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Studying the implementation of mechanical vibration in sportsmentraining

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Abstract. The vibration is the periodic or oscillatory motion of a body or particles of an environment, executed around a position of equilibrium. The vibration of the whole human body (WBV - Whole Body Vibration) represents the exposure of the whole body ensemble to vibrations, the opposite of local vibrations where an isolated muscle or muscle group is stimulated by using a vibrating device. There are numerous specialized studies supporting the utility of mechanical vibration during training and recovery of athletes. Since the mid 90's, mechanical vibrations were used more and more frequently in sports training. In this study we wanted to highlight the impact of general mechanical vibrations-WBV generated by a vibrating bed, on the sportsmen prior to conventional training. In this study, four players, members of the Oradea University FC football team, who participated in official games and competitions, were evaluated. The stance of the subjects who took part in the study was sitting on the vibrating bed with upper limbs on the thighs, inferior members extended and support at spine level in a fixed support. In order to assess the athletes part of the study, we took into account base values, prior to study initiation date and the final values, after 8 weeks of applying the mechanical vibrations, of the following objective parameters: standing long jump; standing high jump; thigh circumference. The benefit of mechanical vibrationsin athlete training is an area that still requires more specialized research to highlight as accurately as possible the manner in which they can be used to improve the athletic performance. The results of this study confirm that under the influence of mechanical vibrations more muscle fibers, motor unitsare activated, respectively, as compared to simple muscle contractions.

Keywords: mechanical vibration, muscle, footbal players, Oradea University FC team

Introduction

The vibratory motion of a mechanical system is defined as its spatially limited displacement, during which the geometrical and kinetic parameters, which determine the positions of the system elements, are alternately changing the direction of variation, in time between well-established values (Ursu-Ficher, 1984; Paleu, 2008).

Numerous specialized studies (Cardinale & Bosco, 2003; Boboc, 2006; Lamont et al., 2010), conducted mainly in the last 20 years, advocate the use of mechanical vibrations in the preparation and recovery of athletes, due to definite benefits resulting from these of this preparation method. The vibratory movements can be classified in several ways (Ionescu, 2008), depending on the cause that produces vibration, the resistance forces, excitation, their analytical representation or their mode of action on the human body.

According to the way vibrations act on the human body, there are 2 types of vibrations:

-that act on the entire human body, namely the global vibrations, whole body vibration- WBV;

-that act only on the human body segments, namely local vibrations, for instanceon the hand-arm system.

Whole body vibration- WBV is realizedby using a vibrating platform or a vibrating bed; the intensity and the direction of vibration generated by the device are essential in terms of the desired effect. The therapeutic benefit of performing WBV at the elderly was demonstrated and supported in the literature (Rubin et al., 2004; Bautmans et al., 2005). In this study, we wanted to emphasize the impact of general mechanical vibration-WBV, generated by a vibrating bed, on athletes prior to carrying out of conventional training.

Thus the specialized research (Boboc & Căpăţână, 2006), has proven that mechanical vibrations can lead to the recruitment of approximately 95%-97% of all muscle fibers on which they act. Comparatively,during a conventional training the amount of muscle fibers recruited is only around 40%-60%. The positive effects of applyingthe vibration training were recorded also in what concerns the improvement of joint flexibility at anatomical areas subject to vibration level. In the case of athletes performing vibration training, the following were also emphasized:

-improvement of local superficial circulation and at muscle vibration application level (Lohman et al., 2007);

-an incrementof the somatotropin secretion, the growth hormone being a very important element in tissue repair (Marin & Rhea, 2010);

-an increase of the testosterone and endorphins, which relieve pain and consecutively improve athlete's mood (Pâncotan, 2012).

Another benefit of using mechanical vibrationson athletes is that they reduce the mechanical pressure on joints (Pâncotan, 2012), ligaments and tendons; because of this aspect the vibrational training is beneficial in preventing injuries but also during athletes' recovery and rehabilitation phase (Marin & Rhea, 2010).

Materials and methods

The working method used in this study, namely evaluation of physical parameters before and after training with mechanical vibration to a group of athletes, follows the research methodology known in the art (Ronnestad, 2004; Rehn et al., 2007).

