Baltic Journal of Health and Physical Activity

Volume 4 | Issue 4 Article 1

2012

The Long Lasting Effects of Whole Body Rotation Vibration in a Fitness Exercise Program on Flexibility and Motor Coordination in Young Females

Tomasz Tomiak
Gdansk University of Physical Education and Sport in Gdansk, Poland

Maria Agnieszka Niewiadomska
Gdansk University of Physical Education and Sport in Gdansk, Poland

Mariusz Zasada
Kazimierz Wielki University in Bydgoszcz, Poland

Ludmila J. Melnik
Scientific Practical Centre of Profilactic and Clinical Medicine of State Administration of Ukraine, Kiev, Ukraine

Viktor S. Mishchenko
Gdansk University of Physical Education and Sport in Gdansk, Polnad

See next page for additional authors

Recommended Citation

Tomiak T, Niewiadomska MA, Zasada M, Melnik LJ, Mishchenko VS, Sawczyn S. The Long Lasting Effects of Whole Body Rotation Vibration in a Fitness Exercise Program on Flexibility and Motor Coordination in Young Females. Balt J Health Phys Act. 2012; 4(4): 221-230. doi: 10.2478/v10131-012-0022-z

VERSITA
BALTIC JOURNAL OF HEALTH AND PHYSICAL ACTIVITY
© Gdansk University of Physical Education and Sport in Gdansk, Vol. 4, No. 4, 2012, 221-230
ORIGINAL ARTICLE

DOI: 10.2478/v10131-012-0022-z

The Long Lasting Effects of Whole Body Rotation Vibration in a Fitness Exercise Program on Flexibility and Motor Coordination in Young Females

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

Tomasz Tomiak[1] (A, B, C, D, E, F, G), Maria Agnieszka Niewiadomska[1] (B, F, G), Mariusz Zasada[2] (C, E, F), Ludmila J. Melnik[3] (D, E, F), Viktor S. Mishchenko[1] (A, D, E, F), Stanisław Sawczyn[1] (A, D, F ,G)

[1] Gdansk University of Physical Education and Sport in Gdansk, Poland
[2] Kazimierz Wielki University in Bydgoszcz, Poland
[3] Scientific Practical Centre of Profilactic and Clinical Medicine of State Administration of Ukraine, Kiev, Ukraine

Key words: *whole body vibration, physical exercise, female, motor coordination, flexibility*

Abstract

Background: *The aim of the study was to determine additional effects of 8 weeks' whole body rotation vibration combined with a fitness exercise program of health-related training on chosen motor coordination abilities and flexibility in young females.*

Material/Methods: *Thirty-seven young females aged 20-25 (students) voluntarily participated in the study. The training program included 24 training sessions which were performed over the course of 8 weeks (3 sessions a week) and was based on basic principles of health-related protocols. The program of sessions was performed by subjects of the experimental group with a working whole body vibration platform (20 Hz), whereas those of the control group performed the same exercises with a non-working (placebo) vibration platform. Chosen motor coordination abilities (body balance, reproducing of strength and whole body rotation angle) and flexibility (active and passive) were measured at the 4th and the 8th week.*

Results: *This study showed additional effects of concomitant whole body vibration and physical exercises for 24 sessions of training (40-50 min). A significant increase in some values of the motor coordination ability (body balance, reproduction of strength and angle in rotation) and hip active and passive flexibility was shown in the experimental group vs. the control one.*

Conclusions: *The results indicate that chronic rotation whole-body vibration, as an accompanying impact to a fitness exercise program, has additional positive effects on coordination and flexibility in young females.*

Word count: 4 725
Tables: 4
Figures: 0
References: 40

Received: May 2012
Accepted: October 2012
Published: December 2012

Corresponding author:
Prof. nadzw. dr hab. Tomasz Tomiak
Gdansk University of Physical Education and Sport, Dep. of Sport
80-336 Gdańsk, Poland, ul. K. Górskiego 1
Phone: +4858 554-72-85
E-mail: tomaszt@awf.gda.pl

