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Whole-Body Vibration Training Improves Muscle and Physical Performance in Community Dwelling with Sarcopenia: A Randomized Controlled Trial

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Abstract

Background: This study examined the efficacy of whole-body vibration (WBV) training for improving muscle size, strength and physical performance in the community dwelling individuals with sarcopenia.
Methods: Forty community dwelling individuals with sarcopenia were recruited and randomly assigned into either the whole-body vibration (WBV) group (frequency: 40Hz; peak-to-peak amplitude: 4 mm) or the control group with no intervention. The WBV training involved 3 exercise sessions per week over 12 weeks. All outcome measurements were done at pre-, mid- (18 sessions) and post-intervention (36 sessions). Assessments included ultrasound cross-sectional area (CSA) measurement of vastus medialis (VM), isometric and isokinetic knee extension, timed-up-and-go test (TUG), five-repetition sit-to-stand test (5STS), and 10-meter walk test (10MWT).
Results: After the training program, the WBV group showed significant within-group improvements in isometric and isokinetic knee extension, TUG, 5STS and 10MWT ($p<0.05$), but not in CSA of VM. The WBV group had significantly better performance than the control group in isokinetic knee extension at 180°/s, TUG, 5STS at both mid- and post-intervention ($p<0.05$).
Conclusion: The present findings suggest that WBV training is an effective and efficient approach for improving muscle strength and physical performance in community dwelling individuals with sarcopenia.

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Introduction

Sarcopenia is defined as age-related loss of muscle mass [1]. It has been reported that more than 15% of the total skeletal muscle mass would be lost when a person reached 75 years of age which is significantly more than the age related muscle loss of 8% between 40 and 50 years of age [2]. The age-related loss of skeletal muscle mass is a major causative factor to strength decline in the seniors. Around 50% of muscle strength decreased between 60 and 80 years of age [3] and the greatest decline is with concentric dynamic contraction at high speed [4]. It has been well documented that age-related loss of skeletal muscle mass and strength would lead to decrease in balance, mobility and daily independence [2,5], which are important predisposing factors for functional impairment and physical disability among the seniors [6].

Physical exercise has been shown to be effective for improving muscle mass, strength and daily life activity in the elderly [7,8]. Sipilä and Suominen [8] reported the cross-sectional area (CSA) of quadriceps increased by 4.5% in the elderly subjects after 18 weeks of lower limb resistance training. Recently, a study with meta-analysis has concluded that medium-term exercise training programs would have positive effects on muscle strength development in the very old age group [9]. On the aspect of physical performance, a randomized controlled trial with 246 elderly people has reported a significant improvement in the timed up-and-go (TUG) test after 18 months of resistance and aerobic training program [10].

Recent studies have used whole-body vibration (WBV) as a therapeutic intervention to improve muscle size, strength and functional performances in the elderly subjects [11,12]. Machado et al. [11] reported 10 weeks of lower extremity training with WBV could improve the muscle size of biceps femoris and vastus medialis in older women by 15.5% and 8.7%, respectively, and they also found concomitant improvements in muscle strength and functional reported a significant increase in isometric knee extension strength after 72 sessions of WBV training in the old people. Whereas, Raimundo et al. [14] reported no significant improvement in muscle strength after 96 sessions of WBV training program, but it should be noted the intensity of the training program in that study might be too light to induce an observable effect despite having 96 sessions of training. For the physical performance, Pollock et al. [15] reported after 24 sessions of WBV training in the frail elderly subjects, the time taken for them to complete TUG had decreased by 38% and the walking speed had increased by 36%.

Considering the positive effects of WBV training on muscle and physical performance in the normal and frail elderly subjects, this mode of exercise could also be beneficial for the senior subjects with sarcopenia. However, no study had examined the effectiveness of WBV training in people with sarcopenia. Therefore, it is necessary to investigate the efficacy of applying WBV training to improve muscle size, strength and physical performance of senior subjects with sarcopenia.

Methods

Subjects

Community dwelling individuals aged 65 years and above were recruited from a local elderly health center. The older individuals without metal implants, uncontrolled heart problem,

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neurodegenerative diseases, peripheral vascular disease, vestibular disorders and severe osteoporosis with fractures within one year prior to the study were invited to undergo a bioelectrical impedance assessment to estimate the skeletal mass with an established formula:

Skeletal mass (SM) = [0.401 * (height2/bio-impedance) + (3.825 * gender index) – (0.071 * age) + 5.102].

