OR ''older women'' OR ''elderly'' AND ''whole body vibration'' OR ''WBV'' AND ''muscle mass'' OR ''lean mass.'' Figure 1 shows a flow diagram of the results from the entire search process.
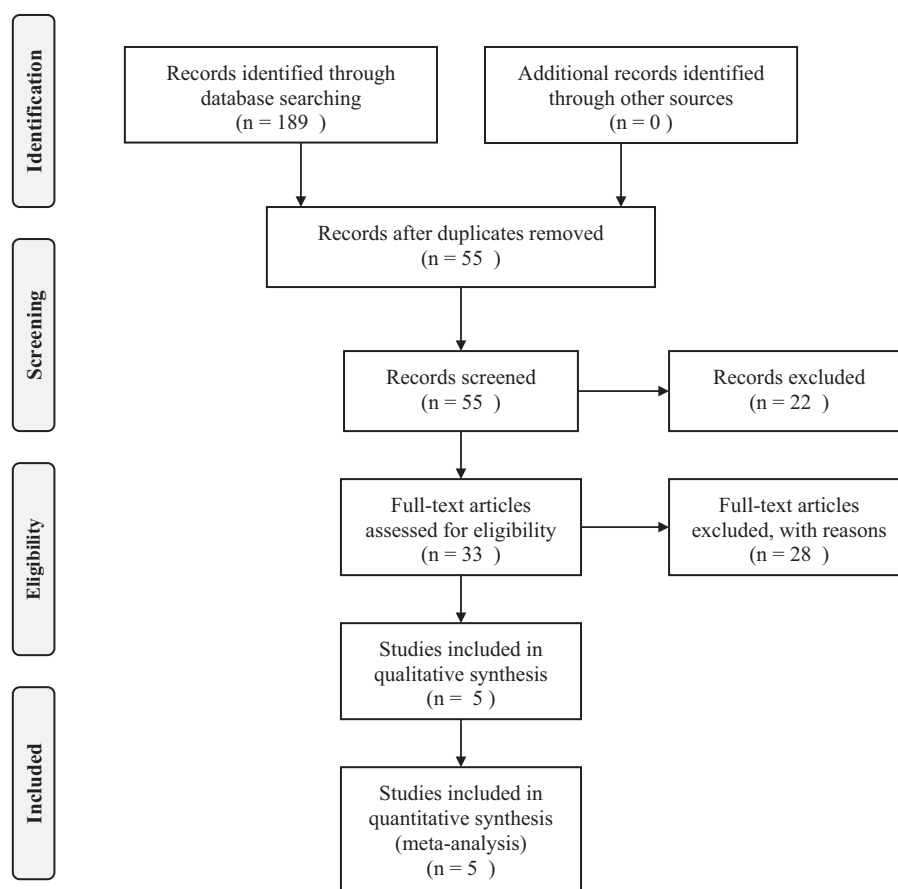

FIG. 1. Flow diagram of the study selection process.

Selection criteria

Only clinical, whole-body vibration, RCTs published in the English language were included. Review articles and case reports were not included and considered for analysis. For the meta-analysis, studies were selected if (1) the aim of the study was to examine the effects of WBVT on muscle mass or lean mass; (2) the age of the target population was between 55 and 75 years; (3) the definition of the postmenopausal period was the years after the year when menstruation ceased; (4) the intervention used was WBVT; (5) the outcome variables were muscle mass, lean mass, or fat-free mass; and (6) the training duration was several weeks long and composed of several training sessions. Studies were excluded if (1) the training intervention was different from WBVT; (2) there was no control group; and (3) the trials were not randomized.

