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Original research article

EFFECTS OF VIBRATION TRAINING ON THE EXPLOSIVE STRENGTH OF UPPER LIMBS

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Mladen Živković, Dejan Stošić, Saša Bubanj,
Katarina Herodek, Dobrica Živković

Faculty of Sport and Physical Education, University of Niš, Serbia

Abstract. *The aim of this study was to determine the effects of 10 weeks of vibration training on changes to the explosive strength of the upper limbs, as well as to determine whether the possible effects were caused by vibrational stimulation of the muscles or static exercises. The research sample comprised 60 male participants, aged 21 ± 6 months, randomly divided into three subsamples. The experimental group (n=15) comprised participants included in a specially designed vibration training using the Flexi-bar, the first control group (n=15) comprised participants included in a specially designed static training, and the second control group comprised participants not included in any specially designed training (n=30). All of the participants were tested at the beginning using the bench press test and the Myotest was used as a measuring instrument . The statistical methods used in this research to investigate the effects of the training were the univariate analysis of covariance (ANCOVA) and multivariate analysis of covariance (MANCOVA). Analyzing the obtained results, it was determined that vibration training using the Flexi-bar does not have a statistically significant influence on the change in the values of the explosive strength of the upper limbs , but that there were changes in the mean values of the studied parameters. In order for the experimental program to produce better results, training should be modified. Vibration training would produce better results if the frequency produced by the Flexi-bar was higher, which is an assumption based on previous research.*

Key words: *Flexi-bar, static exercise, bench press*

INTRODUCTION

Vibration muscle stimulation was first used for medical purposes, as part of the treatment of headache and pain in the lumbar spine (Calvert, 2002), and later in order to

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Corresponding author: Mladen Živković
University of Niš, Faculty of Sport and Physical Education, Čarnojevića 10a, Niš, Serbia
Phone: +381 18 510 900 • E-mail: profzile87@gmail.com

improve the general condition of the joints (Biermann, 1960). Positive effects of vibration stimulation were recognized by the space agencies in order to eliminate the negative impact of antigravity on the reduction of muscle function (Golecki et al, 2012). Vibration training occurs mostly during the preparation of Olympic athletes because it contributes to jump height improvement, strength and flexibility and also reduces the percentage of injuries (Nazarov & Spivak, 1985; Kunnemeyer & Schmidtbleicher, 1997). The application of vibration training causes functional and structural changes (Marković & Gregov, 2005). The changes are visible in the muscles that were previously contracted, so it is possible to apply this method of training to a specific muscle group. Vibration training could be applied to the whole body or part of the body, and therefore the effects can be seen in multiple muscle groups, especially on those body parts that are closest to the source of vibration (Babajić, Bradic, Pojskić, Kovačević, & Abazović, 2013).

A Flexi-bar is exercising equipment used during vibration training, constructed of artificial materials, with a handle located in the middle of the bar and with improvised weights that are located at the ends of the bar. The principle of using the Flexi-bar is that the swings produce vibration, with a frequency of 4.6 Hz, which is transmitted to the handle along the arms and shoulders and to the body (Flexi-Sports, Bislez, Stroud, United Kingdom, 514 g of mass, 1520 mm in length). Vibration training with the Flexi-bar belongs to the group of training exercises where strength exercises are performed with additional vibration stimulation. Stimulation of muscles is caused by the low frequency of 4.6 Hz, but it is enough to affects the parameters of strength (Kassenböhmer, 2005). Research shows that the Flexi-bar can cause more muscle stimulants during submaximal training (Mileva, Kadr, Amin, & Bowtell, 2010). Practicing with the Flexi-bar is a step forward in terms of efficiency of the exercise program for improving strength of the abdominal muscles (Hurley, 2007). The results indicate that the Flexi-bar has the ability to strengthen abdominal muscles because it produces greater muscle activity and increased fatigue compared to the same exercises without additional vibrational stimulation (Kim, So, Bae, & Lee, 2014). During the exercise with the Flexi-bar it was determined that there was the higher electromyographic activity of the muscles that are closer to the bar, i.e. the muscles of the upper extremities (Amin, Mileva, Shot, & Bowtell, 2006). Studies that have investigated electromyographic activity of the muscles using vibrational equipment state that posture of the body and position of the equipment has a significant impact on muscle activity (Sanchez-Zuriaga, Vera-Garcia, Moreside, & McGill, 2009; Goncalves, Marques, Hallal, & Dieen, 2011; Marques, Hallal, & Goncalves, 2012). The most effective is the standing position with bilateral oscillation of the equipment in the frontal plane and unilateral oscillation in the sagittal plane.