In which the height is in centimeters; bio-impedance is in ohms; gender index for male = 1 and female = 0.

Skeletal mass index (SMI) was calculated as SM/height^2 [2,4]. Male and female subjects with SMI less than 8.87kg/m^2 and 6.42kg/m^2, respectively, were classified as sarcopenic [16] and randomly assigned into either a WBV group or a control group with a computer program (Research Randomizer Form v4.0). This study was approved by the Human Ethics Review Board of the administrating institution according to the Declaration of Helsinki. All subjects gave their informed written consent before participating in this study.

Procedures

The vibration training was only conducted in the WBV group in a sports training laboratory of our institution and supervised by a researcher. The training was done 3 days/week for 12 weeks making a total of 36 training sessions. Extra sessions catering for missing appointments were arranged to make sure all subjects have completed the same number of training sessions.

The vertical mode of WBV was used in the present study. The frequency of WBV was set at 40 Hz with a peak-to-peak amplitude at 4mm and one WBV session comprised 4 bouts of 90-second vibration exercise [17]. During training, the subjects stood on the platform of a WBV machine (Fitvibe excel, GymnaUniphy NV, Bilzen, Belgium) without shoes. The knees were kept at 60° of flexion and hands placed onto the rail in front for support. No intervention or training was conducted in the control group. All subjects were asked to maintain their normal lifestyle and physical activity level during the study.

The outcome measurements included muscle size, strength and physical performance. Assessments were conducted at pre- (baseline), mid- (18 sessions) and post- (36 sessions) intervention.

The CSA of VM of the dominant leg was measured with ultrasound imaging. Subjects were positioned supine with a custom-made ankle stabilizer applied to the foot and ankle to keep the leg in neutral rotation. The B-mode of An Aixplorer® ultrasound unit (Supersonic Imaging, Aix-en-Provence, France) was used to capture the CSA of VM at 1/3 of the leg length (measured from anterior superior iliac spine to the medial side of joint line space) above the base of patella [11]. Three images were captured for calculating the average CSA of VM.

The isometric and isokinetic knee extension peak torque of the dominant leg was measured with an isokinetic dynamometer (Cybex Norm, Henley Healthcare, Nauppauge, NY, USA). The isometric peak torque was measured at a knee angle of 90° and isokinetic testing was done at two angular speeds of 60°/s and 180°/s. Subjects were positioned on the testing machine with hip at 80° of flexion and knee axis aligned with the dynamometer axis of rotation. With the trunk and the tested leg firmly secured by straps onto the testing chair, each subject performed two submaximal contractions for familiarization and three maximal contractions for the actual data collection. A 1-minute recovery period was given between testing sessions. The maximum peak torque in the three trials was used for data analysis.

The functional performance test batteries included TUG, 5 times sit-to-stand (5STS) and 10-meter walk (10MWT), as these tests have been recommended to be valid, reliable and suitable assessments for physical function in older people [18,19]. Subjects performed TUG test with their regular footwear and normal walking aid (none, cane, walker). They were to stand up from an armchair, walk a distance of 3 meters, turn and walk back to sit down on the chair with their normal pace without help from another person. Two practice trials were given before the actual test.

For the 5STS test, the subject sat on a chair of 43-47cm high with arms crossed on the chest and feet comfortably placed on the floor. When the researcher said"start", the subject would rise from the chair to assume a full erect standing position and return to sitting for five times without rest in between. The time taken to complete the test was recorded and the average time of three tests was calculated.

The 10MWT was assessed at a self-preferred walking speed, which was recommended as a clinical parameter for diagnosis of sarcopenia [20]. The time was only measured for the middle 6 meters. The first and last two meters were to let the subject accelerate and decelerate. Timing would start and stop as the leading feet passed the 2-meter and 8-meter marks, respectively [21]. Walking aid was allowed in this test. The average walking speed of three trials was used in the data analysis.

Test-retest reliabilities for all the assessments were established with a 7-day interval with 7 age-matched subjects. All the assessments showed good test-retest reliability (ICC3,1=0.90-0.99).

