Urdampilleta, A.; Álvarez-Herms, J.; Martínez Sanz, J.M.; Corbi, F. y Roche, E. (2014). Readaptación física en futbolistas mediante vibraciones mecánicas e hipoxia / Physical rehabilitation in football by mechanical vibration and hypoxia. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 14 (53) pp. 119-134. Http://cdeporte.rediris.es/revista/revista53/artrecuperacion432.htm

ORIGINAL

PHYSICAL REHABILITATION IN FOOTBALL BY MECHANICAL VIBRATION AND HYPOXIA

READAPTACIÓN FÍSICA EN FUTBOLISTAS MEDIANTE VIBRACIONES MECÁNICAS E HIPOXIA

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Código UNESCO / UNESCO Code: 2411.06 Fisiología del ejercicio / Sport Physiology
Clasificación Consejo de Europa / Council of Europe Classification: 6. Fisiología del ejercicio / Sport Physiology

Recibido 28 de septiembre 2011 **Received** September 28, 2011
Aceptado 14 de abril de 2012 **Accepted** April 14, 2012

ABSTRACT

Explosive actions in football are nowadays three times the amount there was during the 60s, reaching 200-215 explosive actions/match. This means that for an elite player, muscular power and resilience are performance limiting factors, and muscular injuries may be frequent. During the injury, conditional qualities are lost; the shorter is the period the lesser are the losses. There are several methods for improving strength and resilience through vibration platforms and intermittent hypoxia (IH). In this study, we show the results of an intervention with vibrating platform and IH in football players suffering from fibrillar break. The results obtained suggest that this new training model allows improvements in the level of maximum force ($p<0.05$) and resilience ($p<0.05$) and helps to keep their initial conditional qualities.

KEY WORDS: Body vibration, intermittent hypoxia, muscle strength, resilience.

RESUMEN

Las acciones explosivas en el fútbol se triplican respecto a los años 60, llegando a las 200-215 acciones explosivas/partido. Esto supone que la potencia muscular y la capacidad de recuperación sean factores limitantes, pudiendo ser frecuentes las lesiones musculares. Durante la lesión se pierden las cualidades condicionales, menos cuanto más corto sea este periodo. Existen diversos métodos para la mejora de la fuerza y capacidad de recuperación mediante las plataformas vibratorias y la hipoxia intermitente (HI). Mostramos resultados de una intervención con plataforma vibratoria y HI en futbolistas convalescientes de una rotura fibrilar. Este nuevo modelo de entrenamiento puede permitir mejoras la fuerza máxima ($p<0,05$) y capacidad de recuperación ($p<0,05$) ayudando en gran medida a no perder las cualidades condicionales.

PALABRAS CLAVE: Plataformas vibratorias, Hipoxia intermitente, fuerza muscular, capacidad de recuperación.

INTRODUCTION

The physical effort performed by a football player has basically intermittent character, alternating high intensity efforts with low ones. Therefore, it is important to improve the recovery of high intensity efforts during low effort periods (Mohr et al., 2010). All this would allow keeping explosive and repeated efforts alternated (Casamichana et al., 2012). Furthermore, trunk muscle stabilization is very important in football in order to coordinate quick moves, especially with situations of instability (González-Arganda, 2010).

Football demands and requirements have changed in the last few years (Randers, 2010). The number of sprints in the 60s was so much lower than currently. In fact, today there is three times this amount, with 190 sprints (around 200-215 explosive actions) (Dufour, 1990; Zubillaga, 2006), 29,5 ± 10,3 abrupt changes of direction and 8,5 ± 3,82 jumps per game (Castellano, 1997). In this sense, football may be considered as a sport of explosive and alternated efforts where resilience in essential for a better performance (Motta, 2006).

On the other hand, during convalescence periods after injury the levels of physical condition and resilience are modified; they generally suffer a decrease that affects most of the qualities. Therefore, it is really important to keep the levels of physical condition as higher as possible in order to accelerate the recovery process. In the last few years, professional football has greatly evolved in the methods used to improve conditional area, recovery, psychological training, injury prevention and rehabilitation, through a better analysis of the football match (Randers et al., 2010).

