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CHRONIC EFFECTS OF APPLYING WHOLE BODY VIBRATIONS TO THE RANGE OF MOVEMENT AND MUSCLE FUNCTION OF FOOTBALLERS' LOWER EXTREMITIES

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Original research:

Abstract
This study involved the application of static stretching exercises in warm-up part of soccer training with vibration stimulus (VSI), compared to an equivalent stretching exercise without applying vibration (SSI). For this purpose, all subjects, are in a randomized manner selected in two equal groups (SSI and VSI). Complete treatment for both groups lasted four weeks (3 x per week). VSI group has implemented an identical training as SSI group, with difference that all exercises performed on the platform (f = 40 Hz, A = 2 mm). Results of the combined analysis of variance, indicating that there is a statistically significant interaction ($p<0.05$) on variables to assess range of motion, in addition to the variable to assess range of motion in the position of plantar flexion ($p = .079$). Results of muscle function of lower limbs showed no differences between the study groups ($p<0.05$). The results of this study suggest that in chronic settings, static stretching with vibration have the potential to cause a substantial increase in range of motion, but without significant improvement of muscle function (jumping and sprinting).

Keywords: warm-up, vibration, static stretching, flexibility, muscle function, lower limbs

Introduction

Warming up puts an athlete in such a physiological state that will improve his sport performance (Elam, 1986), and will allow him to act and perform his activity at the highest possible level. During the heating process, physiological adjustments occur in the respiratory, metabolic, skeletal-muscle system, nervous and circulation system, and many depend on an increase in body temperature (Bennet, 1984, according to Shelllock, 1986). Warming, in addition to improving motor activity performance, is also thought to reduce the risk of injury (McArdle, Catch and Catch, 1991, all according to Young and Behm, 2002). Two warm up methods can be used in sport: passive (increase in body temperature with exogenic factors), and active (increase in body temperature by physical exercise) (Bishop, 2003). When it comes to active warming, then the introductory pre-preparation is usually carried out through three typical common phases. In the first place are different low-intensity aerobic activities, to raise optimal body temperature with the aim of improving nerve-muscle function (McArdle e al., 1991). As regards the part before preparation relating to stretching exercises, most coaches recommend applying static stretching exercises, with the idea that this helps reduce the risk of injuries. However, methods for optimal increase in flexibility, observing in the long term are currently under scientific debate. Vibration training could be an adequate modality to increase flexibility, while not disturbing, or even improving nerve muscle function. It is a relatively newer training technology, and the last training form is known as the vibration of the entire body (WBV – whole body vibration training), which takes place entirely on the vibration platform (Markovic and Gregov, 2005).

While the traditional view is that vibration can carry a high risk of harmfulness, more and more studies are putting their focus on the positive effects of this kind of training modality (Rittweger, 2010). Physiotherapeutic and clinical use of vibration training has shown that vibration applications can have numerous advantages for individuals in rank from elite athletes to physically inactive persons (Issurin, 2005; Nordlund et al., 2007; Rehn et al., 2007; Wilcock et al., 2009). This includes improvements in running speed (Bullock et al., 2008; Paradisis et al., 2007), vertical and horizontal jumps (Bosco e al., 1998; Delecleuse et al., 2003; Paradisis at al., 2007; Roelants at al., 2004. Torvinen at al., 2003, and flexibility (Cochrane et al., 2004; Fagnani at al. 2006; Tillaar, 2006).

In chronic settings to improve stretching exercises, the authors (Dastmenash et al., 2010) tried to combine different types of stretching with the additional application of vibration stimuli to improve the range of movement. The results show that combined training, which incorporates vibration with stretching exercises (vibration + pnf methods), after three weeks, produces much better results in increasing hamstring muscle flexibility compared to the other two protocols separately (squatting on the vibration platform and pnf method without vibration). Another similar study was conducted by Tillarr and associates (2006), when it tried to answer the question of whether whole body vibrations would help increase hamstring muscle flexibility. Both groups stretched systematically 3 times a week, a total of four weeks, by the PNF method (contraction – relaxation). The results show that both groups had a significant increase in hamstrings flexibility compared to the initial measurement, but that the WBV group achieved 30% shifts, while the control group recorded a 14% increase. If all this is truly true, then vibration exercise may be an effective means of warm up athletes directly for the main training or competitive loads, but also as an supplementary exercise modality incorporated into standard warm-up protocols, which athletes regularly conduct at their training.

