# Time to fatigue on lactate threshold and supplementation with sodium bicarbonate in middle-distance college athletes

**Sergio Andrés Galdames Maliqueo[1,2,3], Álvaro Cristian Huerta Ojeda[2,3], Rafael Guisado Barrilao[4], Pablo Andrés Cáceres Serrano[5]**

*[1]Facultad de Ciencias de la Actividad Física y del Deporte, Universidad de Playa Ancha de Ciencias de la Educación, Chile. [2]Grupo de Investigación en Salud, Actividad Física y Deporte ISAFYD. Universidad de Las Américas sede Viña del Mar, Chile. [3]Centro de Capacitación e Investigación Deportiva Alpha Sports, Chile. [4]School of Nursing, University of Granada, Spain. [5]Pontificia Universidad Católica de Valparaíso, Chile.*

**Received:** 27.04.2017
**Accepted:** 10.07.2017

**Summary**

**Introduction:** There have been many researches that have attempted to improve sports performance based on supplementation with different buffer substances. Within this group of substances, sodium bicarbonate supplementation has been widely used in both cyclic and acyclic sports. In the case of cyclic sports, it has been tried to improve the performance of pedestrian races at different percentages of peak oxygen uptake. However, the results on intensity over anaerobic threshold have been contradictory.
**Objective:** To determine the performance variation based on execution in a endurance test after sodium bicarbonate administration. The second aim to evaluate the levels of blood lactate in the finish of endurance test.
**Material and method:** Five college athletes of middle-endurance and endurance race runners were subjects in the study. The variables measured were: effort maximum time (in seconds) measured through a endurance test, and maximum lactate post effort. All athletes were administered sodium bicarbonate (0.3 g•Kg$^{-1}$ body mass) or a placebo (0.045 g•Kg$^{-1}$ body mass) an hour before each endurance test. Student's t-test (lactate) and Wilcoxon (time) was used for the statistical analysis. The size of the effect was calculated with Cohen's d-test.
**Results:** The effort maximum time showed a significant increase ($P < 0.042$; size of the effect = 0.852) as well as lactate concentrations post effort ($P < 0.022$; size of the effect = 1.987).
**Conclusions:** The results of the study showed that the supplementation whit sodium bicarbonate generates an increase in the performance and lactate concentrations post effort, when the race speed surpass by seven percent the anaerobic threshold speed.

**Key words:**
Sodium bicarbonate. Lactate threshold. Athletes. Lactate.

## Tiempo hasta la fatiga sobre el umbral láctico y suplementación con bicarbonato de sodio en corredores de medio fondo universitarios

**Resumen**

**Introducción:** Han sido muchas las investigaciones que han intentado mejorar el rendimiento deportivo en base a la suplementación con diferentes sustancias buffer. Dentro de este grupo de sustancias, la suplementación con bicarbonato de sodio ha sido ampliamente utilizada tanto en deportes cíclicos como acíclicos. En el caso de deportes cíclicos, se ha experimentado mejorar el rendimiento de carreras pedestres a diferentes porcentajes del consumo máximo de oxigeno. Sin embargo, los resultados a intensidades por sobre el umbral láctico han sido contradictorios.
**Objetivo:** Determinar la variación del rendimiento en base al tiempo de ejecución y producción de lactato post esfuerzo en una prueba de resistencia a una intensidad por sobre el UL posterior a la suplementación con bicarbonato de sodio.
**Material y métodos:** Cinco atletas de medio fondo y fondo universitarios fueron parte del estudio. Las variables medidas fueron: tiempo máximo de esfuerzo (segundos) evaluado a través de una prueba de tiempo límite y lactato máximo post esfuerzo. Una hora antes de cada prueba de tiempo límite los atletas fueron suplementados con bicarbonato de sodio (0,3 g•Kg$^{-1}$ masa corporal) o un placebo (0,045 g•Kg$^{-1}$ masa corporal). Para el análisis estadístico se utilizó la prueba *t* de Student (lactato) y Wilcoxon (tiempo). El tamaño del efecto fue calculado con la prueba d de Cohen.
**Resultados:** El tiempo máximo de esfuerzo tuvo incrementos significativos ($p < 0,042$; tamaño del efecto = 0,852), al igual que las concentraciones de lactato post esfuerzo ($p < 0,022$; tamaño del efecto = 1,987).
**Conclusión:** Los resultados del estudio mostraron que la suplementación con bicarbonato de sodio genera un aumento en el rendimiento y en las concentraciones de lactato post esfuerzo, cuando la velocidad de desplazamiento sobrepasa un siete por ciento la velocidad de umbral láctico.