Introduction

Research into whole-body vibration (WBV) has reported its effects on humans ranging from dangerous to beneficial ones [1]. Various types of vibration are present in many situations of everyday life. In fact, vibrations can be found in a wide range of transportation devices or working tools [2-5]. In many sport activities a significant vibration load occurs [6, 7]. Such research has been conducted in occupational medicine or ergonomics where WBV is mainly avoided [8, 9]. Whole body vibration has been proposed as an alternative exercise stimulus of musculoskeletal structures to produce adaptive responses similar to resistance exercise [10-14]. For this reason, most studies have focused on examining the neuromuscular responses to WBV exercise [15]. Vibration training either produces potentiation at the level of the motoneuron pool, or increased efficiency of the Ia afferents in load compensation [10]. In the first case, vibration training provides the potential of increasing the force, speed and/or power in maximal contractions [16]. In the second case, the potential is restricted to contractions in which the Ia feedback could play a role in the build-up of force. Previous work has suggested that vibration exposure elicits small but rapid changes in muscle length producing reflex muscle activity in an attempt to dampen the vibratory waves [1]. In addition, vibration training affects proprioception [7, 17, 18, 19]. Thus vibration training may represent an effective non-pharmacologic therapeutic intervention to target several physiological systems. Influences of WBV on treatment of several diseases as well as on prevention of osteoporosis and some age-related degradation changes has been shown [13, 20]. Earlier vibration training has been successfully applied in maintenance and enhancement of physical fitness of astronauts and athletes [6, 21]. Several controlled studies suggest positive effects of WBV on bone mass [18, 22, 23], on muscle strength development [12, 24, 25] and on body balance [18, 26]. However, other controlled studies have not found significant improvements in strength and power [27], balance [28] or bone mass [29]. This controversy could be explained by the wide range of experimental procedures, duration of vibration loads, the type of vibrations and vibration variables (frequency, amplitude, direction), as well as the studied subjects [30]. Thus, it is difficult to reach definitive conclusions about chronic effects of whole-body vibrations on humans. Several fundamental studies of human body “biomechanical stimulation” and physiological mechanisms of vibration impacts of various frequency, amplitude and duration have been conducted [10, 15, 31]. Today we observe an intensive development of the application of vibration impacts on the whole body [1, 19, 32, 33]. One may observe a rather significant expansion of vibration impacts on the whole body in health related training of people in different age groups for correction of their physical condition [13, 15, 33, 34]. Vibration load increase in training effects has been previously demonstrated for progress in strength and muscle power abilities, increase in body active mass, improvement in muscle tone and resting metabolism. Vibration load depends on the exercise position, for example in case of pushups (hands placed on the vibration platform) the vibration load mainly falls on the upper body. But one should take into account the fact that the vibration load in a typical position on vibration platforms falls on the lower part of the body to the greatest extent. That is why such impacts may be especially efficient for females. It is due to typical of females’ preferential increase in adipose tissue content in the lower part of the body. At the same time utilization of vibration effects for the whole body is restricted by insufficient elaboration of the technology of vibration load application in combination with physical loads. In the course of such studies, mainly acute effects of the vertical type of WBV have been examined [1, 10, 14, 35, 36]. But the specific effects of swing-like WBV (rotation vibration) are not clear. Different aspects of these combined effects of health-related WBV application to subjects of different sex, age and physical condition need further investigation. The study of the vibration effect as an additional means for improving motor abilities in health-related training of females is of particular interest. It has been supposed that the effects of rotation vibration load on the whole body may influence some aspects of body balance, coordination and hip flexibility. The aim of the present study was to determine additional effects of 8 weeks’ whole body rotation vibration combined with a fitness exercise program of health-related training on chosen motor coordination abilities and flexibility in young females.

Material and Methods

Subjects

Forty young females aged 20-25 (students) voluntarily participated in the study (Table 1). All testing procedures and the training protocol were explained and the subjects were informed about the objective of the study. All subjects were screened for contraindications to vibration training (i.e. recent fractures, taking supplements, enrolment in strength training programs or having metal plates in their bones) prior to commencement of the study and were asked to replicate their physical activity level and dietary intake. The protocol was approved by the University Institution Review Board and all participants gave written informed consent prior to engaging in the study. Daily motor activity of females during the period of studies was determined by standard training programs without loading elements. The subjects' morphological characteristics showed no difference between the two groups. The prescribed program was completed from the beginning to the end by 19 females of the experimental group and 18 females of the control group.