Materials and Methods

Subjects

None of the subjects in the selected sample had reported any of the chronic illnesses, nor did they have any medical contraindications, closely related to the practice of vibrational training. Table 1. presents the basic descriptive parameters of all selected entities within the sample (N = 34), which relate to chronological age, body weight, and adipose tissue parameters expressed in percentages. This experiment was started by the planned number of subjects (N=34). However, in part to start the competitive season and the increased number of contact injuries, and also due to their own initial to abandon the experiment, the entire trial was completed by a total of 26 participants s who were taken into further consideration.

Table 1. Basic morphological characteristics of the selected sample

	N	Min	Max	Mean	SD
CHRONOLOGICAL AGE	34	19	24	20.9	1.5
BODY HEIGHT	34	169	186	178.7	4.0
BODY MASS	34	62.6	92.6	76.2	5.9
FAT MASS %	34	6	15	11.0	2.5

Testing procedures and instrumentation

The range of movement of the lower limbs was measured by the goniometer (Baseline Goniometers, 12-1240: 12", 360 °, USA), and the following variables are used only for dominant leg: passive hip flexion (straight leg test), passive hip extension, passive plantar flexion, passive dorsal flexion. To aces explosive power, we used a squat jump and countermovement jump, without the active engagement of the upper limbs. To assess the explosive power in running, a specific football test sprint was used, which was conducted at a distance of fifteen meters (Browers Timing System, IRD-T175, USA). As a set of activation exercises, five static stretching exercises was used on the vibrational (Powrx, Pro Evolution 2.7) platform.

Variables

Table 2. Anthropometric and motoric variables

Range of movement variables		
4.	Passive hip flexion (straight leg raise test)	PHF
5.	Passive hip extension (dominant leg)	PHE
6.	Passive plantar flexion (dominant leg)	PPF
7.	Passive dorsal flexion (dominant leg)	PDF
Explosive power and sprint acceleration variables		
8.	Vertical squat jump	SJ
9.	Vertical counter movement jump	CMJ
10.	Sprint test 15 meters	S15M
Activation exercises on vibration platform		
11.	Static stretching in forward lunge	SSFL
12.	Static stretching in lateral squat	SSLS
13.	Static stretching for calf muscles	SSCM
14.	Static stretching in forward trunk flexion	SSTF
15.	Static stretching in rear lunge	SSRL

Experimental study design

The study implied the application of whole-body vibration training applied in static stretching exercises, performed during the warm up part of football training. For these purposes, the complete sample with randomised selection is divided into two equal groups (VSI – static stretching with vibration and SSI – static stretching without vibration). During the warm up part of football training, VSI group performed 5 static stretching exercises on the vibration platform included (f = 40 Hz, A = 2 mm t = 30 with stretching / 5 with relaxation), while the SSI group performed equivalent stretching exercises, at the same time (in warm up part) as the VSI group, with the difference that it carried them out on a box, which in its shape and dimensions simulates the design and height of the vibration platform. The duration of each exercise, as well as the break time between each exercise, for SSI group subjects was equal to the duration of the identical exercises of the VSI group. To standardize protocols in the introductory and preparatory part of football training, subjects of both groups were subjected to the same modified warm-up protocol (FIFA 11+), a specific football warming up programme. According to research needs, the specific football warming up protocol (FIFA 11+), has been modified in such a way that instead of dynamic stretching exercises, static stretching exercises have been inserted with and without vibration stimulus. Weekly distribution of vibration training is determined by a 3:1 ratio (training/pause). It is important to note that due to the limiting factor (one vibration platform), for the purpose of more efficient flow during one training session, subjects of both groups performed stretching exercises in pairs. The total duration of exposure to vibration with rests, for the selected couple was approximately six minutes, and after both groups finished with the scheduled four-week programs, 48 hours after the last practice unit, the final test was carried out.

Vibration exercise protocol

Vibration training was carried out on vibration platform, German manufacturer Powrx, model Pro Evolution 2.7. The device generates a vertical linear type of vibration (f = 25 –50 Hz), with the ability to adjust the vibration amplitude to two levels (A= 2 –4 mm). For the sake of the needs of this research, five vibration exercises are selected:

Static stretching in the front step – the subject performs the front step, with the front leg flexed in the knee fold (the right angle). By exercising a bow to the hull, it puts the muscles of the hamstrings and gluteal region in an elongated position. The subject retains the position in the given time, according to the protocol of performing vibration exercises. After completion, the subject performs the change, i.e. performs the same exercise with the other leg.