**Palabras clave:**
Bicarbonato de sodio, Umbral láctico. Atletas. Lactato.

**Correspondence:** Sergio Andrés Galdames Maliqueo
E-mail: sergio.galdames@upla.cl

## Introduction

When generating an effort in an anaerobic threshold intensity or higher, the metabolism changes from an aerobic predominance to an anaerobic glycolytic metabolism[1]. Once this occurs, fast fibers start functioning to produce a higher ion hydrogen (H+) concentration, hence reducing blood pH[2]. Muscular acidity caused by H+ accumulation reduces the work capacity through the glycolytic way, causing a reduction in the muscular contractile capacity and preventing from maintain the effort intensity[3]. In order to work against the effects of the metabolic acidosis caused by the glycolytic metabolism, the body possesses physiological buffer systems that keep H+ production under control[4].

Among these natural buffer systems, sodium bicarbonate is considered as the most important compound to maintain an acid-based balance[5]. Drawn from this phenomenon, researchers have tried to determine whether the supplementation with buffering substances such as sodium bicarbonate[6], sodium citrate[7], b-alanine[8], or carnosine[9], can buffer to a larger extent the H+ in order to delay fatigue in athletes and improve their performance[10].

Based upon the foregoing, to exogenously increase sodium bicarbonate levels could reduce H+ levels generated in the anaerobic glycolytic metabolism, hence increasing the lactate flux in the muscles active to the extracellular medium[6]. In this way, the resynthesis of adenosine triphosphate (ATP) by glycolysis may be allowed to continue under more favorable conditions, delaying the onset of muscle fatigue in high intensity efforts[11]. Nevertheless, the physiological mechanisms directly responsible for performance augmentation in humans are unknown[12].

In this line of research, the response to the exogenous administration of sodium bicarbonate and physical performance in cyclic[13,14] and acyclic[15,16] sports have been studied. However, the results have been contradictory and they could not be directly related to the sodium bicarbonate supplementation but rather to the doses used, the level of training of the subjects, or the type of effort[14]. In the case of pedestrian races there are no reports of an increase in the performance after the intake of sodium bicarbonate in distances of 200 m or 400 m[17]. Nevertheless, some researchers have shown evidence of an increase in middle-endurance runners (800 m)[18]. An example was the study developed by Van Monfoort *et al*[19], where they reported an improved response to a sprint until exhaustion test using sodium bicarbonate in comparison to other buffer ergogenic aids. However, the scarce evidence related to the intake of sodium bicarbonate in intensities above lactate threshold (LT) generates questions towards the organic responses generated through the supplementation of sodium bicarbonate in intensities positioned in this intensity zone.

It is interesting then to study the acute response of sodium bicarbonate supplementation in endurance athletes in the aforementioned effort zone. Stimulating runners to real competition intensities by increasing the distance of training repetitions could be an efficient way to increase the performance of subjects. Consequently, will sodium bicarbonate supplementation improve the performance on a time limit test at an intensity higher than the LT in endurance athletes?

### Objectives

To determine the performance variation based on execution in a endurance test after sodium bicarbonate administration. The second aim to evaluate the levels of blood lactate in the finish of endurance test.

## Material and method

*Experimental approach to the study.* The sample for this study consisted of five male college students equivalent to the athlete population of middle-endurance runners of the University of Playa Ancha, Valparaiso, Chile. The inclusion criterion was to be a male athlete with a minimum of three years of experience in college endurance and middle-endurance athletic tests (1500 m a 10.000 m), the capacity to execute and maintain intensities above the lactate threshold and have the ability to execute the requested pace and cadence (Minimum lactate protocol and Endurance Test).

For the protocol application, a quasi-experimental cross-over intra-subject design was used. Each subject had to execute two endurance tests with 72 hours apart. The sodium bicarbonate intake and/or placebo was performed one hour before each endurance test. The administration of sodium bicarbonate and/or placebo was performed with a random double-blind method. Before commencing the study, each subject was measured for weight, height, 12-minute test, and lactate threshold. All participants of the study were told to not eat caffeine, drugs, or any substance that could increase their metabolism during the course of the experiment.

