Turk J Phys Med Rehab 2022;68(1):117-125
DOI: 10.5606/tftrd.2022.7063
Available online at www.turkishjournalpmr.com

Original Article

The effect of adding whole-body vibration exercises to home exercise program on muscle strength in patients with post-polio syndrome

Mahir Topaloğlu[1], Ayşegül Ketenci[2], Barış Baslo[3], Türker Şahinkaya[4]

[1]Department of Physical Medicine and Rehabilitation, Koç University Hospital, Istanbul, Turkey
[2]Department of Physical Medicine and Rehabilitation, Istanbul University, Istanbul Faculty of Medicine, Istanbul, Turkey
[3]Department of Neurology, Istanbul University, Istanbul Faculty of Medicine, Istanbul, Turkey
[4]Istanbul University, Istanbul Faculty of Medicine, Sports Medicine, Istanbul, Turkey

Received: July 15, 2020 **Accepted:** July 08, 2021 **Published online:** March 01, 2022

ABSTRACT

Objectives: This study aims to understand the effectiveness of whole-body vibration (WBV) exercises performed with home exercise program in patients with post-polio syndrome (PPS) in terms of muscle strength, fatigue, the quality of life, and laboratory parameters.

Patients and methods: Between October 2015 and March 2016, a total of 14 patients (7 males, 7 females; mean age: 45.1±6.6 years; range, 34 to 57 years) who were diagnosed with PPS were included in the study. The patients were randomized into two groups: the first group received WBV, home exercise program and patient education while the second (control) group received home exercise program and patient education. The patients were evaluated by knee isometric and isokinetic peak torque, Fatigue Severity Scale (FSS), Fatigue Impact Scale (FIS), Nottingham Health Profile (NHP), serum creatine kinase, aspartate aminotransferase, and alanine aminotransferase at baseline and at the end of the treatment.

Results: At the end of the treatment, the exercise program administered to the patients was found to be effective in increasing knee muscle strength in PPS patients ($p<0.05$). This difference was more apparent on the sequela side, isometric extension peak torque in the group with WBV. There was no significant change in the markers of muscle damage or NHP in both groups.

Conclusion: Inclusion of WBV in home exercise program in PPS patients does not seem to be superior, except for reducing the effect of fatigue on the patient's life.

Keywords: Exercise, muscle strength, poliomyelitis, post-polio syndrome, whole-body vibration.

In 1875, the term post-polio syndrome (PPS) was described by Jean-Martin Charcot;[1] however, it took more than a hundred years for the term to become widely accepted.[1]

Post-polio syndrome is characterized by the appearance of neurological deficits after a period, commonly at least 15 years after the initial infection. It may present with a broad range of symptoms from rather localized progressive muscle weakness, atrophy, limb fatigue, myalgia, arthralgia to generalized fatigue and dysphagia. These symptoms cause a significant impact on patients' quality of life (QoL). The reported of prevalence for PPS among polio patients is somewhat inconsistent, varying between 20 to 85%, depending on the diagnostic criteria used.[2]

Although its preponderance, the PPS remains a less explained topic. Individuals with PPS usually have little option for exercise, as it may exacerbate

Corresponding author: Mahir Topaloğlu, MD. Koç Üniversitesi Hastanesi, Fiziksel Tıp ve Rehabilitasyon Kliniği, 34010 Zeytinburnu, İstanbul, Türkiye.
e-mail: mahir_topaloglu@hotmail.com

Cite this article as:
Topaloğlu M, Ketenci A, Baslo B, Şahinkaya T. The effect of adding whole-body vibration exercises to home exercise program on muscle strength in patients with post-polio syndrome. Turk J Phys Med Rehab 2022;68(1):117-125.

©2022 All right reserved by the Turkish Society of Physical Medicine and Rehabilitation
This is an open access article under the terms of the Creative Commons Attribution-NonCommercial License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes (http://creativecommons.org/licenses/by-nc/4.0/).

PPS symptoms such as pain, fatigue, and muscle weakness.[3] Although PPS is a syndrome in which pharmacological and non-pharmacological treatments are applied for treatment, data on non-pharmacological treatments are limited.

