Marcos, M.; Olcina, G.; Timón, R.; Sánchez, F. y Maynar, M. (2016) Efecto ergogénico de la ingesta de fosfato sódico en sujetos físicamente activos / Ergogenic Effect of Sodium Phosphate Intake in Physically Active Subjects. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 16 (61) pp. 33-44. Http://cdeporte.rediris.es/revista/revista61/artefecto619.htm
DOI: http://dx.doi.org/10.15366/rimcafd2016.61.003

ORIGINAL

THE ERGOGENIC EFFECT OF SODIUM PHOSPHATE INTAKE ON PHYSICALLY ACTIVE SUBJECTS

EFECTO ERGOGÉNICO DE LA INGESTA DE FOSFATO SÓDICO EN SUJETOS FÍSICAMENTE ACTIVOS

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AKNOWLEDGEMENT

This research was funded by the Government of Extremadura. Research Group CTS-036

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

Recibido 25 de junio de 2012 **Received** June 25, 2012
Aceptado 30 de julio de 2015 **Accepted** July 30, 2015

ABSTRACT

This study aims to evaluate the effects of short-term sodium phosphate intake upon body composition, haemogram, maximal ergospirometer parameters and submaximal ones in the maximal fat oxidation zone (Fatmax). 20 active subjects participated in this study randomly divided into two groups: The experimental group which ingested sodium phosphate for 7 days (50 mg/kg lean mass) and the placebo group. Both performed an incremental maximal cycle ergo meter test following the Fatmax protocol, body composition assessment and blood analysis (CBC) before and after the supplementation period. In the experimental group, phosphate supplementation produced a decrease in weight and body mass index (BMI), an increase in maximal power output and it also improved energy efficiency in the Fatmax zone. No changes were observed in the parameters listed in the CBC. These results may attribute an ergogenic effect of sodium phosphate in aerobic activities and sports where body weight is considered to be an important factor for performance.

KEY WORDS: dietary sport supplement, fat mass, BMI, haematocrit, VO_2max, power, energy expenditure.

RESUMEN

Este estudio pretende evaluar los efectos de la ingesta de fosfato sódico a corto plazo, sobre la composición corporal, serie roja y parámetros ergoespirométricos máximos y submáximos. A una muestra de 20 sujetos físicamente activos, separados en dos grupos, se les suministró fosfato sódico durante 7 días (50 mg/kg masa magra) o placebo. Ambos grupos realizaron una prueba de esfuerzo incremental máxima en cicloergómetro, siguiendo el protocolo Fatmax, se les determinó la composición corporal y se les realizó un hemograma antes y después de la suplementación. En el grupo experimental, se observó una disminución en el peso e índice de masa corporal (IMC), un aumento en la potencia máxima alcanzada y una mejor eficiencia energética en la zona Fatmax. No se observaron cambios en parámetros hematológicos. Estos resultados pueden atribuir un efecto ergogénico al fosfato sódico en actividades aeróbicas y aquellas donde el peso corporal influya en el rendimiento.

PALABRAS CLAVE: ayuda ergogénica, masa grasa, IMC, hematocrito, VO_2max, potencia, gasto energético.

INTRODUCTION

Phosphate salts are classified as potentially ergogenic substances and are permitted by sports law. There are many benefits attributed to them because they are involved in many metabolic processes. In exercise, these salts play a very important role as they are involved in the three energy systems. Phosphates are part of ATP and creatine phosphate (CP), which are basic substrates of high energy phosphagen. They are also involved in anaerobic glycolysis, softening acid lactic effects in speed endurance exercises, and they are actively involved in the aerobic energy system (Czuba, Zając, Poprzecki & Cholewa, 2008; Williams, 1998).