Static stretching in lateral squatting – the subject takes the position of lateral squatting, taking the laterally stretched leg to the vibration platform, while descending into the position of unilateral squatting on the opposite leg. The subject ends the descent in the squat to the limit of discomfort, bringing the muscle group of the adductors into an elongated position. At the end of the exercise, the subject makes a change with the other leg.

Static stretching in the position of dorsal flexion – the subject with both feet stands on the vibration platform and steps one foot backwards, towards the back edge of the platform based only on the front of the foot. When starting the exercise, the subject lowers the heel of the back leg below the edge of the platform, putting the foot in the position of dorsal flexion. The subject in this position remains in the given time, and then makes a change with the second leg.

Static stretching in the forward lean – the subject takes the front step position with a stretched front leg in the knee, relying on the platform. Then performs a trunk forward lean (flexion in the hip joint), thus bringing the muscles of the hamstring of the front leg into an elongated position. The end of the movement is determined by a sense of pain. The subject retains the position in the given time, and at the end the subject makes a change, i.e. performs the same exercise with the other leg.

Static stretching in the rear lunge - the subject is facing the back towards the platform and steps backwards by placing the rear leg, a lower leg part placed on the vibration platform (rear lunge). With a flexed front leg in the knee joint (the parallel angle), the subject actively moves the hips forward, bringing the inner muscles region and hip flexors into an elongated position. The subject retains the elongated position in the given time, and at the end of the subject makes a change, performing the exercise with the second leg.

Statistics

All results were calculated with SPSS 20 for the Microsoft Windows Platform (SPSS Inc., Chicago, IL, USA). For all dependent variables and in all measurements, standard descriptive parameters are calculated: arithmetic mean (AS) and standard deviation (SD) have been calculated. Mixed variance analysis (x group time) was used for this research. The normality of distribution was tested by Sapiro-wilk test, and the level of statistical significance was set to $p \leq 0.05$.

Results

In Table 3. descriptive parameters relating to average values (SV) and standard deviations (SD) of all subjects in both groups (SSI and SVI) were given, for all dependent variables measured in initial and final measurement. The same table also gave indirectly calculated the sizes of the effects achieved by group, expressed in percentages (%).

Table 3 Average values (Mean) and standard deviation (SD) of all subjects in both groups for all dependent variables in initial and final measurement, and indirectly calculated sizes of the effects achieved by group (%).

Variables	Standard group (SSI)					Vibration group (VSI)				
	Initial		Final		Effect	Initial		Final		Effect
	SV	SD	SV	SD	MD	SV	SD	SV	SD	MD
SJ	31.	3.2	34.9	2.9	11.5	33.	4.6	37.1	4.2	11.7
CMJ	34.	3.4	35.9	3.2	5.2%	34.	4.6	38.1	4.5	10.7
S15	2.5	0.0	2.41	0.0	4.4%	2.5	0.1	2.35	0.0	6.4%
PHF	93.	6.9	106.	6.0	14%	96.	6.7	118.	4.3	22.3
PHE	27.	2.5	32.2	2.0	18.3	27.	2.8	37.4	1.6	35%
PPF	48.	2.8	54.9	1.5	13.6	49.	3.0	56.5	1.6	14.6
PDF	19.	1.5	23.5	3.4	22.3	19.	1.8	26.3	3.9	32.1

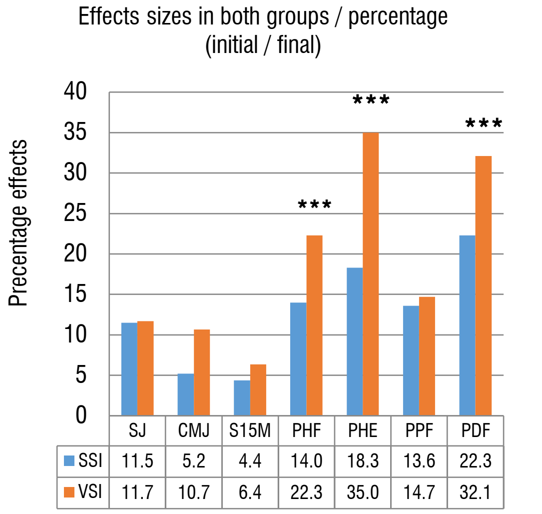
From Table 3. it is evident that both groups (SSI and SVI) have made some progress between the two test periods (pre-post). Looking individually, it can be noted that on variables for assessing the speed-explosiveness abilities of the lower extremities, the experimental group (VSI) recorded slightly greater improvements in the period between initial and final measurement (SJ: 11.7%; EX: 10.7%; S15M: 6.4%), compared to the SSI group (SJ: 11.5%; CMJ: 5.2%; S15M: 4.4%). By observing variables for assessing the range of movement of the lower extremities, certain improvements were observed in both groups in the period before and after treatment. In fact, VSI group on variables to assess the range of movement of lower extremity record slightly higher positive results achievement (PHF: 22.3%; PHE: 35%; PPF: 14.6%; PDF: 32.1%), compared to the SSI group (PHF:14%; EZC: 18.3%; PPF: 13.6; PDF: 22.3%).

