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INNOVATIVE METHODOLOGY

Can whole body vibration exercises promote improvement on quality of life and on chronic pain level of metabolic syndrome patients? A pseudorandomized crossover study

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Paineiras-Domingos LL, Sá-Caputo DC, Francisca-Santos A, Reis-Silva A, Carvalho-Lima RP, Neves MF, Xavier VL, Quinart H, Boyer FC, Sartorio A, Taiar R, Bernardo-Filho M. Can whole body vibration exercises promote improvement on quality of life and on chronic pain level of metabolic syndrome patients? A pseudorandomized crossover study. *J Appl Physiol* 128: 934–940, 2020. First published February 20, 2020; doi:10.1152/japplphysiol.00068.2019.—Quality of life (QoL) is one of the most important health outcome concepts expressed subjectively. Chronic pain (CP) is an unpleasant sensory and emotional experience associated with actual or potential tissue damage. Taking into account the poor QoL and the CP already described in metabolic syndrome (MSy) individuals, this study aimed to evaluate the effects of whole body vibration exercises (WBVE) on these parameters in this population. Thirty-three MSy patients were divided in *subgroups A* [whole body vibration exercise group (WBVeG), $n = 17$, 15 females/2 males, 61.1 ± 8.4 yr] and *B* (control group, $n = 16$, 14 females/2 males, 58.2 ± 9.1 yr). *Subgroup A* performed 10 sessions (2 times/wk) of WBVE (18 min/session, with a frequency from 5 up to 14 Hz and a peak-to-peak displacement of 2.5, 5.0, and 7.5 mm) on a side-alternating vibrating platform (VP). *Subgroup B* did the same protocol, but the VP was turned off. The individuals answered the World Health Organization Quality of Life bref (WHOQoL-bref) questionnaire before the first and after the 10th session. The chronic pain level (CPL) was measured by a numeric rating scale (0–10) before and at the end of each session. Significant improvements were found in physical health ($P = 0.05$) and psychological health ($P = 0.04$) domains of WHOQoL-bref in WBVeG. A significant acute reduction of the CPL was found in the WBVeG after the protocol, considering the first session and at the last session. WBVE marginally improved physical health and psychological health and decrease the CPL in acute interventions.

NEW & NOTEWORTHY Metabolic syndrome patients experience poor quality of life, frequently associated with lack of exercise and bad dietary habits. Additionally, factors such as obesity, neuromusculoskeletal impairment, and peripheral endothelial dysfunction result in a chronic pain level. Whole body vibration exercise might represent a suitable physical therapy, since it is easy to perform, low cost, safe, and capable of promoting an improvement of quality of life and reducing chronic pain level during acute interventions in metabolic syndrome individuals.

chronic pain; exercise; metabolic syndrome; quality of life; vibration

INTRODUCTION

The metabolic syndrome (MSy) presents interrelated risk factors for cardiovascular disease (CVD) associated with abdominal fat accumulation and resistance to insulin (45). These conditions include dysglycemia, raised blood pressure, elevated triglyceride levels, low high-density lipoprotein cholesterol levels, obesity (particularly central adiposity; see Ref. 1), and an increase in waist circumference (WC; see Ref. 9). Studies had previously shown that MSy individuals experience significant poor quality of life (QoL; see Refs. 17, 20, and 47), which is frequently associated also with lack of exercise and bad dietary habits (35, 59, 60). In this sense, lifestyle interventions favoring physical activity in individuals with MSy are reported to be associated with an improvement of QoL scores (45). Amiri et al. (2, 3) reported the negative impact of the MSy conditions on the worsening of QoL, more specifically in the domains of physical health.