In Cochrane review published in 2015, Koopman et al.,[4] reported that data on the effectiveness of muscle strengthening in PPS was controversial. In two studies, strengthening thumb muscles and applying static magnetic field were reliable and effective. There are no available data on the effectiveness of exercise for major muscle groups.[4]

In a systematic review analyzing the effectiveness of exercise in neuromuscular diseases, PPS studies were also examined. In the review, data on performing muscle strengthening exercises and aerobic exercise alone or together have been reported to be insufficient.[5]

Whole-body vibration (WBV) has become a popular form of exercise therapy, particularly among elderly individuals, in past decades. It has been studied in neurological populations with del Pozo-Cruz et al.[6] conducting a systematic review presenting varying results pertaining to impairments, activity limitations, and health-related QoL. Limited data are available in the literature about the WBV in patients with PPS.[6]

In the present study, we aimed to evaluate the effectiveness of the exercises and WBV exercises, which are promising methods in the prevention of progressive muscle weakness, fatigue and improvement of the activities of daily living in PPS patients. Whether these programs damage the motor units in PPS patients was examined through laboratory parameters (aspartate aminotransaminase [AST], alanine aminotransferase [ALT], and creatine kinase [CK]). The main goal of these programs was to increase muscle strength and improve QoL, while not causing damage to the existing motor units and increasing the level of fatigue through the exercise programs we used. Therefore, we evaluated the effectiveness of WBV exercises performed with home exercise program and patient education in patients with PPS on muscle strength, fatigue and QoL. We compared these exercises with home exercise program and patient education alone.

PATIENTS AND METHODS

This single center prospective, randomized-controlled study was conducted at Istanbul University, Istanbul Faculty of Medicine, Department of Physical Medicine and Rehabilitation between October 2015 and March 2016. A total of 14 patients (7 males, 7 females; mean age: 45.1±6.6 years; range, 34 to 57 years) who were diagnosed with PPS according to the 2001 March of Dimes criteria[7] were included in the study. Inclusion criteria were as follows: patients who were diagnosed with poliomyelitis based on electrophysiologically-demonstrated lower motor neuron involvement, aged between 18 and 60 years, having knee flexion and extension muscle strength of >3/5 according to the manual muscle strength evaluation, and walking 300 m alone with or without an assistive device. Exclusion criteria were as follows: epilepsy, the presence of a cardiac pacemaker, previous hip or knee prosthesis, bleeding diathesis, uncontrolled diabetes, obesity (body mass index [BMI] ≥30 kg/m^2) and pregnancy. A written informed consent was obtained from each patient. The study protocol was approved by the Istanbul University, Istanbul Faculty of Medicine Ethics Committee (2015/1262). The study was conducted in accordance with the principles of the Declaration of Helsinki. The study was registered at ClinicalTrials.gov PRS (NCT04387864).

The patients were enumerated according to their admission order to our outpatient clinic and randomized into two groups by software (Figure 1). Home exercise and patient training program were administered to the control group, while WBV exercise twice a week, in addition to this program, was administered to the study group.

Evaluation and follow-up

1. Electrophysiological evaluation

The patients underwent conventional needle electromyography to demonstrate lower motor neuron involvement and to exclude conditions similar to PPS symptoms.

2. Muscle strength assessment

In our study, knee extensor and flexor muscle strengths were measured using a CybexTM (Humac) Norm 350 (Cybex Norm, Lumex Inc., NY, USA) computed isokinetic dynamometer device. Usually, the same time of day was preferred. Each patient underwent a total of two measurements before and after the study. Care was exerted to ensure that the measurements were performed 48 h after the end of the exercise.