Tab. 1. The general characteristics of young females in vibration training and control groups before physical training (mean, SD)

Groups	*Age* [years]	*Body heigh* [cm]	*Body mass* [kg]	*Lean body mass* [kg]	*Body mass index (BMI)* [kg/m^2]
Vibration training group (n=19)	23.25	166.15	63.61	46.45	23.07
	0.67	4.71	7.71	1.90	1.87
Control group (n=18)	20.87	166.05	63.05	46.55	22.69
	0.23	5.54	7.55	2.41	2.58

Study Design

The training program included 24 training sessions which were performed over the course of 8 weeks (3 sessions a week) and was based on basic principles of health-related protocols. A "blind" method was used to divide the subjects into two groups. All subjects completed the controlled study protocol as designed. On the test day the subjects were in the post-absorptive state and had not exercised for at least 24 h. Measurements were conducted by the same individual, according to conventional criteria and measurements procedures. Temperatures in room for training and measurements were kept close to 20-23°C at humidity 50-65%. Whole surface area of the training room was 305 m^2. The program of sessions was performed by subjects of the experimental group (EG) with a working vibration platform, whereas those of the control group (CG) performed the same exercises with a non-working (placebo) vibration platform. The subjects of CG stood on the vibration platform in the same positions as for the vibration treatment, except that in this case no vibration was administered. All other aspects of the protocol for the CG were identical to the protocol of EG. The duration of each session (40-50 min) and the content of exercises were the same in both groups. The workout regime was standardized to control the effects of outside physical activity. The exercise protocol included the control of the type of exercise, training intensity, training volume, the number and duration of rest periods and frequency of training. Seven exercises were used: 1. sanding on the platform V-foot, knee angle flexion 135º; 2. one leg flexion-extension standing on the platform; 3. standing on the platform, isometric half-squat position and dynamic squat; 4. extending the foot & push calibrated tubes back; 5. push calibrated tubes forward; 6. pushing-up on the platform; 7. supporting of abdominals in horizontal stabilization. The same specially trained supervisor and instructor conducted sessions in both groups. Before the first training session, the subjects were familiarized with the vibration platform and training exercises. This included familiarization with leg position on the platform and specific body positions while standing on the platform.

Whole body vibration. The WBV training was administered using a commercially available WBV platform (LADY 1 Pro, New Life Balance GMBH production, Germany). The WBV platform (width 50 cm, height above floor 25 cm) provided a rotation type of vibrations ("inclined vibration") at a frequency of 20 Hz and amplitude of ±2.0, ±3.5 and ±5.0 mm. Such a frequency and amplitude are widely used in commercially available vibration platforms of the whole body rotation type.

The amplitudes were related to the foot position on the swing-like vibration plate. This type of training stimulates stretch-reflex (extension-tension reflex) of muscles [13, 20]. The total duration of the vibration load in one session amounted to 10.5 ±1.1 min. The value of the total duration of vibration load was linked with the duration of vibration loaded exercise in each of 1-2 sets (50-120 s) and rest period between sets (180 s). Ten vibration platforms were used simultaneously.

Training

The training consisted of 24 training days separated with 1-2 days' rest, using a uniform schedule for each week. The subjects of the experimental and control groups performed the same exercises, not including maximal effort, preferentially stimulating leg, hand, trunk as well as back muscles usually used in health-related (fitness) training [37]. In order to enhance the training effect of exercises, elastic bands (tubes) in some exercises were used. Sub-maximal isometric and dynamic muscle contractions were used in training. The content and regime of exercises were aimed at an improvement in motor capacities and conditioning of females. Physical exercises of a versatile character have been performed to improve foot and arm strength, flexibility and general motor coordination. The submaximal effort in dynamic exercises has been used.

For the control group, the subjects stood on the vibration platform in the same position as for the vibration treatment, except that in this instance no vibration was administered. All other aspects of the protocol for the control group were identical to that described above. In the main part of the session, subjects completed a 5-min standardized warm-up. The subjects undertook light squatting, standing in erect position, standing with knee flexed, light jumping, standing on heels and exercises stimulating the stretch-reflex of muscles. In selected exercises, the above was performed with the body mass center displacement. In this case feet and trunk muscles and especially back muscles were stimulated. The exercises in an isometric half-squat position were performed with body mass distributed over the balls of the feet and heels raised off the vibrating platform to prevent vibrations being transmitted to the head. Subjects removed their shoes during the treatment period to ensure that the soles of the footwear would not dampen the vibrations and affect transmissibility. A special mat on the surface of the platform was used. Three minute rest intervals between each exercise were ensured. A longer rest interval was selected to ensure that the subjects had sufficient neural recovery between trials [11].