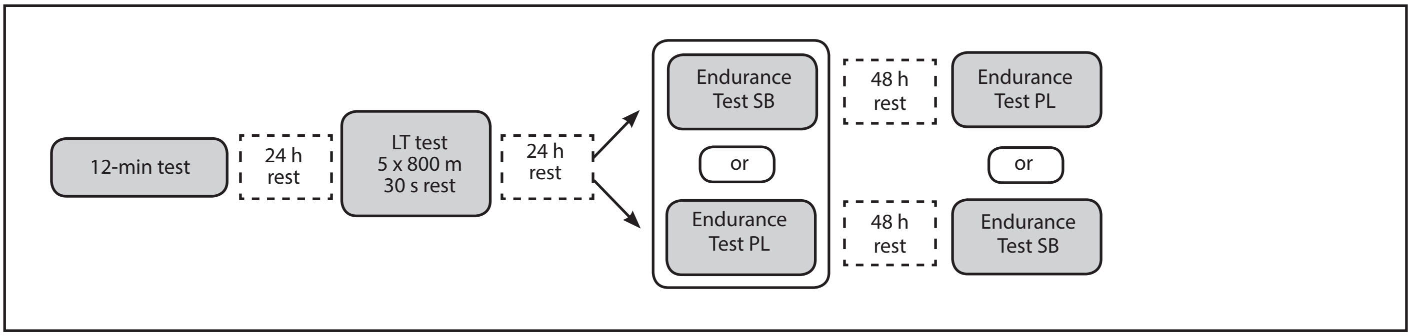
*Subjects.* Five male college athletes whit experience in middle-endurance and endurance races were part of the study. Age: 22.7 ± 1.95 years; weight 67.0 ± 5.3 Kg; height 173.0 ± 0.06 cm; bodily mass index 20.3 ± 2.6 $Kg/m^2$; peak oxygen intake 70.76 ±7.6 $mL{\bullet}kg^{-1}{\bullet}min^{-1}$ (Table 1). All subjects were informed about the objective of the study and the possible risks of the experiment, all of them signed a written consent before the application of the protocol. The written consent, informative document, and the study were approved by the Committee of Bioetic of the University of Playa Ancha, Chile (register number 007/2016).

**Table 1. Characteristics of the sample (median ± SD).**

| | **Experimental Group (n = 05) (median ± SD)** |
|---|---|
| Age (years) | 22.7 ± 0.3 |
| Height (cm) | 173 ± 0.06 |
| Weight (Kg) | 67.0 ± 5.03 |
| BMI ($Kg/m^2$) | 20.3 ± 2.6 |
| Test 12 minutes (m) | 3750 ± 290.6 |
| $VO_2max$ ($ml{\bullet}Kg^{-1}{\bullet}min^{-1}$) | 70.76 ± 6.50 |

BMI (Bodily Mass Index); mL•kg-1•min-1 (milliliters of oxygen consumed by kilogram of bodily weight per minute); SD (standard deviation).

**Figure 1. Methodological design of the treatment application with sodium bicarbonate and placebo.**




12-min test: 12 minutes test; h: hours; LT: lactate threshold; Endurance Test SB: Endurance test with sodium bicarbonate intake; Endurance Test PL: Endurance test with placebo intake; SB: sodium bicarbonate; PL: Placebo.

*Instruments*. For the characterization of the simple, weight and height were measured with a (Health o Meter Professional®) scale and stadiometer.

*Standard warm-up*. For the test and post-test evaluation, the warm-up consisted of 10 minutes of articular mobility including circumduction movements, flexion and extension of the limbs, continuous jog of 10 minutes at 130 beats/minute (heart rate registry was performed with a Polar RS300 cardiac monitor was used), passive flexibility of eigth seconds for each muscular group, heel-stretching exercises, skipping, and three 80-meter ascension race.

*Test and post test*. Each athlete performed three evaluations. In the 12-minute test, all athletes were measured at the same time during the morning. For the lactate threshold, athletes were measured one by one consecutively during the morning. Finally, for the pre and post test through the aerobic resistance test, athletes were measured individually following the same order and the same starting time during the morning.

All three tests were performed every 24 hours, except for the two endurance tests that were performed every 48 hours. All tests were applied in a 400 m athletic court (Figure 1).

*Evaluation 1 (Day 1)*. Peak oxygen uptake ($VO_2$max). The evaluation of indirect $VO_2$max was performed through a 12-minute test (Cooper). Before the evaluation, all subjects were requested to perform the longest distance possible for 12 minutes, and during the application of test the participants received oral cheers from the researchers. The distance each subject run was transformed into Km, and then the peak oxygen uptake was obtained with the following ecuation[20]:

$VO_2$max (ml•Kg$^{-1}$•min$^{-1}$) = (22.351 x distance in kilometers) – 11.288

Furthermore, the median velocity (Vm12-min) was used to determine the effort steps for the lactate threshold test.

Vm12-min (m/s) = (distance in meters performed in 12 minutes / 720 seconds)

*Evaluation 2 (Day 2)*. Lactate Threshold (UL). In order to determine the LT all athletes were part of the minimum lactate protocol (LACmin) proposed by Tegtbur *et al.* (1993)[21]. In order to do so, athletes performed a maximum repetition of 500 m. Then, they performed a passive recovery of 8 minutes. From this minute on, athletes had to perform five repetition at 800 m at 75, 80, 85, 90, and 95% repetitions of Vm 12-min, with a 30-second pause. At the end of each repetition, a blood sample was taken from the earlobe. Lactate concentrations where entered into a registry form, and then put into graphs according to the visual inspection method of the curve to determine LT[22]. For blood lactate measuring, a (h/p/cosmos®) lactometer was used.