Quality assessment

The methodological quality of all randomized trial studies were evaluated according to the modified PEDro scale, using the following criteria: (1) eligibility criteria were specified, (2) women were randomly allocated to groups (in a crossover study, participants were randomly allocated to treatments groups), (3) allocation was concealed, (4) the groups were similar at baseline with regard to the most important prognostic indicators, (5) all participants were blinded to the interventions, (6) all therapists who administered the therapy were blinded, (7) there was blinding of all assessors who measured at least one key outcome, (8) measures of at least one key outcome were obtained from more than 85% of the participants initially allocated to groups, (9) all participants for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome were analyzed by ''intention to treat,'' (10) the results of between-group statistical comparisons were reported for at least one key outcome, and (11) the study provided both point measures and measures of variability for at least one key outcome.

Statistical methods

The meta-analysis and statistical analyses were performed using Review Manager software (RevMan 5.2; Cochrane Collaboration, Oxford, UK) and Comprehensive Meta-analysis software (Version 2; Biostat, Englewood, NJ). For each trial, the effect size of the intervention was calculated by the difference between pre- and postintervention muscle mass or lean mass in WBVT postmenopausal women. For controlled trials, the effect size of the WBVT was also calculated by the difference in muscle mass or lean mass after the WBVT and in control participants, and by the difference in body composition (specifically muscle mass or lean mass) after the intervention between WBVT and control postmenopausal women.

Because there were many different protocols for WBVT among the different studies (Table 1), the inverse variance method[30] was used to standardize the mean differences by dividing the values with their corresponding SD. The standardized mean difference (SMD) in each trial was pooled using the random effects model.[31] According to Cohen guidelines,[32] SMD of 0.2, 0.5, and 0.8 represents small, medium, and large effect sizes, respectively.

Heterogeneity between studies was assessed using I^2 statistics. Potential moderating factors were evaluated by subgroup analysis, comparing trials grouped by dichotomous or continuous variables that could potentially influence muscle mass or lean mass in body composition measurements. Median values of continuous variables were used as cutoff values for grouping the trials. Changes in potential moderating factors were expressed and analyzed as the difference between post- and preintervention values. Publication bias was evaluated using the estimating funnel plot asymmetry test. A P e ≤ 0.05 was considered statistically significant.

RESULTS

The database search found 189 articles, and after removal of all duplicates, only 5 articles complied with the inclusion criteria and were analyzed for meta-analysis. The muscle mass or lean mass of a total of 112 postmenopausal women

TABLE 1. *Characteristics of WBVT intervention and muscle mass or lean mass assessment*

Study (year of publication)	WBVT intervention								Muscle mass or lean mass assessment	
	Type	Frequency, wk^{-1}	Session length, s	Duration, wk	No. of sessions	Frequency, Hz	Amplitude, mm	g	Measure	Units
Beck and Norling (2010)[26]	Hi	2	600	32	64	30	0-14	0.3	DXA	kg
	Low	2	600	32	64	12.5	0-14	1	DXA	kg
Liphardt et al (2015)[27]	A	2-3	600	16	44	20	3-4	2.41-3.22	DXA	kg
	B	2-3	600	32	88	20	3-4		DXA	kg
	C	2-3	600	48	132	20	3-4		DXA	kg
Marín-Cascales et al (2015)[21]		3	5-8 sets (60 s)	12	36	35	4	9.86	DXA	kg
Song et al (2011)[28]		2	600	8	16	22	2	1.98	Body Impedance Analysis	kg
Verschueren et al (2004)[29]		3	1,800	24	72	35-40	1.7-2.5	2.8-5	DXA	kg

Data are mean or range.
DXA, dual-energy x-ray absorpiometry; g, the acceleration (where 1 g is the acceleration due to the Earth's gravitational field or 9.81 m/s^2); WBVT, whole-body vibration training.