Measurements

Baseline measurements were recorded with 12-min rest between different testing procedures a day before the first training session. Measurements at the 4th and the 8th week were made the day after the last training session. Before the first training session, subjects were familiarized with the testing procedures. This included familiarization with devices for strength and power measurements and testing procedures. The following characteristics of flexibility and coordination were measured under standard conditions: 1. active and passive flexibility of hip joints (for the left and the right leg) (goniometry); 2. static body balance according to three tests – body balance stability while standing on one leg (Flamingo balance test) with eyes closed and two tests on a dynamometric force platform PLA-4P, integrated with a tension metric amplifier WNM5 and computer software KKD v.1.1 (JBA, Poland). The force plate had dimensions of 50x50 cm, and it was equipped with four tension metric sensors in four corners each. The platform was linked to a PC via data logger so that sway parameters could be calculated by the software and the final results displayed on a screen and recorded. Amplified signals were recorded by a computer, and then the coordinates of the center of foot pressure were estimated in projection of a horizontal X-Y plane base. The subjects were asked to stand without shoes directly on the platform as still as possible. Body balance was measured according to body balance stability while standing on the platform with eyes closed as well as after a kinetic stimulation by seven rotations around the body vertical axis. The measuring time was 32 s. Parameters calculated by the software included: the mean sway surface area (sway area defined as the area of the smallest polygon, which includes the total trajectory of the force center in the horizontal force plate plane) and the path length (defined as the way of the total trajectory of the force center in the horizontal force plate plane); 3. accuracy of reproducing 50% of maximum strength (average of five trials) while performing isokinetic effort by large muscle groups - for two leg extension (Dyno 2); 4. precision of angle reproduction during whole body rotation (50% of the maximum angle of rotation around the body axis in jumping); 5. sum of maximal angles of rotation around the body axis to the left and to the right. Subjects were performing a maximal revolution round the longitudinal body axis with both feet jump. Three trials were performed with revolutions to the right side and three trials to the left side. The sum was treated as a measure of the global motion coordination level [37].

Statistical Analysis

The standard descriptive statistics were performed. All data were found to be normally distributed; therefore, analysis was carried out using parametric statistical tests. Pre- and post-test means and standard deviations (SD) for the experimental and control groups were calculated. In addition, the mean difference between pretest and post-test measurements was calculated for each group. A t-test for dependent samples was used to examine differences between pre- and post-test scores for each group. A one-way ANOVA was used to assess whether any significant differences existed in the pre-test or post-test scores among the groups. Also, one-way Anova was conducted on difference scores between the pre- and post-test among the groups. A two-way analysis of variance (2-way ANOVA) with repeated measurements was used to determine the impacts of whole body vibration training on some motor coordination and flexibility characteristics. If an interaction was found, Tukey post hoc comparisons were used to identify significant pair group differences. The level of significance for statistical analysis was set at $p<0.05$.

Results

Results of measurements of the analyzed values of passive and active flexibility in hip joints under the influence of vibration training for the whole body in experimental and control group are presented in Table 2.

As is evident in the Table, physical training resulted in flexibility improvement in subjects of both groups. It should be stressed, however, that in the group of vibration training the above improvement was observed in a greater number of values, i.e. five out of six. It was specific to changes in both passive and active flexibility. Meanwhile, in the control group only two values of passive and two characteristics of active flexibility showed a significant increase. Besides, an acceleration of such positive changes under the impact of whole body vibration was noted. For instance, in the group of vibration training, major changes in most values had already occurred after 4 weeks of training, whereas those in the control group occurred only after 8 weeks.

Tab. 2. Changes in passive and active flexibility in hip joints for 8 weeks of whole body vibration training in young females (mean, SD)

Groups		Passive flexibility					
		1	2	3	4	5	6
Vibration training group (n=19)	before	114 8	87* 7	19* 5	108* 9	83* 8	19* 7
	4 weeks	114 7	90 8	24* 3	118* 9	93* 7	26* 3
	8 weeks	118 6	99* 5	26 4	121 8	100* 8	26 4
Control group (n=18)	before	115 9	86* 7	21 4	115 8	87 8	21* 4
	4 weeks	116 9	87 9	23 5	115 10	88 11	24 4
	8 weeks	120 7	92* 8	23 3	118 5	90 8	25* 5

Group		Active flexibility					
		1	2	3	4	5	6
Vibration training group (n=19)	before	133*	97*	26	124*	99*	25*
		7	6	4	9	8	4
	4 weeks	134	104	31	132*	102	34*
		6	9	4	9	8	3
	8 weeks	139*	113*	31	139	112*	36
		10	9	5	9	8	6
Control group (n=18)	before	128*	98*	30	131	101	28
		8	9	5	8	11	4
	4 weeks	133	103	31	135	98	31
		7	8	4	8	11	5
	8 weeks	136*	107*	29	139	104	30
		9	8	3	9	10	4

