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EFFECT OF A DYNAMIC LOADED WARM-UP ON VERTICAL JUMP PERFORMANCE

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ABSTRACT

Introduction: The purpose of this study was to determine if an aerobic warm carried out on a cycle ergometer had influence on vertical jump performance. Material and Methods: Participants: 25 football players males (2nd B, IV. Spanish Football League; age 22.7±3.3 years; height 178.8±3.9 cm, mass 75.3±6.8 kg) The warming-up consisted of pedalling for 5 minutes at 114.8±8.3 hr with a power intensity of 112.2±13.2 w, followed by 5 minutes at 147.2±6.7 hr ($\overline{X}$=197.5±38.4 w).Pre and post-test was carried out in successive days: 1 st5 day: 5 without countermovement vertical jumps (VJ1); 2 nd day:10 seconds repeated VJ 2 and third day: 60 seconds VJ 3. Heart rate was measured while performing and at recovery. Results: In VJ1, the height went from 41.9±5.4 cm in the pre-test to 43.9±5.8 in the post-test; (F=806.0; p=0.001), the flight increased in time (492.21±45.7 ms vs 508.3547.5 ms p≤ 0.001), the contact with the ground decreased (217.4 ±46.5 ms vs 211.2±23.6 ms p≤0.001) and the maximum heart rate raised 111.2±22.1 hr vs 130.0±13.8 hr. In VJ2 the height implies the jump went from 24.9±5.3cm to 25.0±4.9cm (F=329.3; p <0.001). In VJ3 the height shows the jump time went from 21.1±4.5cm to 21.3±4.2 (F=328.2; p <0.001). The number of jumps in VJ2 went from 15.7±1.7 to 15.6±0.9 (p <0.01) and in VJ3 from 97.5±6.6 to 96.6±7.2 (p <0.01). Conclusion: Two phases of 5 minute warm-ups on a cycle ergometer improves both the vertical jump performance and the heart rate throughout the process.

Key words: vertical jump, cycle ergometer, heart rate, football

EFECTO DE UN CALENTAMIENTO CON CARGA DINÁMICA SOBRE EL SALTO VERTICAL

RESUMEN

Introducción: El propósito de este estudio fue determinar si un calentamiento aeróbico realizado en cicloergómetro tenía una influencia sobre el rendimiento del salto vertical. Material y Métodos: Participaron 25 jugadores varones de fútbol (2ª B, Grupo IV de la Liga Española de Fútbol, 22.7 ± 3.3 años, altura 178.8 ± 3.9 cm, peso 75.3 ± 6.8 kg). El calentamiento consistió en pedalear durante 5 minutos a 114.8 ± 8.3 pulsaciones por minuto (ppm) con una resistencia media de 112.2 ± 13.2 w, seguidos de 5 minutos a 147.2 ± 6.7 ppm (resistencia media = 197.5 ± 38.4 w). Los test de salto se realizaron en días sucesivos: Primer día: Se realizaron 5 saltos verticales sin contramovimiento (VJ1); 2º día: Saltos verticales repetidos durante 10 segundos (VJ 2) y tercer día: Saltos verticales repetidos durante 60 segundos (VJ 3). La frecuencia cardíaca se midió durante los saltos y durante la recuperación. Resultados: En VJ1, la altura pasó de 41.9 ± 5.4 cm antes del calentamiento a 43.9 ± 5.8 después del mismo (F = 806.0, p = 0.001), el tiempo de vuelo aumentó (492.21 ± 45.7 ms vs 508.3547.5 ms p≤ 0.001), disminuyó el tiempo de contacto con el suelo (217.4 ± 46.5 ms vs 211.2 ± 23.6 ms p≤0.001) y aumentó la frecuencia cardiaca máxima (111.2 ± 22.1 ppm vs 130.0 ± 13.8 ppm). En VJ2 la altura media de los saltos aumentó de 24.9 ± 5.3 cm a 25.0 ± 4.9 cm (F = 329.3; p <0.001). En VJ3 la altura media de los saltos aumentó de 21.1 ± 4.5 cm a 21.3 ± 4.2 cm (F = 328.2, p <0.001). El número de saltos en VJ2 varió de 15.7 ± 1.7 a 15.6 ± 0.9 (p <0.01) y en VJ3 de 97.5 ± 6.6 a 96.6 ± 7.2 (p <0.01). Conclusión: Dos fases de 5 minutos de calentamiento en ciclioergómetro con resistencia dinámica mejoran tanto el rendimiento del salto vertical como la frecuencia cardíaca durante el mismo.