TABLE 2. *Description of included studies*

Study (year of publication)		n C	WBVT	♀, %	Age, y	Weight	Height	Disease	Medication status
Beck and Norling (2010)[26]	Hi	14	15	100	68.9 ± 7.0	61.4 ± 8.9	157.1 ± 0.1	None	None
	Low		13	100	68.5 ± 8.6	68.4 ± 10.3	160.2 ± 0.1	None	None
Liphardt et al (2015)[27]	A	14	17	100	59.1 ± 4.6	70.5 ± 12.9	159.7 ± 6.2	Osteopenia	None
	B								
	C								
Marín-Cascales et al (2015)[21]		10	14	100	60.1 ± 5.8	78.1 ± 13.5	156.7 ± 5.2	None	None
Song et al (2011)[28]		—	15	100	56.4 ± 4.4	64.4 ± 5.4	154.7 ± 4.9	None	None
Verschueren et al (2004)[29]		23	25	100	64.6 ± 3.3	66.5 ± 8.9	159.0 ± 0.5	None	None

Description of C group only. Data are expressed in mean ± SD or n.
C, control group; WBVT, whole-body vibration training.

who underwent either WBVT or control protocol was evaluated. Figure 1 shows the flow diagram of the study selection process.

The methodological quality of the trials, according to the PEDro scale,[33-35] was high. The mean score was 8 out of a possible 10 points. Based on the funnel plot for the SMD of muscle mass or lean mass between post- and preintervention in WBVT postmenopausal women, participants were notably symmetrical, suggesting the absence of a significant publication bias. Similarly, no significant publication bias was observed in the SMD of postintervention muscle mass or lean mass between WBVT and control postmenopausal women.

Table 2 shows an overall description of the five studies included in this review.[21,26-29] Some of these studies included more than one intervention group or control group (ie, parallel group design). The characteristics of the WBVT intervention and type of muscle mass or lean mass assessment used in each study are shown in Table 1. There were no significant differences by group in the subgroup analyses (Table 3). The results from the SMD between post- and preintervention muscle mass or lean mass (see Fig. 2) and between experimental and control groups (Fig. 3) showed no significant differences.

DISCUSSION

The aim of this meta-analysis was to evaluate the existing literature regarding the effects of WBVT on lean mass in postmenopausal women. The meta-analysis showed that, in the RCTs, WBVT had no significant overall effect on lean mass in postmenopausal women, suggesting that this particular type of training did not provide sufficient stimulus for skeletal muscle hypertrophy.

When comparing the included studies, there were different WBVT protocols used to elicit muscle mass changes. With respect to the intensity level, there were differences in vibration frequency (12.5-40 Hz), vibration amplitude (0-14 mm), and acceleration (g; 0.3-9.86 m/s^2) used between studies. The duration of the different protocols varied from 8 to 36 weeks of training with a weekly frequency of two to three sessions. The total number of sessions ranged from 16 to 132, and the length of each session varied from 300 (eg, 5 sets of 60 s) to 1,800 s. Four out of the five studies included in the

meta-analysis, however, used dual-energy x-ray absorpiometry, whereas one study used the Body Impedance Analysis to measure lean mass.

After WBVT, changes in muscle mass observed in some of the included studies do not seem to be explained by differences in the sample population characteristics (ie, number of participants, age, and body mass index). For example, three studies[27] with more than 15 participants and five studies[21,26,28,29] with a higher number (13-25) of participants showed no changes in muscle mass. In addition, there were no significant differences between studies with different age groups (> 60 y old[21,26,29] or < 60 y old[27,28]), which suggests that age may not be a factor in observed changes in muscle mass after WBVT in postmenopausal women. Furthermore, differences in body mass index did not seem to be a contributing factor in muscle mass changes, indicating that WBVT produces the same effects on women with more than 27 kg/m^2 and with less than 27 kg/m^2.[21,26-29]

Interestingly, the lack of change in muscle mass observed in this meta-analysis seems to be independent of the WBV program characteristics. Studies with different total number of sessions (>44 session[27-29] and with less[21,26]) or different durations of WBVT (> 32 wk of duration[21,26,27] or less[28,29]) obtained similar results. Moreover, the use of different frequencies (>20 Hz[21,26,28,29] or less[26,27]) or different amplitudes (>2 g[21,27,29] or less[26,28]) found similar effects on muscle mass. Finally, studies with more than 8 points[26,29] or less[21,27,28] in the PEDro scale did not show significant differences in muscle mass values, thereby any differences in methodological quality did not affect the data.