Kreider, Miller, Williams, Somma & Nasser (1990) examine different hypotheses for which phosphate supplements may affect performance athletes. Firstly, there would be a general metabolic improvement because the mentioned supplements increase intracellular and extracellular concentrations of phosphate and produce improvements in glycolysis and glycogenolysis in oxidative phosphorylation, causing an ergogenic effect, enhancing energy metabolism and / or energy efficiency. Furthermore, supplementation also provides additional inorganic phosphate to replenish ATP and CP during exercise (Stryer, 1988). In endurance exercise an ergogenic benefit may be witnessed, improving efficiency and / or cardiovascular performance, enhancing peripheral oxygen extraction (Farber, Carlone, Palange, Serra, Paoletti & Fineberg, 1987) and reducing cardiac submaximal expenditure (Farber, Sullivan, Fineberg, Carlone & Manfredi, 1984; Lunne, Zauner, Cade, Wright & Conte, 1990).

One of the first studies on this method was carried out by Cade, Conte, Zauner, Mars, Peterson, Lunne, Hommen & Packer (1984). In this study ten trained male runners took sodium phosphate or placebo supplements and then they performed a stress test. The results revealed an increase in VO2max, depending on the order in which the substances are taken, increasing more in those subjects taking phosphate in two consecutive tests. These results provide the first evidence that sodium phosphate supplementation could improve the capabilities of well-trained athletes.

Kreider *et al.* (1990, 1992) performed other research projects, one of them with elite athletes and another with elite cyclists, where they observed that sodium phosphate intake increases VO_2max and the ventilatory anaerobic threshold. In Stewart, McNaughton, Davies & Tristram (1990) eight trained male cyclists took sodium phosphate over three days, before carrying out a maximal test. There were significant increases in VO_2max and they were able to stand higher loads during the test.

Recently, studies with trained cyclists have shown significant increases in average power and oxygen volume (Folland, Stern y Brickley, 2008), and decreases in maximum heart rate and resting (Czuba, Zajac, Poprzecki & Cholewa, 2008).

There are many different protocols carried out to observe the effects of phosphate supplementation. However, there is no unanimity regarding results, therefore, Buck, Wallman, Dawson y Guelfi (2013), in their review about this subject, indicate that it is important to assess the results as they could be influenced by the differences between the types of supplements or the fitness level of participants in the studies.

There is some controversy regarding the study protocols used, taking maximum data in some cases and submaximal data in other cases. For this reason it would be necessary to obtain data relating to the entire course of the test. In this sense, during an incremental exercise test the intensity at which the subjects reach the fat burning peak, known by the name of Fatmax, could be determined (Jeukendrup & Acthen, 2001; Achten, Gleeson & Jeukendrup, 2002). This can be found at an exercise intensity between 33% and 65% of VO_2max (Jeukendrup & Acthen, 2001; Venables, Achten & Jeukendrup, 2005) but it is not possible to find studies linking phosphate supplementation with metabolic substrate utilisation.

The fact that different benefits during physical activity may occur, such as general metabolic improvement and improved cardiovascular efficiency, both mentioned above, might suggest that there will be several changes in the parameters related to red blood series or even in the body composition of subjects. No founding research related to the study of these parameters has been found and thus, it would be interesting to obtain them for analysis and study.

The aim of this research is to evaluate the potential ergogenic effect of sodium phosphate supplementation in physically active subjects, by analysing blood cell count, body composition and different ergospirometric parameters (VO2, VCO2, RER, heart rate and power) at their maximal and submaximal values in the Fatmax zone.

MATERIAL & METHODS

Participants

The subjects involved in this study were 20 physically active male subjects, who performed weekly physical activity but did not follow any training protocol. The physical activity carried out by the subjects was not done with a high performance objective, and was observed after assessing the subjects via the IPAQ survey (Craig, Marshall, Sjostrom, Bauman, Booth & Ainsworth, 2003). All the participants in the study were previously informed of the protocol and signed a voluntary consent form, ensuring confidentiality of data. All were committed to maintaining a diet similar to the usual. The study complied with the principles of the Declaration of Helsinki and its previous reviews on human studies.

The subjects were randomly divided into two groups: the experimental and placebo group. The baseline characteristics of the sample are shown in Table 1.

