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Short-Term Application of Pulsed Electromagnetic Fields for Static Balance of Functional Flatfeet

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This study investigated the effect of pulsed electromagnetic field (PEMF) on proprioception through static balance after the short-term application of PEMF in people with functional flat feet. Forty-two volunteers participated in the study. The proprioceptive index of all subjects was measured before and after exposure to PEMF for 1 week. Seventeen subjects with normal feet were not exposed to a PEMF (Group I), and PEMF was applied to 17 subjects with normal feet (Group II) and eight with functional flat feet (Group III). In Group I, there were no significant differences in any of the variables. In Group II, a significant difference was observed only in the medio-lateral value when perturbation was applied in the antero-posterior direction. In Group III, significant differences in medio-lateral, antero-posterior, and vertical values were observed when perturbation was applied in the medio-lateral direction in Group III. Although there was a learning effect with repeated measurements, the improvement in balance after PEMF application indicates that PEMF has a positive effect on the nervous system in subjects with functional flat feet.

Keywords : PEMF, faltfoot, balance, electromagnetic field

1. Introduction

Flatfoot is a common orthopedic disorder worldwide. Some investigations have demonstrated that flatfoot causes many problems, such as balance impairment by affecting sole proprioception [1].

Maintaining body balance in an upright position depends on tightly integrated feedback and movement strategies between the hip, knee, and ankle joints [2]. Thus, body balance may be disturbed by reduced afferent feedback or defects in lower extremity strength and mechanical stability [3]. Overpronated foot postures, such as functional flat feet, can affect somatosensory input either through changes in joint mobility or surface contact area or secondarily through changes in muscle strategies to maintain a stable base of support [4].

Proprioception [5] is the ability to sense the position and movement of limb segments relative to one another and is a well-known sensory phenomenon. Many studies have evaluated the relationship between proprioceptive deficits and traumatic disruption of ligaments and joint capsules of the knee, ankle and shoulder [6-9].

Pulsed electromagnetic field (PEMF) therapy, a form of magnetotherapy, induces the intracellular movement of ions owing to the electromagnetic field, resulting in hyperpolarization of the cell membrane and thereby an increase in metabolism. This improves the blood supply to the tissues and increases the partial pressure of oxygen. The advantages of PEMF include equal penetration of the magnetic field through all tissues and the ability to perform procedures through clothing, bandages, or plaster [10].

PEMF expedites the growth and regeneration of neurons, and thus stimulates peripheral nerve functional recovery [11-13]. In the central nervous system, PEMF also promotes neurite outgrowth from spinal neurons and dorsal root ganglions [12]. Some animal experiments have suggested that PEMF intervention facilitates locomotion and sensory recovery in spinal cord injury models by enhancing neurite outgrowth and blood flow, and downregulating inflammation and hazardous substances [14-16].

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Many studies have shown that the application of PEMF has a positive effect on the nervous and musculoskeletal systems; however, studies on its effect on short-term proprioception are insufficient. Therefore, this study investigated the effect of PEMF on proprioception through static balance after short-term application of PEMF in people with functional flat feet.

2. Methods

A total of 42 volunteers participated in the study. The proprioceptive index of all subjects was measured before and after exposure to PEMF for 1 week. Seventeen subjects with normal feet were not exposed to PEMF (Group I), and PEMF was applied to 17 and eight subjects with normal (Group II), and functional flat feet (Group III), respectively.

We used a posture analyzer (Zebris, Posturomed, Haider Bioswing, Germany). Subjects were placed in an upright position with their feet at the center of a circle on a fixed platform. We then removed the pins securing the platform to induce perturbation and assessed the subject's ability to recover their balance as quickly as possible; this was measured using the movement path of the center of gravity. The perturbation of the platform was applied in the antero-posterior (AP) and medio-lateral (ML) directions, respectively. Four types of data were measured: ML, AP, vertical (Vrt), and rotational (Rot) values; where ML value is the amount of left and right shaking, AP value is the amount of forward and backward shaking, Vrt value is the amount of up and down shaking, Rot value is the rotation sway, and represents the amounts of left and right rotation, respectively. A lower value indicates that the subject was able to return to the original position faster, which translates to better proprioception. All measurements were performed before and after the intervention.

Pulsed electromagnetic fields (ASA Easy Terza series, Italy) were used in Groups II and III. Each subject was placed in a comfortable and relaxed position (supine position). The appliance was connected to a main electrical supply of 220 V. The solenoid was adjusted over the ankle joint at a frequency of 50 Hz and an intensity of 20 G for 20 min. The intervention was conducted every day for 1 week.

3. Results and Discussion

Balance recovery before and after PEMF application was compared between the groups. In Group I, subjects with normal feet who were not exposed to PEMF showed no significant differences in any of the variables (Table 1)(Fig. 1). In Group II, subjects with normal feet who were exposed to PEMF, a significant difference was observed in the medio-lateral value only when perturbation was applied in the AP direction (Table 2)(Fig. 1). In Group III, subjects with functional flat feet who were

Table 1. Comparison of static balance according to perturbation direction in Group I.