Palabras clave: salto vertical, cicloergómetro, frecuencia cardiaca, fútbol

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INTRODUCTION

Considering the importance of the vertical jump in several sports, as basketball, volleyball, football, etc., an optimal warm-up protocol may help athletes perform at their maximum level (Chattong, Brown, Coburn, et al, 2010). Warm-up is believed to be one of the most important factors in achieving an optimal performance in all sports. Its purpose is to promote physical capacities such as strength, endurance, flexibility, and to prepare the body for physical activity, increasing the body temperature, the speed of the neuromuscular responses (Vetter, 2007) and is also found to prevent tendon and the ligament injuries (Jamtvedt, Herbert, Flottorp, et al, 2010; Woods , Bishop, Jones et al, 2007).

Warm-up can be classified in two categories: (i) Passive warm-up and (ii) active warm-up. Passive warm up seeks to increase the body temperature through external means (showers, warm cloths, saunas, massage, etc.), whereas the active-warm up is composed of a series of physical exercises whose aim is to increase cardiovascular and metabolic changes rather than in the passive warm-up (Bishop, 2003).

Some of the warm-up protocols consisted of different types (active, passive, and specific) and structures (varying intensity, duration, and rest). Although many studies have looked into the physiological or psychological responses to warm-up, few studies have reported changes in the performance during training or during a competition following a warm-up (Fradkin, Zazryn, & Smoliga, 2010).

A specific dynamic warm-up can be described as a warm-up that addresses key muscle groups and the necessary neuromuscular coordination needed to perform a specific action, such as the vertical jump (Chatong et al, 2010). In addition, studies have also shown a possible postactivation potentiation (PAP) effect when a specific dynamic warm-up was coupled with resistance (Scott & Docherty, 2004).

Previous studies have employed various types of external loading such as dumbbells, weight vests or barbells, coupled with a movement similar to jumping or an active dynamic warm-up and produced significant performance improvements (Fradkin, Zazryn & Smoliga, 2010) They show that regardless of the type used, the concept of external loading coupled with dynamic movements have the potential to produce significant performance improvements on subsequent power exercises.

However, specific warm-up to jump and sprinting in team sports may require a large use of energy and can be potentially harmful (Woods et al, 2007) when it is too long or is done in haste. Sometimes the athlete might not perform a specific warm-up or he might do so in a hurry, which can also lead to an injury risk due to technical, tactical or regulative reasons.

The purpose of this study is to investigate the effect of a dynamic loaded warm-up, carried out on a cycle ergometer, on the vertical jump performance, taking into consideration the time of flight and the contact with the ground. We have chosen the vertical jump because of its importance in multiple sports such as basketball, volleyball, football and athletics, and because it's a common cause of injury, keeping in mind that a dynamic warm-up has had a positive effect in the vertical jump (Scott & Docherty, 2004; Burkett, Phillips & Ziuraitis, 2005) and we chose the bicycle ergometer since it was easier to transfer its effects to the sport and its ability to pedalling next to the sports field.

Therefore, if the vertical height of the jump could be increased by a non-traumatic pedalling warm-up, this could contribute positively to the performance of athletes in different sports and avoiding certain types of injury.

METHOD

Experimental approach to the problem

This study was outlined to observe how a warm-up carried out on a Lode Excalibur Sport cycle ergometer, affects the performance of the vertical jump. For this we have used a intra-group design which measures pre and post measurements.

The independent variable consisted of a warm-up carried out on a Lode Excalibur Sport Cycle Ergometer with Pedal Force Measurement Module (PFM) and Software Lode Ergometry manager (LEM) (Lode BV Groningen, The Netherlands, 2009), with determination of the heart rate (polar monitor Si810) and the resistance of pedalling.

The dependent variables related to the jump test included the time of contact with the ground, time of flight, the height in centimeters, and the number of jumps (in VJ2 and VJ3) measured by means of a contact platform (Tape switch Control mat CKP).

Protocol

a) The pre tests were performed on successive days by the participants in three different Vertical Jump (VJ) without warming.

   VJ1, in which the subject had to jump 5 times to the maximum possible height and then had a 5' rest period between jumps.

   VJ2, in which the subject had to jump as high as possible, with minimum ground contact, for 10 seconds.

   VJ3, in which the subject had to jump as high as possible, with minimum ground contact for 60 seconds.

First Week	1st day	2nd day	3nd day
	(5 jumps)	(Jumps for 10 “)	(Jumps for 60”)

b) Test. They performed the same test jump after pedalling warm-up on three successive days.

