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The effect of 6 months of whole body vibration training on strength in postmenopausal women

O efeito de 6 meses de treino de vibração em todo o corpo na força em mulheres na pós-menopausa

R. van den Tillaar

ARTIGO ORIGINAL | *ORIGINAL ARTICLE*

ABSTRACT

The purpose of this study was to investigate the effect of whole body vibration (WBV) training in postmenopausal women on strength. One hundred and ten postmenopausal women (age 61.5 ± 6.3 years, mass 69.1 ± 11.0 kg, height 1.67 ± .05 m) participated in this study. Isometric strength and dynamic strength of the knee extensors and flexors was tested as peak force before, after 3 months and after 6 months of WBV training. After the pre-test, two groups trained WBV training. The first group (n = 31) trained on a vibration platform that only conducted horizontal vibrations (WBV $group_{hor}$), while the second group (n = 67) trained on a reciprocative vibration (WBV $group_{rec}$). The third group was a control group (n = 12) that did not train WBV. Each training group trained 3 times per week, eight times one minute squatting per session on their respective platform. Both training groups increased their peak force significantly in knee flexion (9.6%) and extension (9.2%) and in the isometric strength (15.7%) of the knee extensors while the control group had no significant increase in strength after the training period. In the WBV $group_{hor}$ the increase was mostly shown in the first three months, while the isometric strength still significantly increased from month three to six (4.3%) in the WBV $group_{rec}$. It was concluded that both types of WBV training can help menopausal women with increasing their leg strength.

Keywords: vibration training, isometrics, isokinetic, osteoporosis

RESUMO

Este estudo pretendeu examinar os efeitos do treino de vibração (Tvb) em mulheres pós-menopáusicas sobre a manifestação de força. Participaram neste estudo 110 mulheres pós-menopáusicas (idade 61.5 ± 6.3 anos, massa 69.1 ± 11.0 kg, altura 1.67 ± .05 m). Foi avaliada a força isométrica e dinâmica dos extensores e flexores do joelho, tal como o pico de força antes, após 3 meses e no final de 6 meses de treino Tvb. Após o pré-teste, a amostra foi dividida três grupos. O primeiro grupo (n = 31) realizou, numa plataforma vibratória, apenas vibrações horizontais (VCI $grupo_{hor}$), enquanto o segundo grupo (n = 67) realizou vibrações recíprocas (VCI $groupo_{rec}$). O terceiro grupo serviu como meio de controlo (n = 12). Cada um grupo dos grupos experimentais realizou 3 sessões semanais, com sessões de 8 minutos na plataforma vibratória. Ambos os grupos de treino aumentaram significativamente a força máxima na flexão (9.6%) e extensão do joelho (9.2%), a força isométrica (15.7%) dos extensores do joelho, enquanto o grupo de controlo não sofreu qualquer alteração de força após o período de treino. No $grupo_{hor}$, o aumento foi essencialmente percebido nos primeiros três meses, enquanto no VCI $grupo_{rec}$ a força isométrica aumentou apenas significativamente a partir do mês 3-6 (4.3%). Concluiu-se que ambos os tipos de Tvb podem ajudar as mulheres na menopausa no aumento da força do trem inferior.

Palavras-chave: treino de vibração, isométricos, isocinético, osteoporose

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As the world population is getting older and older, occurrences of osteoporosis and osteoporotic fracture are an increasingly important public health problem (Kannus, Parkkari, & Niemi, 1995). Norway is one of the countries that have a high occurrence of osteoporosis when compared with the rest of the world. Muscle strength and the ability of the lower extremity muscles to develop force rapidly have been found to be the most common risk factors for falls and hip fractures in older adults (American Geriatrics Society, 2001; Runge, Rehfeld, & Resnicek, 2000). Therefore, the prevention of age-related strength loss and muscle atrophy is a public health issue (Frontera, Hughes, Lutz, & Evans, 1991; Hughes et al., 2001).