The aim of this study was to determine the effects of vibration training during 10 weeks on changes of the explosive strength of the upper limbs, as well as to determine whether the possible effects were caused by vibrational stimulation of the muscles or static exercises.

METHODS

The sample of participants consisted of students of the Faculty of Sport and Physical Education, University of Niš. The criteria for selection was that none of the students were involved in any programmed training process apart from their regular physical activities as part of the faculty curricula courses. The total research sample comprised 60 male participants, aged 21 ± 6 months, randomly divided into three subsamples. The experimental group (n=15) comprised participants included in a specially designed vibration training with the Flexi-bar, body height 177,06 ± 7,62 cm, body mass 73,91 ± 9,30 kg (mean value ± standard deviation). The first control group (n=15) comprised participants included in specially designed static training containing the same exercises as the vibration training but without the additional vibration stimulation, body height 174,07 ± 5,31 cm, body mass 72,51 ± 10,12 kg (mean value ± standard deviation). The second control group (n=30) comprised participants performing only regular daily physical activities envisaged by the faculty curricula practicals, body height 181,37 ± 7,23 cm, body mass 77,19 ± 7,99 kg (mean value ± standard deviation). The anthropometric characteristics of the participants were measured in the following manner: body height was measured with a precision of 0,1 cm (anthropometer by Martin) and body mass was measured with a precision of 0,1 kg (Tanita BWB800, Japan). The participants voluntarily agreed to participate in the study which was conducted in accordance with the Helsinki Declaration.

Upper limb explosive strength was tested using the bench press test, which represents the ability of an individual's neuromuscular system to express muscle strain in the shortest amount of time. Application of the bench press is very common when examining the efficiency of vibration stimulation of muscles (Poston, Holcomb, Guadagnoli, & Linn, 2007; Wilcock, Whatman, Harris, & Keogh, 2009; Rodríguez-Jiménez, Benitez, González, Feliu, & Maffiuletti, 2013). The measuring instrument that was used for testing is the Myotest. The Myotest device (Myotest SA, Sion, Switzerland) provides technology and methodology for assessment of explosive strength, and also its validity of use was scientifically proven (Comstock et al., 2011). The following variables were monitored: power (W), maximum power (W), force (N), velocity (cm/s).

The experimental program lasted for 10 weeks and consisted of 20 training sessions. Strength training was devised by the researchers themselves in accordance with all the recommendations of the Flexi-bar manufacturers, as well as the recommendations of the leading authors investigating this topic (Zatsiorsky & Kraemer, 2009; Verkhoshansky, 1979; Bompa, 2009; Thibaudeau, 2007). The participants of the experimental and first control group performed the same static exercises of the same duration, where during the vibration training the participants coupled the exercises with vibration muscle stimulation produced by the Flexi-bar. The exercises that made up main part of the training are exercises performed in an upright stance (with the Flexi-bar/resistance in front of the body and to the body) and from a prone position (push-up on one hand, the side bridge). Each exercise was performed three times for a duration of 20 seconds after repetition in the first five weeks, and then the training volume increased to 30 seconds after repetition, in the last five weeks. After each repetition there was a relaxation time which lasted for 20 to 30 seconds, and an optimal relaxation time of 60 to 90 seconds upon the finished set. The intensity of the exercising was determined by the participant’s weight.

The statistical analyses consisted of descriptive statistics, a univariate analysis of covariance method (ANCOVA) and multivariate analysis of covariance method (MANCOVA) in order to investigate the effects of the training on the final measurement, comparing all groups mutually. Statistical significance was determined at level $p<0.05$. All of the data were processed using the statistical package SPSS 11.0 (SPSS, Chicago, IL).

Results

The results of the mean values of the variables for the upper limb explosive strength obtained using the bench press test between the experimental group (n=15), the first control group (n=15) and the second control group (n=30) between the initial and final measurings, are given in Table 1.