** significance of increment in the group (p<0.05)*
Designations:
1 – left leg, flexion, knee flexed, 2 – left leg, flexion, knee extended, 3 – Left leg, extension, knee extended, 4 – right leg, flexion, knee flexed, 5 – Right leg, flexion, knee extended, 6 – right leg, extension, knee extended

An analysis of the results of experimental training indicated some differences in expression of vibration effects for the improvement in several aspects of coordination capacities. This was observed with respect to values of both simple and complex coordination. In particular, such a characteristic of simple coordination as the capacity to reproduce the given strength of large muscle groups (foot extensors) changed faster in the experimental group as compared to the control one. The above was true for such a characteristic of complex coordination as the capacity to reproduce the given angle of rotation around the body axis in jumping. Changes in the capacity of body balance maintenance while standing on one foot with closed eyes, as well as in some tests performed on a dynamometric platform were also observed. These data are presented in Tables 3 and 4.

Tab. 3. Changes in the reproduction of 50% max isokinetic strength for two-leg extension, maximum rotation around the body axis in jumping and reproduction of 50 % of maximum rotation characteristics in jump for 8 weeks of whole body vibration training in young females (mean, SD)

Groups		Reproduction of 50% max isokinetic strength for two leg extension		Reproduction rotations in jump (%)			Sum of maximum rotations to the right and to the left [°]
		mean % max strength for 5 bouts	% deflection (-/+) from 50% max	to the right	to the left	mean	
Vibration training group (n=15)**	before	41.4*	- 8.6*	- 9.2	10.1	9.6*	794
		10.1		2.2	2.9		88
	4 weeks	52.4*	+2.4*	- 4.3	- 4.8	4.5*	795
		15.1		4.2	2.8		104
	8 weeks	47.9	- 2.1	- 4.4	- 4.7	4.5	798
		14.8		3.4	3.8		105
Control group (n=14)**	before	36.5*	-10.5*	3.1	5.0	4.0	771
		8.7		1.2	3.3		38
	4 weeks	43.8	- 6.2	- 9.4	- 6.3	7.8	784
		13.2		4.1	3.4		54
	8 weeks	55.0*	+ 5.0*	- 16.4	-15.4	15.9	778
		15.7		4.4	4.2		54

** significance of change in the group (p<0.05)*
*** The planned program was completed from the beginning to the end by 19 females of the vibration training group and 18 females of the control group, except the four females of vibration training group and control group who did not participated in this test procedure.*

As is evident from the Table, the values of coordination capacities tended to increase faster in the group of vibration training as compared to the control group. Moreover, their increase was higher in some values (reproduction of 50% of leg extensors isokinetic maximum strength and reproduction of 50% of maximum rotation around the body axis in jumping), i.e. such an increase occurred faster in the group of vibration training. A significant improvement in the control group occurred only after two months of training.

Data from study of the capacity of body balance maintenance under complicated conditions (when significant differences in vibration training effects were noted) are presented in Table 4.

Tab. 4. Changes in body balance characteristics measured for standing with eyes opened after rotations, for standing with eyes closed and by time of leg standing – eyes closed for 8 weeks whole body vibration training in young females (mean, SD)

Groups		Dynamometric platform				One leg standing eyes closed ("Flamingo")
		Standing after rotations		Standing eyes closed		
		Surface area [mm^2]	Path length [mm]	Surface area [mm^2]	Path length [mm]	Mean time body balance for left and right [s]
Vibration training group (n=19)	before	2291*	427*	380	299*	43.6*
		794	121	89	66	21.5
	4 weeks	1586	327	315	246*	63.7*
		585	109	64	65	25.1
	8 weeks	1152*	274*	319	259	81.8*
		508	91	91	72	27.8
Control group (n=18)	before	1436	263	272	240	49.5*
		608	87	101	83	26.5
	4 weeks	1719	327	330	279	68.8
		730	89	143	101	21.4
	8 weeks	1211	267	206	225	73.7*
		722	61	82	55	29.4

** significance of change in the group (p<0.05)*

It appears from the data in Table 4 that the capacity of body balance maintenance while standing on one foot with closed eyes increased equally within 2 months of training. A significant increase in the time of body balance maintenance was observed after 1 and 2 months of vibration training. It should be outlined that the above increase occurred faster in the group of vibration training.