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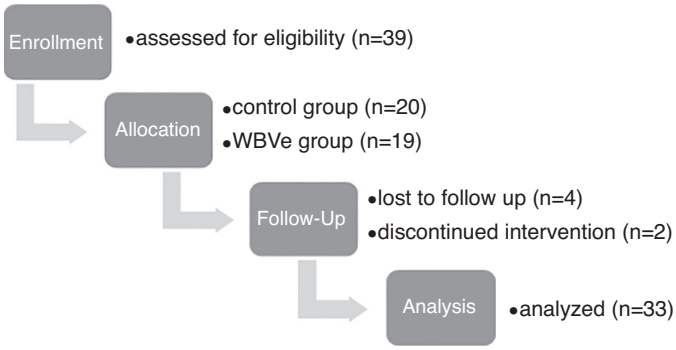

Fig. 1. Flow of participants through each stage of the study. WBVe, whole body vibration exercise.

World Health Organization Quality of Life (WHOQoL) proposed a questionnaire to evaluate the QoL (57). WHOQoL-bref (42) is a short version of the WHOQoL questionnaire. According to Fleck et al. (15), who validate the WHOQoL-bref in Brazil, this questionnaire contains 26 items and comprises the following four domains: physical health, psychological health, social relationship, environment and the overall QoL/health (39).

Pain has been considered one of the primary causes of physical disability, with significant impacts on the QoL (12). The experience of pain is modulated by complex endogenous systems that both facilitate and inhibit pain (52). Additionally, the dysfunction of pain inhibitory systems increases with age (38).

MSy individuals generally present a higher risk of CVD; Lteif et al. (34), Matsuzawa et al. (36), and Taher et al. (56) reported an association between MSy and peripheral endothelial dysfunction (PED) in men with chest pain and/or CVD risk increased. This finding can be allowed earlier and more intensive management of risk factors. Shin (50) pointed out that the accumulation of MSy conditions appears to be associated with a higher intensity of knee pain, independently of the weight. Loevinger et al. (33) have linked the MSy and chronic pain, fatigue, sleep disturbances, disabilities, and habitual physical inactivity, which are common in both conditions. Briggs et al. (4) reported that obesity has been observed in MSy patients additionally with other morbidities, including poor cardiorespiratory fitness, poor QoL, and reports of musculoskeletal pain.

Considering that obesity, neuromusculoskeletal impairment, and PED are constantly present in MSy, the authors suggested that conditions associated with these symptoms are a poor QoL and an increase of chronic pain level (CPL; see Refs. 10, 13, 20, 31, and 32).

Several authors (7, 41, 46) have proposed whole body vibration exercises (WBVE) as a modality of intervention to improve physiological, functional, and clinical parameters, which could directly improve QoL and pain.

Inserted in different rehabilitation programs, the WBVE are a type of physical activity that might increase the muscle strength and performance in athletes, healthy individuals, and elderly (16, 30, 58). WBVE are produced when individuals are exposed to mechanical vibrations generated in a vibrating platform (VP). Biomechanical parameters, such as frequency, peak-to-peak displacement (PPD), acceleration peak, number of sessions, number of bouts, time of execution of the exercise and time to rest, session numbers, periodicity of sessions, positioning of the individual on the base of the VP, association with other interventions/exercises, and the use and type of footwear or barefoot individuals, must be established (6, 41, 43, 44).

Considering that WBVE has been recently reported to improve the QoL in individuals with chronic obstructive pulmonary disease (5), in healthy (16) and elderly people (48), and decrease the CPL in some populations (26), other authors also have found this outcome (7, 46) in MSy individuals, however, only in acute intervention.

In line with previous investigations developed by our group (7, 41, 46) using the same protocol, this current study aimed to identify the effects of the WBVE on the QoL and on the CPL [the acute effect in the first session (FS), the acute effect in the last session (LS), and the cumulative effect] in MSy individuals. The hypothesis of this study is that WBVE can improve QoL and reduce of the CPL of MSy individuals.