Annual periodization in football requires a different structure from other sports of individual performance. Although there are several periodization methodologies in football according to different methods and game systems used, it is common in all of them to look for keeping a high (not maximum) performance during the maximum time possible along the season with a few peaks according to the sports objectives (Alvarez-Herms et al., 2012). Therefore, new methods are needed in order to obtain the lowest muscle fatigue and the highest physical condition along the season.

Vibration platforms are useful tools to improve flexibility (Fangani et al., 2006; Sands et al., 2006) and in the last few studies about that there is shown a tendency to improve and to keep the explosive strength through a vibration training, although the scientific evidence is still poor and more studies are needed in this field with specific groups (Fort-Vanmeerhaeghe et al, 2011; Rechn et al, 2007). Colson et al. (2010), studied the effectiveness of these tools in basketball. To that end, they applied a protocol of vertical vibrations (40Hz and 4mm) to a group of basketball players three times a week. They had to do ½ static sit ups with 30'' of vibrations and 30'' to rest during 20'. After 4 weeks of training the maximal isometric force increased. Other authors claim that in order to produce an increase on the maximal dynamic force of trained sportsmen, vibration frequencies must be between 40-50Hz, with vertical vibrations of 3mm (Ronnestad, 2012). Cormie et al. (2006) also observed that with this kind of training significant improvements were observed in vertical jumps after acute expositions in vibration platforms(30-30’’ to 30Hz and 2.5mm). These authors concluded that these platforms could be valid as warming-up before performing maximum intensity jumps and as a way to recover power after an injury.

On the other hand, Intermittent Hypoxic Training (IHT) is one of the newest programs used to train sportsmen (Meeusen, 2001). In the last few years, several studies have shown how IHT causes interesting adaptations, both peripheral and systematically, which justifies its application as a way of improving sports performance (Geiser, 2001; Roels, 2007; Zoll, 2006). Furthermore, specific IHTs are seen to improve some results of non-specific tests (Urdampilleta, 2010; Vogt, 2010), which justifies its application in different sports.

Despite the fact that there is not much academic background, it is possible to think that IHT improves heart rate recovery from high values (Urdampilleta, 2011). In the same way, studies which combine explosive exercises and intermittent hypoxia show that glycolysis activation is higher (Vogt, 2010) and less time is needed to increase the training load (Hendriksen, 2003). In a previous study of this research group a significant increase of heart rate recovery from a maximum effort after a training protocol of resilience force in intermittent hypoxia was reported (Alvarez-Herms et al, 2011). There are also signs of physiological benefits from hypoxia exposure and training, which may increase individual performance in football players Alvarez-Herms et al, 2012).

Therefore, as Calbet (2006) claims, it is important to apply new methods of intensive training adapted to our sportsmen capable to increase sportsmen adaptive possibilities to continue improving their physical conditions in different situations. This leads us to a hypothesis that claims that in sportsmen just recovered from an injury several conditional qualities and physiological parameters, together with muscle strength and heart rate recovery through innovative means may be maintained using systems that increase systemic and peripheral functional capacities which cause no damage to the organism. The aim of this study is to value the efficiency of physical retraining post injury through a training program with vibration platforms and intermittent hypoxia stimuli.

MATERIALS AND METHODS

This research’s design was experimental with intervention through a training program with vibration platforms and intermittent hypoxia stimuli.

1. Subjects

The study sample was formed by 11 football players (football 7-a-side) from the national league who signed an informed consent.

Table 1. Physiological and anthropometric characteristics of the studies subjects

	Group (n=11)
Age	21.2 ± 2.0
Size (m)	1.76 ± 0.09
Weight (Kg)	76.3 ± 4.4
BMI	24.48 ± 1.31
Basal HR	64 ± 11
Systolic / Diastolic Blood Pressure	120 ± 9 64 ± 8
SaO2%	97.7 ± 0.6

The inclusion criteria followed to participate in this study were the following: 1) no exposure to hypoxia in the previous 3 months; 2) injury in the last 3-4 weeks of myofibrillar break-down in the lower body due to the practice of football; 3) to be clinically recovered (analyzing the injury through imaging by the doctor); and 4) no important clinical background.