2nd Week	**1st day**	**2nd day**	**3nd day**
	10’ warm-up	10’ warm-up	10’ warm-up
	3’ rest.	3’ rest.	3’ rest.
	VJ1	VJ2	VJ3
	(5 VJ)	(VJ for 10 “)	(VJ for 60”)

Participants

All participants had to meet three basic requirements: a) no alterations of the musculoskeletal system for the last 6 months; b) no muscle soreness during the process (DOMS) and c) no intense physical activity in the last 48 hours.

25 healthy football players males (2nd Division B, Group IV. Spanish Football League) without limitations or disabilities took part in the study. Age: 22,7 ± 3.3 years; Height 178.8 ± 3.9 (cm); Mass: 75.3 ± 6.8 (kg); BMI: 23,5 ± 1,2; VO2 max: 41.0 ± 3.9 (ml O^2/kg/min).

Before the experiment, an effort test PWC (physical work capacity) was carried out. For this, protocol PWC 170 was selected which estimates the ability to work at a heart rate of 170 hr as a way to assess the functional capacity of a subject by indirect methodology. The purpose of this test is to assess the capacity of performance from a cardiovascular point of view and diagnose injuries which could not be discovered in a rest situation.

All participants who took part in the test volunteered to participate in the study, which was then submitted to the Ethics Committee of the University of Granada. Before the study began, participants agreed and were informed in written form of the nature, purposes and risks of the study and their right to withdraw from the study without penalty.

Equipment and Material

The warm-up was carried out on a Lode Excalibur Sport cycle ergometer while the jump test was performed in a platform integrated in the Omega Wave system (OW).

The warm-up was carried out on a Lode Excalibur Sport cycle ergometer while the jump test was performed in a platform integrated in the Omega Wave system (OW).

The OW device fulfills all the requirements recommended by the European Society of Cardiology and the North American Society of Pacing and

Electrophysiology Standards for measurement of Heart Rate Variability. The interface module Omega Wave system was used to carry out the jumps test, which have a output connected to a contact platform (Tape switch Control mat CKP).

Procedure

Vertical Jump Tests. Each test took place on successive days.

The first test consisted of 5 vertical jumps to the maximum possible height (VJ 1). Subjects were told they could use the thrust they thought appropriate and they should keep their hands on their waists.

The second vertical jump test, consisted of performing as many leaps and as high as possible for 10 seconds (VJ 2) with as minimum contact as possible with the ground, with their hands on their waist.

The last vertical jump test (VJ 3), was the same as (VJ 2) but for 60 seconds.

Heart rate was recorded continuously during the jump test and within three minutes after each one.

Warm Up

The warm-up was divided into two phases:

The First Phase of the warming-up took 5 minutes. It was carried out with an average of 112,2 ± 13,2 w and with hr. average of 114.8 hr (56.6 ± 6.4 % of the theoretical maximum heart rate calculated by subtracting the age 220 = % hrmax 1) (Table 1).

The Second Phase: Was done again for 5 minutes with an average of 197.5 ± 38.4 w and with a hr. average of 147.2 hr. (74.3 % ± 4.0, hrmax 2) (Table 1).

TABLE 1
Power and heart rates during warm-up.

W1		112.2 ±13.2	w
	Heart Rate1	114.8 ± 20.3	beats/min
	%hrmax1	56.6 ± 6.4	%
W2		197.5 ± 38.4	w
	Heart Rate2	147.2 ± 6.7	beats/min
	%hrmax2	74.3 ± 4.0	%

% hrmax: Percentage of the maximum heart rate.

The loads measured in watts (W) which were used during both stages of warming-up, were established by the OW software according to the heart rate of the subject previously measured.

On successive days, in each of the three test (VJ 1, VJ 2, VJ 3), the subjects performed the VJ as explained above following the instructions precisely.

Three minutes after finishing the warm up, we start to execute each of the three tests.

Statistical Analysis

For the statistical treatment of the data the SPSS software 20.0. was used, by applying a descriptive statistics, a test Shapiro-Wilk and the level of significance p ≤0.05 in order to check the normality of the sample. (Treating was perfomed using the General Linear Model for repeated measures. In the test of within-subjects effects has taken the significance obtained with –Geisser Greenhouse correction in the degrees of freedom for each of the contrasting effects, since there is a slight deviation from the condition of sphericity (Mauchly test)). Subsequently, if there is any significance, it has performed the corresponding comparisons (pairwise comparisons) with Bonferroni correction.