Effects of training related to characteristics of motor coordination demonstrated on a posturograph platform while standing with open eyes were not revealed. They were observed, however, during body balance stability testing after rotations around the body axis as well as that of body balance stability while standing with closed eyes. A significant increase in this capacity was noted in the experimental group after only 8 weeks of vibration training. For instance, values of the "surface area" after rotations around the body axis tended to decrease. Concerning body balance stability while standing with closed eyes, these differences were peculiar to the "path length" index after 4 weeks of vibration training. The obtained results can have application in exercise prescription in health-related training of women. Available data allow approaching elaboration of additional means for flexibility and motor coordination correction on the basis of prompts in the neuromuscular stimulation mechanism.

Discussion

In the last decade, several studies have suggested positive effects of controlled vibration environment on strength and/or power development, flexibility, body balance and bone mass [11,12, 15, 25, 33, 35, 38]. It is well known that sustained vibration applied to a muscle or tendon can stimulate muscle spindles and elicit a tonic vibration reflex primarily via Ia monosynaptic and polysynaptic pathways [39]. Thus, it is difficult to reach definitive conclusions about mechanisms of long-lasting effects of whole-body vibrations on humans [1, 35]. Muscle activity while exposed to vibration could be monitored by recording a root mean square electromyographical signal. Several such studies have reported a significant increase in the electromyographical signal of different lower body muscles after WBV exposure compared with the same position without vibration [18, 24]. These changes have been suggested to be due to an increase in neuromuscular activity [34].

The findings here indicate that the whole body vibration (with a use of a vibration platform) in combination with a specialized program of a complex type of exercises influenced major characteristics of coordination capacities of females in the experimental group. This reflects varying manifestations of such effects upon active and passive flexibility, body balance stability as well as precision of strength reproduction by large muscle groups during isokinetic activity and precision of space (angle) reproduction during rotation in jumping.

Control group training, the content of which repeated that of the experimental group (with the exception of vibration platform being switched off during exercise performance), also produced effects of the same direction although with respect to a smaller number of characteristics. The differences consisted of a greater prominence of these effects resulting from the use of the whole body vibration and a higher rate of improvement from training. It should be mentioned that the obtained data refer to the influence of a complex physical exercise program. One may assume that inclusion of a wider spectrum of coordination exercises in the program might have more distinctly demonstrated the effects of vibration load on the whole body during exercise. The findings indicate that whole body vibration represent an additional factor of exercise effect reinforcement. This factor is expressed, above all, in faster occurrence of positive training effects. It is connected with significantly higher involvement of “stretch-reflex” during vibration impacts on muscles and with activation of muscle and joint proprioreceptors [31, 35]. Thus the direct application of vibration to the surface of the muscle unit has to separate the impact through WBV. Some WBV frequencies seem to produce a higher electromyographical signal than others [36]. It was shown that 30 Hz whole-body vibration frequency provoked a significantly higher response than the 50 Hz one [11, 15]. It was shown that lower leg muscles vibration characteristics induced changes in postural orientation characterized by the centre of pressure on the force platform surface on which the subjects were standing. The relationship between the magnitude of the postural response and the frequency of vibration differed between vibration applied to tibialis anterior and lateral gastrocnemius muscles [38]. The direction of body tilt induced by local muscle vibration did not depend on the vibration frequency at a lower frequency of 40-60 Hz [38]. This may also suggest the role of the whole-body vibration type for body balance. Long lasting (four-month) vertically vibrated intervention showed no effect on dynamic or static balance of the subjects [24]. During application in the given study rotation vibration, stimulating impacts upon the mechanism of body balance maintenance have a character close to the one natural during walking, reinforced by vibration impacts [5, 10]. In the present study, the above positive effects of WBV has been shown for young females. One may suppose that these approaches could be of greater importance for elderly females to whom age-induced decrease in several aspects of coordination capacities is peculiar [6, 13]. The most common mechanism of positive action of vibration effects of the analyzed type along with physical exercises of a specific content is an improvement in the muscle energy state and the body as a whole [12, 13, 35]. Additional energy consumption by vibration was not detectable under natural perfusion. The additional energy consumption by vibration was probably compensated by oxidative phosphorylation enabled by additional perfusion [40]. However, there are no studies concerning the effects of different external loads and frequencies on effects of intermittent vibration load. Qullier et al. [5] showed that postural stability and sensorimotor coordination remain perturbed after a day of prolonged exposure to whole-body vibration by a vehicle. It requires immediate treatment, “sensorimotor recalibration” to correct postural instability. The treatment may be based on a set of customized voluntary movements, muscle stretching, joint rotation, and plantar pressures. Maintenance of upright posture is processed by the brain and depends on inputs from visual, proprioceptive and vestibular receptors.