Table 1. *Participant Characteristics*

	Experimental Group	Placebo Group
Age (years)	23,4±2,3	24±3,5
Physical Activity (hours/week)	5,3±1,8	6,8±1,7
Height (cm)	174,7±7,6	180±4,5
Weight (kg)	73,0±10,1	72,6±6,9
Fat Free Mass (MLG) (kg)	61,4±7,1	62,6±5,3
Fat Mass (MG) (kg)	11,6±3,4	10,0±2,5
IMC	23,8±1,9	22,3±1,8

Experimental Protocol

A protocol was developed for all the subjects to undertake the study under similar conditions. The subjects were submitted to an interview where they answered various questions and the experimental protocol was explained, so that all subjects had a general idea of the whole process which would take place. The most relevant answers to our study were the number of hours of physical activity, in order to check that they really were not high-level trained athletes.

The sample was randomly divided into two groups: the experimental group took tribasic sodium phosphate three times daily for a week. The doses were prepared taking into account the fat free mass of subjects (50mg/kg), as did Minson (2000) and Czuba, Zajac, Poprzecki & Cholewa (2008). The placebo group took 50mg/kg of a fat-free mass of sodium bicarbonate, also three times daily for a week. There were twenty-one doses in capsules for both groups, in order to avoid the subjects being able to identify the substance they were taking.

Before starting their intake, the subjects performed the following protocol. All participants were given an appointment at the Laboratory of Physiology at the University of Extremadura, during the same time slot (between 9 and 11 am) and without food intake. They conducted an assessment of body composition by bio impedance (Tanita® BF-350). The collected parameters were: weight (kg), fat mass (kg and % of total weight), fat mass (kg and % of total weight), body water (kg and % of total weight) and BMI (body mass index).

A blood sample was taken from the antecubital vein to obtain two 10 ml tubes which were used to immediately perform a complete blood count (Coulter A^{c}.T) the collected data were: haematocrit (%), haemoglobin (g / dL), RBC (x10ˆ 3/uL), mean corpuscular volume (fL).

Subjects were allowed to take a standardised breakfast and an hour later performed a cycle ergometer exercise test (ERGO-METRICS 900) following the adapted Fatmax protocol (Achten, Gleeson & Jeukendrup, 2002). The exercise test began with a load of 100W and was increased by 25W every 3 minutes until they could not maintain the intensity of effort. Throughout the test the ventilatory response was recorded by a gas analyser (CORTEX METAMAX) and heart rate with a heart rate monitor (Polar ® S610i). The spirometric response was collected every 20 seconds.

The data collected for further analysis were those related to relative oxygen consumption (ml / min / kg), CO2 production (l / min) respiratory quotient (RER), heart rate (bpm), reserve heart rate percentage and power (W) at maximum parameters and those reached in the Fatmax zone. This area was determined following principles of indirect calorimetry, as carbohydrates, fats and proteins have different chemical compositions and therefore need different amounts of oxygen, and produce different amounts of carbon dioxide to be oxidized, which allows areas in which one type of substrate or another dominates, to be analysed (Jeukendrup & Wallis, 2005). To calculate the values obtained at each stage of the test and Fatmax zone the average data for each step of the exercise test was recorded.

After a week of supplementation, phosphate or placebo, the subjects undertook the same protocol (body composition assessment, blood sampling and an incremental exercise test). In this way, the initial use of metabolic substrates during testing being influenced or conditioned by prior exercise was prevented, carrying out similar energy expenditure in the two tests, due to being separated in time (Jeukendrup &Walls, 2005).

Data analysis

Once all the data was collected SPSS 19.0 was used and a data normality study was carried out using the Kolmogorov-Smirnov test.

As the data did not meet the normal data criteria a nonparametric statistical test was performed in order to evaluate the effects of sodium phosphate intake. The Wilcoxon test was used for 2 related samples, with differences of $p < 0.05$ being regarded as significant. Results were expressed as mean ± standard deviation.