All of them were in the last phase of recovery from a 1cm fibriliar break-down (quadriceps, soleus muscle or biceps femoris). The frequency of training they used to have was two times a week plus a match, with no more physical exercise than that. These football players competed in football 7-a-side in the 1st group of the Basque League of the Basque Federation during the season 2010-2011.

All of them were three weeks without any training with their teams due to the injury and the needed periodic period. None of the participants in this study received neither economic nor in-kind reward for their participation.

2. Materials

A vibration platform VibraLaster was used for the intervention. It makes mechanical vibrations between 19 and 60HZ and a maximum vertical acceleration of 4mm.

Participants with intermittent hypoxia performed trainings in a GO2Altitude Hypoxic tent (Biometech, Australia). This hypoxic tent uses the molecular separation through membrane to obtain oxygen and so to transform hypoxic air, decreasing oxygen concentration inside the hypoxic tent (hypoxia normobaria). This system does not cause increases in temperature, in humidity (if no physical exercise is performed inside it), nor in CO_2 on hypoxic air. In order to generate hypoxic air ERA II compressors were used, and also the Hypoxic tent Portatil Plus compressor as an additional support.

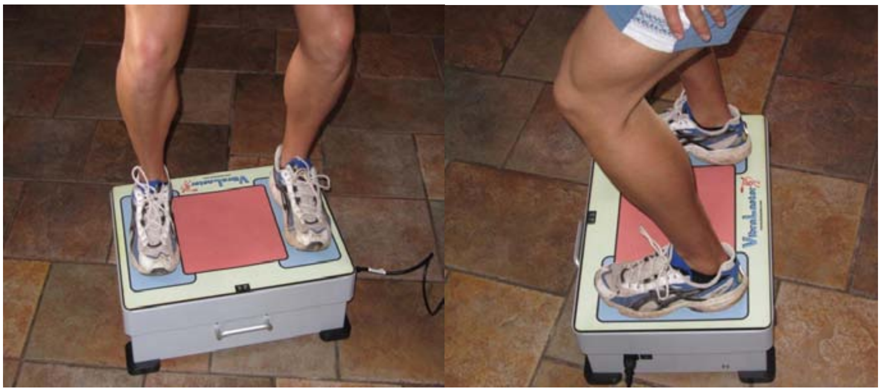

Image 1. Materials used for the study. Vibration platform BibraLaster (Biolaster).

Image 2. Materials used for the study. GOA2Altitude Hypoxic tent (left). Hypoxic tent Portatil Plus compressor (middle). Hypoxic tent prepared for trainings in hipoxia with BibraLaster vibration platform (right).

3. Training protocol

The training program consisted of 3 sessions per week (Monday-Wednesday-Friday) of mechanical vibrations **inside the hypoxic tent**, according to the training protocol suggested by Colson et al. (2010). Such protocol was slightly adapted following Ronestad (2009) indications, and two 60' sessions of passive intermittent hypoxia (with no physical activity) were added Tuesdays and Thursdays. Therefore, in total, participants in this study trained 5 days a week.

Table 2. Structuring week trainings for group control (C) and experimental group (H).

Training plan for groups C and H	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Team training		C H		C H	C H
Vibration platform sessions	C		C		C
Active intermittent hypoxia session	H		H		H
Passive intermittent hypoxia sessions (post warming-up with the team)		H		H	

The protocol used in the **vibration platform** consisted of 8-14 series of 30'' at 40Hz of frequency and 3-4mm of amplitude. Inter-series recovery was of 60'' (1st week). Vibration frequency was increased up to 50Hz after the 2nd week. In total, the volume of training was between 12 and 21' of work per session (one more series of work per session after the 2nd week). The exercise used in training sessions was the sip-up. Individual trainings intensity in the vibration platform was controlled according to the character of the effort (Gonzalez Badillo, 2002). Therefore, the vibration machine suggested several training ranges.

Table 3. Characteristics of the strength training with mechanical vibrations.

Trainings **Vibration platform**	Series-recoveries	Vibrations frequency	Amplitude
Week 1	8 x 30''// 60''	40 Hz	3-4 mm
Week 2	11 x 30''// 60''	40-50 Hz	4mm
Week 3	14 x 30''// 60''	40-50 Hz	4mm

Group H training took place inside the **normobaric hypoxic tent** (1.80 x 1.80 x 1.80m) which simulated between 4000 and 5000m (FiO2 = 12.5-11%) and increased the hypoxic exposure 500m of altitude per week (decrease of 0.5% of oxygen in ambient air). Trainings were two by two and after the second one with the vibration platform subjects rested lied down until accomplishing the 60'.