Although the studies presented in this meta-analysis showed no increase in muscle mass after WBVT in postmenopausal women, studies have reported WBVT benefits in younger individuals. Six weeks of WBVT at a high intensity have been demonstrated to produce muscular hypertrophy in young, active participants.[36] In addition, significant increases in fat-free mass were observed after 24 weeks of training in sedentary women compared with other intervention groups.[23] As our results show, the increases in muscle mass cannot, however, be solely explained by the age of the women.

Several authors have suggested that WBVT could increase muscle strength,[6,9,11-14] specifically by activating

TABLE 3. *Subgroup analyses assessing potential moderating factors for muscle mass or lean mass*

Group	Studies Number[a]	References	Muscle mass or lean mass SMD (95% CI)	I^2	P	$P_{\text{Difference}}$
Population characteristics						
N						0.92
>15	3	Liphardt et al (2015) A, B, C[27]	0.07 (−0.31 to 0.46)	0	0.71	
≤ 15	5	Marín-Cascales et al (2015)[21]; Beck and Norling (2010) Hi, Low[26]; Verschueren et al (2004)[29]	0.05 (−0.26 to 0.35)	0	0.63	
Age						0.62
≥ 60 y	4	Marín-Cascales et al (2015)[21]; Beck and Norling (2010) Hi, Low[26]; Verschueren et al (2004)[29]	0.12 (−0.22 to 0.65)	0	0.50	
< 60 y	4	Liphardt et al (2015) A, B, C[27]; Song et al (2011)[28]	−0.00 (−0.35 to 0.34)	0	0.98	
BMI						0.41
≥ 27 kg/m^2	4	Marín-Cascales et al (2015)[21]; Liphardt et al (2015) A, B, C[27]	0.16 (−0.18 to 0.51)	0	0.36	
< 27 kg/m^2	4	Beck and Norling (2010) Hi, Low[26]; Song et al (2011)[28]; Verschueren et al (2004)[29]	−0.04 (−0.38 to 0.29)	0	0.81	
Exercise characteristics						
No. of sessions						0.37
≥44 sessions	5	Liphardt et al (2015) A, B, C[27]; Song et al (2011)[28]; Verschueren et al (2004)[29]	−0.02 (−0.31 to 0.27)	0	0.91	
<44 sessions	3	Marín-Cascales et al (2015)[21]; Beck and Norling (2010) Hi, Low[26]	0.22 (−0.21 to 0.65)	0	0.32	
Duration						0.33
≥32 wk	5	Liphardt et al (2015) B, C[27]; Marín-Cascales et al (2015)[21]; Beck and Norling (2010) Hi, Low[26]	0.16 (−0.16 to 0.48)	0	0.32	
<32 wk	3	Liphardt et al (2015) A[27]; Song et al (2011)[28]; Verschueren et al (2004)[29]	−0.08 (−0.45 to 0.29)	0	0.67	
WBV frequency						0.68
>20 Hz	4	Marín-Cascales et al (2015)[21]; Beck and Norling (2010) Hi[26]; Song et al (2011)[28]; Verschueren et al (2004)[29]	0.01 (−0.33 to 0.34)	0	0.97	
≤20 Hz	4	Beck and Norling (2010) Low[26]; Liphardt et al (2015) A, B, C[27]	0.11 (−0.24 to 0.46)	0	0.53	
WBV amplitude						0.60
>2 g	5	Marín-Cascales et al (2015)[21]; Liphardt et al (2015) A, B, C[27]; Verschueren et al (2004)[29]	0.10 (−0.19 to 0.40)	0	0.50	
≤2 g	3	Beck and Norling (2010) Hi, Low[26]; Song et al (2011)[28]	−0.04 (−0.46 to 0.39)	0	0.87	
Methodological quality						
PEDro scale						0.81
≥8 points	3	Beck and Norling (2010) Hi, Low[26]; Verschueren et al (2004)[29]	0.02 (−0.36 to 0.40)	0	0.91	
<8 points	5	Marín-Cascales et al (2015)[21]; Liphardt et al (2015) A, B, C[27]; Song et al (2011)[28]	0.08 (−0.23 to 0.39)	0	0.55	