RESULTS

The results obtained in the study may be seen below. Table 2 shows detailed data of body composition before and after the intake of sodium phosphate or placebo.

Table 2. *Body composition before and after intake of placebo or sodium phosphate*

VARIABLE	EXPERIMENTAL GROUP			PLACEBO GROUP		
	Pre-Ingestion	**Post-Ingestion**	**Sig.**	**Pre-Ingestion**	**Post-Ingestion**	**Sig.**
Weight (kg)	73,08±10,15	72,63±9,96*	0,024	72,62±6,91	73,24±6,80	0,075
IMC (weight/height^2)	23,84±1,99	23,70±1,95*	0,044	22,39±1,88	22,59±1,91	0,079
Fat Free Mass (FFM) (kg)	61,46±7,10	61,48±7,03	0,799	62,60±5,37	63,16±5,20	0,079
Fat Mass (FM) (kg)	11,62±3,45	11,15±3,20	0,059	10,02±2,53	10,07±2,50	0,799
Water (kg)	45,00±5,21	45,00±5,14	0,959	45,84±3,92	46,25±3,80	0,090
% FFM	84,41±2,81	84,92±2,51	0,092	86,32±2,79	86,35±2,72	0,799
% FM	15,61±2,82	15,08±2,50	0,074	13,69±2,78	13,64±2,71	0,674
% Water	61,78±2,04	62,15±1,86	0,092	63,19±2,05	63,22±1,99	0,733

p<0,05 comparing Pre-ingesta vs. Post-ingesta

As is observed, after supplementation with sodium phosphate a statistically significant decrease in body weight and BMI occurs in subjects from the experimental group, unlike those from the placebo group who experienced a slight increase in both parameters.

Table 3 shows the results obtained after performing blood counts before and after the ingestion of sodium phosphate or placebo.

Table 3. *Haematological values before and after intake of placebo or sodium phosphate*

VARIABLE	EXPERIMENTAL GROUP			PLACEBO GROUP		
	Pre-Ingestion	**Post-Ingestion**	**Sig.**	**Pre-Ingestion**	**Post-Ingestion**	**Sig.**
HCT (%)	41,74±2,96	41,33±2,26	0,445	41,99±2,31	41,73±1,73	0,779
Hb (g/dL)	13,84±0,88	13,41±0,72	0,114	14,12±0,51	13,60±0,66	0,050
RC (x10^3/uL)	4,91±0,31	4,86±0,30	0,333	4,89±0,28	4,96±0,33	0,889
MCV (fL)	85,03±3,03	85,17±3,18	0,507	85,87±2,99	85,62±2,89	0,237

HCT: haematocrit; Hb: haemoglobin; RC: red cells; MCV: mean corpuscular volume

There are no changes in haematocrit values in any of the two groups after the ingestion of substances. There are also no changes in other red cell parameters: haemoglobin, red blood cells or mean corpuscular volume in any group.

Tables 4 and 5 show the ergometric parameters obtained from the incremental exercise test.

Table 4. *Ergoespirometric parameters in the Fat Max zone.*

VARIABLE	EXPERIMENTAL GROUP			PLACEBO GROUP		
	Pre-Ingestion	**Post-Ingestion**	**Sig.**	**Pre-Ingestion**	**Post-Ingestion**	**Sig.**
VO2 (ml/min/kg)	19,60±2,59	18,10±3,41*	0,031	25,25±12,15	25,50±13	0,746
VCO2 (l/min)	1,16±0,13	1,06±0,17*	0,038	1,43±0,57	1,50±0,60	0,123
RER	0,85±0,07	0,82±0,06	0,092	0,84±0,04	0,86±0,05	0,207
HR (ppm)	121,70±17,88	116,40±14,28	0,386	126,12±31,48	120,00±24,24	0,176
%HRR	55,10±12,59	50,20±6,65	0,507	56,50±21,21	53,12±16,92	0,395
Power (W)	105±15,81	105±10,54	1	131,25±47,72	134,38±51,65	0,317

* p<0,05) comparing Pre-ingestion vs. Post-ingestion
VO2: oxygen consumption; VCO2: carbon dioxide consumption; RER: respiratory quotient; HR: heart rate; %HRR: heart rate reserve percentage

There are significant increases after sodium phosphate intake, oxygen uptake values (VO_2) and carbon dioxide production (VCO_2), not producing any change in these variables in the placebo group.