Table 1. *Baseline descriptive characteristics of the MSy individuals (CG and WBVeG)*

	Control Group (n = 16, 14 female/2 male) Mean ± SD	WBV Exercise Group (n = 17, 15 female/2 male) Mean ± SD	P Value
Age, yr	58.20 ± 9.11	61.10 ± 8.39	0.38
Stature, m	1.61 ± 0.08	1.63 ± 0.07	0.74
Body mass, kg	87.43 ± 18.02	83.65 ± 16.27	0.70
BMI, kg/m^2	32.79 ± 6.94	31.16 ± 5.35	0.55
WC, cm	108.3 ± 15.55	103.0 ± 11.09	0.32
Total COL, mmol/L	212.10 ± 41.10	213.80 ± 36.66	0.99
HDL, mmol/L	55.63 ± 12.66	52.41 ± 11.68	0.67
TG, mmol/L	154.10 ± 55.67	168.50 ± 85.12	0.81
FBG, mmol/L	114.0 ± 38.17	113.20 ± 32.54	0.93
SBP, mmHg	126.3 ± 14.05	131.8 ± 15.93	0.23
DBP, mmHg	70.31 ± 10.76	71.59 ± 10.90	>0.99
WHOQoL-bref (global score)	68.86 ± 15.15	73.53 ± 13.49	0.40
	Mean ± SE	Mean ± SE	
NRS (score 0–10)	2.68 ± 0.71	2.88 ± 0.74	0.90
	%	%	
Hypertension	93.75	94.12	
Diabetes	37.5	41.18	
Smoker	6.25	5.88	
Alcohol intake	12.5	11.76	
Medications			
Antihypertensive	81.25	76.50	
Diuretics	37.50	52.95	
Gastric protector	18.75	17.64	
Oral hypoglycemic agent	18.75	29.41	
Antiplatelet agent	6.25	5.88	
Anxiolytic	0	5.88	

n, No. of subjects. MSy, metabolic syndrome; CG, control group; WBVeG, whole body vibration exercise group; WBV, whole body vibration; BMI, body mass index; WC, waist circumference; COL, cholesterol; HDL, high-density lipoproteins; TG, triglycerides; FBG, fasting blood glucose; SBP, systolic blood pressure; DBP, diastolic blood pressure; WhoQoL-bref, World Health Organization Quality of Life bref questionnaire; NRS, numeric rating scale. $P \leq 0.05$.

Table 2. *Four domains and the global score of the WHOQoL-bref of MSy individuals*

Domains	CG Before Protocol	CG After Protocol	*P* Value	WBVeG Before Protocol	WBVeG After Protocol	*P* Value
Physical health	20.21 ± 5.04	22.07 ± 2.64	0.15	20.35 ± 3.90	22.18 ± 4.39	0.05*
Psychological health	18.43 ± 4.63	19.64 ± 4.70	0.12	18.65 ± 4.67	20.59 ± 5.16	0.04*
Social relationships	8.28 ± 3.64	9.35 ± 2.62	0.41	9.88 ± 3.01	9.41 ± 2.69	0.39
Environment	21.93 ± 4.34	23.79 ± 2.35	0.24	23.71 ± 3.17	23.24 ± 2.33	0.96
Global score	68.86 ± 15.15	74.86 ± 10.49	0.07	73.53 ± 13.49	74.47 ± 10.09	0.61

Data are means ± SD. WhoQoL-bref, World Health Organization Quality of Life bref questionnaire; MSy, metabolic syndrome; CG, control group; WBVeG, whole body vibration exercise group. Intragroup *P* values are shown. *$P \leq 0.05$.

MATERIALS AND METHODS

All of the different phases of this intervention were based in the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) statements (11), a tool specifically developed to guide standardized reporting of nonrandomized controlled trials.

This investigation is a cross-sectional and longitudinal (10 wk) study approved by the Ethics Committee on research in humans of the Hospital Universitário Pedro Ernesto (HUPE), Universidade do Estado do Rio de Janeiro (CAAE 19826413.8.0000.5259). Clinical trial registration numbers were as follows: Research Ethics Committee with the number CAAE 54981315.6.0000.5259; register in the Registro Brasileiro de Ensaios Clínicos with the number RBR 2bghmh and UTN: U1111–1181–1177.

The procedures of this study were carried out in Laboratório de Vibrações Mecânicas e Práticas Integrativas. The principles embodied in the Declaration of Helsinki were followed.