BMI, body mass index; I^2, heterogeneity; P, test for overall effect; $P_{\text{Difference}}$, test for subgroup differences; SMD, standardized mean difference; WBV, whole-body vibration.
[a]The total number of whole-body vibration-trained postmenopausal women groups.

fast-twitch muscle fibers.[14,37] With aging there is a decline in muscle mass that is mainly attributed to the decreases in the size of type II fibers and not due to substantial muscle fiber loss.[38] Thus, it is plausible that the muscle strength increases observed with WBVT may be due to neuromuscular adaptations, and WBVT may help maintain muscle mass (ie, muscle fiber size) in postmenopausal women.
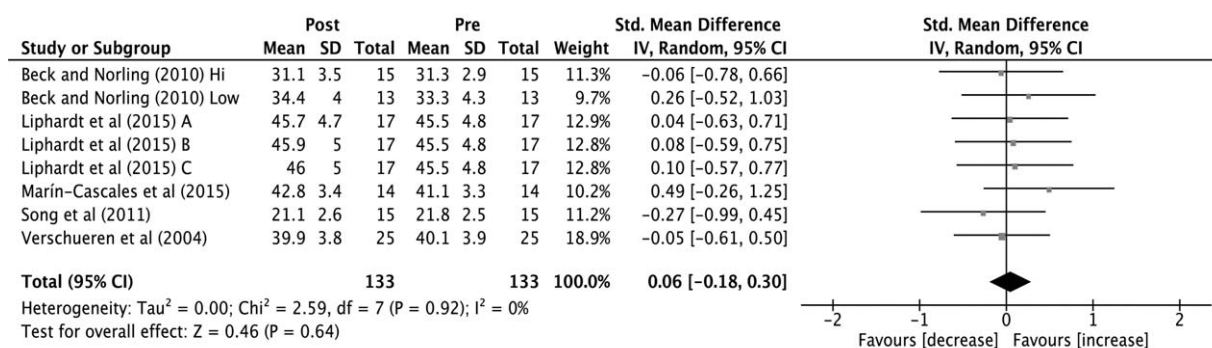

