Original article

Effect of acute supplementation with sodium bicarbonate on the performance of professional military pentathletes in the obstacle course

Sergio Andrés Galdames Maliqueo[1,3], Álvaro Cristian Huerta Ojeda[2,3,5*], Andrea Verónica Pastene Rivas[4]

[1]Facultad de Ciencias de la Actividad Física y del Deporte. Universidad de Playa Ancha de Ciencias de la Educación, Valparaíso, Chile. [2]Facultad de Educación. Universidad de Las Américas sede Viña del Mar, Chile. [3]Grupo de Investigación en Salud, Actividad Física y Deporte ISAFYD. Escuela de Educación Física. Universidad de Las Américas sede Viña del Mar, Chile. [4]Instituto Profesional y Centro de Formación Técnica, Universidad Santo Tomás, Viña del Mar. [5]Centro de Capacitación e Investigación Deportiva Alpha Sports. Valparaíso, Chile.

Received: 12/07/2019
Accepted: 05/12/2019

Summary

Introduction: Sodium bicarbonate (SB) supplementation has been widely used to delay fatigue in high intensity sports. However, there is no evidence on acute supplementation with SB in the obstacle run in Military Pentathlon.
Objective: To determine the effect of acute supplementation with SB on performance on the obstacle run in military pentathletes.
Material and method: Ten professional military pentathletes were part of the study. The design was double blind, cross-over intra-subject, while supplementation was 0.3 g•Kg^{-1} SB diluted in 500 mL of distilled water or 0.045 mg•Kg^{-1} of sodium chloride diluted in 500 mL of distilled water (PL), both solutions ingested 60 minutes before performing the obstacle run. The variables were: execution time (s) and lactate concentration ([La]) in minutes 1, 3, 5, 7 and 9. The statistical analysis was performed through a Student's t test for independent samples, while the effect size (ES) was calculated with the Cohen d test.
Results: The time in the obstacle run showed a significant decrease after the SB supplementation ($p < 0.01$, ES = 0.48, Δ = 3.7%), while the [La] showed significant differences between both groups in the 5, 7, and 9 minutes ($p < 0.05$).
Conclusions: At the end of the study, it was found that acute supplementation with SB increased performance in the obstacle run. Therefore, acute SB ingestion could be considered as an ergogenic aid by military pentathletes.

Key words:
Sodium bicarbonate. High intensity. Physical performance. Military personnel.

Efecto de la suplementación aguda con bicarbonato sódico sobre el rendimiento en la cancha con obstáculos en pentatletas militares profesionales

Resumen

Introducción: La suplementación con bicarbonato sódico (BS) ha sido ampliamente utilizada para retrasar la fatiga en deportes de alta intensidad. Sin embargo, no existe evidencia sobre la suplementación aguda con BS en la prueba de cancha con obstáculos del Pentatlón Militar.
Objetivo: Determinar el efecto de la suplementación aguda con BS sobre el rendimiento en la cancha con obstáculos en pentatletas militares.
Material y método: Diez pentatletas militares profesionales fueron parte del estudio. El diseño fue de doble ciego, cruzado intrasujeto, mientras que la suplementación fue de 0,3 g•Kg^{-1} de BS diluida en 500 mL de agua destilada o 0,045 mg•Kg^{-1} de cloruro de sodio diluido en 500 mL de agua destilada (PL), ambas soluciones fueron ingeridas 60 minutos antes de realizar la prueba de cancha con obstáculos. Las variables fueron: tiempo de ejecución (s) y concentración de lactato ([La]) en los minutos 1, 3, 5, 7 y 9. El análisis estadístico fue realizado a través de una t de Student para muestras independientes, mientras que el tamaño del efecto (ES) fue calculado con la prueba d de Cohen.
Resultados: El tiempo en la cancha con obstáculos evidenció un descenso significativo luego de la suplementación con BS ($p < 0,01$; ES = 0,48; Δ = 3,7%), mientras que las [La] mostraron diferencias significativas entre ambos grupos en los minutos 5, 7 y 9 ($p < 0,05$).
Conclusiones: Al término del estudio, se comprobó que la suplementación aguda con BS aumentó el rendimiento en la prueba de cancha con obstáculos. Por lo tanto, la ingesta aguda con BS podría ser considerada como una ayuda ergogénica por los pentatletas militares.