The last decade whole-body–vibration (WBV) training has been promoted as an efficient alternative for resistance training. Subjects use little time on the WBV training sessions (10-20 minutes) with similar strength increase as in one hours of resistance training (Roelants, Delecluse, Goris, & Verschueren, 2004). In WBV training, the subject stands or moves on a platform that generates a mechanical stimulus characterized by an oscillatory motion. The biomechanical parameters can be given in terms of frequency, amplitude and magnitude. The amplitude of the vibration is the extent of the oscillatory motion (peak-to-peak displacement in mm). The repetition rate of the cycles of oscillation determines the frequency of the vibration (measured in Hz). The acceleration determines the magnitude of the vibration. The vibrations can be given reciprocating vertical displacements in the left and right side of a fulcrum (Rees, Murphy, & Watsford, 2007), the whole plate oscillating uniformly up and down vertically (Machano, Garcıa-Lopez, Gonzalez-Gallego, & Garatachea, 2010; Raimundo, Gusi, & Tomas-Carus, 2009; Verschueren et al, 2004) or horizontally (Pel et al., 2009) at frequencies varying from 5 Hz and 50 Hz.

Earlier studies of WBV training on long term effect in strength in older women are limited. Rees et al (2007) found already an increase of 8% in knee extension strength after just 8 weeks of WBV training. Machano et al. (2010) found that after 10 weeks of WBV training the maximal isometric strength increased with 38%. Studies over longer training periods showed some contradictive results. Roelants, Delecluse and Verschueren (2004) and Verschueren et al (2004) showed that 24 weeks and 6 months of WBV training induced isometric and dynamic knee extensor strength gains (15-16%) in postmenopausal women. However, Raimundo et al. (2009) did not find any significant changes after 8 months of WBV training on the dynamic strength of the lower limb. Verschueren et al (2011) found that after 6 months of WBV training dynamic strength improved, but isometric strength did not change. However, in a similar study of Bogaerts et al (2011) it was shown that maximal isometric knee extension strength improved. These differences can be explained by the different training protocols and vibration devices used.

Most of the earlier studies used a plate oscillating uniformly up and down vertically (Bogaerts et al., 2011; Machano et al., 2010; Raimundo et al. 2009; Roelants et al., 2004a; Verschueren et al., 2011). Only Rees et al (2007) used a reciprocating WBV plate, while Abercromby et al. (2007a) found that training with the same load the health risk with up-and-down vibration plates are much higher than when using a reciprocative vibration platform). Furthermore, they concluded that the neuromuscular activity of the leg muscles with training on a reciprocative vibration platform was higher than during training on an up-and-down vibration platform (Abercromby et al., 2007b). However, to the best of our knowledge, no prior study has to date measured the effect of a WBV device that only vibrated in horizontal direction on strength. Mostly reasoning of not using these last type of WBV devices is that it does not induces vertical accelerations that are transmitted to the body. Thereby the leg muscles will not be activated and stimulated to damp these accelerations (Nigg & Wakeling, 2001). Pel et al (2009) found that this type of vibration platforms would have mostly transmission of acceleration to the lower legs and not higher up in the body.

Therefore, the aim of this study was to investigate the effect of two different types of vibration training upon the maximal static and dynamic strength of the knee flexors and extensors in postmenopausal women. It was hypothesized that both WBV training groups would increase strength in the leg muscles due to the extra workload the muscles get through the training program compared to the control group. However, it was also expected that the reciprocal WBV training group would increase their strength the most since the vibration stimulus is vertical to the body and has to be damped by different muscles around the joints of the under extremity (Nigg & Wakeling, 2001). Thereby a higher muscle activity during training is expected, while in horizontal WBV training these vertical accelerations almost not exist and therefore do not have a large impact on the muscles.

METHODS

Subjects

Hundred-ten postmenopausal women (age 61.5 ± 6.3 yr, body mass 69.1 ± 11 kg, height 1.67 ± .05 m) participated in this study. Assessment of eligibility for participation was based on a screening by questionnaire and a thorough medical examination. Women were non-institutionalized, and free from diseases or medications known to affect bone metabolism or muscle strength. Their last menstruation was at least five years ago to be included in the present study.

The subjects were fully informed about the protocol before participating in this study. Informed consent was obtained prior to all testing from all subjects, in accordance with the approval of local ethical committee and current ethical standards in sports and exercise research.