Differences in size of changes made between vibration and standard group

Mixed analysis of variance (Mixed ANOVA) tested the impact of two different program treatments (SSI and VSI) on the results of dependent variables, measured over two periods of time (before and after intervention). The interaction of factors (group x time) shows not only that the results on the observed variables (a combination of both groups together) changed within two time points (pre and after), but also that these changes were significantly different from the type of treatment the groups underwent.

The analysis of the effects achieved between the standard (SSI) and the vibration (VSI) group is shown in chart 1. In detail, it is observed that the effects of the vibration group (VSI) are statistically significantly greater than the effects of the standard group (SSI) in the three observed variables for assessing passive range of movement (PHF, PHE, PDF). In fact, the *Chart*

1. Change size (%) in power, sprint speed and range of movement in analysed groups after four wee SJ of treatments ($p < 0.05$; ** $p < 0.01$; * $p < 0.001$*



results of the mixed analysis of variance for repeated measurements (interaction of factors "group x time") show that the effects on the passive range of movement of the lower extremities (flexion in and extension in the hip joint, dorsal flexion) statistically significantly higher at the level ($p<0,001$) in the vibration group (VSI) compared to the effects of the standard group (SSI). PHF; F = 31.127 p = .000 partial η2 = .567; EEA; F = 43.435 p = .000 partial η2 = .644; PDF F = 24.874 p = .000 partial η2 = .509. On the other side, an analysis of the differences in the size of the effects achieved between (VSI) and (SSI) of the group shows that there is no statistical significance ($p>0.05$) in the size of the sprint speed effects achieved at 15 meters, the height of vertical jumps, as well as the range of movements in the position of plantar flexion. In fact, the results of the combined variance analysis on variables for assessing the height of vertical jumps (group x time) show next values: SJ: F = 0.33 p = .856, partial η2 = .001; and for eccentric concentric jump CMJ; F = .976 p = .333, partial η2= .260). Furthermore, no significant interaction was also established on the sprint variable (S15M; F = 1.867 p = .185, partial η2 = .072). The identical situation is also with the variable for assessing the passive range of foot movement PPF (range of movement in plantar flexion position), which identified only a significant impact of the "time" factor, with both groups (SSI and VSI) seeing an improvement in results on the observed variable in the period between the initial and final testing (PPF; F = 290 p = .595 partial η2 = .012).