Palabras clave:
Bicarbonato sódico. Alta intensidad. Rendimiento físico. Personal militar.

Correspondence: Álvaro Cristian Huerta Ojeda
E-mail: achuertao@yahoo.es

Introduction

The Military Pentathlon is the most important sports discipline for the military[1], with a history dating back to 1947. Over the years, it has developed into the most important sports event of the International Military Sports Council (CISM)[2]. The Military Pentathlon is divided into the following contests: shooting with a standard rifle (200 m or 300 m), obstacle run (500 m with 20 obstacles), obstacle swimming (50 m with 5 obstacles), grenade throwing (16 precision throws and 3 maximum power throws) and cross country (8 km)[1]. For the five contests there is a base performance that gives 1000 pentathlon points, with some events associated with a greater score (shooting and grenade throwing). For those athletes performing better than the base, then they will obtain more than 1000 pentathlon points. For obstacle swimming, cross country and the obstacle running course, performance is associated with a lower completion time. Specifically, for the obstacle course, in order to obtain the 1000 pentathlon points, the course must be completed in 2 minutes 40 seconds and, for each second above or below this mark, 7 pentathlon points are either deducted from or added to the 1000 base points, respectively[3].

The obstacle course contest is in the form of a race, in which the athletes are required to complete the course in the shortest possible time, combining their ability to climb, run, jump, crawl and maintain their balance on thin obstacles[4]. Lazar (2011)[4] contends that, during this contest, the heart rate may reach 200 beats per minute with great predominance of the anaerobic metabolism. From a physiological point of view, maximum efforts on the obstacle course, just like tests with glycolytic predominance, accumulate a series of deleterious metabolites (H^+, Pi), which can reduce the force of the active muscles[5]. That is how the accumulation of H^+ may alter the blood pH, disrupting the acid-base balance, the extent of which depends on the intensity and duration of the effort6. As a compensatory measure, the body adjusts its buffers and pulmonary ventilation increases in order to mitigate the pH modifications[7].

It has been postulated that, by exogenously increasing the sodium bicarbonate (SB) levels, it would be possible to reduce the levels of H^+ generated in the anaerobic glucose metabolism, increasing the lactate flow from the active muscles to the extracellular medium[8]. Due to this background information, the intake of SB has been extensively studied for its potential benefits to delay the onset of fatigue in short duration, high-intensity effort[9], proving to be a beneficial buffer in this type of physical stimuli[10]. In the literature, it has been described that the ergogenic effect of SB on exercise is due to the reinforced extracellular bicarbonate buffer capacity to regulate the acid-base balance during exercise[11]. Therefore, the exogenous incorporation of SB would give rise to bicarbonate ions, promoting an alkaline environment in the extracellular fluid compartments[12]. In this way, a review made by Siegler et al. (2016)[11], recommends an SB supplementation between 0.2 to 0.3g•kg^{-1}, although the investigators also concluded that individual supplementation strategies should be sought considering the gastrointestinal discomfort or any physiological change shown by athletes[11].

Some of the studies published to determine the effectiveness of SB supplementation used endurance tests with a short[13], medium[14] and long duration[15] based on foot sports[16], swimming[17], cycling[18] and rowing[19]. In the specific case of military sports, although evidence is available on the use of sports supplements and ergogenic aids in soldiers during a training process[20], the ingestion of creatine[21] and minerals[22], unfortunately this evidence was collected from physically active soldiers and not from military pentathletes. In relation to the studies that relate buffer supplementation and military personnel performance, although there is evidence on the use of beta-alanine[23], due to the little evidence available for the military population, the investigators conclude that the use of beta-alanine as a buffer is not safe for this population.

