





Acute Effects of Whole-Body Vibration Alone or in Combination With Maximal Voluntary Contractions on Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Obese Male Adolescents

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Abstract

Musculoskeletal and neuromotor fitness (MSMF) is reduced in obesity. Physical exercise (including whole-body vibration exercise [WBVE]) is reported to improve components related to MSMF. The aim of the study is to evaluate the acute effects of WBVE and maximal voluntary contraction (MVC), alone and in combination, on the cardiorespiratory and MSMF in obese adolescents. Eight obese adolescents performed 3 tests (WBVE, MVC, and MVC + WBVE) in different days and randomly. The outcome measures were diastolic blood pressure (DBP), systolic blood pressure (SBP), mean arterial pressure (MAP), heart rate (HR), peripheral oxygen saturation (SpO₂), handgrip strength (HS), one-leg standing balance (OLSB) test, sit-and-reach (SR) test, stair climbing test (time: T_{SCT} and power: P_{SCT}), and sit-to-stand test (time: T_{STS} and power: P_{STS}). No significant changes were observed in SBP, DBP, MAP, and SpO₂ after the 3 tests, only an HR increase being observed after MVC + WBVE ($P < .01$) and MVC alone ($P < .05$). No significant differences were found in HS, OLSB, T_{STS} , and P_{STS} after the 3 different sessions. An increase in SR was found after MVC + WBVE, MVC, and WBVE ($P < .01$, $P < .05$, and $P < .01$, respectively), while a decrease in T_{SCT} ($P < .01$) and an increase in P_{SCT} were observed only after WBVE ($P < .01$). Taking into account the positive WBVE effects on cardiorespiratory and MSMF, WBVE might represent a nonimpact, viable, and safe exercise suitable for obese patients, which need MSMF improvement without overloading joints.

Keywords

obesity, whole-body vibration, metabolic rehabilitation, neuromotor fitness, exercise

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Introduction

Obesity is reported to be associated with biomechanical changes leading to physical disabilities, which hamper the accomplishment of the normal daily activities.¹ Alterations in skeletal muscle system observed in obese patients determine an impairment of muscle strength and power, flexibility, balance, and cardiopulmonary functions.^{1,2} According to the American College of Sports Medicine guidelines, these parameters are important in evaluating musculoskeletal and neuromotor fitness (MSMF).²⁻⁵ Although few studies have investigated the association between MSMF and obesity, an inverse relationship between BMI and MSMF scores has been described.^{2,4,6,7} Kjær et al² underlined that improving MSMF in the obese population is desirable for maintaining an independent lifestyle and preventing concurrent diseases and mortality.

Physical exercise is recommended to improve each component related to MSMF³ and in the treatment of obesity⁸ to ameliorate the cardiopulmonary and musculoskeletal functions.⁹ In obese patients, exercises improve muscle strength, flexibility, and neuromotor function related to balance, coordination, agility, and gait and are strongly recommended in order to counteract physical disability, increase the level of autonomy, promote general well-being, and increase quality of life.¹⁰

Several authors reported that whole-body vibration exercise (WBVE), a safe and viable type of exercise, is able to produce changes in the length-tension of the spindle muscle by generating a tonic vibration reflex and increasing the excitatory neuromuscular state,^{5,11,12} which improves cardiopulmonary and musculoskeletal functions both in athletes and sedentary individuals.¹³ To optimize these effects, other exercises have been associated with WBVE, such as external load,¹⁴ resistance training,^{15,16} and maximal voluntary contractions (MVC).¹⁷⁻¹⁹

Childhood obesity is a largely broad and complex clinical condition, requiring early and focused multidisciplinary interventions to counteract the metabolic complications and the potential risk of persistence also in adulthood.²⁰

Since no studies are available on the effects of WBVE and MVC on the MSMF of obese adolescents to date, the aim of the present study is to evaluate the acute effects of WBVE and MVC, alone and in combination, on some parameters of cardiorespiratory and MSMF in obese adolescents.