Procedures

After a standardized warm up in which the subjects had to cycle upon an ergometer cycle for 5 minutes the maximal isokinetic strength of the extension and flexion of the knee was measured. The strength was recorded on a motor-driven dynamometer (kin com model 125AP, Isokinetic International, TN, USA) unilaterally on the right side in a seated position on a backward-inclined (12°) chair. Firstly the subjects performed a series of three isokinetic extension-flexion movements against the lever arm of the dynamometer that moved at a velocity of 100°/s separated by a 1-minute rest interval. The knee extension was initiated at a joint angle of 90° and ended at 160° (Roelants et al. 2004a). Following each extension, the leg was returned with maximal effort back to the starting position (knee flexion). The knee was extended and flexed twice in every series. The peak torque (Nm) in the knee extension and flexion recorded at each series was determined as maximal isokinetic strength. After the isokinetic trials the maximal voluntary isometric (0°/s) torque (Nm) of the knee extensors at a knee joint angle of 130° was measured three times (Roelants et al, 2004a). The highest peak torque from the three attempts was used for further analysis. The isometric strength and dynamic strength was evaluated at baseline and after three and six months.

After the pre-test, two groups trained WBV training. The first group (n = 67) trained on a reciprocal vibration platform (Galileo 2000, Novotec Medical GmbH, Pforzheim, Germany) (WBV group$_{rec}$), while the second group (n = 31; WBV group$_{hor}$) trained on a vibration platform that only conducted horizontal vibrations (Nordic Vibroplate II, Nordic Fitness AS, Drammen, Norway). The third group was a control group (n = 12) that did not train WBV. Each training group trained 3 times per week on their respective platform. The training load was low at the beginning (4×1 minute of training per session) but progressed slowly to 8×1 minute of vibration training according to the overload principle. The intensity increased by using different frequencies, starting from a static position with bended knees to squatting on the platform and by changing the positions of the feet on the reciprocal WBV platform (Fig. 1). The pause between each training minute was approximately (Table 1 and 2 for the detailed training programs on the WBV platforms).

Control subjects were instructed to maintain their current level of physical activity during the study and not to engage in any new form of exercise. All the subjects completed a questionnaire detailing their physical activity at the beginning of the study and at monthly intervals thereafter.

Statistical Analysis

A oneway ANOVA was performed on the anthropometrics and the maximal peak force for each exercise of the different groups at the pre test. To compare the effects of the training protocols, a mixed design 3 (test occasion: pre, 3 months, 6 months: repeated measures) × 3 (group: WBV group$_{hor}$, WBV group$_{rec}$, control group) analysis of variance (ANOVA) for each exercise was used. A post hoc test using Bonferroni probability adjustments was used to locate significant differences. The test-retest reliability calculated at the pre-test (3 attempts per test) as indicated by intra-class correlations (ICC) was .96 for isokinetic extension, .95 for the isokinetic flexion of the knee and .98 for isometric condition. Effect size was evaluated with η^2_p (Eta partial squared) where $.01 < \eta^2 < .06$ constitutes as a small effect, a medium effect and when $.06 < \eta^2 < .14$ and a large effect when $\eta^2 > .14$ (Cohen, 1988). The effect size and statistical power are presented in Table 4. The level of significance was set at $p \leq .05$.