Thus, stability of upright position requires an interaction of the peripheral and the central nervous system. An increase in postural stability in standing with eyes closed seems to be a good tool for examining the positive effects of whole body vibration training on the proprioreceptor. In this experimental condition (eyes closed) signals from vision are switched off, and response reflects the availability of cues from proprioreceptors and slightly increased input from the vestibular system in comparison to the eyes open condition [18].

Conclusion

WBV load is closely related to whole body motor coordination abilities. Further specific investigation is needed to explore the degree of impact that whole body vibration training transfers. That vibration reinforces toning up effects may result in finding such types and regimes of physical exercises which would provide purposeful orientation on the improvement in various aspects of coordination capacities of females of different ages. The results showed that vibration effects on the whole body, in combination with a customized program of exercises, increased major characteristics of active and passive flexibility, body balance stability as well as sensorimotor characteristics – precision of strength reproduction by large muscle groups during isokinetic activity and precision of angle reproduction during rotation in jumping of young females. Therefore, the obtained results indicate additional possibilities for coordination capacity improvement in the process of health-related training by means of supplementing physical exercise programs with controlled whole-body vibration impacts.

References

1. Rittweger J. Vibration as an exercise modality: how it may work, and what its potential might be. *Eur J Appl Phys* 2010;108(5):877-87.
2. Cederlund R, Nordenskiold U, Lundborg G. Hand-arm vibration exposure influences performance of daily activities. *Disability and Rehabilitation* 2001;23: 570-77.
3. de Oliveira CG, Simpson DM, Nadal J. Lumbar back muscle activity of helicopter pilots and whole-body vibration. *J Biomech* 2001; 34:1309-15.
4. Chen JC, Chang WR, Shih TS, et al. Predictors of whole-body vibration levels among urban taxi drivers. *Ergonomics* 2003; 46: 1075-90.
5. Qullier O, Kavaunoudias A, Duclos C, Albert F, Roll J, Roll R. Countering postural post effects following prolonged exposure to whole-body vibration: a sensorimotor treatment. *Eur J Appl Physiol* 2009;105(2): 235-45.
6. Mester J. Biological reaction to vibration-implications for sport. *J Sci Med Sport* 1999; 2: 211-26.
7. Thompson C, Belanger M. Effects of vibration in inline skating on the Hoffmann reflex, force, and proprioception. *Med Sci Sport Exer* 2002; 34: 2037-44.
8. Bovenzi M, Hulshof CT. An updated review of epidemiologic studies on the relationship between exposure to whole-body vibration and low back pain (1986-1997). *Int Arch Occup Environ Health* 1999;72: 351-65.
9. Lings S, Leboeuf-Yde C. Whole-body vibration and low back pain: a systematic, critical review of the epidemiological literature 1992-1999. Int *Arch Occup Environ Health* 2000;73: 290-97.
10. Diemen A. Vibration training and possible mechanisms relating to structural adaptations and acute effects. *Sweelinkplein Nederland* 2002;1:21-34.
11. Cardinalle M, Bosco C. The use of vibration as an exercise intervention. *Exercise Sport Sci Rev* 2003; 31:3-9.
12. Delecluse C, Roelants M, Verschueren S. Strength increase after whole-body vibration compared with resistance training. *Med SciSport Exer* 2003;35:1033-41.
13. Mester J. Vibration training: benefits and risk. *J Biomech* 2006;39:1056-65.
14. Rehn B, Lidstrom J, Skoglund J, Lindstrom B. Effects on leg musculature performance from whole-body vibration exercise: a systematic review. *Scand J Med Sci Spor* 2007;17:2-10.
15. Cardinale M,Wakeling J. Whole body vibration exercise: are vibrations good for you? *Br J Sport Med* 2005; 39: 585-89.
16. Bosco C, Colli R, Adaptive responses of human skeletal muscle to vibration exposure. *Clin Physiol (England)* 1999;19(2):183-89.
17. Torvinen S, Sievanen H, Jarvinen TA. Effect of 4-min vertical whole body vibration on muscle performance and body balance. *Int J Sport Med* 2002; 23: 374-81.