Participants

The participants were recruited from September 2014 up to October 2016 in the Departamento de Clínica Médica of the HUPE, diagnosed with MSy by an endocrinologist according to the International Diabetes Federation. After this recruitment, the MSy individuals were pseudorandomized and allocated to two age- and sex-matched subgroups as follows: the whole body vibration exercise group (WBVeG) and the control (CG) group. Individuals were pseudorandomized according to the sequence of entrance in the study.

The inclusion criteria were to be female or male individuals with MSy over 40 yr old.

The exclusion criteria were individuals with: *1*) very high blood pressure (≥180 × 110 mmHg); *2*) cardiovascular disease (coronary artery disease or stroke); *3*) neurological, musculoskeletal, or rheumatologic diseases that do not permit performance of the WBVE; and *4*) those individuals who refused to sign the informed consent form for participation.

Interventions

The individuals of *subgroup A* (WBVeG) were positioned on the side-alternating VP (Novaplate; Fitness Evolution, São Paulo, Brazil). In the first session, the individuals sat in a chair in front of the VP with the hands on their knees and the feet positioned on the base of the VP in three positions (PPD of 2.5, 5.0, and 7.5 mm) at a frequency of 5 Hz as in previous studies performed in patients with MSy (7, 41, 46). The work time was 1 min and 1 min rest in each position. This procedure was done three times with the total time of WBV exercise of 18 min. From the second to the tenth (last) session, individuals were subjected to the same protocol; however, they were standing on the base of the VP with knees flexed at 130° (squatting position; see Ref. 54). The frequency used in the second session was 6 Hz and 14 Hz in the last session. The individuals of *subgroup B* (CG) were in all the same positions for the same time of the individuals of the WBVeG; however, the VP was turned off.

Sample size

The sample size determination was developed by the formula

$$n = \left(\frac{Z\alpha/2 \times \delta}{E} \right)^2$$

where n is the sample size; $Z\alpha/2$ is the critical value for the desired degree of confidence, usually 1.96 (95%); δ is the population SD of the variable; and E is the SE, usually ±5% proportion of cases (absolute precision) or ±5% of the mean (37).

The sample size determined was 10 individuals in each group, considering a previous study that assessed the QoL of MSy individuals (7). In this current study 39 patients with MSy were recruited. Six were excluded in the follow up, resulting in 33 MSy individuals included in the protocol (WBVeG = 17 and CG = 16).

Measurements

Anthropometric data and other characteristics of the MSy individuals. The individuals were evaluated in basal conditions. Anthropometric data (body mass and height) were measured. Information regarding possible concomitant diseases (such as hypertension, diabetes mellitus, or others), smoking, and the use of medications were collected.

WC was measured by the supervisor, using as reference the midpoint between the last rib and the iliac crest. This measurement was performed before and after the protocol following previous studies (7, 41, 46).

The WHOQoL-bref questionnaire. All of the individuals filled the WHOQoL-bref questionnaire before the FS and after the tenth session (LS). The version in Portuguese (Brazil) of WHOQoL-bref was used (51). Although this instrument would be filled by the individuals, it was decided to use direct interviews because of the frequent difficulty in reading and problems with vision and with low level of schooling in the populations evaluated (51). This questionnaire is made up of 26 questions, separated in the following four domains: physical health, psychological health, social relationships, and environment.

Table 3. *Paired analysis of CPL in CG and WBVeG*

CPL	CG Before Protocol	CG After Protocol	*P* Value	WBVeG Before Protocol	WBVeG After Protocol	*P* Value
Acute effect FS	2.68 ± 0.71	2.81 ± 0.72	0.75	2.88 ± 0.74	2.47 ± 0.65	0.03*
Acute effect LS	1.75 ± 0.64	1.93 ± 0.70	0.50	2.76 ± 0.60	1.29 ± 0.54	0.001*
Cumulative effect	2.68 ± 0.71	1.75 ± 0.64	0.25	2.88 ± 0.74	2.76 ± 0.60	0.78

Data are means ± SE. CG, control group; CPL, chronic pain level; WBVeG, whole body vibration exercise group; FS, first session; LS, last session. *$P \leq 0.05$, intragroups.