With regard to SB supplementation in the military population, studies have been reported with an increase in the physical performance of enlisted soldiers through the Wingate power test[24]. However, just like the aforementioned references, this investigation was on enlisted soldiers and not on military pentathletes. In relation to the background information set out above and, to the best of our knowledge, there are no investigations on the ingestion of SB as a buffer supplement in the Military Pentathlon obstacle course contest. Consequently, the main objective of this study was to determine the effect of acute supplementation with SB on the performance of professional military pentathletes in the obstacle course

Material and method

Experimental study of approximation

In this study, the sample comprised 10 professional military pentathletes, equivalent to 100% of the population of professional military pentathletes in the Chilean Navy. It is important to mention that these military pentathletes, as described in the characterisation of this sport, must take part in the five contests forming part of the competition1. As a result of the above, the military pentathletes forming part of the study were solely dedicated to practising this sport. In other words, there was a six-hour daily training time, divided between these five competition events. Furthermore, the inclusion criteria were: male with a minimum experience of three years training for the Military Pentathlon. The exclusion criteria were: the prevalence of musculoskeletal injuries and the inability to perform the obstacle course contest at maximum intensity. For the application of the protocol, a quasi-experimental, cross-over, intra-subject design was used. Each subject performed the obstacle course test twice, 72 hours apart. The supplementation with SB or a placebo (PL) was performed 60 min before each obstacle course test. The administration of SB or PL was based on a double-blind randomised method. Before the start of the study, a measurement was made of the weight, height and skin folds of all subjects. All participants in the investigation were requested to abstain from the intake of caffeine, medicines and any substance that could increase the metabolism during the entire experiment.

Subjects

10 professional military pentathletes took part in the study (age: 25.5 ± 6.0 years; weight: 67.0 ± 2.0 Kg; height: 172.7 ± 3.6 cm; body mass index: 22.5 ± 1.0 kg/m2; fat percentage; 12.0 ± 2.6%. All subjects were informed of the study objective and the possible risks of the experiment, all signed their informed consent before the implementation of the protocol. The informed consent and the study were approved by the Bioethics Committee of the University Playa Ancha de Ciencias de la Educación, Valparaíso, Chile (record number 933).

Instruments

For the characterisation of the sample, the weight and height were measured with the Scales and Stadiometer Health o Meter Professional®. In order to determine the fat percentage, skinfold measurements were taken at the following sites: biceps, triceps, subscapular, supraspinal with an F.A.G.A.® caliper based on the Durnin and Womersley method (1974)[25]. In order to record the obstacle course test time, Chronojump® photocells were used, and chronojump software Version 1.4.6.0®. This measurement considered an open gate and a closed gate and the start and finish of the obstacle course, respectively. The post effort capillary lactate concentration was measured using an h/p/cosmos® lactometer to detect lactate enzymatic amperometric detection with an accuracy of ± 3%.

Standardised warm-up

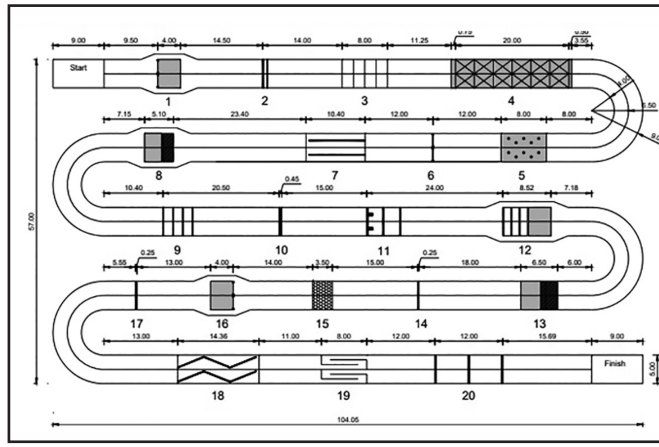
For all evaluations, the standardised warm-up consisted of 10 minutes of joint mobility, performing abduction, adduction movements and rotations of the upper and lower limbs. Subsequently, the pentathletes did a continuous jog for 15 minutes at 130 beats/minute (to record the heart rate, a Polar® model RS300 heart monitor was used), 8 second passive flexibility for each muscle group, heel striking exercises, skipping and three 80-metre accelerations.