18. Verschueren SM, Roelants M, Delecluse C, Swinnen S, Vanderschueren D, Boonen S. Effect of 6-month whole body vibration training on hip density, muscle strength, and postural control in postmenopausal women: a randomized controlled pilot study. *J Bone Miner Res* 2004;19:352-59.
19. Fowler DE, Tok MI, Çolakoglu M, Bademkiran F, Çolakoglu Z. Exercise with vibration dumb-bell enhances neuromuscular excitability measured using TMS. *J Sport Med Phys Fit* 2010;50(3):336-42.
20. Weber R. Muskelstimmulation durch Vibration. *Leistungssport* 1997; 1: 73-97.
21. Spitzenpfeil P, Mester J.Vibrationsbelastung beim alpinen Skilauf. *Sportorthopädie, Sporttraumatologie* 1997;1:13-4.
22. Rubin C, Recker R, Cullen D, Ryaby J, McCabe J, McLeod K. Prevention of postmenopausal bone loss by a low-magnitude, high-frequency mechanical stimuli: a clinical trial assessing compliance, efficacy, and safety. *J Bone Miner Res* 2004;19: 343-51.
23. Ward K, Alsop C, Caulton J, Rubin C, Adams J, Mughal Z. Low magnitude mechanical loading is osteogenic in children with disabilities conditions. *J Bone Miner Res* 2004;19:360-69.
24. Torvinen S, Kannus P, Sievanen H, et al. Effect of four-month vertical whole body vibration on performance and balance. *Med Sci Sport Exer* 2002;34:1523-28.
25. Roelants M, Delecluse C, Goris M, Verschueren S. Effects of 24 weeks of whole body vibration training on body composition and muscle strength in untrained females. *Int J Sport Med* 2004;25:1-5.
26. Bruyere O, Wuidart MA, Di Palma E, Gourlay M, Ethgen O, Reginster JY. Controlled whole body vibration to decrease fall risk and improve health-related quality of life of nursing home residents. *Arch Phys Med Rehabil* 2005; 86: 303-7.
27. de Ruiter CJ, van Raak SM, Schilperoort JV, Hollander AP, de Haan A. The effects of 11 weeks whole body vibration training on jump height, contractile properties and activation of human knee extensors. *Eur J Appl Physiol* 2003;90:595-600.
28. Torvinen S, Kannus P, Sievanen H, et al. Effect of 8-month vertical whole body vibration on bone, muscle performance, and body balance: a randomized controlled study. *J Bone Miner Res* 2003;18:876-84.
29. Russo CR, Lauretani F, Bandinelli S, et al. High-frequency vibration training increases muscle power in postmenopausal women. *Arch Phys Med Rehabil* 2003;84:1854-57.
30. Warman G, Humprhries B, Purton P. The effects of timing and application of vibration on muscular contractions. *Aviat Space Environ Med* 2002;73:119-27.
31. Rittweger J. Acute changes in neuromuscular excitability after exhaustive whole body vibration exercise as compared to exhaustion by squatting exercise. *Clinical Physiology and Functional Imaging* 2003;23:81-6.
32. Cheng CF, Hsu WC, Lee CL, Chung PK. Effects of the different frequencies of whole-body vibration during the recovery phase after exhaustive exercise. *J Sport Med Phys Fit* 2010;50(4):407-12.
33. Di Giminiani R, Manno R, Scrimaglio R, Sementilli G, Tihanyi J. Effects of individualized whole-body vibration on muscle flexibility and mechanical power. *J Sport Med Phys Fit* 2010;50(1):139-45.
34. Erscine J, Smille I, Leiper J, Ball D, Cardinale M. Neuromuscular and hormonal responses to a single session of whole body vibration exercise in healthy young men. *Clinical Physiology and Functional Imaging* 2007;27:242-48.
35. Schmidtbleicher D. Krafttraining unter Vibrationseinwirkung. *Sportverlag Sportschad* 2001;15:3-7.
36. Moras G, Tous J, Muñoz C, Padullés J, Vallejo L. Electromyographic response during whole-body vibrations of different frequencies with progressive external loads. *Revista Digital, Buenos Aires* 2006;10(93):2-9.
37. Starosta W. Motor abilities of coordination. Warszawa: MSMP; 2003.
38. Polonyova A, Hlavacka E. Human postural responses to different frequency vibrations of lower leg muscles. *Physiol Res* 2001; 50: 405-10.
39. Martin BJ, Park HS. Analysis of the tonic vibration reflex: influence of vibration variables on motor unit synchronization and fatigue. *Eur J Appl Physiol O* 1997;75:504-11.
40. Zange J, Haller T, Müller K, Liphardt A, Mester J. Energy metabolism in human calf muscle performing isometric plantar flexion superimposed by 20-Hz vibration. *Eur J Appl Physiol* 2009;105(2):265-70.