The first two questions evaluate the self-perceived QoL (denominated WHOQoL-1) and satisfaction with health (denominated WHOQOL-2; see Ref. 15).

Each domain has questions, and the scores vary between one and five. The WHOQoL-bref contains the following five Likert style response scales: "very poor to very good" (evaluation scale), "very dissatisfied to very satisfied" (evaluation scale), "none to extremely" (intensity scale), "none to complete" (capacity scale), and "never to always" (frequency scale) (14).

Perera et al. (42) described the domains in WHOQoL-bref, according to the WHO group as: *1*) the physical domain reflects individuals' perceptions of their physical health; *2*) the psychological health domain involves individuals' perceptions of their cognitive and affective states; *3*) the social domain refers to individuals' subjective evaluations of interpersonal relationships, social support, and sexual activity, and *4*) the environment domain reflects individuals' perceptions of salient aspects of the environment, such as physical safety and security, financial resources, and accessibility and quality of health care.

Chronic pain level. Several instruments have been used to assess the level of pain in individuals with chronic diseases. Among the most used, we can highlight the Visual Analog Scale (21) and the Numeric Rating Scale (NRS) (61). In this current study, the CPL was assessed by the NRS, a subjective measure in which individuals rate their pain (61) on an 11-point numerical scale, from 0 to 10, where 0 is no pain and 10 is the worst pain imaginable. Commonly used NRS are 11 point (0–10), 21 point (0–20), and 101 point (0–100) (60). Over 50% of subjects rated their pain in multiples of 10 (equivalent to an 11-point scale), and, according Kalita et al. (22), the NRS score classifies the pain as severe (7–10), moderate (4–6), mild (1–3), and no pain (0).

The MSy individuals reported their CPL before and after the 10 sessions. In the basal condition, all of the individuals of this study reported a mild CPL. The analysis of the CPL was performed before and after the protocol considering the following three moments: *1*) the acute effect of WBVE in the FS, *2*) the acute effect of WBVE in the LS, and *3*) the cumulative effect of WBVE, analyzing the basal values of the FS vs. the LS.

Statistical Methods

Results were analyzed with the GraphPad Prism 6 program, and $P \leq 0.05$ was considered statistically significant. Descriptive data, QoL domains, and CPL were expressed by percentage (%), mean, SD, or SE. The Shapiro-Wilk test was used to assess the distribution of the variables and then, for variables without normal distribution, Wilcoxon rank test (before and after protocol) and Mann-Whitney *U*-test (intergroups) were used.

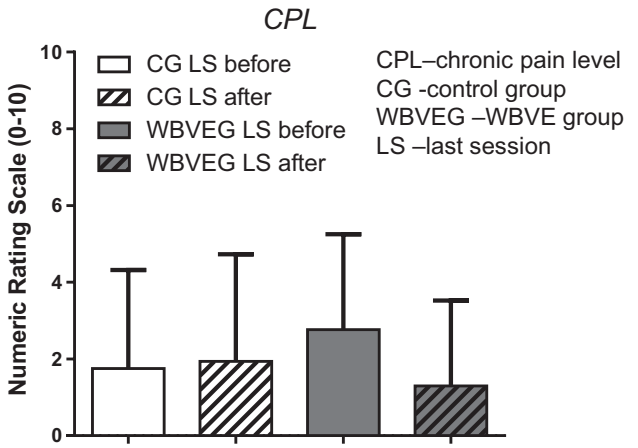

Fig. 3. Acute effect of the chronic pain level (CPL) in the last session (LS). CG, control group; WBVEG, whole body vibration exercise group.

RESULTS

Figure 1 shows the flow of participants through each stage of the study. Thirty-nine individuals were allocated in a nonrandomized way in both groups. However, throughout the study, four individuals in the CG did not complete the protocol, while two individuals in the WBVeG discontinued their participation.