Variables			Group I	t	*p*
AP	ML value	*pre*	38.85±19.80	0.932	0.364
		post	33.37±12.47		
	AP value	*pre*	166.64±40.25	0.094	0.926
		post	165.19±60.18		
	Vrt value	*pre*	41.24±9.33	-0.033	0.974
		post	41.37±14.83		
	Rot value	*pre*	4.17±1.20	0.117	0.908
		post	4.12±1.63		
ML	ML value	*pre*	245.00±50.97	0.984	0.338
		post	229.39±47.43		
	AP value	*pre*	64.64±20.06	-0.464	0.648
		post	69.03±32.28		
	Vrt value	*pre*	58.86±12.44	0.830	0.418
		post	55.52±11.78		
	Rot value	*pre*	7.11±1.60	1.630	0.120
		post	6.28±1.09		

*p<0.05 by paired t-test
AP; antero-posterior, ML; medio-lateral, Vrt; vertical, Rot; rotational

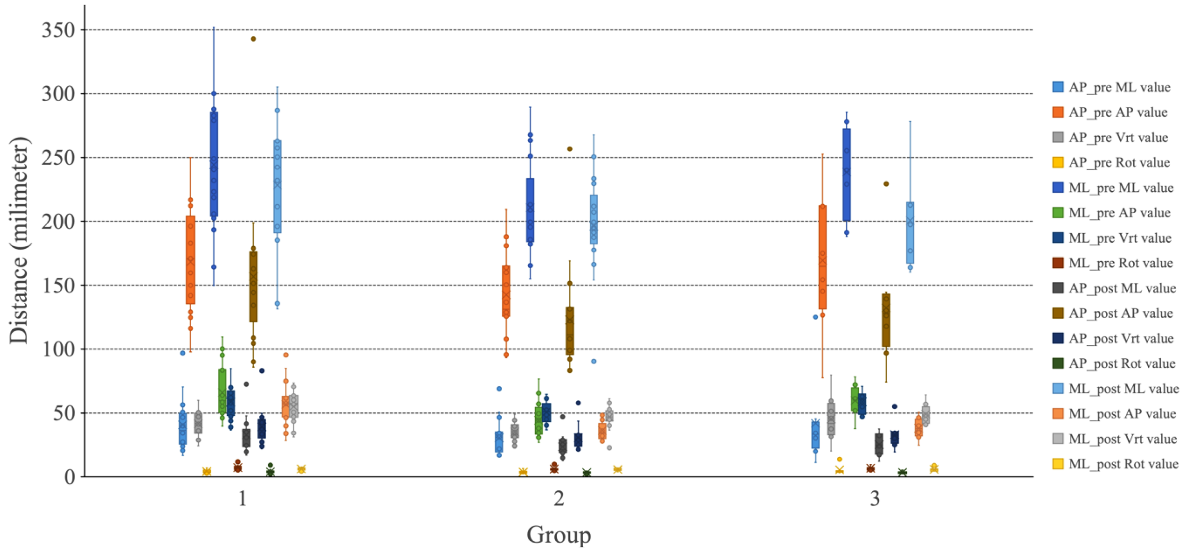

Fig. 1. (Color online) Summarized Comparison of static balance according to all directions in Group I, II and III. AP; antero-posterior, ML; medio-lateral, Vrt; vertical, Rot; rotational

Table 2. Comparison of static balance according to perturbation direction in Group II.

Variables			Group II	t	*p*
AP	ML value	*pre*	30.42±13.38	2.150	0.045*
		post	24.31±8.14		
	AP value	*pre*	141.38±30.58	1.540	0.141
		post	23.06±40.00		
	Vrt value	*pre*	34.94±7.06	1.501	0.151
		post	30.84±8.76		
	Rot value	*pre*	3.85±1.16	1.453	0.163
		post	3.43±0.69		
ML	ML value	*pre*	214.22±37.63	1.216	0.240
		post	200.16±40.13		
	AP value	*pre*	38.50±6.55	-1.890	0.075
		post	50.01±28.76		
	Vrt value	*pre*	51.48±8.15	-0.118	0.907
		post	52.00±19.51		
	Rot value	*pre*	6.01±1.21	-0.492	0.628
		post	6.37±3.07		

*p<0.05 by paired t-test
AP; antero-posterior, ML; medio-lateral, Vrt; vertical, Rot; rotational

exposed to PEMF, showed significant differences in ML, AP, and Vrt values when perturbation was applied in the ML direction, while no significant differences were observed in all values when perturbation was applied in the AP direction (Table 3)(Fig. 1).

There were no statistically significant differences between the groups before and after PEMF application, but the greatest difference was observed in the AP value when perturbation was applied in the ML direction. In particular, the AP value decreased significantly in subjects with functional flat feet (Table 4).