Methods

Participants

Eight obese male adolescents participated in this study (mean age \pm standard deviation: 17.1 \pm 3.3 years; body mass: 107.4 \pm 17.8 kg; height: 1.72 \pm 0.05 m; body mass index [BMI]: 36.5 \pm 6.6 kg/m²; BMI standard deviation score: 3.1 \pm 0.6; waist circumference [WC]: 118.3 \pm 18.0 cm). All the patients were hospitalized at the Division of Auxology, Istituto Auxologico Italiano, Piancavallo (VB), Italy, for a 3-week multidisciplinary integrated body weight reduction program. The study protocol was approved by the ethical committee of Istituto Auxologico Italiano, Milan, Italy, in accordance with the

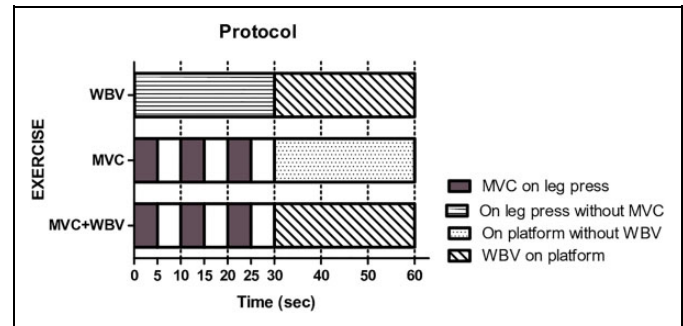


Figure 1. Description of the exercise protocols: whole-body vibration exercise (WBVE), maximal voluntary contractions (MVC), and combined MVC + WBVE.

principles expressed in the Declaration of Helsinki. The parents of each participant signed the written informed consent.

All the patients were sedentary and none reported musculoskeletal disorders that could influence the execution of the tests. Any strenuous exercise was forbidden for at least 48 hours prior the experiment and the patients were admitted to the laboratory 1 hour before the tests, which started between 8.00 and 8.30 AM.

Training Sessions

Each individual performed 3 different tests in different days and in random order: (1) WBVE, (2) MVC, (3) the combination of the 2 exercises (MVC + WBVE). The training sessions were separated by at least 2 days in between (mean interval: 5.6 \pm 1.4 days, range: 2-8 days). Before starting each session, all the participants performed a standardized warmup (5 minutes on a cycloergometer; power: 50 W; cadence: 60 rpm).

During the WBVE session, individuals sat on a leg press machine (Technogym, Gambettola, Italy) in the posture of the MVC exercise (see subsequently) without exerting any effort for 30 seconds. Then they stood in a static squat position on the vibrating platform (VP) with vertical sinusoidal vibrations (Nevisys H1; RME, Ferrara, Italy), with a 110° knee flexion, at a frequency of 35 Hz and peak-to-peak displacement of 5 mm for 30 seconds. The acceleration peak of the vibration was 2.85 g, as assessed by magnetic monoaxial accelerometer (Vibration Meter, Lutron VB-8200, Lutron Electronic Enterprise Co., LTD, Taipei, Taiwan). This sequence was repeated 15 times in a row without rest.¹⁸

During the MVC session, participants seated on the leg press machine, with the trunk-thigh and thigh-shank angles at 80°, for 30 seconds, making three 5-second MVC with isometric efforts, separated by 5-second rest time. Then the individuals stayed in a static squat position with a 110° knee flexion on the VP for 30 seconds, without mechanical vibration. This sequence was repeated 15 times in a row without rest.¹⁸

During the MVC + WBVE session, individuals initially performed the 30-second MVC with isometric efforts, which were followed by the 30-second WBVE bouts, as in the MVC

and WBVE session alone (Figure 1). This sequence was repeated 15 times in a row without rest.¹⁸

Outcomes Measures

Anthropometric Measures

A scale with a stadiometer was used to determine the height and the body weight of the individuals (Wunder Sa.Bi., WU150, Trezzo sull'Adda, Italy). Leg length (ie, the distance from the greater trochanter of the femur to the malleolus lateralis) and WC were measured with a flexible tape measure. Leg length was used in the equations for the determination of stair climbing test (SCT) power (P_{SCT}) and sit-to-stand (STS) test power (P_{STS}).

All the following parameters were evaluated before and at the end of the 3 exercise sessions.

Blood Pressure, Heart Rate, and Peripheral Oxygen Saturation

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured twice (3-minute interval in between) on the dominant arm with an aneroid sphygmomanometer (TemaCertus, Milan, Italy), using appropriately sized cuffs. The mean values were calculated and rounded to the nearest 5 mm Hg value. The mean arterial pressure (MAP) was calculated through a traditional formula $(SBP + [2DBP])/3$.²¹ Heart rate (HR) and peripheral oxygen saturation (SpO_2) were measured with a pulse oximetry device (Nonin Medical Inc, Plymouth, Minnesota) placed on the patient's second finger.