Four players, members of the FC University Oradea football team, who participated in official matches and competitionswere evaluated in this study. They performed regular weekly physical activities comprising minimum 8 hours of training and circa 90 minutes official match. The subjects of study were males ofclose age, weight and height. Thus, theywere between 20 and 23 years, weighing about 75 +\- 10 kg. and of anapproximately 175 +\- 10 cm height, the exact details are found in the factsheet of each candidate. All subjects included in the study expressed written consent to participate in the study. Initially,there were eight players recruited but two of them dropped for subjectivereasons; theydid not want to perform the vibration therapy anymore while the other two have given up for objective reasons: they were injured during the study.

The exclusion criteria of the applying vibrations to athletes study were:

-presence of an accute inflammatory process irrespective of its location;

-any type of comorbidities or neoplasms;

-mental illness;

-subject under treatment with antibiotics or under psychotropic medication;

-presence of metal parts in the body;

-occurrence of adverse reactions of any intensity or nature;

-inavailability to perform physical activities;

The stance of the subjects taking part in the study was sitting on the bed with upper limbs on their thighs and inferior limbs extended to provide support for the spine in a fixed support. The main components of the complex generating mechanical vibrations system used in our study were:

-the vibrating bed;

-the vibration generating electric engine attached to the bed, with a maximum power of 1.5 kW;

-2-patchlike triaxial accelerometers vibration sensors for measuring vibrations generated by the vibrating assembly: accelerometer sat directly on the bed and on the anterior face of the thigh.

The mechanical vibrations were applied three-directionally: vertical- X axis, horizontal-Y axis and axial–Z axis, in a room benefiting from appropriate thermal comfort, over a period of 8 weeks, with a variable frequency according to each subject.

A very important aspect, to be mentioned and respected in practice, is that according to the characteristic parameters, the WBV action may constitute a risk factor on the body athletes (Platon & Niculescu, 2007). Vibrations acting on a human body can produce the disturbance of physical and intellectual activity, and mechanical impairments and or subjective phenomena (Picu, 2010). Because of these issues we have established a study protocol, similar to those in other papers that discussed this topic.

Each mechanical vibration training session was performed with a frequency of 40 Hz and lasted for 13 minutes, a 60 seconds session being repeated 7 times. There was a 60 seconds break between sessions, during which the subjects remained in the stance during the study.

Table 1. Parameters (displacement, velocity, vibration acceleration) of vibration summarized according to the 2 vibration sensors used

	Vertically (X)			Horizontally (Y)			Pivotally (Y)		
	Acc [g-RMS]	Velocity [mm/s-RMS]	Movement [ym-P-P]	Acc [g-RMS]	Velocity [mm/s-RMS]	Movement [ym-P-P]	Acc [g-RMS]	Velocity [mm/s-RMS]	Movement [ym-P-P]
1	0.17	11	240	0.2	14	310	0.06	4	88
2	*0.06*	*3.7*	*150*	*0.05*	*7*	*200*	*0.02*	*1.6*	*56*

1.-exact values of vibration parameters: movement, velocity, acceleration measured by the accelerometer on the bed;

2.-exact values of the vibration parameters: movement, velocity, acceleration measured by the accelerometer on the anterior face of the thigh;

In the table 1 the exact values of the three parameters of vibration are summarized: displacement, velocity, vibration acceleration according to the 2 vibration sensors used.

The meaning and values of other data listed in the table are thus: 1g = gravitational acceleration = 9.81 m/s^2, RMS - vibration media, Peak to Peak (P-P) - peak to peak vibration = 2xP = 2x1.414 RMS, Peak (P) = 1.414 RMS.

In order to assess the players taking part in the study, we took into account the base values, prior to study initiation date and the final values, after 8 weeks of applyingthe mechanical vibrations of the following objective parameters:

-standing long jump;

-standing high jump;

-thigh circumference.

The material used for the standing long jump isthe roulette fixed on the outer edge of the line of departure; the athlete performs a knee flexion then jumps horizontally, legs in a parallel position, as far as possible. The jump is measured in centimeters from the outer edge of the line of departure to the point at the rear of the place where the legs of the athlete have landed. The standing vertical jump, with the reaching of the apex with two hands, comprises the following steps: arms impulse, knee flexion, standing vertical jump and reaching as high as possible with both hands. The material used is the graded roulette fixed on a vertical wall; the jump is measured in centimeters from ground level to the lowest point of fingers' place of contact on the vertical wall.