**Table 2. Velocity of Treatment (UL+7% additional load).**

| Subject | LT (m/s) | Rhythm Km | LT + 7% (m/s) | Rhythm Km |
|---|---|---|---|---|
| 1 | 5.5 | 3 m 02 s | 5,9 | 2 m 49 s |
| 2 | 4.8 | 3 m 28 s | 5,2 | 3 m 13 s |
| 3 | 4.5 | 3 m 42 s | 4,9 | 3 m 26 s |
| 4 | 4.5 | 3 m 42 s | 4,9 | 3 m 26 s |
| 5 | 4.9 | 3m 24 s | 5,3 | 3 m 09 s |

m/s (meters per second); Km (kilometer); LT (lactate threshold).

*Evaluation 3 (Day 3)*. Endurance Test. In this evaluation, athletes must run for as long as possible at a LT +7% velocity of additional load of the LT velocity in m/s (Table 2). This test was executed with the supplementation of sodium bicarbonate or placebo (Figure 2).

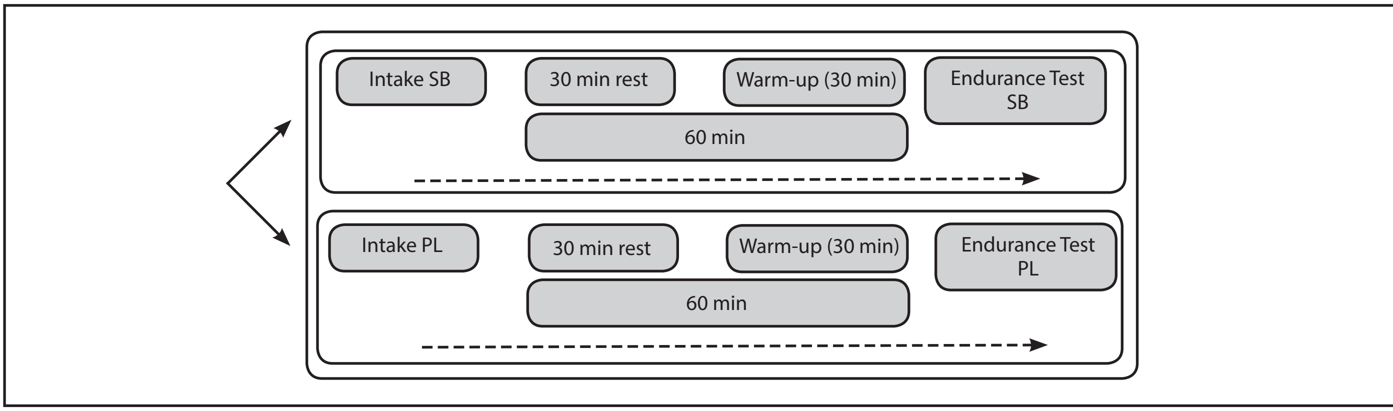
In the administration of endurance test, the race velocity was controlled every 100 m with a beep sound. When athletes did not reach the marked line by the time the beep was heard, the test was considered finished and the final time (s) and lactate (mmol•L) was measured.

*Ergogenic aid*. One hour after executing the Endurance test[21], all athletes ate a sodium bicarbonate solution or a placebo. The first solution had a concentration of 0.3 g•Kg$^{-1}$ of bodily mass diluted in 300 mL of distilled water[6,23]. The second solution (sodium chloride) had a concentration of 0.045 mg•Kg$^{-1}$ of bodily mass diluted in 300 mL of distilled water[24]. Considering the design used for the application of sodium bicarbonate or the placebo, a 48-hour difference was established between the second endurance test (Figure 1). The administration of the sodium bicarbonate solution or the placebo was at random with a double-blind protocol.

## Statistical Analysis

Time and lactate variables were submitted to the Shapiro-Wilk normalcy test. If the variables showed a normal distribution, they were

**Figure 2. Waiting time between sodium bicarbonate or placebo intake and the Endurance Test.**




SB: sodium bicarbonate; PL: Placebo; Endurance Test SB: Endurance test with sodium bicarbonate intake; Endurance Test PL: Endurance test with placebo intake.

submitted to a Student's t test. If the opposite occurred, the Wilcoxon test was applied.