Magnetic field therapy is considered an efficient modality in physical therapy for the treatment of many pathological conditions as it exhibits various activities, such as vasodilation, analgesia, anti-inflammatory, and edema effects [17]. In particular, PEMF has analgesic,

Table 3. Comparison of static balance according to perturbation direction in Group III.

Variables			Group III	t	*p*
AP	ML value	*pre*	41.93±35.17	1.302	0.234
		post	25.22±8.88		
	AP value	*pre*	169.50±55.72	2.095	0.074
		post	132.31±45.53		
	Vrt value	*pre*	45.36±18.41	1.844	0.108
		post	33.05±10.34		
	Rot value	*pre*	5.47±3.42	1.794	0.116
		post	3.41±1.02		
ML	ML value	*pre*	238.66±35.72	3.228	0.014*
		post	200.70±37.70		
	AP value	*pre*	59.68±12.64	3.751	0.007*
		post	38.00±8.31		
	Vrt value	*pre*	58.67±8.76	3.266	0.014*
		post	49.10±8.04		
	Rot value	*pre*	6.68±1.46	2.129	0.071
		post	5.81±1.50		

*p<0.05 by paired t-test
AP; antero-posterior, ML; medio-lateral, Vrt; vertical, Rot; rotational

Table 4. Comparison of static balance between groups according to perturbation direction.

Variables		Group I	Group II	Group III	f	*p*
AP	ML value	-5.47±25.61	-6.11±12.39	-16.70±36.27	0.714	0.495
	AP value	-1.44±67.39	-18.31±51.83	-37.18±50.20	1.110	0.339
	Vrt value	0.12±16.52	-4.10±11.90	-12.31±18.88	1.887	0.164
	Rot value	-0.05±2.15	-0.42±1.27	-2.06±3.25	2.663	0.081
ML	ML value	-15.60±69.11	-14.05±50.40	-37.96±33.26	0.549	0.582
	AP value	4.39±41.28	11.50±26.53	-21.68±16.35	2.988	0.061
	Vrt value	-3.34±17.56	0.52±19.25	-9.57±8.29	0.985	0.382
	Rot value	-0.82±2.20	0.36±3.21	-0.87±1.16	1.227	0.303

*p<0.05 by one-way ANOVA
AP; antero-posterior, ML; medio-lateral, Vrt; vertical, Rot; rotational

neurostimulatory, trophic, and vasoactiveactions [18].

The sensory perception of body movements, appropriate motor responses, and integration of sensorimotor information into the central nervous system are essential for maintaining postural balance. Many musculoskeletal and neurological disorders can alter balance control, and require continuous adjustments to muscle activity and joint position [19].

Functional flat feet, in which the longitudinal arch of the foot collapses during weight bearing, has been shown to be less balanced than normal feet. Balance is often used as a measure of lower-extremity function and is defined as the process of maintaining the center of gravity within the body's base of support [20]. The central and peripheral components of the nervous system constantly interact to control body alignment and the center of gravity over the base of support in an upright stance [21, 22].

Postural stabilization in the upright position is typically modeled as a single-segment linear feedback control system that predicts ankle joint torque based on changes in ankle joint kinematics [23]. It is well known that people with flat feet have weaker ankle strategies than those with normal feet.

Research has been continuously conducted to investigate the effects of PEMF on various subjects.

A previous study by Graak *et al.* (2009) showed that PEMF treatment has the opportunity to modulate neuropathic pain and nerve irritation through reduction of intraneural hypoxia and by improving microcirculation, resulting in positive changes after 30 minutes of PEMF treatment for 12 consecutive days. They also reported that the effect of PEMF is to evoke biological responses such as cell proliferation that enhance nerve regeneration and accelerate recovery [24]. Filimban *et al.* (2015) indicated that PEMF can accelerate nerve conduction velocity and increase compound action potentials in the sciatic nerve, enhance nerve growth factor levels, and reduce both oxidative damage and nerve loss [25]. Battecha (2017) investigated the efficacy of PEMF on pain and nerve conduction velocity in patients with diabetic neuropathy and reported that PEMF reduced pain intensity and significantly increased nerve conduction velocity [26].

It is well established that subjects with functional flat feet have more difficulty maintaining balance than normal feet. Even though our study applied PEMF for a short period of time, the change in balance values in subjects with functional flat feet as well as normal feet can be considered a significant result.

Normal formation of the arch of the foot is very important for improving balance. Stimulating the sensory nerves of the feet helps form or support the arches [27]. In the results of our study, after applying PEMF, the improvement in balance in response to ML purterbation was particularly noticeable in subjects with functional flat feet.

4. Conclusion

Our study aimed to investigate the effect of short-term application of PEMF to the ankle joints of subjects with functional flat feet on balance. Even if there is a learning effect by repeated measurement, the improvement in balance ability after applying PEMF suggests that PEMF has a positive effect on the nervous system and musculoskeletal system of subjects with functional flat feet.

This study has several limitations, one of which is the relatively small sample size. Therefore, further investigations with in larger and more diverse populations, including controls, are needed to support our findings.

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