The circumference of the thigh was determinedby using the measuring tape positioned horizontally, just below the buttocks, the last gluteal fold. The measuring (in centimeteres) is done as the athlete is standing in an orthostatic position, with the legs slightly apart and body weight equally distributed on both feet.

Futhermore, for an interpretation as accurate as possible of the values of this parameter the skinfold was also measured before and after the vibration training. The measuring of the thickness of the cutaneous plica was done was performed by using the adipocentimeter for the 1/3 average of the anterior face of the thigh, on the anterior midline. The lower limb under examination was relaxed, leaning lightly on the top of the foot; so that the entire body weight was distributed on the collateral inferior limb.

During the study, the participants must comply with the following rules:

-before applying the vibrations: they must not eat for 2 hours, not drink for 30 minutes and not perform exercise;

-when applying the vibrations: they do not perform any kind of physical or intellectual activity;

-following the vibration training, within 30 minutes, the subjects perform a specific physical training.

Results and discussion

The results of the monitored parameters before and after concluding the research and the factsheets of the four subjects part of the study were as follows:

Athlete number 1:

-factsheet: age-20; size-174 cm.; weight: 72 kg -before the study, 72.7 kg,- after study; skinfold thickness: 13.1 mm -before the study, 13.1 mm -after study; training frequency: 6 sessions\week, a total of 48 meetings with a pause on Sunday;

-objective parameters, mentioned below:

Studied parameters	Initial values -before the survey	Final values -after the survey
long jump	238 cm	246 cm
high jump	55 cm	62 cm
left thigh circumference: relaxation-contraction	57-57,7 cm	58-59 cm
right thigh circumference: relaxation-contraction	57,3-57,8 cm	58,1-59 cm

Athlete number 2:

-factsheet: age-21; size-177 cm; weight: 78 kg -before the study, 77.8 kg -after study; skinfold thickness: 14.3 mm -before the study, 14.2 mm -after study; training frequency: 5 sessions\week, total 40 sessions with pause during weekends;

-objective parameters, mentioned below:

Studied parameters	Initial values -before the survey	Final values -after the survey
long jump	236 cm	243 cm
high jump	43 cm	30 cm
left thigh circumference: relaxation-contraction	59,5-60,4 cm	61,1-62 cm
right thigh circumference: relaxation-contraction	59,6-60,4 cm	61,5-62,2 cm

Athlete number 3:

-factsheet: age-23; size-184 cm; weight: 83 kg -before the study, 84 kg -after study; skinfold thickness: 14.8 mm -before the study, 14.9 mm -after study; training frequency: training every second day - a total of 28 sessions;

-objective parameters, mentioned below:

Studied parameters	Initial values -before the survey	Final values -after the survey
long jump	238 cm	241 cm
high jump	50 cm	52 cm
left thigh circumference: relaxation-contraction	56-56,7 cm	56,4-58,1 cm
right thigh circumference: relaxation-contraction	57-58 cm	57,3-58,2 cm

Athlete number 4:

-factsheet: age-22; size-180 cm; weight: 82 kg -before the study, 82.4 kg -after study; skinfold thickness: 14.7 mm -before the study, 14.7 mm -after study; training frequency: 2 trainings\week, a total of 16 sessions;

-objective parameters, mentioned below:

Studied parameters	Initial values -before the survey	Final values -after the survey
long jump	222 cm	223 cm
high jump	44 cm	44 cm
left thigh circumference: relaxation-contraction	62,1-63,2 cm	62,2-63,5 cm
right thigh circumference: relaxation-contraction	61,5-63,1 cm	61,5-63,3 cm

By analyzing the factsheets of the 4 subjects who took part in the study, it was noticed that the number of mechanical vibration trainings did not significantly affect the evolution of the body weight of the subjects or the skinfold thickness. Pratically, with regard to the body weight, the most significant development occurred was in teh case of the subject who performed 28 training sessions, from 83 kg to 84 kg, a weight increase of 1.2%, respectively.