According to the foregoing, the behavior of the variables during the Endurance Test application was submitted to a Student t test in order to compare the final Lactate concentrations in the test and post test. Wilcoxon test was applied to compare the total time of the Endurance test and post test. The size of the effect (ES) for this analysis was calculated using Cohen's d test. This analysis considers an insignificant effect ($d < 0.2$), small ($d = 0.2$ to $0.6$), moderate ($d = 0.6$ to $1.2$), large ($d = 1.2$ to $2,0$) or very large ($d > 2.0$). The level of significance for all statistical analysis was $P < 0.05$. The data analysis was performed with statistics SPSS software, version 12.0.

## Results

Once the Students t test was applied, the final lactate produced in the endurance test supplemented with sodium bicarbonate presented a significant increase compared to the placebo supplementation ($P < 0.022$; TE = 1.987). Once the Wilcoxon was applied, the maximum time reached in the limit time test supplemented with sodium bicarbonate showed a significant increase in comparison to the placebo supplementation ($P < 0.042$; TE = 0.852). The results are presented in Table 3 and Table 4.

## Discussion

In connection to the main goal of the study, supplementing sodium bicarbonate to college endurance race athletes and submit them to endurance test at an intensity higher than LT (LT velocity +7% of the LT velocity in m/s), a significant increase was shown in the performance when contrasting the maximum time of effort ($p< 0.05$). There was also a significant difference in the production of post effort Lactate ($p< 0.05$).

Recent studies suggest the need for individual analysis of the results given the high variation in the response that athletes may have to this type of supplementation protocol[25,26]. In relation to the above, all athletes were able to increase their maximum effort time and lactate concentrations post effort despite the individual differences in their lactate threshold and indirect peak oxygen uptake

In relation to the already existing researches on sodium bicarbonate supplementation, Peart *et al.* (2012)[27] performed a revision and analysis of 40 studies where the intention was to improve the performance based on the ergogenic aid. Of the aforementioned studies, only six presented a treatment based on endurance races with maximum distance of 1500 m.

Additionally, the authors concluded that the protocols used do not exceed 120 s in average. In the case of this study, the time of effort maintained by the athletes supplemented with placebo was 426.6 s in

**Table 3. Lactate production and maximum time spent on the Endurance Test under sodium bicarbonate and a placebo supplementation.**

| | **Lactate production on Endurance Test** | | | |
|---|---|---|---|---|
| | **Placebo median ± SD** | **Bicarbonate median ± SD** | ***t-Student test*** | ***d de Cohen*** |
| Lactate (mmol•L) | 13.32 ± 2.5 | 16.6 ± 0.8 | * | 1.987 |
| | **Maximum time spent on Endurance Test** | | | |
| | **Placebo median ± SD** | **Bicarbonate median ± SD** | ***Wilcoxon's test*** | ***d de Cohen*** |
| time (s) | 426.6 ± 66.6 | 486.8 ± 74.7 | * | 0.8520 |

s (second); SD (standard deviation); * p < 0.05; mmol•L (milimols per Litre).

**Table 4. Delta of individual performances after placebo and sodium bicarbonate supplementation in relationship with lactate threshold**

| Subject | LT (m/s) | Time Pl (s) | Time Bic (s) | Δ (m) | Percent increment between Time Pl and Time Bic (%) |
|---|---|---|---|---|---|
| 1 | 5.5 | 544 | 612 | 68 | 11,1 |
| 2 | 4.8 | 400 | 480 | 80 | 16,7 |
| 3 | 4.5 | 400 | 440 | 40 | 9,1 |
| 4 | 4.5 | 407 | 444 | 37 | 8,3 |
| 5 | 4.9 | 380 | 418 | 38 | 9,1 |

m/s (meters per second); LT (lactate threshold); Pl (placebo); Bic (Bicarbonate); (s) seconds; Δ (delta).

comparison to the athletes supplemented with sodium bicarbonate that was 486.8 s. The execution time experimented by the athletes supplemented sodium bicarbonate largely exceed the protocol of time employed in other sudies[3,5].

Miller *et al*. (2016)[28], used an intake protocol similar to that used in the present study, but used for the treatment of RSA (repeated sprint ability). Although the intensities differ with the present study (both are high) it was possible to establish that sodium bicarbonate supplementation allows a greater amount of work to be done to athletes, as well to the present study.

Siegler *et al.* (2016)[29] conclude that sodium bicarbonate supplementation may improve sports performance when the intensity of effort is in the anaerobic aerobic transition zone. In this study, the additional effort load (7%), enters the athletes in this area. Therefore, when observing the result of effort time allows to determine the effectiveness of this compound for such zone of effort.