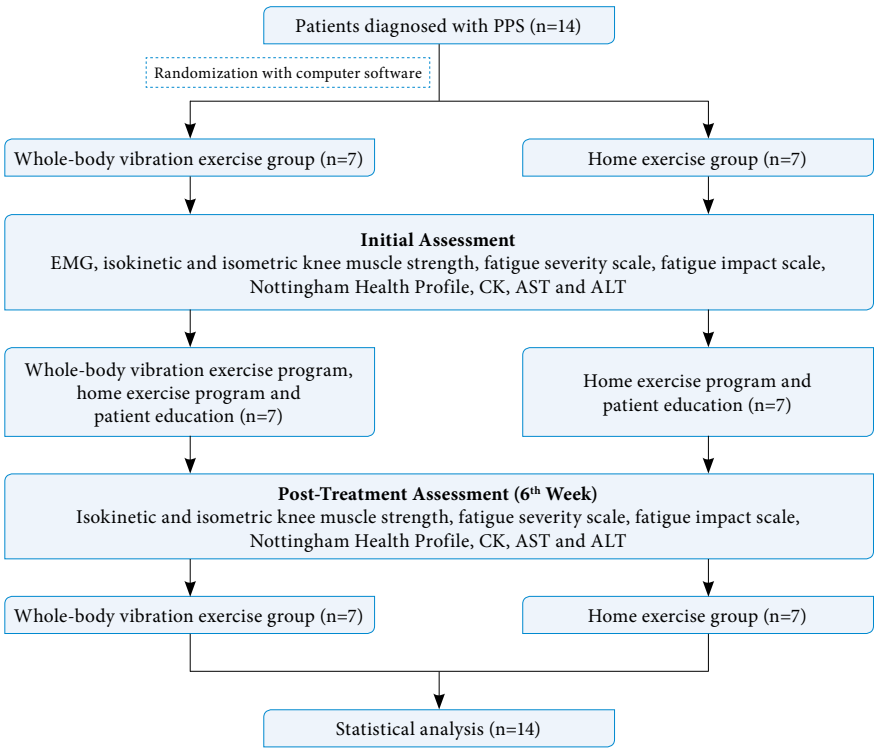

Figure 1. Study flow chart.

PPS: Post-polio syndrome; EMG: Electromyography; CK: Creatine kinase; AST: Aspartate aminotransaminase; ALT: Alanine aminotransferase.

a. Isokinetic test protocol

In the knee of the healthy lower extremity, the lever arm of the device was set from 90-degree flexion to full extension. Extension-flexion was performed on the healthy leg three times at a velocity of 60°/s without resistance, after a six-second break, extension-flexion isokinetic contraction was performed three times with maximum force. In the sequela knee of the lower extremity, the lever arm of the device was set to be the maximum range of motion the patient can do. Extension-flexion was performed the same with healthy extremity. In all isokinetic tests, the healthy leg was first completed, and then the sequela leg. Additionally, we did not detect any measurement error for isokinetic muscle torque measurements.

b. Isometric test protocol

After the isokinetic measurements, the patients took a 2-min break. Afterwards, isometric extension was performed on the knee of the healthy leg two times with light force, with a contraction of 5 sec at a 90-degree joint angle (warm-up); after a 6-sec break, isometric extension was performed twice with maximum force, with a contraction of 5 sec. A 6-sec rest period was given between the isometric extension contractions. The same procedure was then performed for the sequela leg.

3. Fatigue assessment

a. Fatigue severity scale (FSS)

The FSS is a scale developed to measure the severity of fatigue which measures the severity of fatigue within the previous month. The scale consists of nine items, and each item is rated on a 7-point scale. High scores indicate fatigue, while a score of ≥28 points indicate the presence of fatigue.[8] It is valid and reliable assessment scale for evaluating PPS-related fatigue.[9]

b. Fatigue impact scale (FIS)

The FIS was developed to evaluate fatigue symptoms in chronic diseases. It assesses the effects of fatigue on three dimensions of daily life activities: cognitive function, physical function, and psychosocial function. The scale questions the previous month. Each question is rated between 0 and 4 (no-maximum problem). The highest score is 160 points.[10] The Turkish validity and reliability

study of the FSS and FIS scales were conducted by Oncu et al.[11] and both scales were found to be reliable.

4. Quality of life assessment

a. Nottingham health profile (NHP)

This scale includes a total of 38 items and consists of six dimensions. Pain and physical activity are questioned in eight items, sleep in five items, fatigue in three items, social isolation in five items and emotional reaction are questioned in nine items.[12] The NHP is one of the most frequently used instruments to assess QoL of polio survivors.[13,14]

5. Muscle damage assessment

The levels of CK, AST, and ALT were studied in the serum of the patients before and 48 h after the exercise program was completed to evaluate muscle damage.

Interventions

1. Whole-body vibration exercise

The patients in the WBV exercise group underwent WBV exercise sessions two days a week (72 h in between) for a total of six weeks. Each exercise session was performed under the supervision of a physician.

Before each vibration, the patients underwent 5 min of stretching exercises, particularly for the quadriceps muscle (warm-up program). After each vibration, 10 min of stretching exercises were performed, particularly for the quadriceps muscle (cool-down program).