The skinfold thickness of only 2 subjects was influenced by the mechanical vibration training:

-the subject who completed 40 sessions from 14.3 mm to 14.2 mm, a 0.7% decrease of the skinfold thickness;

-the subject who performed 28 sessions from 14.8 mm to 14.9 mm, a 0.67% increase of the skinfold thickness;

Analysis of the comparative evolution, before and after the study, of the results obtained, for the long jump, shows that the training sessions number has direct impact on the achieved performance. Thus, one can notice in the data listed in the table below, that the performance increase percentage decreases from 3.36%, for the subject who performed 48 sessions, to only 0.45% in the case ofthe subject who performed 16 meetings. Upon comparingthe 4 results reflecting the benefit of the researchand highlighted in the table below (table 2), one has learned that there is a significant difference between the success of athletes performing 48-40 training sessions and those performing 28 to 16 training sessions ($p < 0.001$).

Table 2. The comparative evolution of the results in long jump depending on the number of meetings conducted

Number of performed sessions	**Long jump (cm)**		**% increase**
	Initial	**Final**	
48 sessions	238	246	+3,36%
40 sessions	236	243	+2,97%
28 sessions	238	241	+1,20%
16 sessions	222	223	+0,45%

Comparative graphical representation of the 4 growth percentageregarding the lenght of the long jump, obtained after having carried out the study in question is presented in figure 1.

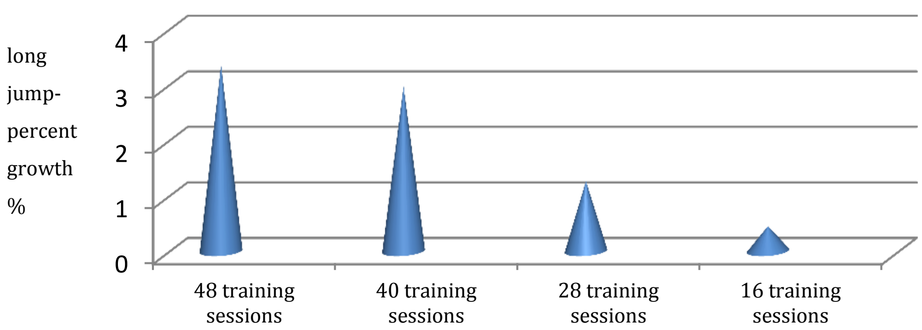

Figure 1. Graphical representation of the 4 growth percentage regarding the lenght of the long jump, obtained after having carried out the study in question.

The number of training sessions has a direct impact on the performance of the high jump, on the growth rate of results obtained after having carried out the study, being directly proportional to the number of repetitions. The comparative analysis of the initial and the final results, summarized in the table below, for the subject having attended 48 sessions show an improvement of the performance from 55 cm to 62 cm.

The growth rate of the obtained results (table 3), compared to the training sessions frequency, is the highest for the subject who performed 40 repetitions, while in the case of the athlete who attended only 16 sessions no improvement of the initial performance was noticed

Table 3. The comparative evolution of the results in high jump depending on the number of meetings conducted

Number of performed sessions	High jump (cm)		% increase
	Initial	Final	
48 sessions	55	62	+12,73%
40 sessions	43	50	+16,28%
28 sessions	50	52	+4,0%
16 sessions	44	44	0,0%

The graphical representation of the evolution of high jump for the 4 subjects that took part in the study (figure 2), namely the length of the high jump, after the completion of the study as compared to that measured before its carrying out is shown below.

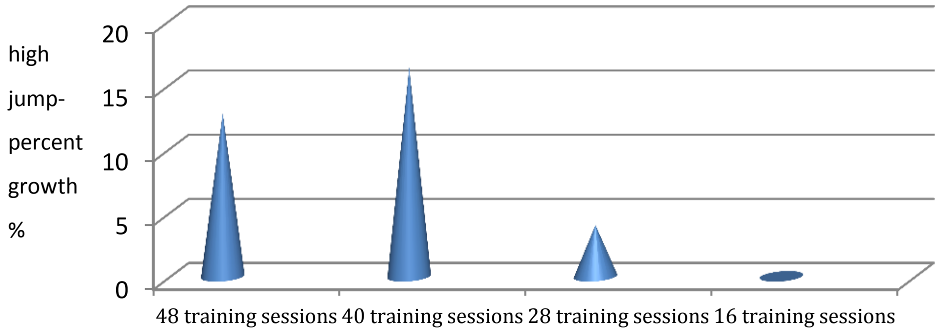

Figure 2. Graphical representation of the 4 growth percentage regarding the lenght of the high jump, obtained after having carried out the study in question