Table 5. Maximal ergoespirometric parameters

VARIABLE	EXPERIMENTAL GROUP			PLACEBO GROUP		
	Pre-Ingestion	**Post-Ingestion**	**Sig.**	**Pre-Ingestion**	**Post-Ingestion**	**Sig.**
VO2 (ml/min/kg)	47,09±10,36	47,87±9,99	0,203	53,71±4,67	52,74±8,22	1
VCO2 (l/min)	3,25 ± 0,42	3,36 ± 0,36	0,168	3,65 ± 0,56	3,89 ± 0,43	0,086
RER	1,02 ± 0,03	1,01 ± 0,04	0,558	0,99 ± 0,05	1,01± 0,02	0,263
HR (ppm)	184,20±7,38	187,20±8,63	0,173	186,88±7,43	185,63±8,4	0,348
Power (W)	235,00±39,44	247,50±32,17*	0,025	275,00±55,10	290,63±55	0,059

* p<0,05) comparing Pre-ingestion vs. Post-ingestion

VO2: oxygen consumption; VCO2: carbon dioxide consumption; RER: respiratory quotient; HR: heart rate

There are no significant differences after intake on maximal oxygen consumption or maximum heart rate values in any of the two groups. However, after supplementation there is an increase in the maximum power output during the test in the experimental group.

DISCUSSION

Other research analysing the effects of sodium phosphate intake on body composition parameters is lacking. In this research project a decrease in body weight and BMI of subjects in the experimental group was observed. This may be caused by a general metabolic improvement which would increase tissue oxygenation and the ability to burn metabolic substrates, as suggested by Kreider *et al.* (1992). This could propose a potential ergogenic effect of sodium phosphate short term intake in fat mass decrease, which would be useful in sports requiring a mass reduction for performance (jumping, endurance sports) or to establish a category of competition as in combat sports (judo, taekwondo, etc.), yet this needs to be studied in more depth in future research.

On the other hand, an analysis of blood parameters related to the red series such as haematocrit, haemoglobin, red blood cells and the mean corpuscular volumen, was conducted. The fact that, in Cade *et al.* (1984), Farber *et al.* (1987), Kreider *et al.* (1990, 1992), Folland *et al.* (2008) and, Czuba *et al.* (2008), there were improvements in metabolic regulation and oxygen consumption, leads us to believe that the study of red series is another possible way of improving aerobic performance. Not obtaining increases in these parameters before and after ingestion may be due to the fact that the increase in body temperature during exercise affects red blood cells. In addition, increasing the speed circulation would cause erythrocytes to collide, thus increasing the possibility of their destruction, or the stress produced during exercise would increase the fragility of red cell membranes (Terrados & Leibar, 1995; cited in Legaz Arrese, 2000).

The data obtained in the Fatmax zone show that the experimental subjects lower their oxygen consumption and carbon dioxide production during this part of the test. This must be due to sodium phosphate intake, as these results were not experienced by the placebo group. As there is an absence of data from previous studies to compare with our own, it could be said that that these new results indicate that the experimental subjects achieved significant improvements in fat burning, improving energy efficiency, at least under the conditions and characteristics of our research. These results may be related to claims made by Jeukendrup, Saris & Wagenmakers (1998), who indicate that an enhanced ability to oxidise fatty acids is associated with improved performance.