Handgrip Strength

Handgrip strength (HS) of the dominant hand was measured with a dynamometer (mod. 78010; Lafayette Instrument Company, Lafayette, Indiana), with standardized positioning and instructions. The patients were in upright position with their shoulder adducted and neutrally rotated, forearm in neutral position, and wrist between 0° and 30° dorsiflexion and between 0° and 15° of ulnar deviation.²² Three trials were performed with a 60-second rest in between and the highest attained value (kgf) was used for the analysis.

One-Leg Standing Balance Test

The individuals were asked to stand on one leg, looking straight ahead, and to maintain the position without touching the floor with the lifted foot as long as possible or up to 60 seconds.²³ This test was performed on both legs.

Sit-and-Reach Test

The patients completed the sit-and-reach (SR) test for flexibility, according to the protocol described by Chen et al.²⁴ A flexible measuring tape was fixed to an exercise mat and patients sat on the mat with their knees extended and the tape between their legs. Patients were asked to reach forward

slowly, as far as possible, with their hands overlapped and to hold the end position for 2 seconds. Three trials were allowed, and the mean farthest point reached with the fingertips, using the level of the heels as recording 0 (so that any measure that did not reach the heels was negative and any measure beyond the heels was positive), was the attained SR distance.

Stair Climbing Test

The patients were invited to climb up ordinary stairs (13 steps of 15.3 cm each, vertical distance: 1.99 m) at the highest possible speed, according to their capabilities. The SCT time (T_{SCT}) taken to perform the test was measured with a digital stopwatch. The determination of the time starts when the first foot was elevated and finishes with the contact of the foot on the floor of the last step.

P_{SCT} was calculated by the following equation^{25,26}:

$$P_{SCT} = \frac{bm \times h \times g}{T_{SCT}},$$

where bm represents body mass (expressed in kg), h is height (m) of the total vertical distance of the stairs, and g (m/s^2) the acceleration of gravity that is $9.81 m/s^2$.

Sit-to-Stand Test

The participants stood up and sat down on a chair (sitting height: 46 cm) in 10 repetitions in their fastest time possible. The STS time (T_{STS}) was recorded by a supervisor. P_{STS} was calculated using the following equation²⁷:

$$P_{STS} = \frac{(L - h) \times bm \times g \times 10}{T_{STS}},$$

where L (expressed in m) represents leg length, h (m) is the chair height, bm is body mass (kg), and g (m/s^2) the acceleration of gravity ($9.81 m/s^2$).

Statistical Analysis

All continuous variables were reported as median and interquartile range because all variables did not follow a normal distribution. The nonparametric Wilcoxon signed rank sum test was used, for each variable of interest, to test the differences between "baseline" and "after" (ie, post-exercise) values in each session. A level of significance of $P < .05$ was used for all data analyses.

Results

All the baseline values were comparable between the 3 different study days, with the only exception of P_{SCT} between MVC + WBVE and MVC and between MVC + WBVE and WBVE ($P < .05$). Table 1 presents the comparison between baseline and post-exercise values for SBP, DBP, MAP, HR, and SpO_2 .

No significant changes were observed in SBP, DBP, MAP, and SpO_2 after the 3 tests, only a significant HR increase being observed after MVC + WBVE ($P < .01$) and MVC alone ($P < .05$).

Table 1. Effects of MVC + WBVE, MVC, and WBVE on SBP, DBP, MAP, HR, and SpO₂.