Table 1 shows the descriptive data (baseline) with anthropometric evaluation, some characteristics, and the variables of interest of all individuals included in this current study. No significant differences were found between the two subgroups ($P > 0.05$).

Table 2 shows the results of the domains of the WHOQoL-bref in control (CG) and intervention (WBVeG) groups before and after the 10 sessions of the study protocol. Significant improvements were found in physical health ($P = 0.05$) and psychological health ($P = 0.04$) domains in individuals of

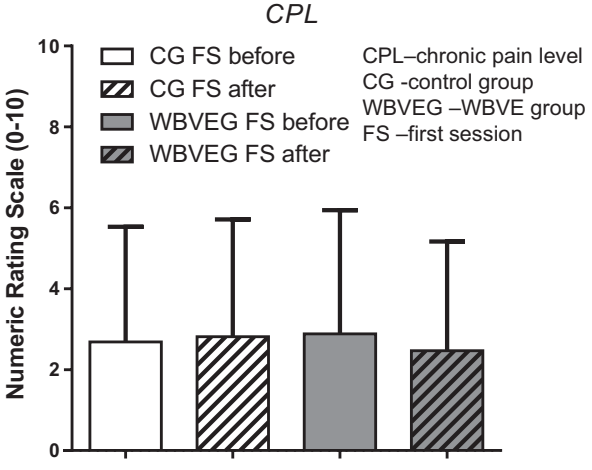

Fig. 2. Acute effect of the chronic pain level (CPL) in the first session (FS). CG, control group; WBVEG, whole body vibration exercise group.

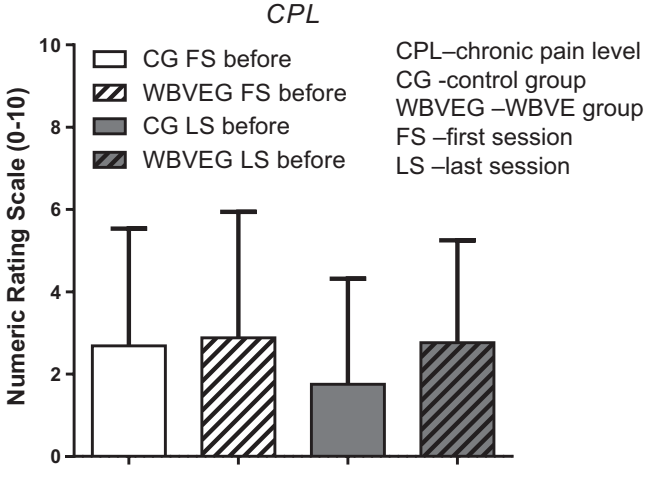

Fig. 4. Cumulative effect of the chronic pain level (CPL). CG, control group; FS, first session; LS, last session; WBVEG, whole body vibration exercise group.

WBVeG. No significant changes in any domains were found in CG.

Table 3 shows the analysis of the CPL of the CG and WBVeG in the following three moments: *1*) the acute effect in the FS, *2*) the acute effect in the LS, and *3*) the cumulative effect (basal of the FS vs. basal of the LS). With the use of the NRS score (23), evaluated before and after the sessions, both groups presented mild CPL in the tree analysis. Significant decrease of the CPL was found in MSy individuals of the WBVeG, as an acute effect (FS, $P = 0.03$ and LS, $P = 0.001$). Regarding the cumulative effect in both groups, there were no significant changes in CPL.

Figures 2 (FS), 3 (LS), and 4 (cumulative effect) show the CPL between groups (CG × WBVeG) before and after the WBVE protocol.

DISCUSSION

Different studies have recently associated MSy, QoL, and CPL (13, 20, 45). Because MSy is frequently associated with obesity and overweight, the concomitant poor QoL and CPL can frequently hamper these patients in performing the normal daily activities (19, 58).

Interventional studies evaluating lifestyle changes of MSy individuals have shown significant improvements in QoL (22, 24, 31, 49, 53). Malhotra et al. (35) studied the lifestyle-related factors associated with MSy and their impact on functioning and QoL in patients with bipolar disorder and schizophrenia. These authors concluded that the presence of MSy was associated with lower scores on the domains of physical health and psychological health. Furthermore, other studies on patients with MSy (without known psychiatric disorders) demonstrated significant poor QoL associated with various lifestyle factors, such as lack of exercise and bad dietary habits (58, 59).