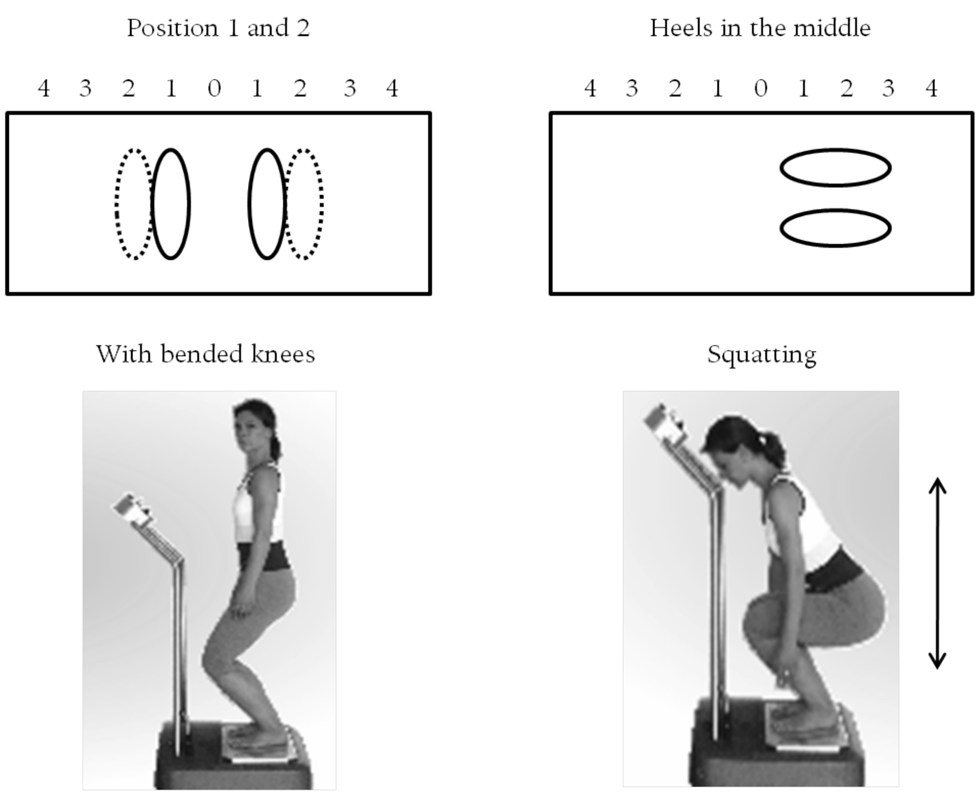

Figure 1. The different positions on the vibration platforms

Table 1

Training program on the reciprocal vibration platform

Week	*Program on reciprocal vibration platform*
1+2	1 min 5 Hz, 3 × 1 min 12.5 Hz with bended knees on position 1
3+4	1 min 5 Hz, 3 × 1 min 12.5 Hz, **1 min 18 Hz** with bended knees on position
5+6	1 min 5 Hz, 3 × 1 min 12.5 Hz, 1 min 18 Hz, **1 min 22 Hz** bended knees on position
7+8	1 min 5 Hz, 3 × 1 min 12.5 Hz, **2 × 1 min 18 Hz**, 1 min 22 Hz bended knees on position 1
9+10	1 min 5 Hz, 2 × 1 min 12.5 Hz, 2 × 1 min 18 Hz, **2** × 1 min 22 Hz bended knees on position 1
11+12	1 min **6** Hz, 2 × 1min 12.5 Hz, 2 × 1min 18 Hz all with bended knees, 2 × 1 min 22 Hz **squatting** all on position 1
13+14	1 min 6 Hz with bended knees, 2 × 1min 12.5 Hz **squatting**, 2 × 1min 18 Hz, bended knees on position 1, 2 × 1 min 22 Hz squatting all on position 1
15+16	1 min 6 Hz with bended knees, 2 × 1min 12.5 Hz squatting, 2 × 1min 18 Hz **squatting**, 2 × 1 min 22 Hz squatting all on position 1, **1 min 5 Hz with heels in the middle**
17+18	1 min 6 Hz with bended knees, 2 × 1min 12.5 Hz squatting, 2 × 1min 18 Hz squatting, 2 × 1 min 22 Hz squatting all on position **2**, 1 min 5 Hz with heels in the middle
19+20	1 min 6 Hz with bended knees, 2 × 1min 12.5 Hz squatting, 2 × 1min 18 Hz squatting, 2 × 1 min **23** Hz squatting all on position 2, 1 min 5 Hz with heels in the middle
21+22	1 min 6 Hz with bended knees, 2 × 1min **14** Hz squatting, 2 × 1min 18 Hz squatting, 2 × 1 min **24** Hz squatting all on position 2, 1 min 5 Hz with heels in the middle
23+24	1 min 6 Hz with bended knees, 2 × 1min 14 Hz squatting, 2 × 1min 18 Hz squatting, 2 × 1 min **25** Hz squatting all on position 2, 1 min 5 Hz with heels in the middle
25+26	1 min 6 Hz with bended knees, 2 × 1min 14 Hz squatting, 2 × 1min 18 Hz squatting, 2 × 1 min **26** Hz squatting all on position 2, 1 min 5 Hz with heels in the middle

Note: Changes in the program from week to week are shown in bold; Rest between every training minute was approximately 1 minute; Test after week thirteen and twenty six.