In studies where sodium bicarbonate has been supplemented using continuous protocols but at LT intensities, there were only significant changes in the performance (race time increase of 17%) but not in lactate production ($p > 0.05$)[30]. In connection to this study, significant changes were shown in both the execution time and the lactate production with sodium bicarbonate supplementation in endurance test (presented in Table 3). Possibly, the race velocity used in this study – faster than the one used by George *et al*. (1988)[30] – lead to a larger lactate production. At the same time, the final lactate production found in this study can also be attributed to the increase of bicarbonate levels in the extracellular medium (ergogenic aid), since this compound favors the production of H+ and lactate from the active muscles into the blood stream[31].

In another study with continuum protocol, endurance race athletes had to run at a LT rhythm for 30 minutes. After this race time, athletes had to perform until exhaustion with a race intensity of 110% of LT. The results showed that sodium bicarbonate intake produced favorable metabolic conditions for 30 minutes of steady exercise at a LT rhythm; however there was no evidence of a significant improvement in the performance at 110% LT[32]. The present research showed significant differences to supplementation with sodium bicarbonate at intensities above the LT, with a more representative protocol to speed of competition in middle distance races.

Other studies that have searched an ergogenic potential of sodium bicarbonate in prolonged exercises of high intensity have showed diverse and controversial results. The former could be explained by the methodology used, the dosage of the compound, the post intake waiting time, the tests applied, the level of training of the athletes or the capacity of the subjects to generate large quantities of lactate with the selected exercise[5,31].

On a different scope of endurance training but with objectives similar to the ones of this study, cyclo-ergometers have been used in cyclists. In this area, Stephen *et al.* (2002)[33] reported that the administration of sodium bicarbonate does not improve the performance when working at 77% of $VO_2$max. The evidence shows that in order to generate an increase in performance it is necessary to select an adequate intensity that generates differences in blood pH[34]. For that matter, low effort intensities do not generate performance increase in tests with a glycolytic predominance considering that the acid-base balance during exercise in these characteristics is not modified and the sodium bicarbonate present in the body does not act as a buffer of the H+ that are released to the extracellular medium together with Lactate. According to the previously mentioned, it is important to mention that to have positive effects in sodium bicarbonate supplementation the race intensity must surpass LT[35], since it I from this point on that the anaerobic metabolism start to show predominance1, increasing muscular acidity.

An important variable in diverse researches is the intake time and the start of the treatment. Intake times fluctuating between 20 to 120 minutes have been found in literature[11,23]. Peart *et al*. (2012)[27] concluded that a 60-min intake time showed a greater buffer effect in the blood compared to shorter intake times.

The optimal time suggested for the intake of sodium bicarbonate with a 0.3 gr•kg$^{-1}$ dosage is 60 minutes[23]. That is the time used in this study.

In connection to the sodium bicarbonate dose, there are studies from the 1980's[36] that have carried out tests with doses lower than the ones used in this study. In that research, 0.2 gr•kg$^{-1}$ were used but there were no differences in the cyclists' performance that the researchers could observe. Several ulterior studies have suggested doses that range from 0.2 a 0.5 gr•kg$^{-1}$.

Mc Naughton *et al*. (1992)[37], a dose of 0.3 gr•kg$^{-1}$ is used in cyclists under a long duration exercise, suggesting that this is the recommended dose in order to improve resistance in long-distance resistance tests, providing evidence about its usage in athletes with a large dose. Particularly in athletics, Bird *et al.* (1995)[38], used a dose of 0.3 gr•kg$^{-1}$ in middle-endurance athletes. Jones *et al.* (2016)[25], concluded that bicarbonate concentrations and arterial pH increased significantly from the baseline after testing different doses, finding that the concentration of 0.3 gm•kg$^{-1}$ showed the higger increments.

It can be concluded that supplementation with sodium bicarbonate has ergogenic effects for the distance. In recent studies, Carr *et al.* (2011)[39] concluded that, in connection to the values of arterial PH and arterial bicarbonate, the recommended dose is 0.3 gr•kg$^{-1}$, which was used in this study. The results showed statistical significant differences in the variables studied.

## Conclusions

According to the results obtained, there is evidence that sodium bicarbonate supplementation can significantly increase the performance of endurance race athletes since they are capable of prolong their effort for a longer period of time at a seven percent intensity above LT velocity. Also, the intake of this solution generates a higher concentration of final lactate post effort, which demonstrates its efficacy when released to the blood torrent allowing the generation of more energy. All athletes were able to improve their performance despite having different levels of lactic threshold, even with a difference of 0.5 m•s.

### Practical applications

The treatment used equals to a race intensity employed generally by athletes both in trainings and in competitions. Therefore, rhythm control by the subjects was no impediment to carry out the study, in addition to represent a competence situation provided by the surrounding and the race rhythm.

In connection to the dosage of sodium bicarbonate used, 0.3 g•Kg$^{-1}$ bodily mass, it was observed that it was appropriate to increase the performance of athletes.