Table 1 Descriptive statistical parameters for groups at the initial and final measuring

Variable (unit)	Measurement	Experimental group		First control group		Second c ontrol group	
		Mean	SD	Mean	SD	Mean	SD
Power	Initial	617,33	151,61	616,53	160,56	609,90	150,88
(W)	Final	623,73	133,22	627,87	159,92	616,70	121,88
Maximum power	Initial	660,40	149,76	660,07	189,53	657,33	155,51
(W)	Final	675,47	146,22	673,80	145,87	660,83	118,20
Force	Initial	485,60	59,98	494,73	64,80	472,97	70,15
(N)	Final	498,33	50,04	491,67	61,69	485,67	45,29
Velocity	Initial	166,73	26,49	163,80	31,28	170,83	24,35
(cm/s)	Final	169,07	23,71	167,47	30,39	167,30	22,56

Legend: Mean - mean values; SD – standard deviation

Tables 2, 3, and 4 show the results of the multivariate analysis of covariance (MANCOVA) which assesses the effects of the experimental program on the values for the explosive strength of the upper limbs obtained by a bench press test for all three groups of participants. The results in the tables are shown each time comparing two groups. Table 2 shows the results of the experimental group and the first control group. Table 3 shows the results of the experimental group and the second control group. Table 4 shows the results of the first control group and second control group.

Table 2 Results of the MANCOVA method between the participants of the experimental group (n=15) and the first control group (n=15)

Variable	Wilks' Lambda	F	Sig.
Experimental program	0,76	1,65	0,199

Legend: Wilks' Lambda –Wilks' Lambda statistic; F – F statistic; Sig. – Statistical significance

Table 3 Results of the MANCOVA method between the participants of the experimental group (n=15) and the second control group (n=30)

Variable	Wilks' Lambda	F	Sig.
Experimental program	0,79	2,44	0,064

Legend: Wilks' Lambda –Wilks' Lambda statistic; F – F statistic; Sig. – Statistical significance

Table 4 Results of the MANCOVA method between the participants of the first control group (n=15) and the second control group (n=30)

Variable	Wilks' Lambda	F	Sig.
Experimental program	0,91	0,86	0,495

Legend: Wilks' Lambda –Wilks' Lambda statistic; F – F statistic; Sig. – Statistical significance

The obtained results lead us to the conclusion that the effects of the experimental program on the studied group of participants do not show a statistically significant difference. The experimental program does not exhibit statistically significant effects on the change of the values for the explosive strength of the upper limbs of the participants of the experimental group and the first control group (sig=0,199), the experimental and the second control group (sig=0,064), the first and the second control group (sig=0,495).

Tables 5, 6, and 7 show the results of the ANCOVA method which assesses the effects of the experimental program on the values for the upper limb explosive strength obtained during the bench press test for all three groups of participants. The results in the tables are shown each time comparing two groups. Table 5 shows the results of the experimental group and first control group. Table 6 shows the results of the experimental group and the second control group. Table 7 shows the results of the first and the second control group.

Table 5 Results of the ANCOVA method between the participants of the experimental group (n=15) and the first control group (n=15)

Variable (unit)	F	Sig.
Power (W)	0,08	0,776
Maximum power (W)	0,00	0,964
Force (N)	3,97	0,056
Velocity (cm/s)	0,09	0,770

Legend: F – F statistic; Sig. – Statistical significance

Table 6 Results of the ANCOVA method between the participants of the experimental group (n=15) and the second control group (n=30)

Variable (unit)	F	Sig.
Power (W)	0,01	0,932
Maximum power (W)	0,24	0,623
Force (N)	0,37	0,546
Velocity (cm/s)	2,59	0,115

Legend: F – F statistic; Sig. – Statistical significance

Table 7 Results of the ANCOVA method between the participants of the first control group (n=15) and the second control group (n=30)

Variable (unit)	F	Sig.
Power (W)	0,07	0,797
Maximum power (W)	0,17	0,682
Force (N)	0,14	0,714
Velocity (cm/s)	3,23	0,080

Legend: F – F statistic; Sig. – Statistical significance

On the basis of the obtained statistical significances, one can conclude that there are no differences between the observed groups of participants. The experimental program does not exhibit any statistically significant effect on any given observed values for the explosive strength of the upper limbs, taking into account all groups of participants.