Table 2

Training program on the horizontal vibration platform

Week	*Program on horizontal vibration platform*
1+2	1 min 20 Hz (1), 3 × 1 min 30 Hz (6) all with bended knees
3+4	1 min 20 Hz (1), 3 × 1 min 30 Hz (6), **1 min 35 Hz (8.5)** all with bended knees
5+6	1 min 20 Hz (1), 3 × 1 min 30 Hz (6), 1 min 35 Hz (8.5), **1 min 40 Hz (11)** all with bended knees
7+8	1 min 20 Hz (1), 3 × 1 min 30 Hz (6), **2 × 1 min 35 Hz (8.5)**, 1 min 40 Hz (11 all with bended knees
9+10	1 min 20 Hz (1), 2 × 1 min 30 Hz (6), 2 × 1 min 35 Hz (8.5), **2 × 1 min 40 Hz (11)** all with bended knees
11+12	1 min 20 Hz (1) with bended knees, 2 × 1min 30 Hz (6), 2 × 1min, 35 Hz (8.5) all with bended knees, 2 × 1min 40 Hz (11) **squatting**
13+14	1 min 20 Hz (1) with bended knees, 2 × 1min 30 Hz (6) **squatting**, 2 × 1min 35 Hz (8.5) with bended knees, 2 × 1min 40 Hz (11) squatting
15+16	**2 min 20 Hz (1)** with bended knees, 2 × 1min 30 Hz (6) squatting, 2 × 1min 35 Hz (8.5) **squatting**, 2 × 1min 40 Hz (11) squatting
17+18	2 min 20 Hz (1) with bended knees, 2 × 1min 30 Hz (6) squatting, 2 × 1min 35 Hz (8.5) squatting, 2 × 1min 40 Hz (11) squatting
19+20	2 min 20 Hz (1) with bended knees, 2 × 1min 30 Hz (6) squatting, 2 × 1min 35 Hz (8.5) squatting, **2 × 1min 41 Hz (11.5)** squatting
21+22	2 min 20 Hz (1) with bended knees, 2 × **1min 32 Hz (7),** squatting, 2 × 1min 35 Hz (8.5) squatting, **2 × 1min 42 Hz (12)** squatting
23+24	2 min 20 Hz (1) with bended knees, 2 × 1min 32 Hz (7), squatting, 2 × 1min 35 Hz (8.5) squatting, **2 × 1min 43 Hz (12.5)** squatting
25+26	2 min 20 Hz (1) with bended knees, 2 × 1min 32 Hz (7), squatting, 2 × 1min 35 Hz (8.5) squatting, **2 × 1min 44 Hz (13)** squatting

Note: Changes in the program from week to week are shown in bold; Rest between every training minute was approximately 1 minute; Test after week thirteen and twenty six; () is the intensity on the platform shown from 1 to 15 with correspond with a vibration of 20 to 50 Hz.

RESULTS

At the pre-test no significant difference between the three groups were found in the parameters age, weight and height (Table 3; $F \leq 2.1$, $p \geq .12$). Furthermore, no significant differences were found at the pre-test between the three groups for the maximal peak forces in the isometric situation ($F = 1.6$, $p = .20$) and the isokinetic extension ($F = 2.1$, $p = .12$) and flexion ($F = 1.6$, $p = .21$) of the knee (see Table 3).

For the dynamic strength (isokinetic extension and flexion) no significant increase was observed after 6 months of training (Table 4). However, a training x group interaction was found for the peak force of the isokinetic extension parameter, which showed that the control group had another development of peak force compared to the other two groups (Table 4; Fig. 2). Pos hoc comparison showed that both WBV training groups increased their peak force in extension and flexion the first 3 months (Fig. 2), while the control group did not change their peak force during the whole training period (Fig. 2).

The isometric strength was increased significantly after 6 month for the whole group (Table 4). However, pos hoc comparison showed that both WBV training groups had a significant increase in peak force with no significant difference between the groups ($p > .05$), while the control group did not have any significant changes (Fig. 3). In both WBV training groups also the gain in isometric strength (15.7 %) was significantly higher ($p < .001$) compared to the gain in isokinetic strength (9.4%).

