International Journal of Medical, Medicine and Health Sciences
ISSN: 2517-9969
Vol:9, No:7, 2015

Assessment of Influence of Short-Lasting Whole-Body Vibration on Joint Position Sense and Body Balance–A Randomised Masked Study

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***Abstract*—**Introduction: Whole-Body Vibration (WBV) uses high frequency mechanical stimuli generated by a vibration plate and transmitted through bone, muscle and connective tissues to the whole body. Research has shown that long-term vibration-plate training improves neuromuscular facilitation, especially in afferent neural pathways, responsible for the conduction of vibration and proprioceptive stimuli, muscle function, balance and proprioception. Some researchers suggest that the vibration stimulus briefly inhibits the conduction of afferent signals from proprioceptors and can interfere with the maintenance of body balance. The aim of this study was to evaluate the influence of a single set of exercises associated with whole-body vibration on the joint position sense and body balance. Material and methods: The study enrolled 55 people aged 19-24 years. These individuals were randomly divided into a test group (30 persons) and a control group (25 persons). Both groups performed the same set of exercises on a vibration plate. The following vibration parameters: frequency of 20Hz and amplitude of 3mm, were used in the test group. The control group performed exercises on the vibration plate while it was off. All participants were instructed to perform six dynamic exercises lasting 30 seconds each with a 60-second period of rest between them. The exercises involved large muscle groups of the trunk, pelvis and lower limbs. Measurements were carried out before and immediately after exercise. Joint position sense (JPS) was measured in the knee joint for the starting position at 45° in an open kinematic chain. JPS error was measured using a digital inclinometer. Balance was assessed in a standing position with both feet on the ground with the eyes open and closed (each test lasting 30 sec). Balance was assessed using Matscan with FootMat 7.0 SAM software. The surface of the ellipse of confidence and front-back as well as right-left swing were measured to assess balance. Statistical analysis was performed using Statistica 10.0 PL software. Results: There were no significant differences between the groups, both before and after the exercise ($p > 0.05$). JPS did not change in both the test (10.7° vs. 8.4°) and control groups (9.0° vs. 8.4°). No significant differences were shown in any of the test parameters during balance tests with the eyes open or closed in both the test and control groups ($p > 0.05$). Conclusions: 1. Deterioration in proprioception or balance was not observed immediately after the vibration stimulus. This suggests that vibration-induced blockage of proprioceptive stimuli conduction can have only a short-lasting effect that occurs only as long as a vibration stimulus is present. 2. Short-term use of vibration in treatment does not impair proprioception and seems to be safe for patients with proprioceptive impairment. 3. These results need to be supplemented with an assessment of proprioception during the application of vibration stimuli. Additionally, the impact of vibration parameters used in the exercises should be evaluated.

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***Keywords*—**Balance, joint position sense, proprioception, whole body vibration.

I. Introduction

WHOLE BODY VIBRATION (WBV) training refers to physical exercises performed on a plate generating mechanical vibration [1]. Early attempts to use vibration to stimulate the human body date back to the second half of the 20th century [2], [3]. Since then, vibration exercises have been the subject of considerable research assessing their efficacy and influence on the human body. At present, vibration exercises are used in medical rehabilitation, as well as by people who practise sport either competitively or as recreation. In physiotherapy, whole body vibration is used in the rehabilitation of patients in various age groups. In young patients, this therapy is employed in rehabilitation following musculoskeletal injuries. In older patients, vibration exercises are used in the treatment of conditions resulting in neurological deficits, as well as in patients with increased risk of falls.

Research on whole body vibration indicates that this therapy is effective. Favourable effects have been observed for both short- and long-term vibration training [1]. Studies have shown, among other things, that vibration exercises increase muscle elasticity, strength and power [4]-[8]. Studies in older patients have revealed improved gait parameters and body posture, with the resulting reduction in fall risk. [9]-[13]. Among studies of the favourable effects of vibration exercises, many have demonstrated a favourable influence of vibration exercises on proprioception and body balance [1], [14]-[16].