RESULTS

In the ordinary test, if the level of significance is 0.05, the (null) hypothesis H0 is accepted, that is to say, it the data follows a normal distribution, since the p-value associated with this test was always greater than the threshold 0.05.

We have noticed significant differences (p ≤0.000) in heart rates obtained in the VJ 1. No difference was observed in the heart rate either in the pre or post warming-up in VJ 2 and VJ 3 (p>0.05) (Table 2).

TABLE 2
Heart rate (bpm) in relation to the warm-up in the VJ.

	H.R.	Without warm-up	With warm-up
	Final	111.2 ±22.1*	130.0 ±13.8*
VJ 1 Recovery	1min	68.7 ±10.0*	96.7 ±16.5*
	2min	69.3 ±7.9*	92.0 ±13.1*
	3min	72.5 ±9.9*	87.9 ±11.6*
	Final	114.7 ±18.3*	134.9 ±10.9*
VJ 2 Recovery	1min	70.5 ±13.9*	92.21 ±16.6*
	2min	71.4 ±13.6*	92.8 ±10.7*
	3min	76.2 ±18.1	89.5 ±12.0
	Final	152.1 ±12.7*	160.0 ±22.1*
VJ 3 Recovery	1min	109.2 ±18.2	108.0 ±16.7
	2min	87.7 ±14.8	89.5 ± 15.5
	3min	79.9±10.3	87.2±11.7

** Significant difference preceding and following the warm-up (p≤0.001).*

Student's t-test for related samples showed that there was a statistically significant increase in the VJ height (p ≤0.000), best jump height (p ≤0.000), and the time of flight (p ≤0.001) at VJ 1 (Table 3).

TABLE 3
Mean ± SD of the VJ.

		Without warm-up	**With warm-up**	**Difference mean**	**Significance**
VJ 1	Average Height VJ (cm)	**41.95±5.47**	**43.96±5.84**	**2.01**	**0.001**
	Maximum Height VJ (cm)	**43.37±5.60**	**45.81±6.04**	**2.44**	**0.001**
	Flight Time (ms)	**492.21±45.70**	**508.35±47.50**	**16.14**	**0.000**
	Range Height VJ (%)	39.11 to 44.72	41.10 to 46.91		
	C.I. 95 Height VJ	2.77	2.96		
	Range Best VJ (%)	40.54 to 46.22	42.72 to 48.81		
	C.I. 95 Best VJ	2.83	3.06		
VJ 2	Height VJ 2 (cm)	24.90±5.34	25.07±4.94	0.17	Ns
	Contact Time (ms)	217.43±46.50	211.29±23.67	-6.14	Ns
	Number of VJ 2 (n1)	15.71±1.72	15.64±.92	-0.07	Ns
	Flight Time (ms)	448.29±48.04	450.21±45.45	1.92	Ns
	Index of alactic power (W/kg)	3.65±.0.52	3.69±.0.52	0.04	Ns
VJ 3	Height VJ 3 (cm)	21.10±4.53	21.34±4.22	0.24	Ns
	Contact Time (ms)	207.07±20.91	210.43±26.94	3.36	Ns
	Number of VJ 3 (n2)	97.57±6.67	96.64±7.27	-0.93	Ns
	Flight Time (ms)	412.64±44.41	415.36±40.49	2.72	Ns
	Index of lactic power (W/kg)	3.31±.0.51	3.32±.0.46	0.01	Ns

Ns: No significance.

There was no significant difference (p>0.05) in the analyzed variables in the leap VJ 2 and VJ 3, the heights of jump, flight time, and time of contact with the ground, of post warm-up were similar to the values achieved in the pre warm-up. In table 3 we can see both the average and standard deviation of the analyzed variables in each of the VJ.

DISCUSSION

The objective of this study was to investigate the effect of a warming-up through dynamic pedalling, carried out on a cycle ergometer on the performance of the VJ (height, flight time and time of contact with the ground) and the heart rate after the VJ in young men between the ages of 20 and 30 years old who train 5 days per week and compete every weekend.

The improvement in the sport performance linked to a warm-up activity has often proved the belief that prior to any athletic activity a warm-up is required (Fradkin, Zazryn & Smoliga, 2010; Faigenbaum, Bellucci, Bernieri et al 2005; Aguilar, DiStefano, Brown, et al, 2012; Perrier, Pavol & Hoffman, 2011). Nevertheless these studies have focused on assessing the effect of different types of stretching on the vertical jump, without any aerobic exercises, which we believe are essential to prepare and activate the body before an intensive sporting activity. However, a specific warm up along with dynamic exercises, although it increases the flexibility of the hamstring muscles and the maximum torque of force carried out by the quadriceps in concentric exercise, it may not bring significant improvements in the performance of the vertical jump (Gelen, 2011).