Discussion

The focus of the research was on determining the chronic effects of additional whole body vibration training, performed in the warm up part of football training on the range of movement and muscle function of the lower extremities, in relation to the same exercises applied in the warm up part of football training. The results on the range of movement variables indicate that there have been positive changes in the increase in the range of movements of observed body regions, and that there is a statistically significant difference between the two protocols applied (VSI and SSI), except in the test for assessing the range of movements in the plantar flexion position. There are a significant number of studies dealing with similar issues, which report significant improvements in the range of movement when applying vibration training, thus confirming the results of this research (Issurin et al., 1994: Tillarr et al. 2006; Fagnani et al. 2006; Sands et al. 2006; Kholvadia and Baard 2012; Dastmenash et al. 2010). However, it is also important to note that rare studies that, as dependent tests, and to assess the effects of vibration exercise on the range of movement, used only a standard goniometric method, while assessing muscle function. Also, the number of research used exclusively static stretching exercises as treatment variables (vibration exercises) was also deficit, conducted exclusively on a vibration platform intended for whole body vibration training.
A number of studies list several different physiological mechanisms suitable for improvements in the use of vibration training. These mechanisms include circulatory and thermoregulation mechanisms, as well as the possibility that the vibration stimuli applied results in a certain type of analgesic effect on the (vibration) exposed muscle or muscle group, then increased excitation of GTO (Goldji's tendon organ), which can produce significant inhibition of muscle contraction, caused immediately after muscle relaxation, resulting from vibration training (Fagnani et al., 2006). Also, acute soft tissue deformation as a result of exposure to vibration, can lead to activation of muscle receptors tasked with detecting muscle length changes, and thus cause improvements in the reflex arc of stretching (Cardinale et al., 2003, all according to Tillaar, 2006). It also states that vibration training can cause proprioceptive feedback potency, while inhibiting the sensation of muscle pain.
In addition to determining chronic effects on improving range of movement, this study established the existence of chronic effects of additional vibration training, performed in the warm up part of football training, on the muscle function of the lower extremities, more specifically the sprint speed, and the height of vertical jumps. The data reveal that none of the observed muscular function assessment variables (SJ, CMJ, S15M) had statistically significant differences between the SSI and the VSI protocol. According to the fact that the combined analysis of variance on any dependent variable for assessing muscle function did not determine interaction effects (group x time), it can be found that there are no significant differences in treatments carried out between SSI and VSI groups. Ultimately, and given the results of this research, it could be concluded that there are no significant differences in the expression of muscle function when there is additional use of vibration stimulus.
In fact, most knowledge in the field of vibration training, in the form of full-body vibrations, and its effect on improving strength and power still under the wide scope of scientists. The results of the studies, which aimed to determine its effectiveness to improve strength and strength, sometimes report opposite results, often leading to confusing and insufficiently clear conclusions. In the available literature, often repeatedly information is mentioned, that well-trained athletes have significantly less room for nerve-muscle adjustment compared to untrained subjects. In a recommendation on improving speed-power performance in athletes, the authors of the review article (Wilcock et al., 2009) cite a number of strategies when it comes to improving sports performance by applying vibration training. Among other things, it states that if coaches want improvements in strength, power and speed in their athletes, then training methods used regularly in training to develop them are applied with supplementary vibration. In particular, this means that, if the aim is to develop leg strength with a submaximum or maximum load, then it should also be considered that they are performed using additional vibration stimuli. Also, if the goal is to develop the explosive strength of the lower extremities, then weight should be moved at the maximum speed of muscle contraction with the use of vibration stimuli. Such training can be based on light to moderate plyometric content (jumps from the platform to one or two legs). A thing that should certainly be taken into account, in this kind of exercise modality, refers to the security aspects of its implementation.
In any case, all the knowledge collected suggests that vibration training in the form of whole-body vibrations can be an effective exercise modality to improve nerve-muscle performance. However, it would also be appropriate to consider all relevant factors of primary importance, when it comes to vibration training applications in different age categories, or training ranks of subjects. It is also necessary to open up the scientific field of research in long-term settings as much as possible, in order to determine as validly and

precisely as possible the factors that contribute to chronic improvements in the use of vibration training.

Conclusion

Whole body vibration training performed in the warm up part of football training, after four weeks, very effectively improves the range of movement of lower extremity, compared to the same protocol without applying vibrations. However, whole body vibration training conducted in the warm up part of football training, after four weeks does not produce significant chronic improvements in muscle function of the lower extremities, compared to the identical warm up protocol without vibrations. In conclusion, the study demonstrated that whole body vibration training used in static stretching exercises, and carried out in the warm up part of football training (three times a week), after four weeks significantly affects the increase in the range of movement, but not on the improvement of muscle function measured through an increase in sprint speed and the height of vertical jumps (regardless of whether they are under concentric or eccentric-concentric conditions) compared to the same warm up protocol without the application of vibration. In chronic settings, vibration training applied as an integrated part of warm up protocol has proved to be an effective modality when it comes to improving the passive range of movement of lower extremities in footballers. Although the results demonstrate that vibration training in these settings does not affect a significant improvement in speed-explosive properties, it is nevertheless necessary to point out that this type of exercise should also be considered under different conditions of application, and that this type of training can contribute more as a supplementary training tool, than as a replacement to standard-applied methods for enhancing observed abilities. The results obtained significantly widening our knowledge of adaptation the nervous-muscle system with use of whole-body vibration training. Given the wide range of different training protocols of vibration training, future research should require a more complete analysis of all input-output load factors, both in acute and chronic training settings.

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