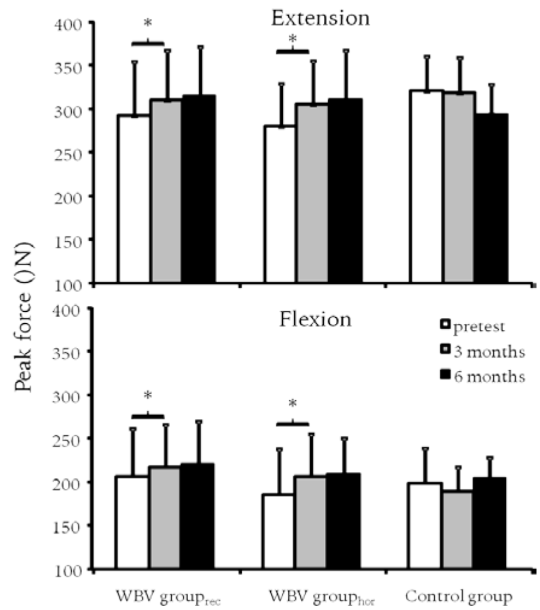

Figure 2. Mean (SD) peak force during isokinetic extension and flexion of the knee averaged per group at the pre-test, after 3 months and after 6 months of training

Table 3
Anthropometrics and maximal peak force of all groups at the pre-test (Mean ± SD)

Group	WBV group$_{rec}$ $n = 67$	WBV group$_{hor}$ $n = 31$	Control group $n = 12$
Weight (kg)	70.2 ± 11.8	65.7 ± 7.1	71.8 ± 14.3
Height (m)	1.68 ± .06	1.66 ± .06	1.67 ± .04
Age (yr)	62.2 ± 5.5	60.7±8.1	59.8 ± 4.0
Peak force extension (N)	293.0 ± 62.4	280.7 ± 49.2	320.9 ± 40.7
Peak force flexion (N)	206.3 ± 54.8	185.7 ± 52.8	198.1 ± 41.6
Peak force isometric (N)	410.9 ± 97.1	380.5 ± 90.5	429.7 ± 64.4

Table 4
Statistical analysis of the effect of WBV training on isokinetic and isometric strength of the knee on all subject data combined

Parameter	Training effect				Effect between groups		
	% Change (95% CI)	*p*	Effect size	Statistical Power	*p*	Effect size	Statistical Power
Isokinetic extension	3.1 (−2.9 to 9.1)	.176	.019	.365	.028	.057	.755
Isokinetic flexion	6.4 (−1.4 to 14.1)	.074	.028	.520	.331	.025	.359
Isometric extension	9.1 (2.0 to 16.2)	<.001	.096	.980	.109	.040	.571

Note: Overall effect is based on the ANOVA's main training effect and effect between groups on training x group interaction

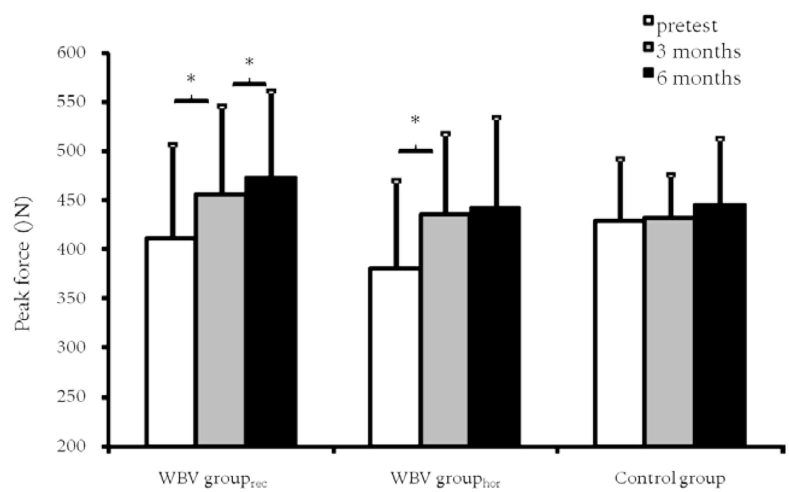

Figure 3. Mean (SD) peak force during isometric extension of the knee (50° flexion) averaged per group at the pre-test, after 3 months and after 6 months of training

DISCUSSION

This study investigated the long-term effects on strength of WBV training on two different types of platforms in postmenopausal women. Both WBV training groups demonstrated an increase in their dynamic and static strength in the knee extensors and flexors after three months of training. The additional improvement from three six months of training was small. Between the two WBV training groups no significant differences were found indicating that both types of WBV training result in strength gains in the knee extensors and flexors.