The patients received support from both hands on the WBV platform and both knees were positioned statically at 40° to 60° degree flexion (high squat position). All patients stood on the platform with sports socks to avoid the shoes absorbing vibration. The patients were not allowed to change position during vibration. Vibration was given by a Power Plate® (pro5™; Power Plate North America, Inc., IL, USA) device where a three-plane oscillation occurs (most vertical, Z axis). In all vibrations, 30-Hz frequency and 2-mm amplitude (low amplitude) were used. The vibration time was set to be 30 sec in the first two weeks, 45 sec in the next two weeks, and 60 sec in the last two weeks. The repetition of vibration was increased by one repetition every week, starting with five, and 10 repetitions were given in the last week. A 1-min rest period was given between each repetition.

2. Home exercise program

The home program, which included isometric and isotonic exercises, was followed at home for six weeks. Three sets of quadriceps setting as five repetitions, 5-sec contractions, and three sets of isotonic quadriceps exercise in seating position with weights as 12 repetitions were administered to be performed two days a week. While the patients included in the study group attended to WBV exercise two days a week, the patients in the control group performed quadriceps setting exercises also on those days. The patients were invited to the physician follow-up on Wednesday every week for motivation and follow-up. The rate of compliance of the patients to the home exercise program was 89.3%.

Statistical analysis

The sample size was calculated in dependent groups using the "ankle weight lifted" variable as previously described (d: 1,32, α: 0,05, 1-β err prob: 0,99).[15] Statistical analysis was performed using the IBM SPSS for Windows version 20.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (25^{th}-75^{th} percentiles) or number and frequency, where applicable. The Kolmogorov-Smirnov normality test was used to test the normality of the total scores. The median scores were compared using the Mann-Whitney U tests and Wilcoxon test. A p value of <0.05 was considered statistically significant.

RESULTS

The demographic characteristics of the participants were similar between both groups (for age p=0.620; for sex p=0.593). When the post-treatment change was analyzed separately, there was no statistically significant difference between the WBV group and the control group before the treatment in terms of muscle strength, FSS, FIS-cognitive, FIS-physical, and NHP subscales scores (for each one, p>0.05). The FIS-psychosocial and FIS-total scores decreased with treatment in the WBV group, but did not change in the control group (Tables 1 and 2).

When the post-treatment recovery rates were compared, following addition of WBV program to home exercise program, it constituted a statistically significant difference in the total score by influencing cognitive psychosocial dimensions and total of FIS (Table 3).

TABLE 1
Distribution of post-treatment change in scale scores in WBV group

	WBV group						Test statistics
	Pre-treatment			Post-treatment			
	Median	IQR 25	IQR 75	Median	IQR 25	IQR 75	*p*
FSS	48.00	42.00	58.00	35.00	29.00	46.00	0.063
FIS-cognitive	8.00	1.00	18.00	6.00	0.00	9.00	0.207
FIS-physical	13.00	8.00	30.00	10.00	7.00	21.00	0.138
FIS-psychosocial	24.00	7.00	41.00	6.00	3.00	27.00	0.028
FIS-total	45.00	14.00	89.00	23.00	11.00	54.00	0.028
NHP-pain	50.00	25.00	75.00	37.50	12.50	62.50	0.414
NHP-physical	25.00	25.00	37.50	37.50	12.50	37.50	0.705
NHP-fatigue	33.33	0.00	66.67	0.00	0.00	66.67	0.317
NHP-sleep	20.00	20.00	40.00	20.00	20.00	40.00	0.317
NHP-social	0.00	0.00	20.00	0.00	0.00	40.00	0.317
NHP-emotional	0.00	0.00	55.56	0.00	0.00	11.11	0.066

WBV: Whole-body vibration; IQR: Interquartile range; FSS: Fatigue severity scale; FIS: Fatigue impact scale; NHP: Nottingham health profile; Wilcoxon test was used in dependent groups.

For muscle strength, the isokinetic flexion peak torque (IKFPT) on the healthy side and the isometric extension peak torque (IMEPT) on the sequela side statistically significantly increased in the WBV group after the treatment (p=0.043 and p=0.034, respectively). There was no statistically significant change in the other torque values in the WBV group (Table 4).