Statistical Analysis

Kolmogorov-Smirnov test was used to examine whether the data followed a normal distribution. To compare the baseline characteristics of the two groups, independent-sample t-test or Mann Whitney U-test was conducted. Two-way repeated measures ANOVA (time × group) was used to analyze the raw data for examining the effects of WBV on muscle and physical function. If time effect was significant, contrast analysis would be conducted to analyze the raw data to examine the within-group changes of each group.

Percentage changes from baseline (mid minus pre; post minus pre)/pre × 100 in outcome variables were calculated. Between-group difference at each time point was tested using independent-sample t-test. The last observation carried forward method (LOCF) of intention-to-treat (ITT) analysis was used for data analysis.

Descriptive analyses were reported as means ± standard deviation. SPSS 20.0 (SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis. Significance level was set at p<0.05, unless otherwise state.

Results

Forty subjects were recruited in this study (Figure 1). No adverse effect was reported by any of the subjects during the study. The outcome variables of subjects at baseline are summarized in Table 1. No between-group difference in physical characteristics and outcome variables was found at baseline (p>0.05) (Table 1).

Significant time × group interaction effects were found for the 180o/s isokinetic knee extension ($F_{2,76}$=6.216; p=0.003), TUG ($F_{2,76}$=8.161; p=0.001) and 5STS tests($F_{2,76}$=9.220; p<0.001). Subjects in the WBV group showed significant within-group improvements

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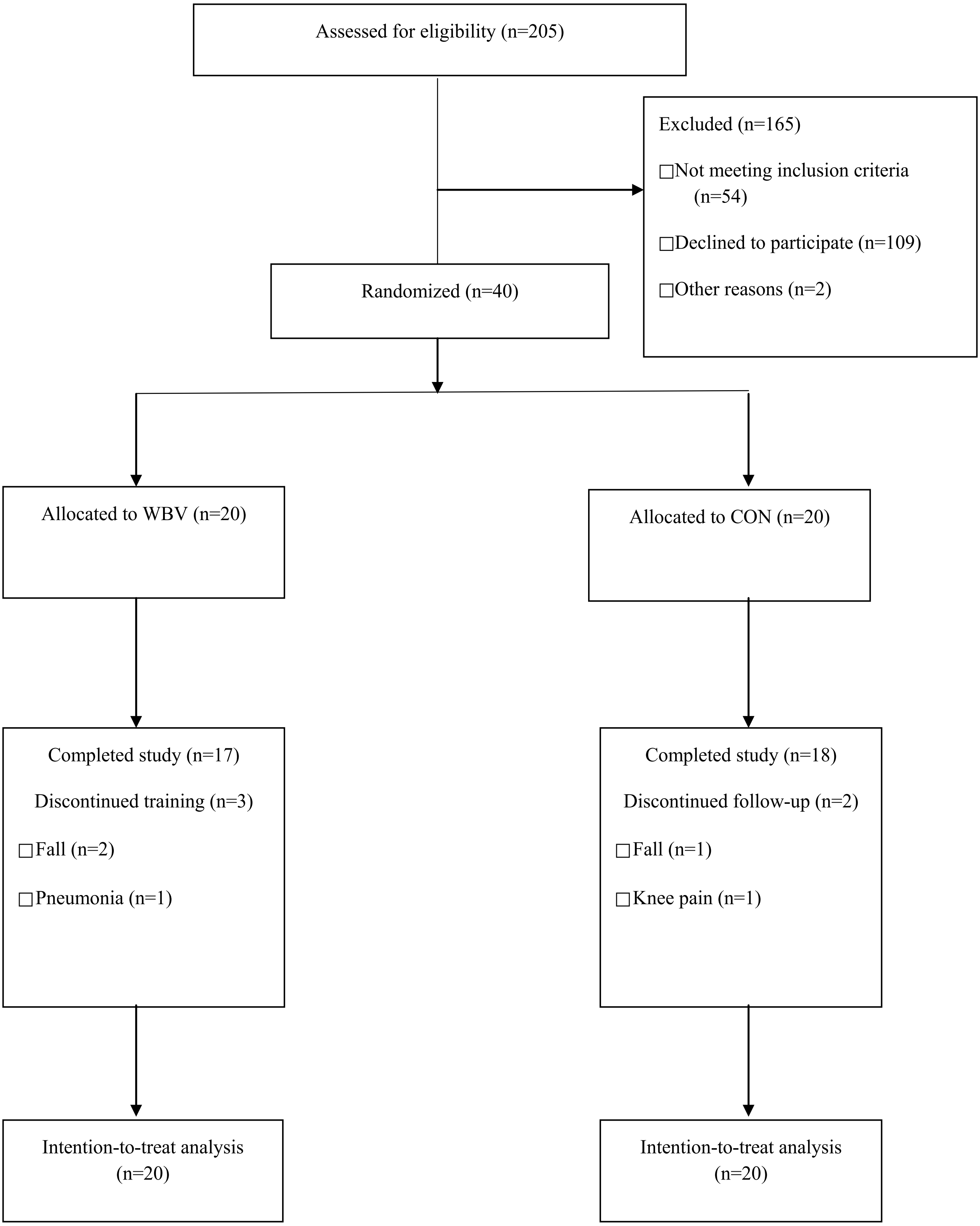