Tuesdays and Thursdays they started training with their team, performing specific football exercises, matches and lower body strengthening exercises at the end of the training sessions. After that, participants in group H rested during 60' in hypoxia at 4000-5000m. In total, they had 15 hours of intermittent hypoxia during 3 weeks (3 specific sessions with vibration platform and 2 sessions resting in intermittent hypoxia each week). This hypoxic training load used was due to a recent study which demonstrated that 15 hours of hypoxic exposure were enough to improve sports performance (Bonetti, 2009).

Table 4. Training frequency per week in both control and experimental groups.

Frequency/week	**Group control (C) n=5**	**Experimental group (H) n=6**
Trainings with the team	2	2
Trainings with mechanical vibrations	3	3
Trainings in active hypoxia	0 (No)	3
Trainings in passive hypoxia	0 (No)	2

4. Assessing strength and resilience

In order to assess the results obtained during the trainings, SJ and CMJ tests were used to measure the jumping ability. Both tests are from the battery of tests Bosco (1983). A warm-up took place before performing these tests. In addition, the technical realization of the test received special attention.

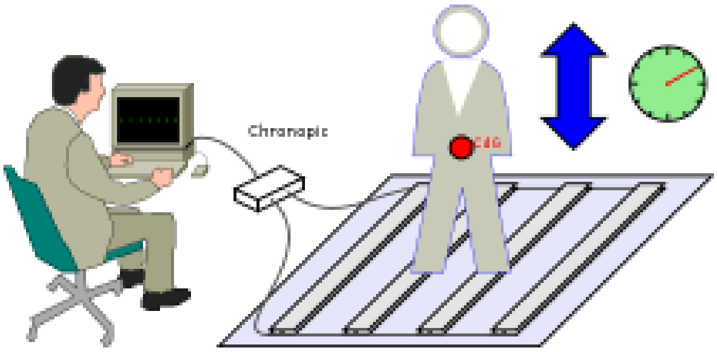

Image 3. Bosco tests (SJ and CMJ) and material used. Ergo Jump Bosco System platform formed by a contact map of 1.75m length with a distance between contacts of 5cm.

Before and after the intervention, football players were assessed through a 1 RM indirect half sit-up test. To ensure they performed half sit-up, a Swiss bench was used; they had to touch it with their gluteus in each repetition. They performed 20 repetitions (one every two seconds) with the maximum weight they could handle. The formula used to estimate 1RM was the one proposed by Epley (1985): 1RM= (0.0333 x rep x kg) + kg.

After the 1RM indirect test and with the subject in a seated position the recovery beats were registered (1', 2' and 3') and the recovery rate (RR) was estimated through the formula established by Lamiel-Luengo (Aros et al, 2000; Calderón et al, 2002): RR = HRmax – HR 1, 2, 3 / theoretical HRmax / HRmax reached.4

5. Statistical analysis

The tool used for the data statistical analysis was Excel 2003 and SPSS statistics base 175.0 for Windows. The first statistical analysis performed was the descriptive one. Since the sample accomplished all the normality criteria we performed the parametric statistical test (T TESTS) for related samples. The studied variables were: pre-test and port-test of CMJ, SJ and 1RM tests. The second analysis performed was the correlation one. We used the Pearson bivariate correlation test, since we wanted to know the relationship between the intervention and the heart rate recovery variables.

In order to estimate the recovery rate we performed a t-test for the same group (pre and post training) in the minutes 1, 2 and 3 of the recovery. We also used the Shapiro-Wilk test in all of them. The level of statistical significance used was $P < 0.05$.

RESULTS

Table 5. CMJ t-test

	Differences						
1 CMJ Pre- test Post-test	Mean	DT	Standard error	95% confidence interval Lower	95% confidence interval Higher	t	P (bilateral)
	-0.015	0.003	0.009	-0.035	0.004	-1.697	0.117

Table 6. SJ t-test.