On muscle strength test performed in the control group, there was a statistically significant increase in the IKEPT of the sequela side and in the IKFPT of the sequela side and in the IMEPT of the healthy and sequela side after the treatment (p=0.018, p=0.027, p=0.018, and p=0.018, respectively). There was no statistically significant difference in other torque values (Table 5). No significant difference was

TABLE 2
Distribution of post-treatment change in scale scores in control group

	Control group						Test statistics
	Pre-treatment			Post-treatment			
	Median	IQR 25	IQR 75	Median	IQR 25	IQR 75	*p*
FSS	55.00	46.00	59.00	40.00	35.00	59.00	0.735
FIS-cognitive	18.00	2.00	24.00	18.00	4.00	28.00	0.071
FIS-physical	24.00	13.00	33.00	29.00	8.00	35.00	1.000
FIS-psychosocial	44.00	8.00	61.00	50.00	12.00	64.00	0.270
FIS-total	86.00	23.00	119.00	103.00	20.00	130.00	0.233
NHP-pain	62.50	25.00	62.50	50.00	0.00	75.00	0.480
NHP-physical	37.50	25.00	75.00	37.50	25.00	62.50	0.257
NHP-fatigue	33.33	.00	66.67	33.33	0.00	66.67	0.317
NHP-sleep	20.00	20.00	40.00	20.00	20.00	40.00	1.000
NHP-social	0.00	0.00	60.00	0.00	0.00	60.00	1.000
NHP-emotional	11.11	.00	55.56	0.00	0.00	55.56	0.577

IQR: Interquartile range; FSS: Fatigue severity scale; FIS: Fatigue impact scale; NHP: Nottingham health profile; Wilcoxon test was used in dependent groups.

TABLE 3
Comparison of post-treatment changes in scale scores in study groups

	Control			WBV			Test statistics
	Median	IQR 25	IQR 75	Median	IQR 25	IQR 75	*p*
FSS	2.00	-20.00	9.00	-10.00	-23.00	-2.00	0.456
FIS-cognitive	2.00	0.00	4.00	-1.00	-13.00	1.00	**0.038**
FIS-physical	0.00	-4.00	3.00	-1.00	-10.00	0.00	0.128
FIS-psychosocial	4.00	-1.00	8.00	-10.00	-37.00	-4.00	**0.017**
FIS-total	3.00	-3.00	18.00	-7.00	-60.00	-3.00	0.011
NHP-pain	0.00	-12.50	12.50	0.00	-12.50	0.00	1.000
NHP-physical	0.00	-12.50	0.00	.00	-12.50	12.50	0.620
NHP-fatigue	0.00	0.00	0.00	0.00	0.00	0.00	0.456
NHP-sleep	0.00	0.00	0.00	0.00	0.00	0.00	0.710
NHP-social	0.00	0.00	0.00	0.00	0.00	0.00	0.710
NHP-emotional	0.00	-11.11	0.00	-11.11	-22.22	0.00	0.456

WBV: Whole-body vibration; IQR: Interquartile range; FSS: Fatigue severity scale; FIS: Fatigue impact scale; NHP: Nottingham health profile; Wilcoxon test was used in dependent groups.

TABLE 4
Distribution of post-treatment change in muscle strength in WBV group

	WBV group						
	Pre-treatment			Post-treatment			Test statistics
	Median	IQR 25	IQR 75	Median	IQR 25	IQR 75	*p*
IKEPT-Healthy (60°/s, Nm)	71.00	52.00	193.00	95.00	76.00	201.00	0.063
IKEPT-Sequela (60°/s, Nm)	12.00	9.00	38.00	18.00	12.00	68.00	0.310
IKFPT-Healthy (60°/s, Nm)	43.00	34.00	96.00	54.00	50.00	118.00	**0.043**
IKFPT-Sequela (60°/s, Nm)	24.00	12.00	31.00	30.00	12.00	49.00	0.108
IMEPT-Healthy (MVC, Nm)	96.00	77.00	170.00	119.00	84.00	179.00	0.108
IMEPT-Sequela (MVC, Nm)	22.00	12.00	60.00	23.00	20.00	83.00	**0.034**

WBV: Whole-body vibration; IQR: Interquartile range; IKEPT: Isokinetic Extension Peak Torque; Nm: Newton-meter; IKFPT: Isokinetic Flexion Peak Torque; IMEPT: Isometric Extension Peak Torque; MVC: Maximal voluntary contraction; Wilcoxon test was used in dependent groups.