Figure 1: Flowchart of subject group assignment for the study.

after 36 training sessions in most outcome variables, except for VM size. After 18 training sessions, the TUG and 5STS performances were only significantly improved in the WBV group. Table 2 listed the within-group difference in all outcome variables.

Significant between-group differences in percentage changes from baseline were found in isokinetic knee extension at 180°/s and 60°/s (Figure 2 & 3), TUG and 5STS at mid-intervention. At post-assessment, significant between-group differences were found in isokinetic knee extension at 180°/s (Figure 2), TUG, 5STS and 10MWT.

Discussion

This is the first report of WBV training program on muscle size, strength and physical function in the community dwelling individuals with sarcopenia. The findings of this study suggested that WBV training could effectively improve muscle strength and physical performance in these subjects.

Despite the difference is not statistically significant, the muscle size increased 1.53% in the WBV group. Considering the subjects were community dwelling individuals with sarcopenia who were prone to lose their muscle mass, it would be difficult for the muscles to grow significantly with only 36 sessions of training. For muscle performance, there were significant increases in isometric and isokinetic knee extension after the training in the WBV group, which is comparable to some previous studies that reported the beneficial effects of WBV training for muscle performance in the elderly [11,22,23]. Interestingly, we found the between-group difference in isokinetic strength at 180°/s was significant at both mid- and post-assessments but the 60°/s only showed a significant between-group difference at mid-intervention. Furthermore, when compared with 60°/s, the within-group improvement in 180°/s was greater. It is speculated that the fast-twitch fibers in our subjects might have been preferentially stimulated with WBV training because Pollock et al. [24] had demonstrated a lowering in recruitment threshold of fast-twitch motor units after a single session of 6-minute WBV training. If a long-term WBV training program could facilitate the fast-twitch fibers recruitment, it will be extremely important for the management of sarcopenia and frailty in elderly people because the fast twitch muscles are significantly weakened with these conditions. Further research is warranted to shed more lights on this issue.

Increase in muscle strength is associated with better physical performance [25]. Subjects in the WBV group had significant improvements in TUG, 5STS and 10MWT with self-preferred walking speed. The performance in TUG and 5STS had improved after 18 training sessions, which echoed with previous studies that reported significant improvements in 5STS and TUG after 18 and 24 sessions of WBV training [15,23].

Unlike the TUG and 5STS which had improved after 18 training sessions, the 10MWT did not improve in the first half of the training but it improved within the WBV group after the entire 36 training sessions. It is well known that TUG contained several action components of standing up, walking, turning and sitting down. Therefore, it is possible that the improved completion time of TUG in the first half of training is due to less time spent in standing up. Also, the coordination and balance have a significant role in TUG. A systematic review with meta-analysis reported that WBV could improve balance in the elderly [26] and this could help explain the improved performance in TUG of this study.

There are some limitations in this study. First, the control group had not any intervention. It would have been better to include a sham group to distinguish the effect of static squatting from the effects of WBV training. Second, although all our subjects suffered from sarcopenia, some of them were still quite physically active. The subjects who had difficulty in daily activity could not endure the 36 training sessions and dropped out. Thus, the results of this study may not be generalized to the population with very poor physical condition.

Conclusion

A 12-week WBV training program with 36 sessions of 40Hz/360s per session of exercise has positive effects on muscle strength and physical performance in the community dwelling individuals with sarcopenia. The present findings suggested that WBV training is a suitable therapeutic component for improving muscle and physical performance of the community dwelling individuals with sarcopenia.