	Differences						
1 SJ Pre- test Post-test	Mean	DT	Standard error	95% confidence interval Lower	95% confidence interval Higher	t	P (bilateral)
	-0.023	0.027	0.007	-0.039	0.006	-3.048	0.058

Table 7. 1RM t-test

	Differences						
1 RM Pre- test Post- test	Mean	DT	Standard error	95% confidence interval		t	P (bilateral)
	-0.023	0.027	0.007	-0.039	0.006	-3.048	**0.039***

Table 8. Heart Rate recovery after the 1 RM indirect half sit-up test

HR	**PRE-TEST**	**POST-TEST**	***P***
Final HR	170,2 ± 1,72	175,5 ± 2,43	NS
Rec-1	137,8 ± 13,1	126,8 ± 12,6	**<0.05**
Rec-2	119,7 ± 10,6	104,5 ± 8,9	**<0.05**
Rec-3	102,32± 9,8	97,3 ± 5,5	NS

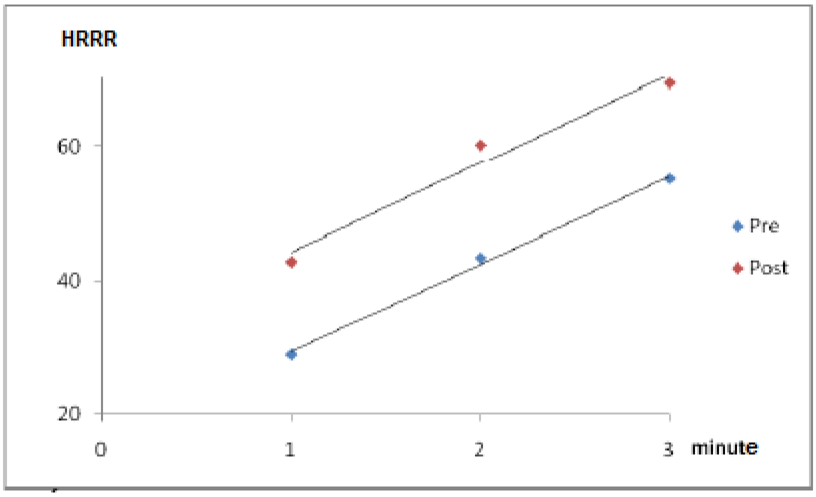

Diagram 1. Heart Rate Recovery Rate (HRRR) in minutes 1, 2 and 3 after sit-ups in both C and H groups before (pre) and after (post) the intervention.

DISCUSSION

Regarding the ability to jump in this study we did not found significant differences between the results obtain before and after the protocol during the CMJ test (*P*=0.117) (Table 1). However, although there was not a statistically significant result there was a general improvement in the CMJ test results, compared to the group control. Some of the reasons why there were not significant improvements could be the followings: 1) the lack of coordination amongst the players during the test; or 2) the lack of more training exercises related to the elastic component (Bompa, 2004). Related to the SJ test, there was not either significant differences when comparing jump performances before and after the protocol (*P*=0.058) (Table 6). Nevertheless, with this test we also observed a little improvement in jump performances.

On the other hand, there were some significant differences in the R1 indirect test (*P*=0.039) (Table 7). The results obtained coincided with the obtained by Colson et al. (2010), who justified the improvements registered with an increase of inter and intramuscular coordination of the low body muscles.

Although several authors (Cormie et al, 2006; González-Badillo, 2002; Rechn et al, 2006) confirm the relationship between the improvement of maximal force and the improvement of explosive force, in this study we did not find significant improvements in the explosive force, although we observed a certain tendency to it. Some authors claim that these explosive force improvements may be due to a better flexibility of sportsmen (Fort-Vanmeerhaeghe et al, 2011; Sands et al, 2006).

Related to the heart rate recovery we observed a significant improvement (*P*<0.05) of the heart rate during the first two minutes after a maximal force exercise (Table 8). These data are important, since with almost no aerobic exercise there is an improvement in heart rate recovery after an intervention of 15 hours of intermittent hypoxia plus force exercises with a vibration platform. These data confirm the results obtained in other studies about the improvement of heart rate recovery after maximum exercise in the first three minutes (Alvarez-Herms et al, 2011; Urdampilleta et al, 2011). All in all seems to indicate that training in intermittent hypoxia causes molecular and physiological adaptations that allow the acceleration of recovery processes after maximum efforts which have an anaerobic energy support (Roels, 2007; Wilber, 2007).