TABLE 5
Distribution of post-treatment change in muscle strength in control group

	Control						
	Pre-treatment			Post-treatment			Test statistics
	Median	IQR 25	IQR 75	Median	IQR 25	IQR 75	*p*
IKEPT-Healthy (60°/s, Nm)	46.00	20.00	114.00	80.00	27.00	104.00	0.398
IKEPT-Sequela (60°/s, Nm)	12.00	7.00	14.00	23.00	12.00	24.00	0.018
IKFPT-Healthy (60°/s, Nm)	43.00	38.00	77.00	53.00	37.00	75.00	0.233
IKFPT-Sequela (60°/s, Nm)	14.00	5.00	18.00	22.00	9.00	37.00	0.027
IMEPT-Healthy (MVC, Nm)	73.00	23.00	111.00	111.00	28.00	149.00	0.018
IMEPT-Sequela (MVC, Nm)	18.00	16.00	26.00	27.00	22.00	41.00	0.018

IQR: Interquartile range; IKEPT: Isokinetic Extension Peak Torque; Nm: Newton-meter; IKFPT: Isokinetic Flexion Peak Torque; IMEPT: Isometric Extension Peak Torque; MVC: Maximal voluntary contraction; Wilcoxon test was used in dependent groups.

TABLE 6
Distribution of post-treatment change in laboratory parameters in the groups

		Pre-treatment			Post-treatment			Test statistics
		Median	IQR 25	IQR 75	Median	IQR 25	IQR 75	*p*
WBV	AST	20.00	18.00	23.00	21.00	16.00	26.00	0.606
	ALT	21.00	13.00	42.00	20.00	10.00	31.00	0.062
	CK	218.00	118.00	494.00	137.00	101.00	403.00	0.499
Control	AST	20.00	18.00	26.00	20.00	19.00	28.00	0.168
	ALT	19.00	16.00	34.00	25.00	16.00	31.00	0.917
	CK	188.00	145.00	267.00	181.00	108.00	367.00	0.866

WBV: Whole-body vibration; IQR: Interquartile range; AST: Aspartate aminotransferase; ALT: Alanine transaminase; CK: Creatine kinase; Wilcoxon test was used in dependent groups.

observed in the amount of change in muscle strength between the groups (p>0.05 for all).

Furthermore, there was no statistically significant difference in the change in post-treatment laboratory parameters (AST, ALT, CK) between the WBV group and control groups, and no change which would give rise to the thought of muscle damage (p>0.05 for all).

DISCUSSION

Exercise is known to cause muscle damage to varying extents. Muscle damage is a condition that causes exhaustion, loss of function, weakness and pain in muscles after unfamiliar and heavy exercise.[16]

Considering the results of our study, it was found that WBV exercises performed in addition to home exercises for six weeks in PPS patients with lower extremity weakness increased the values of isokinetic and isometric quadriceps muscle contraction in both healthy and sequela legs. Similarly, in the home exercise group, the values of isokinetic and isometric quadriceps muscle contractions were increased in both legs. When the post-treatment muscle strength parameters were compared between the groups, we found no significant difference. In both groups, there were no statistically significant changes in the level of enzymes, indicating no muscle damage. In both exercise programs, there was no statistically significant difference in the fatigue level and QoL. Although the addition of WBV treatment to home exercise program did not change the severity of fatigue, it changed the effect of fatigue, and the psychosocial status and cognitions of patients were better, when the difference between the changes in the two groups was examined.

There is a limited number of studies evaluating the effectiveness of different types of exercise when applied together or alone in PPS; however, there are few studies investigating WBV exercises in patients with poliomyelitis.[17-19] A study which is a pilot study including five patients,[19] in the studies of Da Silva[17] and Da Silva et al.,[18] different WBV intensities were compared and it was reported that applying high intensity before low intensity was more effective on walking distance and pain. There is still no consensus on the use of WBV exercises in muscle strengthening in addition to other treatment methods or as a separate treatment method. It has been stated that WBV exercises alone would not be sufficient in preventing other risk factors associated with the cardiovascular, metabolic or musculoskeletal system, and the WBV treatment is not an intervention to replace conventional exercises.[20] It has been recommended that WBV exercises are not performed alone, but in combination with a conventional exercise program.[21] Therefore, WBV exercises were performed in combination with quadriceps strengthening exercises as home exercise in our study. Following the same home exercise program, both exercise groups allowed for the isolated effects of WBV exercises to be estimated.