Note that flight time, time of taking off and height of the jump can predict athletic performance. Many coaches believe a good performance in the vertical jump test is essential, being closely related to the success achieved in many sports (Whitmer, Fry, Forsythe et al, 2015).

There has been an increase in the height of the vertical jump (Chattong, Brown, Coburn et a , 2010; Sotiropoulos , Smilios , Christou et al, 2010; Faulkinbury, Stieg, Tran et a, 2011; Alikhajeh, Ramezanpour & Moghaddam, 2011) and in the flexibility of the hamstring and quadriceps muscles (Frantz & Ruiz, 2011) when performing static and dynamic stretching. Positive results have also been obtained in the performance of the sprint (Ayala, 2010; Bishop, 2003). Surprisingly, studies that used specific jump warm-ups, for example jumping on and off a platform and drop jumps (plyometric jump), which involve an explosive vertical jump after landing, did not improve the performance of the vertical jump (Bishop, 2003). In the present study the height of the vertical jump and the time of flight increased significantly ($p \leq 0.001$), the time of contact with the ground decreased and the maximum heart rate increased in the VJ1 after performing a warming-up through dynamic pedalling on the cycle ergometer, while there were no statistically significant improvements in the VJ2 and VJ3.

Accumulated fatigue and the intensity of exercise can play an important role in the performance of the vertical jump. It is commonly believed that the fatigue and empowerment exercises coexist in the skeletal muscle after a maximum action or submaximal exercise even though it may have a negative effect on the production of force when there is too much fatigue, and/or insufficient intensity in the effort. Therefore, the rest intervals can also have an effect on the performance as their duration should be long enough to allow a decrease in fatigue, but not too long, so that as it will not lose the beneficial effects of the warm-up and not too short in order to allow a certain recovery. Burkett, Phillips & Ziuraitis (2005) studied university football players during four differentiated warm-up sessions establishing two minutes rest before the performance of the vertical jump test, while Vetter (2007) conducted a study on six different types of warm-up, leaving no time to rest before performing the vertical jump test, finding a performance increase when combined with the warming dynamic stretching. These data suggest that the main activity should be performed during a relatively short time, between 1 and 5 minutes after a warm-up session to maximize the effect of warm-up on this activity. In our study an initial warm-up was carried out for 5 minutes with an average heart rate of 114.8 ±20.32 hr (56.67 ±6.42 % hrmax1) and a medium power of 112.2 ±13.21 w. These values of heart rate and resistance indicate a mild exercise compatible with those of the beginning of a physical activity followed by an increase in the intensity preparing the body for activity requiring high intensity from the lower limbs. Following a load-balancing concept, which prevents to run out of energy and then facilitate its recovery, subjects were given a 3 minute break before proceeding with the warm-up, then 5 minutes of pedalling to 147.2 ±6.71 hr, (74.38 ±4.06 % hrmax.) with a medium power of 197.5 ±38.48 w.

By carrying out this type of warm-up, we believe the warming up can be increased prior to the competition and/or follow a specific training a basic principle of continuity and functional energy to finally perform the object tests of study, 3 minutes after the end of the warm-up in a chronology that simulates an intensive training or competition. Therefore pedalling with the suggested heart rate frequency can facilitate achieving an optimized performance.

Practical Applications

Our study proposes a warming-up through dynamic pedalling on the cycle ergometer based on an aerobic exercise, therefore applicable to the majority of sports and can be performed in circumstances that in some sports would facilitate the implementation of the athlete into action e.g. players that are at complete rest on the bench and who have to start a competition at short notice.

The practical application of these observations may be useful in sports in which jumps have a vital importance avoiding specific warm-ups which can be potentially harmful and can cause misspending of energy. The coach can count on having his athletes in the required moment and in an optimal physiological state for them to immediately take part in the sporting activity and proves wrong the widespread belief among many coaches that a warm-up based on pedalling does not have a positive effect on running and jumping activities. This warm-up would not be inconsistent with traditional warm-ups of each sport specialty, which the athlete could carry out on a regular basis, but if the sporting activity was delayed, the cycle ergometer would be a valuable way to keep the athletes active and fit, keeping them from losing specific qualities when they are required for the jump.

In future studies, we need to focus on integrating this type of warm-up with specific technical actions of various sporting disciplines for which the athlete should undertake a full warm-up, minimizing the risk of injury, and enhancing the neuromuscular activity.

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