The administration of sodium bicarbonate in middle-endurance and endurance races with intensities below LT could have no beneficial effect for the performance of athletes because the natural buffering mechanisms of H+ and the lactate removal would function efficiently. In this case if a 5000 m runner shows a race rhythm lower than their LT, the sodium bicarbonate might not have any benefits in their performance.

### Suggestions and limitations

Within the limitations for the realization of continuous protocols at intensities above the lactate threshold is the level of training of subjects. They must have experience at lactate threshold intensities or superior. The individual responses to intensities above the lactate threshold are highly variable, so many studies have very dissimilar results. According to the above, the samples of the studies are small because of the technical, psychological and physical specificity required to maintain an effort in those intensities. In addition, for lactate threshold protocol, it is necessary for athletes to have optimal rhythm control so that they can adequately complete the different steps of effort as it is the fundamental requirement for setting the pace of treatment.

It is suggested for future research to be able to determine the individual intake time before applying the protocol. This could lead to better results of the study, given that in this study a standard intake time was given to all athletes. The dosage used seems to be the most appropriate according to the literature. If possible, it could give greater support to the results found with some biomedical variables such as arterial pH and blood bicarbonate, as well as many studies cited.

## Bibliography


1. Calderón F, Benito P, Peinado A, Díaz V. Significado fisiológico de la transición aeróbica-anaeróbica. *Rev Int Med Cienc Act Fís Deporte.* 2008;8(32):321-37.
2. Kemp G. Muscle cell volume and pH changes due to glycolytic ATP synthesis. *J Physiol (Lond ).* 2007;582(1):461-5.
3. Zajac A, Cholewa J, Poprzecki S, Waskiewicz Z, Langfort J. Effects of sodium bicarbonate ingestion on swim performance in youth athletes. *J Sports Sci Med.* 2009;8(1):45-50.
4. Hidalgo I, Mena V, Fernández B, Heredero M, Ruiz W. Acidosis metabólica: Un reto para los intensivistas. *Rev Cubana Pediatr.* 2005;77(2):0-0.
5. McNaughton L, Siegler J, Midgley A. Ergogenic effects of sodium bicarbonate. *Curr Sports Med Rep.* 2008;7(4):230-6.
6. Burke L, Pyne D. Bicarbonate loading to enhance training and competitive performance. *Int J Sports Physiol Perform.* 2007;2(1):93.
7. Oopik V, Saaremets I, Medijainen L, Karelson K, Janson T, Timpmann S. Effects of sodium citrate ingestion before exercise on endurance performance in well trained college runners. *Br J Sports Med*. 2003;37(6):485-9.
8. Sale C, Saunders B, Harris RC. Effect of beta-alanine supplementation on muscle carnosine concentrations and exercise performance. *Amino Acids*. 2010;39(2):321-33.
9. Sale C, Artioli G, Gualano B, Saunders B, Hobson RM, Harris RC. Carnosine: From exercise performance to health. *Amino Acids.* 2013;44(6):1477-91.
10. Wu C, Shih M, Yang C, Huang M, Chang C. Sodium bicarbonate supplementation prevents skilled tennis performance decline after a simulated match. *J Int Society Sports Nutr.* 2010;7(1):1.
11. Junior A, de Salles P, Saunders B, Artioli G. Nutritional strategies to modulate intracellular and extracellular buffering capacity during high-intensity exercise. *Sports Med.* 2015;45(1):71-81.
12. Siegler J, Marshall P. The effect of metabolic alkalosis on central and peripheral mechanisms associated with exercise-induced muscle fatigue in humans. *Exp Physiol.* 2015;100(5):519-30.
13. Zabala M, Peinado AB, Calderón FJ, Sampedro J, Castillo MJ, Benito PJ. Bicarbonate ingestion has no ergogenic effect on consecutive all out sprint tests in BMX elite cyclists. *Eur J Appl Physiol.* 2011;111(12):3127-34.
14. Siegler J, Gleadall-Siddall D. Sodium bicarbonate ingestion and repeated swim sprint performance. *J Strength Cond Res*. 2010;24(11):3105-11.
15. Kazemi M, Hashemvarzi S, FallahMohammadi Z. The combined effect of creatine and sodium bicarbonate supplementation on blood lactate and anaerobic power in young taekwondo players. *Intl J Sport Std.* 2013;3(9):963-69.
16. Siegler J, Hirscher K. Sodium bicarbonate ingestion and boxing performance. *J Strength Cond Res.* 2010;24(1):103-8.
17. Brisola G, Miyagi W, da Silva H, Zagatto A. Sodium bicarbonate supplementation improved MAOD but is not correlated with 200-and 400-m running performances: A double-blind, crossover, and placebo-controlled study. *Appl Physiol Nutr Metab.* 2015;40(9):931-7.
18. Stellingwerff T, Boit M, Res P. Nutritional strategies to optimize training and racing in middle-distance athletes. *J Sports Sci*. 2007;25(S1):S17-S28.
19. Van Montfoort M, Van Dieren L, Hopkins W, Shearman J. Effects of ingestion of bicarbonate, citrate, lactate, and chloride on sprint running. *Med Sci Sports Exerc.* 2004;36(7):1239-43.
20. Cooper K. A means of assessing maximal oxygen intake: Correlation between field and treadmill testing. *JAMA.* 1968;203(3):201-4.
21. Tegtbur U, Busse M, Braumann K. Estimation of an individual equilibrium between lactate production and catabolism during exercise. *Med Sci Sports Exerc*. 1993;25(5):620-7.
22. Fernández-Castanys B, Delgado M. Evolución y aplicación práctica del umbral anaeróbico en el entrenamiento deportivo: Revisión. *Eur J Human Movement.* 1996(2):39-53.
23. Siegler J, Midgley A, Polman R, Lever R. Effects of various sodium bicarbonate loading protocols on the time-dependent extracellular buffering profile. *J Strength Cond Res.* 2010;24(9):2551-7.
24. Materko W, Santos E, Novaes J. Effect of bicarbonate supplementation on muscular strength. *J Exerc Physiol Online*. 2008;11(6).