	MVC + WBVE (Intragroup Comparison)			MVC (Intragroup Comparison)			WBVE (Intragroup Comparison)		
	Baseline Median (IQR)	After Median (IQR)	P Value	Baseline Median (IQR)	After Median (IQR)	P Value	Baseline Median (IQR)	After Median (IQR)	P Value
SBP (mm Hg)	116.5 (111-122.5)	125.5 (115.5-131.0)	.08	109.0 (105.0-115.0)	119.0 (103.0-122.0)	.09	113.0 (105.5-128.0)	117.5 (102.5-124.5)	.47
DBP (mm Hg)	70.5 (61.0-76.5)	69.0 (55.5-72.0)	.23	62.0 (60.0-65.0)	71.0 (61.0-75.0)	.09	70.0 (64.5-74.0)	68.0 (62.5-70.0)	.25
MAP (mm Hg)	84.8 (78.7-93.8)	88.2 (75.5-92.5)	.93	79.0 (74.3-81.0)	84.7 (80.0-91.7)	.08	83.2 (79.7-89.2)	85.2 (75.7-86.2)	.25
HR (bpm)	72.0 (66.0-79.0)	102.0 (93.5-102.5)	<.01	62.0 (58.5-69.5)	79.5 (75.0-82.0)	<.05	63.5 (59.0-68.0)	66.0 (59.5-78.5)	.48
SpO ₂ (%)	95.5 (95.0-96.0)	95.0 (94.5-96.0)	.66	95.5 (95.0-96.0)	95.0 (94.0-96.0)	.44	95.5 (95.0-96.0)	95.0 (95.0-95.5)	.78

Abbreviations: DBP, diastolic blood pressure; HR, heart rate; IQR, interquartile range; MAP, mean arterial pressure; MVC, maximal voluntary contraction; SBP, systolic blood pressure; SpO₂, peripheral oxygen saturation; WBVE, whole-body vibration.

The effects of MVC + WBVE, MVC, and WBVE on the parameters of musculoskeletal functions are given in Table 2. No significant differences were found in HS, one leg standing balance (OLSB, right and left), T_{STS} , and P_{STS} after the 3 different sessions.

A significant increase in SR was found after MVC + WBVE, MVC, and WBVE ($P < .01$, $P < .05$, and $P < .01$, respectively), while a significant decrease was found only in T_{SCT} after WBVE ($P < .01$). By contrast, a significant increase in P_{SCT} was found only after WBVE ($P < .01$).

Discussion

Obese individuals are reported to have a decrease in MSMF,² and this finding was also confirmed by Bonney et al²⁸ who have found that overweight and obese girls have decreased MSMF in comparison to normal-weight peers. Since the reduction of MSMF negatively affects the execution of the common daily activities of obese patients, the improvement in MSMF throughout “adapted” physical activity is highly recommended.²⁸

The present study was aimed to analyze the acute effects of 3 different training sessions (MVC plus WBVE, MVC alone, and WBVE alone) on the cardiorespiratory and MSMF of obese male adolescents. No significant changes were observed in SBP, DBP, MAP, and SpO₂ after the 3 tests, and only a significant HR increase being observed after MVC + WBVE ($P < .01$) and MVC alone ($P < .05$).

Taking into account the lack of WBVE effect on HR, this type of exercise may represent a nonimpact, viable, and safe solution in populations with increased cardiovascular risk, such as the obese population. Furthermore, the reflex muscle contractions generated by mechanical vibrations could improve the venous return that offsets the need of increased post-exercise HR to the level observed during inactive recovery.²⁹

As far as musculoskeletal functions are concerned, none of the 3 exercise protocols improved HS, OLSB, and STS time and power. A significant increase in SR was found after MVC + WBVE, MVC alone, and WBVE alone, the effect on flexibility being more evident with WBVE alone. As reported in a meta-analysis describing the effects of vibration on flexibility, this type of exercise appeared to be associated with additive improvements in flexibility.³⁰

It is of interest that a significant decrease in T_{SCT} , indicating an improvement in the stair climbing performance, was found only after WBVE ($P < .01$). This WBVE exclusive effect on T_{SCT} determined a significant increase in lower limb muscle power (ie, P_{SCT}).

In line with this observation, Dickin et al³¹ reported a significant increase in walking speed, stride length, and dynamic ankle range of motion in adults with cerebral palsy exposed to WBVE. Annino et al³² suggested that strength performance could be related to the decrease in the antagonist activity as a consequence of the vibratory stimulus, capable to modify the corticomotor excitability via spinal reflexes³³ and to favor an increase in the muscle flexibility and in the speed of contraction in explosive movements.³²

Table 2. Effects of MVC + WBVE, MVC, and WBVE on Musculoskeletal Functions.