Processing

The Military Pentathlon obstacle course contest consists in completing a 500 m circuit with 20 standardised obstacles of varying heights and difficulty levels. It consists in climbing 5 m and 4 m high ladders (obstacles 1 and 17 respectively), crawling through a 20 m long network of wires (obstacle 4), climbing a 3m high sloping wall (obstacle 8), zigzag running along an 8.5 m long balance beam (obstacle 18); only one lane should be used and it is not permitted to move from one lane to the other[3] (Figures 1 and 2).

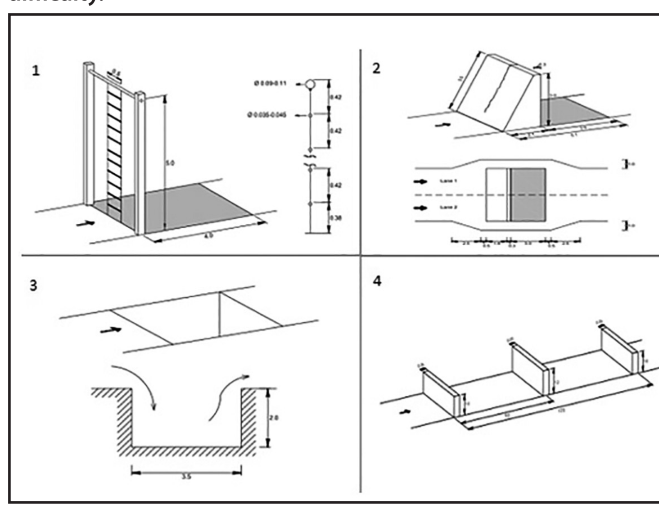
Each pentathlete was measured individually, always following the same order and evaluation time (all evaluations were made in the morning). Each athlete had to perform the obstacle course test with two opportunities, 72 hours apart, with an SB or PL supplement (Figure 3).

Figure 1. Obstacle course.



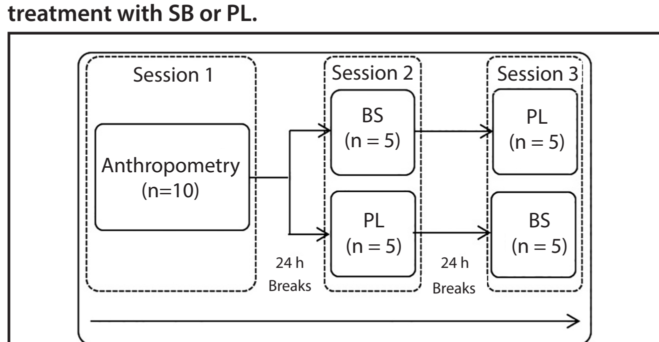
1: 5 m steel rope ladder; 2: double beam; 3: trip wire; 4. network of wires; 5. ford; 6: espalier; 7: balance beam; 8: sloping wall with rope; 9: horizontal beams (over - under); 10: Irish table; 11: tunnel and twin beams; 12: four steps of beams; 13: banquette and pit; 14: assault wall; 15: pit; 16: vertical ladder 4 m; 17: second assault wall; 18: balance beam (zigzag): 19: chicane; 20: 3 assault walls in succession.

Figure 2. Obstacle course stations with the greatest technical difficulty.