When the results of our study are evaluated, the home exercise program performed for six weeks has been shown to provide a statistically significant increase in both healthy and sequela leg quadriceps IMEPT (p=0.018 and p=0.018). Moreover, WBV exercises added to home exercise for six weeks have been shown to provide a significant increase in the quadriceps IMEPT in the sequela leg (p<0.001).

The study by Chan et al.[22] is the only randomized-controlled study examining muscle strength in PPS accompanied by exercise program. The study included 10 PPS patients with at least one upper extremity involvement and a strengthening

program for the thenar muscles was given to a group. At the end of 12 weeks, the exercise group achieved a significant increase in muscle strength compared to the control group. We examined the number of motor units before and after treatment electrophysiologically, and the exercise was not found to have harmful effects. The results of our study are similar to the study of Chan et al.[22] Our study is the first randomized-controlled study examining the effect of strengthening exercises on muscle strength in PPS patients with lower extremity involvement. It is also important in terms of prospective, randomized-controlled analysis of the effectiveness of exercise in the large muscle group.

Review of the literature reveals that the first study examining the effectiveness of WBV exercises in poliomyelitis patients was conducted by Brogårdh et al.[19] In this study, two sessions of WBV exercises per week for five weeks were administered to five patients who had poliomyelitis sequelae in the lower extremity. There was no significant difference in terms of isometric and isokinetic knee extension muscle strength values and walking performance tests of the patients.

In a meta-analysis study including healthy individuals, significant effects of exercises along with WBV on extensor muscle strength of both knees were shown compared to the control group.[23]

There is no PPS-specific scale to assess QoL. The NHP, Short Form-36 (SF-36), and FIS are the most frequently used scales. The studies conducted with these scales have shown that new symptoms associated with PPS lead to loss of function and a significant deterioration in QoL.[14,24-26] These studies have always focused on the effect of new muscle weakness on QoL, and not on the effect of fatigue. However, fatigue is the most disturbing symptom for patients with PPS.[14] In a study conducted by Nollet et al.,[13] muscle weakness was shown to affect QoL only partially.

The main limitations of the present study are the low number of patients and relatively short follow-up. Difficulty in mobilization of patients, difficulty in attending to the hospital, mostly not being able to use public transportation, and difficulties in finding car parking space limited the number of patients included in the treatment program. However, the patients attended to the hospital regularly after starting treatment and there were no patients who walked out of control during follow-up. This is significant in the patients who experience functional limitation such as PPS, as reported by Da Silva et al.[18] In addition, since muscle strengths were desired to be evaluated as isokinetic and, thus, individual errors were attempted to be avoided, the patients were required to be at height and weight that could be attached to the isokinetic device, to be able to adapt to the device, and to have at least three-strength quadriceps muscles in the sequelae leg.

On the other hand, the main strengths of our study are the inclusion of patients with electrophysiologically-demonstrated lower motor neuron involvement, electrophysiological exclusion of conditions with symptoms resembling PPS, isokinetic evaluation of muscle strength along with the laboratory measurement of possible side effects, and evaluation of QoL and treatment efficacy. An increase in the peak isometric torque of quadriceps, which is a very significant muscle in walking in lower leg extremity, has been shown with the application of the exercise program.

In conclusion, regular home exercise program should be recommended to polio patients, particularly to PPS. Patients' fears about exercise should be overcome with training, and it should be kept in mind that WBV exercises can be administered. Further large-scale studies with a long-term follow-up are needed to evaluate the effectiveness of treatment method of WBV whether alone or including WBV to home exercise program in PPS patients.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

REFERENCES

1. Gawne AC, Halstead LS. Post-polio syndrome: historical perspective, epidemiology and clinical presentation. Neuro Rehabilitation 1997;8:73-81.
2. Li Hi Shing S, Chipika RH, Finegan E, Murray D, Hardiman O, Bede P. Post-polio syndrome: More than just a lower motor neuron disease. Front Neurol 2019;10:773.
3. Bruno RL. The polio paradox: What you need to know. New York: Warner Books; 2009.
4. Koopman FS, Beelen A, Gilhus NE, de Visser M, Nollet F. Treatment for postpolio syndrome. Cochrane Database Syst Rev 2015;(5):CD007818.
5. Cup EH, Pieterse AJ, Ten Broek-Pastoor JM, Munneke M, van Engelen BG, Hendricks HT, et al. Exercise therapy and other types of physical therapy for patients with neuromuscular diseases: A systematic review. Arch Phys Med Rehabil 2007;88:1452-64.