	WBV (n=20)	CON (n=20)	p value	Mean difference (95%CI)
Age (yrs)	75(6)	76(6)	0.772	-0.70(-4.66,3.26)
Height (cm)	156.1(8.8)	152.1(8.3)	0.147	0.04(-0.01,0.09)
Weight (kg)	56.9(6.40)	55.3(8.4)	0.500	1.61(-3.17,6.38)
BMI (kg/m^2)	23.44(2.47)	23.83(2.65)	0.632	-0.39(-2.03,1.25)
SMI (kg/m^2)	6.44(1.03)	6.39(1.31)	0.900	0.05(-0.71,0.80)
CSA of VM (cm^2)	4.13(1.21)	4.25(1.19)	0.739	-0.13(-0.90,0.64)
Isometric knee extension (Nm)	86.30(32.99)	82.30(26.06)	0.673	4.00(-15.03,23.03)
Isokinetic knee extension at 180°/s (Nm)	27.90(17.26)	33.30(12.10)	0.259	-5.40(-14.94,4.14)
Isokinetic knee extension at 60°/s (Nm)	55.35(26.92)	56.30(17.26)	0.895	7.15(-15.42,13.53)
TUG (s)	13.58(2.61)	12.28(2.76)	0.134	1.30(-0.42,3.02)
5STS (s)	12.96(2.83)	11.54(3.42)	0.159	1.43(-0.58,3.44)
10MWT at self-preferred speed (m/s)	0.96(0.19)	1.03(0.17)	0.252	-0.07(-0.18,0.05)

Table 1: The characteristics of participants at baseline (Mean(SD)).

WBV: whole body vibration group; CON: control group; CSA: cross-sectional area; VM; vastus medialis; TUG: Timed up-and-go test; 5STS: Five-repetition sit-to-stand test; 10MWT: 10-meter walking test. The p values were for between group comparisons.

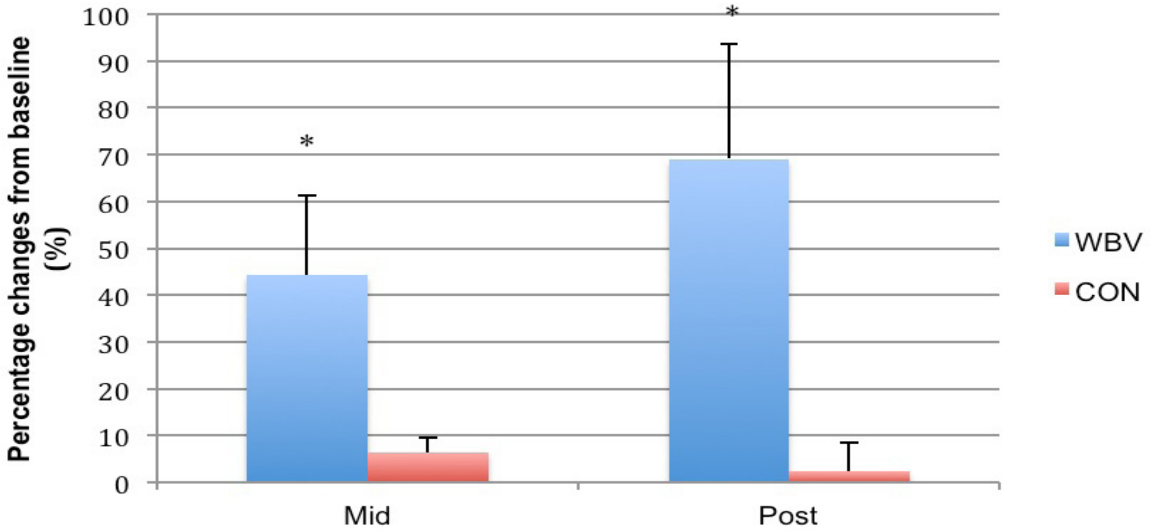

Figure 2: Group differences in isokinetic knee extension at 180 °/s at mid- and post-intervention.