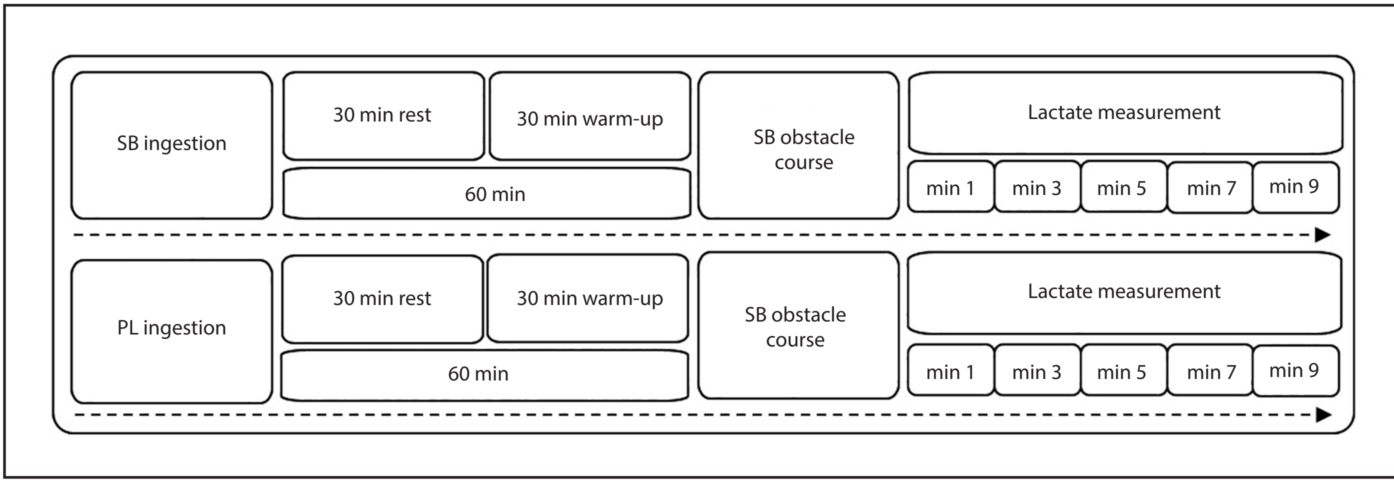
1: 5 m steel rope ladder; 2: sloping wall with rope; 3: pit; 4: assault walls in succession.

Figure 3. Methodological design for the application of the treatment with SB or PL.



h: hours; BS: Sodium bicarbonate (SB) ; PL: Placebo.

Figure 4. Time between the ingestion of SB or PL and the execution of the obstacle course test.



BS: Sodium bicarbonate (SB) ; PL: Placebo; min: minute.

On completion of each test, the time taken was recorded and the post effort capillary [La] (mmol•L^{-1}) was evaluated at minutes 1, 3, 5, 7 and 9 (Figure 4). All the tests were conducted at the obstacle course located on the premises of the Academia Politécnica Naval de Viña del Mar navy school, Chile.

Supplementation

Carbohydrate intake prior to the performance of the obstacle course test (nutritional timing). All athletes were available two hours before the start of the obstacle course test under fasting conditions. This was for the purpose of standardising a pre-evaluation meal, comprising 2 g of simple carbohydrates per kilogram of body weight[26].

SB or PL supplementation One hour before the obstacle course test, the athletes ingested a solution of SB or PL[27]. The former had a concentration of 0.3 g•Kg^{-1} of body mass diluted in 500 mL of distilled water[8]. While the latter (sodium chloride) had a concentration of 0.045 mg•Kg^{-1} of body mass diluted in 500 mL of distilled water [28]. The administration of the placebo or sodium bicarbonate solution was random, with a double blind format.

Statistical analysis

The values measured for the variables of time and [La] were subjected to the Shapiro-Wilk test of normality. Subsequently, the time and the [La] were analysed through the Student t-test for independent samples. The size of the effect was calculated using Cohen's d test. This latter analysis considered an insignificant effect (d < 0.2), small (d = 0.2 up 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 the statistical analyses was p < 0.05. The data analysis was made with the Graphpad Instat Versión 3.05® software.