	MVC + WBVE (Intragroup Comparison)			MVC (Intragroup Comparison)			WBVE (Intragroup Comparison)		
	Baseline Median (IQR)	After Median (IQR)	P Value	Baseline Median (IQR)	After Median (IQR)	P Value	Baseline Median (IQR)	After Median (IQR)	P Value
HS (kgf)	36.5 (31.8-46.7)	38.3 (32.7-43.0)	.59	38.0 (32.3-47.2)	38.3 (32.7-51.0)	.47	36.7 (33.3-41.2)	36.0 (33.0-42.0)	.59
OLSB right (s)	60.0 (51.1-60.0)	60.0 (60.0-60.0)	.50	60.0 (60.0-60.0)	60.0 (60.0-60.0)	1.00	60.0 (60.0-60.0)	60.0 (60.0-60.0)	1.00
OLSB left (s)	60.0 (44.3-60.0)	60.0 (54.8-60.0)	.50	60.0 (60.0-60.0)	60.0 (42.4-60.0)	.50	60.0 (60.0-60.0)	60.0 (53.2-60.0)	1.00
SR (cm)	0.0 (-6.5-3.5)	1.3 (-1.0-5.5)	<.01	4.3 (-1.5-5.5)	6.5 (1.5-8.5)	<.05	1.0 (-2.5-4.5)	4.5 (3.0-7.5)	<.01
T _{SCT} (seconds)	2.84 (2.30-2.95)	2.98 (2.41-3.05)	.19	2.73 (2.36-3.18)	2.93 (2.40-3.10)	.23	2.92 (2.47-3.04)	2.85 (2.42-2.95)	<.01
P _{SCT} (W)	781.9 (698.6-841.1)	770.7 (725.2-809.0)	.20	714.8 (652.2-828.7)	719.8 (645.5-785.7)	.15	744.0 (700.1-809.5)	749.7 (729.5-833.0)	<.01
T _{STS} (seconds)	15.4 (14.5-17.6)	15.0 (13.3-17.2)	.15	15.4 (13.3-16.9)	15.2 (13.5-16.5)	.95	14.6 (14.3-15.3)	14.7 (14.3-16.6)	.55
P _{STS} (W)	220.3 (202.0-288.4)	251.4 (224.1-279.9)	.31	242.4 (203.1-305.4)	236.7 (206.1-301.3)	.74	251.1 (205.6-305.6)	239.2 (199.3-312.4)	.74

Abbreviations: HS, handgrip strength; IQR, interquartile range; OLSB, one leg standing balance; MVC, maximal voluntary contraction; SR, sit-and-reach; WBVE, whole-body vibration. T_{SCT}, time of stair climbing test; P_{SCT}, power of stair climbing test; T_{STS}, time of sit-to-stand test; and P_{STS}, power of sit-to-stand test.

Taking into account the lower increasing effect of WBVE on HR and the positive effect on flexibility (SR), T_{SCT}, and P_{SCT} compared with MVC and MVC + WBVE, WBVE can be considered suitable for individuals who need improvement in their MSMF without overloading joints, such as the obese patients who have frequently limitations and difficulty in performing physical exercises.²⁰ Considering the negative impact of MVC on joints, which are usually compromised in obese individuals,³⁴ WBVE could be taken into consideration in rehabilitative programs for obesity.

Some limitations should be however mentioned. First, since only a small number of obese individuals were recruited in the present study, the results should be cautiously interpreted. Second, the recruitment of only obese male adolescents cannot allow to extend this information to the other gender, since gender-related differences are reported to affect all MSMF tests.²

In conclusion, the preliminary results of the present study seem to suggest that WBVE can be considered as a nonimpact, viable, and safe type of exercise, capable to positively influence cardiorespiratory and MSMF. The positive effects of WBVE might be useful in the physical rehabilitation of obese individuals as a way for gradually introducing physical exercise into their lives and for contributing to maintain an independent lifestyle.

Authors' Note

A.S., C.R.S.G., and M.B.F. designed the study. G.T., R.D.M., and C.R.S.G. enrolled the participants and performed the tests. S.T., D.S.C., E.M.M., and L.P.D. elaborated the database and analyzed the data. A.S., C.R.S.G., M.B.F., and S.T. wrote the manuscript. R.T. and M.B.F. contributed to the interpretation and discussion writing. D.S. contributed to the statistical analysis. All authors contributed to the revision of manuscript. The present study was approved by the ethical committee of Istituto Auxologico Italiano (research project code: 01C727, acronym: VIBRAGHOBES). Written informed consent was obtained from the parents of all patients.

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Declaration of Conflicting Interests


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