Vibrations generated by a vibration plate are transmitted to the central nervous system through proprioception pathways. Intense stimulation of the nervous system during vibration exercises may cause fatigue. Therefore, the question arises whether vibration exercises may provoke short-lasting impairment of the joint position sense and balance immediately after the exercises have been performed.

II. Objective

The aim of this study was to evaluate the influence of a single set of exercises combined with whole-body vibration on the knee joint position sense and ability to maintain body balance.

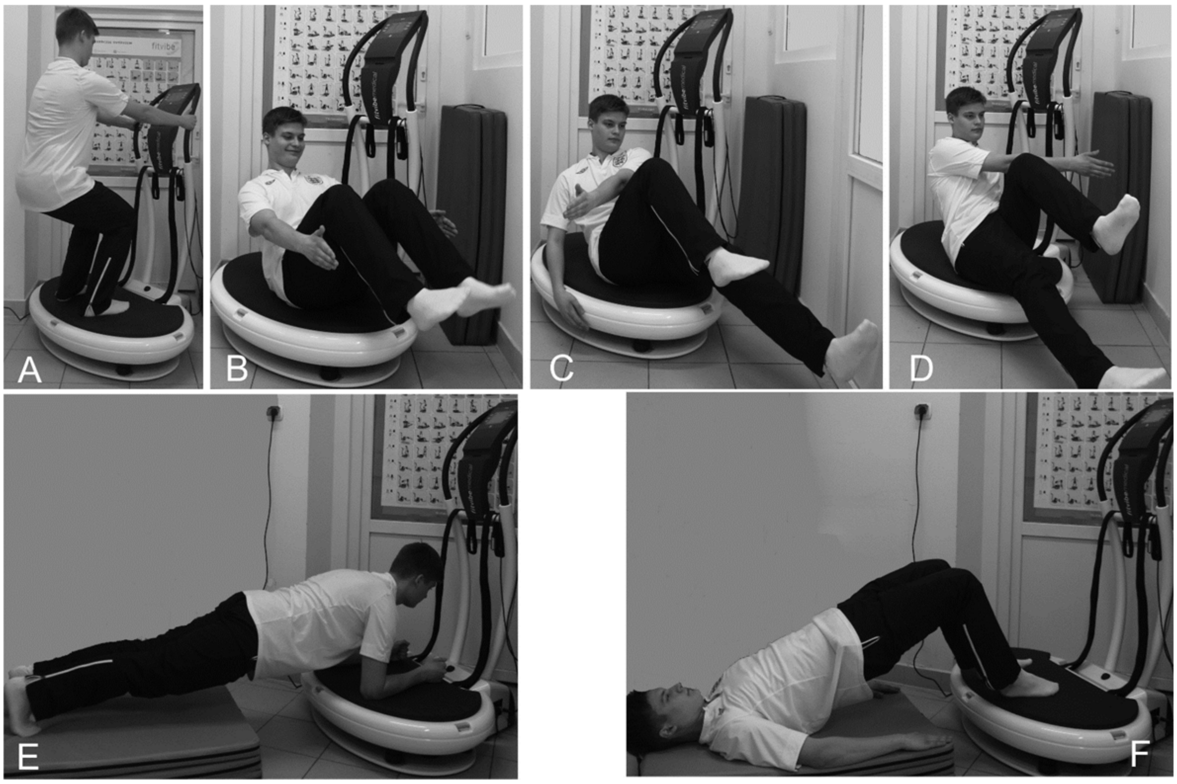

Fig. 1 The set of exercises performed on a vibration plate: (A) squat, (B) sit-ups, (C) right oblique sit-ups, (D) left oblique sit-ups, (E) plank, (F) bridge

TABLE I
ASSESSMENT OF BALANCE IN THE TEST GROUP AND THE CONTROL GROUP WITH THE EYES OPEN AND CLOSED – MEANS ± STANDARD DEVIATIONS