Results

Once the Student's t-test was applied, those subjects supplemented with SB showed a statistically significant decrease in the time taken to complete the obstacle course test compared to the supplementation with PL (p < 0.01; ES (effect size) = 0.48).

On the other hand, the post effort lactate concentrations [La] of those subjects with SB supplementation showed a significant increase in comparison to the supplementation with PL for 5, 7 and 9 minutes (Tables 1 and 2).

Discussion

With regard to the main objective of the study, the acute supplementation with SB at a dose of 0.3 g•kg-1 in professional military pentathletes who were then subjected to a maximum intensity glycolytic test, highlighted a significant decrease in the time taken to complete the Military Pentathlon obstacle course when compared to the PL

Table 1. Time to complete the obstacle course, post-ingestion of SB or PL.

		time (s)
Time	Mean PL ± SD	155.0 ± 6.5
	Mean SB ± SD	152.6 ± 9.0
	Δ PL – SB (s)	2.4
	% PL - SB	3.7%
	Student's t-test	**
	Cohen's d-test	0.48

PL: placebo; SB: Sodium bicarbonate; SD: standard deviation; Δ: delta; s (seconds); **(p<0.05)

Table 2. Lactate production before and after the obstacle course trial with ingestion of SB or PL.

	Lactate						
	Start	End	min 1	min 3	min 5	min 7	min 9
PL ($mmol•L^{-1}$)	1.9 ± 0.6	11.6 ± 3.2	15.5 ± 2.5	16.5 ± 2.9	16.2 ± 1.8	15.3 ± 2.7	13.9 ± 2.6
SB ($mmol•L^{-1}$)	2.3 ± 0.6	12.1 ± 4.7	16.6 ± 3.4	18.4 ± 2.3	18.4 ± 2.1	18.9 ± 2.4	17.0 ± 3.2
Δ PL – SB ($mmol•L^{-1}$)	-0.41	-0.50	-1.10	-1.90	-2.20	-3.60	-3.10
% PL - SB	21.0%	4.3%	7.0%	11.5%	13.5%	23.5%	22.3%
Student's t	ns	ns	ns	ns	*	*	*
Cohen's d	0.62	0.14	0.37	0.74	1.08	1.37	1.03

PL: placebo; SB: Sodium bicarbonate; SD: standard deviation;mmol•L-1: millimoles per litre; min: (minute); *(p<0.05): ns: not significant.

group ($p < 0.05$). Although the literature suggests that metabolic alkalinity through SB supplementation would permit a greater performance in maximal intensity stimuli[28], this is the first work to demonstrate an increase in the performance of military pentathletes in the obstacle course event. With regard to the above, it is important to emphasise that the final classification system in a military pentathlon competition depends on the score obtained in each of the events. Therefore, the 2.4 second decrease in the average through SB ingestion allows the athletes to add 17.1 points to the event[3], this increase in performance, associated with the Military Pentathlon scoring system could mean an improvement to the final position or make it possible to win the competition. Likewise, it is important to make an individual analysis of the results obtained against the variation in performance that the athletes may show for protocols of this type[29] (Table 3).

With regard to the post-effort lactate concentrations [La], Saunders *et al.* (2014)[30] consider that the exercise intensity for protocols of this type must be sufficient to achieve a high accumulation of H^+ and, therefore, these efforts are limited by the increase in muscular acidosis. In this study, the post-effort lactate concentrations [La] at minute 3 for the PL group were 16.5 ± 2.9 $mmol•L^{-1}$. This reflects high metabolic activity and high intensity of effort[31]. A comparison of the group supplemented with SB and the PL group, showed significant post-effort differences at 5, 7 and 9 minutes ($p < 0.05$). In comparison with similar experimental designs, Lindh *et al.* (2008)[10] took a group of swimmers to maximum fatigue, reporting post-effort blood lactate concentrations [La] over 15 $mmol•L^{-1}$, showing an improvement in the 200 m freestyle performance time, but with a difference in the post-effort lactate concentrations [La] from minute 4 onwards. However, this present study shows significant differences in lactate concentrations [La] between the group supplemented with SB and the PL group from minute 5 up to minute 9. The differences between the study conducted by Lindh *et al.* (2008)[10] and this present investigation could be explained by the fact that swimming efforts generate a far higher and earlier production of lactate than efforts made during running[32]. On the other hand, the significant increase in the production of lactate in the group supplemented with SB in comparison with the PL group, could be associated with an increase in the concentrations