Table 4. The values of the thighs circumference before and after the study

	Left thigh			Right thigh		
	Initial-cm	Final-cm	% increase	Initial-cm	Final-cm	% increase
Relaxation						
48 sessions	59,5	61,1	2,69	59,6	61,5	3,19
40 sessions	57,0	58,0	1,75	57,3	58,1	1,40
28 sessions	56,0	56,4	0,71	57,0	57,3	0,53
16 sessions	62,1	62,2	0,16	61,5	61,5	0,00
Contraction						
48 sessions	60,4	62,0	2,65	60,4	62,2	2,98
40 sessions	57,7	59,0	2,25	57,8	59,0	2,08
28 sessions	56,7	58,1	2,47	58,0	58,2	0,34
16 sessions	63,2	63,5	0,47	63,1	63,3	0,32

By analyzing the table below (table 4), which includes the initial and final values of the circumference of both thighs, both in relaxation and contraction state, it was noticed that the greatest benefit was recorded in the case of the athlete having performed 48 training sessions. Compared to this topic, the development of the thigh circumference, in relaxation and contraction state, of the athlete who carried out 40 repetitions was slightly lower ($p > 0.05$). Alternatively, compared to the same topic, the development of thigh circumference in the case of the athlete having taken part in 16 training sessions, was significantly lower ($p < 0.001$).

Identically, in the case of the athlete having participated in 28 sessions: the thigh circumference development was significantly lower ($p < 0.001$) except the circumference of the left thigh in contraction state, where an increase from 56.7 cm to 58.1 cm ($p = 0.807$) was noticed.

Figure 3. The evolution of the circumference of the relaxed thigh circumferenceof the 4 subjects who participatedin the study.

The graphical representation of the evolution of the circumference of the relaxed thigh circumferenceof the 4 subjects who participatedin the studyis presented in figure 3. The right column represents the the evolution of the thigh circumference growth percentage subsequentto the performing of the mechanical vibration therapy while horizontally the number of training sessions each subject performes is stated.

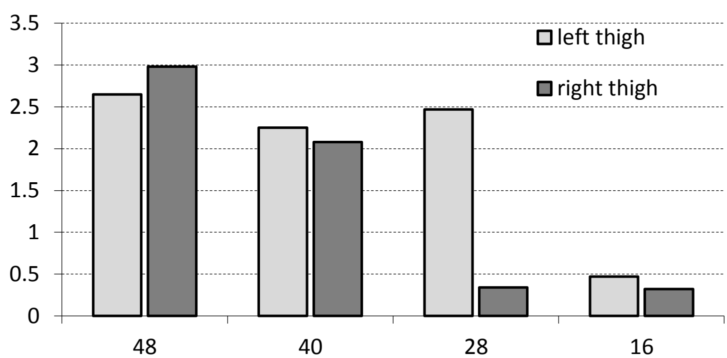

Figure 4. The evolution of the circumference of the contracted thigh circumference of the 4 subjects who participated in the study.

The graphical representationof the evolution of the circumference of the contracted thigh circumference of the 4 subjects who participated in the studyis presented in figure 4. The left column represents the evolution of the thigh circumference growth percentage subsequent to the performing of the mechanical vibration therapy while horizontally the number of training sessions each subject performes is stated.

Conclusions

First, it should be noted that this study represents only one step in the framework of an investigation that is to be continued and developped. According to research in the field (Hopkins, 2000), the relevance of the results is questionable, because of the small number of subjects monitored, however some distinct conclusions consistent with the literature are highlighted.

The results of this study confirm that under the influence of mechanical vibrations more muscle fibers are activated, namely motor units, as compared to the simple muscle contractions. There is a directly proportional relationship, clearly highlighted, between the number of training sand the results of the parameters monitored during the clinical trial. Obviously, the mechanical vibration training is an effective tool in athlete training when it is accompanied by physical exercices part of the athlete classical training. Thus, the muscle groups subject to mechanical vibration are better trained, the immediate effect being that the muscles can be used quicker and and more efficient, also being able to generate more energy. A significant increase of the thigh circumference for the athletes who have performed at least 5 training sessions a week was also noticed.

The benefit of mechanical vibrationsin the athlete training is an area that still requires more specialized research in order to highlight as accurate as possible the manner in which they can be used to improve the athletic performance.

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