Malhotra et al. (35) and Heesterbeek et al. (18) have recently demonstrated the effects of different forms of passive exercise, including WBVE, on QoL, activities of daily living, cognitive and physical functioning, and care burden of institutionalized patients with dementia. These authors hypothesized that passive exercise, such as WBVE, might be a feasible and efficient alternative vs. physical activity for individuals unable of or staying in conditions to practice active interventions.

In agreement with this last idea, the current study demonstrates positive effects of WBVE on physical health and psychological domains of the QoL in individuals with MSy (Table 2). In line with the findings of the present study, Carvalho-Lima et al. (7) have described a significant QoL improvement in the physical and social relationships domain of the WHOQoL-bref after the WBVE in a small group of MSy individuals.

As far as the CPL is concerned, Hunter and Riordan (19) reported a marked pain-related functional impairment characterized by difficulty with many aspects of daily activity in adults with arthritis. Świerkosz and Nowak (55), demonstrated that a combination of rehabilitation exercises and soft manual therapy is effective in reducing low back pain in adolescents and enhancing the somatic facet of the QoL.

By studying the effects of exercise on the CPL, Koltyn et al. (27) reported an attenuation of pain following exercise in healthy young adults. Various modes of exercise have been studied, including aerobic exercise, resistance exercise, and isometric exercise (8, 28, 29, 40).

In the present study, a gentle mechanical vibration resulting from WBVE is associated with an acute positive effect (reduction vs. basal) on the CPL (FS and LS) in the WBVeG. The study protocol adopted in the present study is in line with the recommendation by Kaur (25) who underlined the need to increase slowly in intensity and duration, starting from a low intensity in sedentary subjects (such as those with MSy and/or obesity), to avoid excessive fatigue, muscle pain, strains, or injuries.

Although the current work reports relevant new information, it is necessary to underline some limitations in it. Some factors that could influence the results were not considered, such as the type and the level of the physical activity, the presence of CVD risk factors, information on the presence of liver steatosis, gout, atrial fibrillation, high-sensitivity C-reactive protein, chronic kidney disease, or family history of stroke.

Furthermore, the biomechanical characteristics of the WBVE did not consider the individuals' body mass, and the tailoring of intervention was not based on patient comorbidities or tolerance.

Because of the above limitations in the present study protocol, future studies are warranted to evaluate the possible interfering role on WBVE effects of *1*) body mass, *2*) physical activity, *3*) presence of CVD risk factors, and *4*) comorbidities or tolerance of the individuals. Additionally, future studies should also replicate the procedure, with adequate randomization to confirm or refute these results.

Conclusions

In conclusion, WBVE in MSy individuals is capable of significantly *1*) promoting an improvement of QoL considering the physical and psychological domains, as a cumulative effect, and *2*) reducing CPL in the acute interventions in the first and in the last sessions. Therefore, WBVE would represent a suitable and useful physical activity that could be included in health programs for MSy individuals, following the WHO recommendations.

GRANTS

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

L.L.P.-D. and M.B.-F. conceived and designed research; L.L.P.-D., A.F.-S., and A.R.-S. performed experiments; L.L.P.-D. and R.T. analyzed data; L.L.P.-D. prepared figures; L.L.P.-D., A.R.-S., M.F.T.N., H.Q., F.C.B., A.S., R.T., and M.B.-F. edited and revised manuscript; L.L.P.-D., D.d.C.S.-C., A.F.-S., A.R.-S., R.P.C.-L., M.F.T.N., V.L.X., F.C.B., A.S., R.T., and M.B.-F. approved final version of manuscript; D.d.C.S.-C., V.L.X., and M.B.-F. interpreted results of experiments; D.d.C.S.-C., R.P.C.-L., and M.F.T.N. drafted manuscript.

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