The increase of leg strength in the present study was in line with the findings in earlier studies of Verschueren et al. (2004), Bogaerts et al (2011) and Verschueren et al (2011). The development of the strength gain from the first three months to the second three months was similar to what Roelants et al (2004a) found: a high increase followed by a small strength gain, while the control group did not show any strength gains (Fig. 2 and 3). These earlier studies used a vertical inducing WBV platform, while we used two other types of platforms (WBV_{hor}, WBV_{rec}). Rees et al (2007) used the same platform as we did in their study and found already an increase of 8% after just 8 weeks of training in knee extension strength, while we reported this strength gain (8%) after six months of training. The differences between our study with Rees et al (2007) was that they used only 26 Hz of frequency and a higher amplitude (5-8 mm), while we used different frequencies (5-6, 12-14, 18, 22-26 Hz) and a lower amplitude (2-4mm). Therefore, the gain in our study occurred after a longer training period. However, we used different frequencies and smaller amplitudes to train also other body properties like balance, blood circulation and bone density (Rittweger, 2010).

In our study both WBV training groups showed a similar strength gain in the knee extensors and flexors after three and six months of WBV training (Fig. 2 and 3) indicated that both types of WBV training are equally effective to gain knee strength in postmenopausal women. This is one of the first studies that investigated the effect of horizontally induced WBV training on strength in postmenopausal women. It was expected that this type of WBV training would be less affected than reciprocal WBV training due to the minimal vertical accelerations of the WBV device upon the body. However, it seems that also these horizontally vibrations stimulate muscle activity and thereby strength. As Pel et al. (2009) showed was the transmission of the vibration in percentage higher in the ankle, knee and hip with the use of the horizontally induced WBV platform, which indicates that this type of vibration also can have cause a reaction of the muscles as shown in our study by increased leg strength. As Pel et al. (2009) stated that the use of short training sessions with horizontally induced WBV devices is more safely to the human body due to the small vertical accelerations.

Some limitations of the present study were that the WBV training consisted of mainly two components: the vibration stimulus and the specific exercises performed on the platform. Although WBV training is reported to facilitate strength gains, it must be acknowledged that the exercises performed on the platform, can also contribute to the improvements in strength, particularly in older adults. However, in the present study most strength gain occurred in the first three months in which the participants most of the time only stood on the platform. Only two weeks for the 3 months test they started with squatting on the platform. Furthermore, the participants had all ready a very high level of leg strength at the pre-test compared to a similar study on older women of Verschueren et al. (2004); 292 N *vs*. 81 N in isokinetic knee extension strength and 404 N *vs*. 113 N in isometric strength. In addition, Delecluse, Roelants, and Verschueren (2003) found in a placebo-controlled study that the strength gains were provoked by the WBV stimuli and not the squatting exercise. Another limitation is that the WBV training groups had an additional workload 3 times per week, compared with the control group. However, all three groups were besides WBV training very active in their leisure time. The monthly questionnaire showed that on average mostly all participants were 3 times per week for one hour at the time moderately active. Mainly walking in the hills and mountains was the activity the participants reported and sometimes also dance and circuit training. The activity level of the participants besides the WBV training did not change during the experiment indicating that the difference in strength must be the result of WBV training.

In the present study only the effect of a half-year of reciprocally and horizontally induced WBV training upon the isokinetic and isometric strength in postmenopausal women was investigated. More studies with these types of WBV training and with also other parameters that influences osteoporosis like balance and bone density should be conducted before it can be stated that this type of WBV training would have a positive effect upon osteoporosis in older women.

CONCLUSIONS

Based on the results of the present study it was concluded that both horizontal and reciprocal induced whole body vibration training can help postmenopausal women with increasing their leg strength. It can be said that both types of WBV training are a suitable and efficient strength training method for postmenopausal women.

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