		Test group			Control group		
		Before	After	*p-value*	Before	After	*p-value*
Eyes open	Surface area of ellipse of confidence [cm2]	0.85±0.49	0.90±0.44	NS	0.91±0.59	0.99±0.70	NS
	Front-back swing [cm]	1.74±0.59	1.88±0.59	NS	1.73±0.66	1.96±0.87	NS
	Right-left swing [cm]	1.05±0.34	1.20±0.53	NS	1.14±0.41	1.30±0.51	NS
Eyes closed	Surface area of ellipse of confidence [cm2]	0.95±0.89	0.69±0.35	NS	0.82±0.77	0.71±0.48	NS
	Front-back swing [cm]	1.93±0.91	1.73±0.48	NS	1.80±0.88	1.82±0.69	NS
	Right-left swing [cm]	1.01±0.46	0.86±0.31	NS	1.04±0.59	0.94±0.35	NS

NS = non-significant

III. MATERIAL AND METHODS

The study enrolled 55 healthy people aged 19-24 years. These individuals were randomly divided into a test group (30 persons) and a control group (25 persons).

The test group performed a set of six dynamic exercises on a vibration plate involving: 1. squats, 2. sit-ups, 3. right oblique sit-ups, 4. left oblique sit-ups, 5. a plank with forward and backward movement while leaning on forearms, 6. a bridge with hip raising and lowering (Fig. 1). Each exercise lasted 30 seconds and a period of rest between exercises lasted 60 seconds. The tests were performed using a Fitvibexcel Pro Medical vibration plate (Uniphy Elektromedizin GmbH&Co. KG, Germany) and the following vibration parameters: frequency of 20Hz and amplitude of 1.5 mm. The control group performed the same set of exercises with the same exercise and rest intervals, but with the vibration plate off.

Measurements were carried out before and immediately after the exercise session. The assessment was made by an independent researcher. Joint position sense was measured using a Saunders digital inclinometer to an accuracy of 1º in an open kinematic chain. The knee joint was chosen for the examination due to the key role it plays in stabilization of the lower limb. The statistic of the test was the absolute difference between the given starting position (45° flexion in the knee joint) and the position reproduced by the study participant; the attempted reproduction was performed each time from flexion to extension. Balance was assessed using a Matscan pressure floor mat (Tekscan Inc., U.S.A.) with FootMat 7.0 Sway Analysis Module software in a standing position with both feet on the ground with the eyes open and closed (each test lasting 30 sec). The surface area of the ellipse of confidence and front-back as well as right-left swing (in cm) were measured.

Statistical analysis was performed using Statistica 10.0 PL software. Due to the small size of the groups the following nonparametric statistics were used: Wilcoxon's pair sequences test and the Mann-Whitney U test. The results were presented as means and standard deviations.

This study was financed from Statutory Research Grant No. 2F1/N/14 WUM.

IV. Results

Baseline comparisons between the groups before the exercise showed no statistically significant differences in any of the parameters studied.

In the JPS test, the score of the test group was 10.7° ± 7.6° at baseline compared to 8.4° ± 5.8° after the exercise while in the control group the respective mean JPS scores were 9.0° ± 5.9° before the exercise and 8.4° ± 5.7° after the exercise. There were no statistically significant differences between the results of both groups or between the scores obtained before and after the vibration exercise.

No significant differences were shown in any of the test parameters during the balance tests with the eyes open or closed in both the test and control groups before and after the exercise ($p>0.05$, see Table I for detailed results). No statistically significant differences were revealed between both groups in the test after the exercise.

V. Discussion

The results of the present study suggest that a single set of exercises on a vibration plate set at low frequency produces no changes in joint position sense in the knee joint and postural control in young individuals. Similar data were obtained by Pollock et al. and Hannah et al. Pollock et al. assessed not only joint position sense (JPS) and balance, but also cutaneous sensation. They used a vibration frequency of 30Hz and amplitude of 4 or 8 mm. The study participants were exposed to vibration five times over one minute each, with 30-second intervals between and maintained a static position throughout the experiment. No significant differences were demonstrated before and after vibration exposure in the first two test parameters. Only cutaneous sensation in the distal parts decreased after high frequency vibration exposure [17]. The participants of Hannah et al.'s study took part in one session of vibration with a frequency of 30 Hz and amplitude of 4 mm administered five times over one minute each (WBV) and the next day the same individuals performed an isometric exercise without vibration. No changes in joint position sense were observed in either group [18]. Thus, both these experiments corroborate the results of the present study, despite differences in exercise methodology: the two studies used static exercises, while the present study used dynamic exercises. The differences between the vibration exposure parameters used are minor; both the parameters employed in the present study and the parameters in the two studies mentioned above are regarded as low intensity vibration.