Research studies in scientific literature have followed the line of research initiated by Cade *et al.* (1984), revealing significant increases in VO_2max, like in research carried out by Kreider *et al.* (1990), Stewart *et al.* (1990), Kreider *et al.* (1992) and Czuba *et al.* (2008). As in our results there are no changes in maximal oxygen consumption, our study provides evidence to the contrary, following the trend of the work of Folland *et al.* (2008), where changes in VO_2max were not significant. The fact that there are no changes in this variable may be due to the lack of training of our subjects during the supplementation period, which did not occur in previous reviewed investigations, where the subjects were trained athletes who continued with their normal training regimen during the entire process.

The increase in maximum power values of the experimental subjects leads us to talk about an improvement in the subjects' performance and therefore an ergogenic effect. These are supported by data obtained in Stewart *et al.* (1990) and Kreider *et al.* (1992), where improvements were found in the reached power output and time of tests. There were also significant increases in average power, as in Folland, Stern & Brickley (2008). These enhancements may be due to a general metabolic improvement, to changes brought about by the action of 2,3 DPG (Cade *et al.*, 1984). Body weight and BMI decreases may also affect the increased maximum power but these changes would be greater in other activities, where body weight had to be shifted, as may be the race on foot, if the tests had been conducted on a treadmill.

CONCLUSIONS

1. Sodium phosphate supplementation under the conditions of this research decreases body weight and BMI so that short-term intake is useful for sports activities whose performance depends on body weight.
2. Sodium phosphate supplementation improves effort economy in the Fat Max zone, where major metabolic substrate for energy production is fat oxidation.
3. Sodium phosphate supplementation may provide an ergogenic effect related to the maximum power developed in predominantly aerobic tests in untrained subjects and under the conditions of our research.

4. In the short term, sodium phosphate intake does not cause changes in blood parameters related to the red series, such as haematocrit, haemoglobin or red blood cells.
5. Sodium phosphate intake does not alter VO_2max values under the conditions of our research.

RESEARCH LIMITATIONS

In most of the research papers reviewed, such as Cade *et al.* (1984), Farber *et al.* (1984), Kreider *et al.* (1990), Stewart *et al.* (1990), Bremner *et al.* (2002), Czuba *et al.* (2008), cardiac parameters like serum phosphate concentration or 2,3 DPG levels were studied. These parameters have not been analysed in our study, due to the lack of tools and techniques needed to carry out the analysis at the time of our research.

For future research it would be preferable to extend the evaluation time of red blood series following a period of 'washing' without ingesting any substance. Then it would be possible to assess the potential creation of substances that allow an improvement in oxygen transport in the body.

The possibility that subjects have experienced an improvement in psychological responses to exercise is also conceivable, due to the placebo effect, as the act of taking a substance may have allowed them to exercise at a greater intensity and / or for a longer duration, perceiving the same stress or being more motivated.

REFERENCES

Achten,J., Gleeson, M. y Jeukendrup, A.E. (2002) Determination of the exercise intensity that elicits maximal fat oxidation. *Medicine & Science in Sports & Exercise, 34*(1), 92-97. http://dx.doi.org/10.1097/00005768-200201000-00015

Bremner, K., Bubb, W.A., Kemp, G.J., Trenell, M.I. y Thompson, C.H. (2002) The effect of phosphate loading on erythrocyte 2,3-bisphosphoglycerate levels. *Clinica Chimica Acta, 323,* 111-114. http://dx.doi.org/10.1016/S0009-8981(02)00165-1

Cade, R., Conte, M., Zauner, C., Mars, D., Peterson, J., Lunne, D., Hommen, N. y Packer, D. (1984) Effects of phosphate loading on 2,3-diphosphoglycerate and maximal oxygen uptake. *Medicine & Science in Sports & Exercise, 16,* 263-268. http://dx.doi.org/10.1249/00005768-198406000-00011

Craig, C.L., Marshall, A.L., Sjostrom, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E. (2003) International physical activity questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise*, *35,* 1381-95. http://dx.doi.org/10.1249/01.MSS.0000078924.61453.FB