FIG. 2. SMD between post- and preintervention lean mass (kg) in WBVT postmenopausal women. Squares represent the SMD for each trial. Diamonds represent the pooled SMD across trials. Because the SMD method does not correct for differences in the direction of the scale, mean values of some trials were multiplied by −1 to ensure that all scales pointed in the same direction. SMD, standardized mean difference; WBVT, whole-body vibration training.
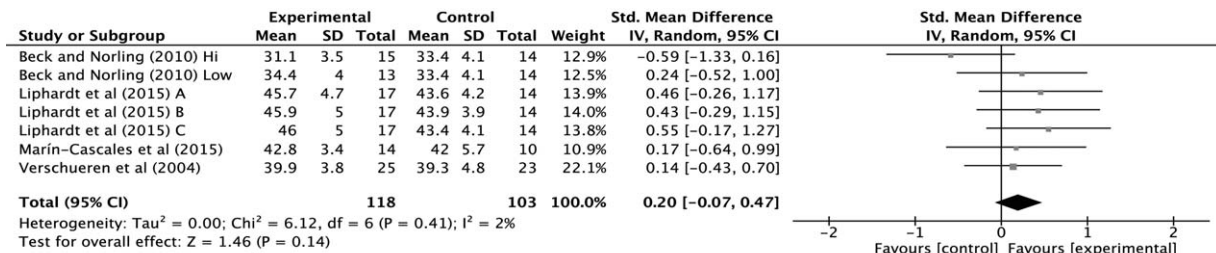
Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Beck and Norling (2010) Hi	31.1	3.5	15	33.4	4.1	14	12.9%	−0.59 [−1.33, 0.16]
Beck and Norling (2010) Low	34.4	4	13	33.4	4.1	14	12.5%	0.24 [−0.52, 1.00]
Liphardt et al (2015) A	45.7	4.7	17	43.6	4.2	14	13.9%	0.46 [−0.26, 1.17]
Liphardt et al (2015) B	45.9	5	17	43.9	3.9	14	14.0%	0.43 [−0.29, 1.15]
Liphardt et al (2015) C	46	5	17	43.4	4.1	14	13.8%	0.55 [−0.17, 1.27]
Marín–Cascales et al (2015)	42.8	3.4	14	42	5.7	10	10.9%	0.17 [−0.64, 0.99]
Verschueren et al (2004)	39.9	3.8	25	39.3	4.8	23	22.1%	0.14 [−0.43, 0.70]
Total (95% CI)			**118**			**103**	**100.0%**	**0.20 [−0.07, 0.47]**

Heterogeneity: Tau^2 = 0.00; Chi^2 = 6.12, df = 6 (P = 0.41); I^2 = 2%
Test for overall effect: Z = 1.46 (P = 0.14)

FIG. 3. SMD in postintervention lean mass (kg) between WBVT and control postmenopausal women. Squares represent the SMD for each trial. Diamonds represent the pooled SMD across trials. SMD, standardized mean difference; WBVT, whole-body vibration training.

It has also been proposed that endocrine reactions may mediate the training effect,[39] as increases in the concentration of testosterone,[40] growth hormone,[40-42] catecholamine,[43] increases in protein synthesis,[44] and decreased cortisol[40,42] have been observed with WBVT. Thus, the studies using this type of training provide some evidence for the potential benefits of its application in postmenopausal women. The absence of improvement in muscle mass after WBVT observed in this meta-analysis may, however, be explained by the already lower production of hormones in postmenopausal women. The hormonal changes during menopause (eg, increases in interleukin-6, tumor necrosis factor-α, and decreases in estrogen, estrone, dehydroepiandrosterone (DHEA), thyroxin, progesterone, and lipoprotein lipase) have shown to increase intramuscular fat, increase type I fibers, decrease type II fibers, and decrease the number of estrogen receptors.[4] In addition, it is possible that postmenopausal women may have higher anabolic resistance,[45] leading to an inability of the skeletal muscle to maintain adequate protein synthesis due to lower muscle protein anabolism and greater breakdown.[46] Therefore, vibration training alone may not be an effective system for increasing muscle mass in postmenopausal women.

There are some limitations to the present meta-analysis that should be considered: (1) the low number of included studies due to the few publications in the existing literature that focused on the effect of WBVT intervention on lean mass in postmenopausal women; (2) the studies used primarily dual-energy x-ray absorpiometry scans to obtain lean mass which do not purely measure skeletal muscle mass; (3) the authors of the studies used a wide age range when defining postmenopausal women, which included older women.

CONCLUSIONS

This meta-analysis demonstrated that WBVT alone does not increase lean mass in postmenopausal women, independent of the vibratory dose (frequency, amplitude, working, and recovery time) and intervention characteristics (duration, frequency, volume, and intensity of the training). Therefore, other training protocols with a greater external load (ie, high intensity resistance training) should be considered in this population. If WBVT is used, complimentary training methods, however, should be applied to increase muscle size

in women with lower hormonal responses. In addition, individualized vibration training stimuli for greater muscle responses are recommended.

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