Numerous studies investigating the influence of whole-body vibration (WBV) on postural control, balance, proprioception and other factors had a set-up where vibration was administered over several weeks. The length of the cycle of vibration varied between the experiments. Vibration parameters also varied, as did the performance of study participants who either made additional movements while on the plate or only maintained a static position. The majority of these studies suggest that balance is the parameter that improves after a training cycle on a vibration plate [19], [20]. Fu et al. used whole-body vibration for 8 weeks in patients after anterior cruciate ligament reconstruction as an adjunct to standard rehabilitation. Vibration frequency ranged between 20 and 60 Hz with 5 Hz increments, and amplitude was low (2mm) or high (4mm). Tests performed at three and six months after surgery indicated significant differences in postural control between the control group, which had undergone only rehabilitation, and the test group, to the advantage of the latter. No differences in joint position sense were observed between the groups [19]. Ritzman et al., who investigated whole-body vibration, also assessed balance among other things. All participants of that study attended a four-week programme of exercise three times a week, with vibration in the test group and no vibration in the control group. The VBW parameters comprised a frequency of 25Hz and amplitude of 4 mm. Significant reduction of inclinations of the center of gravity (COG) in the anterior-posterior and medio-lateral direction was observed only in the test group [20].

By contrast, a study by Pollock et al., which employed exercises combined with whole-body vibration in a group of elderly people, demonstrated an improvement in balance both in the test group who underwent vibration and the control group. There were no significant differences between the groups [12]. In Trans et al.'s study, the group which demonstrated an improvement in proprioception was exposed to vibration on a plate using a balance board. The same study demonstrated no differences in test parameters, particularly in the threshold for detection of passive movement, in both the group who only attended vibration exercise sessions and in the control group. The exercise cycle in all groups lasted 8 weeks. The improvement might have been an effect of using a balance board, and vibration exercise alone did not improve proprioception [8]. A study by Hiroshige et al. also confirmed that eight-week vibration training do not influence knee joint position sense. The authors suggested that an inadequate dose of vibration (frequency of 20Hz, peak amplitude of 1mm during the first 4 weeks and 2 mm during the next four weeks) might have contributed to lack of significant changes in the results of the study participants [21].

The results of the present study as well as results of other studies indicate that the vibration parameters used might have been too low to induce functional changes in the peripheral nervous system and thus impair the parameters of balance and joint position sense, which the authors of the present study expected. The combination of two parameters of a vibration plate: frequency and amplitude, has an influence on the conduction of impulses in the peripheral nervous system and on the excitability of this system, which may be decreased due to the effect of the vibration stimulus. Such reduction in excitability should cause deterioration in proprioception, which is conducted via the same pathways and received partly by the same receptors (mechanoreceptors). The results suggest that the effect of the vibration stimulus was subliminal and too small to result in a functional change in the stimulus conduction system. Perhaps a significant change in the test parameters could have been obtained by increasing the vibration amplitude and/or frequency. There is also a possibility that the vibration had only a short-lasting effect that was present only as long as a vibration stimulus continued. To confirm this further investigation is required, yet such mechanism would enable the use of vibration also in patients with impaired proprioception and balance. Further deterioration of proprioception in such patients, even lasting a few minutes after exercise, is inadvisable due to a rise in the risk of falls and serious fall-related health consequences.

VI. Conclusions

1. Deterioration in proprioception or balance was not observed immediately after the vibration stimulus. This suggests that vibration-induced blockage of proprioceptive stimuli conduction can have only a short-lasting effect that occurs only as long as a vibration stimulus is present.
2. Short-term use of vibration in treatment does not impair proprioception and seems to be safe for patients with proprioceptive impairment.
3. These results need to be supplemented with an assessment of proprioception during the application of vibration stimuli. Additionally, the impact of vibration parameters used in the exercises should be evaluated.

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