Czuba, M., Zając, A., Poprzecki, S. y Cholewa, J. (2008) The Influence of Sodium Phosphate Supplementation on VO2max, Serum 2,3-diphosphoglycerate Level and Heart Rate in Off-road Cyclists. *Journal of Human Kinetics, 19,* 149-164. http://dx.doi.org/10.2478/v10078-008-0012-z

Farber, M., Carlone, S., Palange, P., Serra, P., Paoletti, V. y Fineberg, N. (1987) Effect of inorganic phosphate in hypoxemic chronic obstructive lung disease patients during exercise. *Chest, 92,* 310-312. http://dx.doi.org/10.1378/chest.92.2.310

Farber, M., Sullivan, T., Fineberg, N., Carlone, S. y Manfredi, F. (1984) Effect of decreased O2 affinity of hemoglobin on work performance during exercise in healthy humans. *Journal of Laboratory and Clinical Medicine, 104, 166-175*.

Folland, J.P., Stern, R. y Brickley, G. (2008). Sodium phosphate loading improves laboratory cycling time-trial performance in trained cyclists. *Journal of Science and Medicine in Sport, 11,* 464-468. http://dx.doi.org/10.1016/j.jsams.2007.04.004

Jeukendrup, A.E., Saris, W.H. y Wagenmakers, A.J. (1998) Fat metabolism during exercise: a review--part II: regulation of metabolism and the effects of training. *International Journal Sports Medicine,19*(5), 293-302. http://dx.doi.org/10.1055/s-2007-971921

Jeukendrup, A.E. y Achten, J. (2001) Fatmax: A new concept to optimize fat oxidation during exercise?. *European Journal of Sport Science, 1,* 1-5. http://dx.doi.org/10.1080/17461390100071507

Jeukendrup, A.E. y Wallis, G.A. (2005) Measurements of Substrate Oxidation During Exercise by Means of Gas Exchange Measurements. *International Journal Sports Medicine, 26,* 28-37. http://dx.doi.org/10.1055/s-2004-830512

Kreider, R.B., Miller, G.W., Williams, M.H., Somma, C.T. y Nasser, T. (1990) Effects of phosphate loading on oxygen uptake, ventilatory anaerobic threshold, and run performance. *Medicine & Science in Sports & Exercise, 22, 250-255.*

Kreider R.B., Miller G.W., Schenck D., Cortes C.W., Miriel V., Somma C.T., Rowland P., Turner C. y Hill D. (1992) Effects of phosphate loading on metabolic and myocardial responses to maximal and endurance exercise. *International Journal of Sport Nutrition and Exercise Metabolism, 2, 20-47.*

Legaz Arrese, A. (2000) Atletismo Español: Análisis básico de la pseudoanemia, anemia ferropénica y anemia megaloblástica. *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte*, *1(1), 65-83.*

Lunne, D., Zauner, C., Cade, R., Wright, T. y Conte, M. (1990) Effect of phosphate loading on RBC 2,3-DPG, cardiac output, and oxygen utilization at rest and during vigorous exercise. *Clinical Research in Cardiology, 28, 810.*

Minson, C.T. (2000) Loading effects of phosphate on 2,3-DPG and aerobic capacity. *Eugene, Or. : Microform Publications, University of Oregon.*

Stryer, L. (1988) Biochemistry. *New York: WH Freeman*

Stewart, I., McNaughton, L., Davies, P. y Tristram S. (1990) Phosphate loading and the effects of VO2max in trained cyclists. *Research Quarterly for Exercise and Sport, 61,* 80-84. http://dx.doi.org/10.1080/02701367.1990.10607481

Venables, M.C., Achten, J. y Jeukendrup, A.E. (2005) Determinants of fat oxidation during exercise in healthy men and women: a cross-sectional study. *Journal of Applied Physiology, 98*(1), 160-167. http://dx.doi.org/10.1152/japplphysiol.00662.2003

Williams, M.H. (1998) The ergogenics edge: pushing the limits of sport performance. *Champaign, Human Kinetics.*

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Rev.int.med.cienc.act.fís.deporte - vol. 16 - número 61 - ISSN: 1577-0354