6. del Pozo-Cruz B, Adsuar JC, Parraca JA, del Pozo-Cruz J, Olivares PR, Gusi N. Using whole-body vibration training in patients affected with common neurological diseases: A systematic literature review. J Altern Complement Med 2012;18:29-41.
7. Trojan DA, Cashman NR. Post-poliomyelitis syndrome. Muscle Nerve 2005;31:6-19.
8. Krupp LB, LaRocca NG, Muir-Nash J, Steinberg AD. The fatigue severity scale. Application to patients with multiple sclerosis and systemic lupus erythematosus. Arch Neurol 1989;46:1121-3.
9. Koopman FS, Brehm MA, Heerkens YF, Nollet F, Beelen A. Measuring fatigue in polio survivors: Content comparison and reliability of the Fatigue Severity Scale and the Checklist Individual Strength. J Rehabil Med 2014;46:761-7.
10. Fisk JD, Ritvo PG, Ross L, Haase DA, Marrie TJ, Schlech WF. Measuring the functional impact of fatigue: Initial validation of the fatigue impact scale. Clin Infect Dis 1994;18 Suppl 1:S79-83.
11. Oncu J, Atamaz F, Durmaz B, On A. Psychometric properties of fatigue severity and fatigue impact scales in postpolio patients. Int J Rehabil Res 2013;36:339-45.
12. Kücükdeveci AA, McKenna SP, Kutlay S, Gürsel Y, Whalley D, Arasil T. The development and psychometric assessment of the Turkish version of the Nottingham Health Profile. Int J Rehabil Res 2000;23:31-8.
13. Nollet F, Beelen A, Prins MH, de Visser M, Sargeant AJ, Lankhorst GJ, et al. Disability and functional assessment in former polio patients with and without postpolio syndrome. Arch Phys Med Rehabil 1999;80:136-43.
14. On AY, Oncu J, Atamaz F, Durmaz B. Impact of post-polio-related fatigue on quality of life. J Rehabil Med 2006;38:329-32.
15. Agre JC, Rodriquez AA, Franke TM. Strength, endurance, and work capacity after muscle strengthening exercise in postpolio subjects. Arch Phys Med Rehabil 1997;78:681-6.
16. Nie J, Tong TK, George K, Fu FH, Lin H, Shi Q. Resting and post-exercise serum biomarkers of cardiac and skeletal muscle damage in adolescent runners. Scand J Med Sci Sports 2011;21:625-9.
17. Da Silva CP. Whole body vibration methods with survivors of polio. J Vis Exp 2018;(140):58449.
18. Da Silva CP, Szot CL, deSa N. Whole body vibration on people with sequelae of polio. Physiother Theory Pract 2019;35:554-64.
19. Brogårdh C, Flansbjer UB, Lexell J. No effects of whole-body vibration training on muscle strength and gait performance in persons with late effects of polio: A pilot study. Arch Phys Med Rehabil 2010;91:1474-7.
20. Kosar AC, Candow DG, Putland JT. Potential beneficial effects of whole-body vibration for muscle recovery after exercise. J Strength Cond Res 2012;26:2907-11.
21. Bemben DA, Palmer IJ, Bemben MG, Knehans AW. Effects of combined whole-body vibration and resistance training on muscular strength and bone metabolism in postmenopausal women. Bone 2010;47:650-6.
22. Chan KM, Amirjani N, Sumrain M, Clarke A, Strohschein FJ. Randomized controlled trial of strength training in post-polio patients. Muscle Nerve 2003;27:332-8.
23. Osawa Y, Oguma Y, Ishii N. The effects of whole-body vibration on muscle strength and power: A meta-analysis. J Musculoskelet Neuronal Interact 2013;13:380-90.
24. Burger H, Marincek C. The influence of post-polio syndrome on independence and life satisfaction. Disabil Rehabil 2000;22:318-22.
25. Kling C, Persson A, Gardulf A. The health-related quality of life of patients suffering from the late effects of polio (post-polio). J Adv Nurs 2000;32:164-73.
26. Thorén-Jönsson AL, Grimby G. Ability and perceived difficulty in daily activities in people with poliomyelitis sequelae. J Rehabil Med 2001;33:4-11.