The fact that intermittent exposure to hypoxia increases the maximum heart rate (HRmax) to a greater extent may be interesting for long-duration sports and for sports with intermittent efforts such as football, since, as a result of the great training load performed at low intensity, there is usually a tendency to decrease the HRmax (Jouven et al., 2005). Therefore, the use of IH stimuli could be interesting in the tuning phase or before the main competitions since it could be an anaerobic training stimulus and, at the same time, it could help to improve resilience. The study of heart rate variability happens to be very interesting for the functional assessment in team sports (Rodas et al., 2008).

When competing in hypoxia physiological effects are significant. The organic physiological response has been analyzed in order to obtain information which allows getting a position (Federation Internationale de Football Association. Bartch et al, 2008). It is said that if football is played in moderate altitude and with no previous acclimatization, the physical performance may be reduced and the subjective perception of effort increased, which may have a negative effect on the players' psychological aspect (Demo et al., 2007). Levine et al. (2008) claimed that a football player, as any other sportsman, suffers a decrease of his/her Vo2max (maximal aerobic capacity) when competing at moderate altitude and an increase of effort relative intensity with lower capacity for phosphagen system resilience. This aspect would improve the ability to repeat high intensity actions, which would be important in football, where a great part of these actions has a significant technical component.

Although physiological parameters achieved in a football match are not that high compared to those reached in some individual sports, the improvement obtained with training in hypoxia could make the player's technical and tactical skills increase. In this case, Helgerud et al. (2001) studied youth football teams of Norway and observed that a Vo2max improvement of 10% was related to an increase of 20% of the distance covered and of 100% in the number of sprints performed.

Apart from applying intermittent hypoxia to improve resilience, it is shown that when the competition is placed on altitudes higher than 2000m, to train previously in hypoxia improves sports performance in mixed sports, especially in the aerobic ones (Calbet et al, 2007; Meeusen et al, 2001; Roels et al, 2007; Tabidi et al, 2007; Rodriguez et al, 2002; Vogt & Hoppeler, 2010). Therefore, it would be interesting to add trainings in hypoxia both for football players' physical retraining and for the optimization of sports performance (resilience improvement).

There are professional players who have used normobaric hypoxic tents (intermittent exposure) seeking an improvement of individual performance. Obviously, its use must be supervised by a professional. The possible benefits an intermittent hypoxia exposure (active or passive) may have would be related to resilience improvement (central parameters (cardiovascular–respiratory) and peripheral parameters (muscular – enzymatic)), increasing both the aerobic and the anaerobic abilities. In addition, there may be some subjects with poor tolerance or low sensitivity (bad responders) to hypoxia. In this case, the effect would not be positive, although there is not registered either negative effect on health. However, there are several models of intermittent hypoxia exposure (intense and short or long and light) that resulted also efficient at least for hematopoietic responses (Casas et al., 2000).

Nevertheless, the key seems to be in the lowest hypoxic dose every sportsman needs to obtain these effects (Wilber et al., 2007).

CONCLUSIONS

After applying a training program of 15 hours of intermittent hypoxia exposure during 3 weeks (3 specific sessions with a vibration platform and 2 sessions of 60’ each resting in intermittent hypoxia per week) to a group of 11 football players (football 7-a-side) from a national team, we obtained the following conclusions:

1. There is a significant improvement in maximal force levels (1RM) with the half sit-up test ($P<0.05$).

2. There is a significant improvement in heart rate recovery during the first two minutes after a maximal effort of strength-endurance ($P<0.05$).

3. There is a slight tendency to improve explosive strength and maximum heart rate.

It would be interesting to add another group control with no more trainings than the ones with their teams (with technical and tactical character). It is clear that the improvements are due to the active and passive hypoxia stimuli applied (differential characteristic regarding trainings between group control and hypoxia), but we did not study the effects that trainings only with vibration platforms have in physical retraining.

A bigger sample and more applied studies to team sports would be necessary to allow injured players to keep training with their teams and make their recovery as quick as possible.

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