25. Jones R, Stellingwerff T, Artioli GG, Saunders B, Cooper S, Sale C. Dose-response of sodium bicarbonate ingestion highlights individuality in time course of blood analyte responses. *Int J Sport Nutr Exerc Metab*. 2016;26(5):445-53.
26. de Araujo G, Silva V, Salles V, Venta C, Artioli G, Gualano B, *et al*. (In) consistencies in responses to sodium bicarbonate supplementation: A randomised, repeated measures, counterbalanced and double-blind study. *PloS one.* 2015;10(11):e0143086.
27. Peart D, Siegler J, Vince R. Practical recommendations for coaches and athletes: A meta-analysis of sodium bicarbonate use for athletic performance. *J Strength Cond Res.* 2012;26(7):1975-83.
28. Miller P, Robinson A, Sparks S, Bridge C, Bentley D, McNaughton L. The effects of novel ingestion of sodium bicarbonate on repeated sprint ability. *J Strength Cond Res.* 2016;30(2):561-568.
29. Siegler J, Marshall P, Bishop D, Shaw G, Green S. Mechanistic insights into the efficacy of sodium bicarbonate supplementation to improve athletic performance. *Sports med open*. 2016;2(1):41.
30. George K, MacLaren D. The effect of induced alkalosis and acidosis on endurance running at an intensity corresponding to 4 mM blood lactate. *Ergonomics.* 1988;31(11):1639-45.
31. Requena B, Zabala M, Padial P, Feriche B. Sodium bicarbonate and sodium citrate: Ergogenic aids? *J Strength Cond Res*. 2005;19(1):213-24.
32. Potteiger JA, Webster MJ, Nickel GL, Haub MD, Palmer RJ. The effects of buffer ingestion on metabolic factors related to distance running performance. *Eur J Appl Physiol Occup Physiol.* 1996;72(4):365-71.
33. Stephens TJ, McKenna MJ, Canny BJ, Snow RJ, McConell GK. Effect of sodium bicarbonate on muscle metabolism during intense endurance cycling. *Med Sci Sports Exerc.* 2002;34(4):614-21.
34. Marx JO, Gordon SE, Vos NH, *et al*. Effect of alkalosis on plasma epinephrine responses to high intensity cycle exercise in humans. *Eur J Appl Physiol*. 2002;87(1):72-7.
35. Price M, Moss P, Rance S. Effects of sodium bicarbonate ingestion on prolonged intermittent exercise. *Med Sci Sports Exerc.* 2003;35(8):1303-8.
36. Horswill CA, Costill DL, Fink WJ, Flynn MG, Kirwan JP, Mitchell JB, *et al.* Influence of sodium bicarbonate on sprint performance: Relationship to dosage. *Med Sci Sports Exerc.* 1988;20(6):566-9.
37. McNaughton LR. Sodium bicarbonate ingestion and its effects on anaerobic exercise of various durations. *J Sports Sci.* 1992;10(5):425-35.
38. Bird S, Wiles J, Robbins J. The effect of sodium bicarbonate ingestion on 1500 m racing time. *J Sports Sci.* 1995;13(5):399-403.
39. Carr A, Slater G, Gore C, Dawson B, Burke L. Effect of sodium bicarbonate on [HCO3-], pH, and gastrointestinal symptoms. *Int J Sport Nutr Exerc Metab.* 2011;21(3):189.