Discussion

The use of vibration equipment during exercise is considered to be an effective and safe method of training under static conditions, in order to develop the strength of the upper extremities (Rodríguez-Jiménez et al., 2014). A study conducted by Poston et al. (2007) aimed to investigate the influence of mechanical vibrations on strength during the performance of the bench press test. The results indicate that maximum strength and average strength are higher during vibration muscle stimulation, compared with the control measuring when there was no vibration stimulation. There is evidence of acute effects of vibration training on the improvement of the strength of the upper and lower extremities, and also there are indications that long-term training causes an increase in strength (Cochrane, 2011). In the study that examined electromyographic activity of the muscles of the upper limbs in static and vibration conditions, the authors observed improvement during the vibration training using vibrating dumbbells (Bosco, Cardinale, & Tsarpela, 1999). The strength of the frequency applied to the muscle does not guarantee and improve muscular activity during exercise (Hazell, Jakobi, & Kenno, 2007). During the bench press exercise with vibration equipment that vibrates at 0.25 and 45 Hz, there was a statistically significant increase in electromyographic activity in both conditions, compared to 0 Hz (Moras, Rodríguez-Jiménez, Tous-Fajardo, Ranz, & Mujika, 2010).

These studies undoubtedly speak about the positive effects of vibration training on the improvement of strength, and that the same exercises without vibration stimulation applied in static conditions do not give the same results. The results of this study are not in accordance with the aforementioned studies, because there has been no improvement in the values of explosive strength of the upper extremities. The reason for that could be the insufficient frequency of 4.6 Hz produced by the Flexi-bar. In order to activate the muscles most effectively, the frequency should be in the range of 30 to 50 Hz. In addition, elite athletes can benefit more from vibration training than non-athletes (Luo, McNamara, & Moran, 2005). The specific angle at which static exercises are performed can be another reason why there has been no increase in the value of explosive strength of the upper extremities. Improvements in strength parameters always come in the trained angle compared to other angles during the upper extremity strength training, so it can be concluded that there is no transfer of strength in other positions (Thepaut-Mathieu, Van Hoecke, & Martin, 1988).

Conclusion

The importance of this research is reflected in the examination of the effects of vibration training on the explosive strength of the upper limbs, and in the determination of differences between the two control groups. The research results provide useful information about the neuro-muscular response when the body is exposed to vibration training, and allow successful practical application of these exercises in the training process. The changes that are caused by using vibration training with the Flexi-bar on the explosive power of the upper extremities were not statistically significant. Looking at the mean value, at the initial and final measuring, there were noticeable changes in all the values, but not at a level of statistical significance. These results suggest that the application of vibration training influences the improvement of parameters of explosive strength, but in order for the changes to be statistically significant, the training should be modified. Based on previous research we can assume that vibration training would yield better results if the frequency produced by the Flexi-bar was higher.

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EFEKTI VIBRACIONOG TRENINGA NA EKSPLOZIVNU SNAGU GORNJIH EKSTREMITETA

Cilj ovog istraživanjabio je da se utvrde efekti vibracionog treninga u trajanju od 10 nedelja na promenu eksplozivne snage gornjih ekstremiteta, kao i da se utvrdi da li su eventualni efekti izazvani vibracionom stimulacijom mišića ili statičkim vežbama. Ukupan uzorak ispitanika u ovom istraživanju sačinjavalo je 60 muškaraca, starosti 21 godina ± 6 meseci, nasumično raspoređenih u tri subuzorka. Eksperimentalnu grupu (n=15) činili su ispitanici koji su bili uključeni u posebno programirani vibracioni trening sa Flexi-bar-om, prvu kontrolnu grupu (n=15) činili su ispitanici koji su bili uključeni u posebno programirani statički trening, drugu kontrolnu grupu činili su ispitanici koji nisu bili uključeni ni u jedan programirani trening (n=30). Ispitanici su testirani na početku i na kraju eksperimentalnog programa testom potisak sa grudi, kao merni instrument korišćen je Myotest. Statističke metode koje su korišćene u ovom radu sa ciljem utvrđivanja efekata treninga bile su metoda univarijantne analize kovarijanse (ANCOVA) i metoda multivarijantne analize kovarijanse (MANCOVA). Analizom dobijenih rezultata utvrđeno je da vibracioni trening sa Flexi-bar-om ne utiče statistički značajno na promenu vrednosti eksploziivne snage gornjih ekstremiteta, ali da dolazi do promena srednjih vrednosti posmatranih varijabli. Kako bi eksperimentalni program dao bolje rezultate treninzi bi morali da se modifikuju. Vibracioni trening bi dao bolje rezultate ukoliko bi frekvencija koju proizvodi Flexi-bar bila veća, pretpostavka je na osnovu dosadašnjih istraživanja.

Ključne reči: *Flexi-bar, statičke vežbe, potisak sa grudi.*