WBV: Whole-body vibration training group; CON: Control group; Mid: completion the half of all training sessions (18 sessions); Post: completion all training sessions (36 sessions); * p<0.05 vs. CON

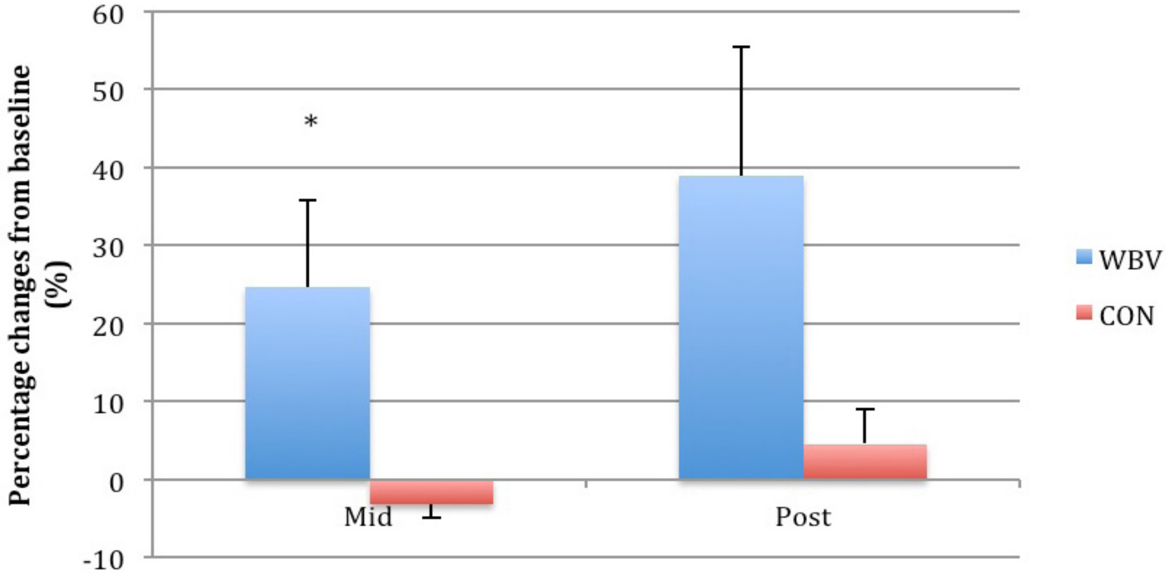

Table 1: The characteristics of participants at baseline (Mean(SD)).

WBV: whole body vibration group; CON: control group; CSA: cross-sectional area; VM; vastus medialis; TUG: Timed up-and-go test; 5STS: Five-repetition sit-to-stand test; 10MWT: 10-meter walking test. The p values were for between group comparisons.

	WBV (n=20)		CON (n=20)	
	Mid	Post	Mid	Post
CSA of VM (cm²)	4.14(1.23)	4.18(1.23)	4.19(1.12)	4.11(1.23)
Isometric knee extension (Nm)	91.25(23.98)	94.50(34.09)*	82.00(24.16)	81.00(22.99)
Isokinetic knee extension at 180°/s (Nm)	33.25(13.69)	38.60(19.18)**	34.75(12.26)	33.15(13.19)
Isokinetic knee extension at 60°/s (Nm)	60.50(19.62)	66.60(27.43)*	54.20(15.65)	58.50(20.59)
TUG (s)	12.31(2.01)**	11.32(1.72)**	12.85(3.96)	12.38(3.21)
5STS (s)	11.12(2.32)**	10.46(2.28)**	11.84(3.36)	11.40(2.99)
10MWT at self-preferred speed (m/s)	1.00(0.13)	1.05(0.16)*	1.03(0.17)	1.02(0.17)

Table 2: Within-group differences in muscle and physical performance (Mean(SD)).

Mid: completion half training session (18 sessions); Post: completion all training session (36 sessions); WBV: whole body vibration group; CON: control group; CSA: cross-sectional area; VM; vastus medialis; TUG: Timed up-and-go test; 5STS: Five-repetition sit-to-stand test; 10MWT: 10-meter walking test. The p values were within-group comparisons versus baseline; * p<0.05 and ** p<0.01.

Competing Interests

The authors declare that they have no conflict of interest.

Author Contributions

Gabriel YF Ng, Shamay SM Ng and Marco YC Pang: study design and critical review.
Ruby SY Lee and Mary CK Lau: data collection.
Ning Wei: data collection, data analysis and drafting.

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