Table 3. Individual performance delta with PL and SB supplementation

Subjects	Time with PL (s)	Time with SB (s)	Δ (s)	Differences time percentage points between PL and SB (%)
1	151.8	145.4	6.4	9.7
2	149.6	144.6	5.0	7.5
3	164.2	171.1	-6.9	-11.3
4	148.0	146.9	1.1	1.6
5	158.4	154.7	3.7	5.9
6	147.1	141.0	6.1	9.0
7	152.0	151.6	0.4	0.6
8	163.3	155.4	7.9	12.9
9	154,0	153,1	0,9	11,4
10	162.5	162.7	-0.2	-0,3

PL (placebo); SB (sodium bicarbonate); (s) seconds; Δ (delta).

of bicarbonate in the blood, given that this buffer produces an increase in parallel to the intracellular / extracellular H^+ gradient, increasing the activity of the lactate/H^+ co-transporters, generating an increase in the flow of H^+ and lactate from the active muscles to the extracellular medium[33]. Therefore, the attenuation of the accumulation of H^+ in the muscles allows the glycolytic resynthesis of ATP to continue in more favourable conditions, delaying muscle fatigue during the high-intensity exercise[33]. This would make it possible to associate greater glycolytic activity with increased performance and higher lactate levels[34]. From the above, Wang *et al.* (2019)[35] maintain that the peak lactate level after exercise represents the body's maximum tolerance to lactic acid. It also reflects the capacity of the glycolytic system to produce ATP.

With regard to the SB ingestion protocol and the waiting time between ingestion and the maximum tests, the first studies to analyse this variable suggested waiting times of two hours for the application of the treatment[36]. In contrast to the protocol used by Siegler *et al.* (2010)[36], Maliqueo *et al.* (2018)[14] reported favourable results in a time limit test over the lactic threshold speed, using a 60 minute waiting time between ingestion and the application of the maximum test. Likewise, Miller *et al.* (2016)[18] studied the individual ingestion response time and athletic performance in a speed endurance test, establishing that the mean ingestion time to reach an individual maximum pH level was 68 minutes post-ingestion (a similar time to the one used in this present study). Although the evidence is demonstrating that the time between ingestion and the application of the maximum test must be determined individually[37], it would be of interest to consider the individual variation of elite athletes at different ingestion times, given that most studies either consider recreational athletes or do not specify their sports level[38].

With regard to the dose level used in this study, there are recommendations that a safe dose for humans is 0.3 g•Kg^{-1}[8], thereby maintaining more favourable arterial bicarbonate and pH values[12]. For this reason, and given the lack of background information on sodium bicarbonate supplementation in military athletes, this study established the dose level that had the greatest number of favourable scientific reports, whether for short or long duration running efforts39 or short-duration high-intensity protocols[40].

Conclusions

Based on the results obtains, it can be concluded that the acute supplementation with SB, with a dose of 0.3 g•Kg^{-1} ingested 60 minutes before the obstacle course test, significantly reduces the EXECUTION time of professional military pentathletes, leading to improved performance. Furthermore, the SB ingestion generated a higher post-effort blood lactate concentration, highlighting the effectiveness of the output of this metabolite from the active muscles to the bloodstream. Therefore, military pentathletes could consider the acute supplementation with SB to be an ergogenic aid.

Practical applications

In order to achieve the desired performance effects, firstly the pre-recommended carbohydrate loading needs to be performed[26], avoiding the consumption of sports supplements. The latter for the purpose of minimising gastrointestinal discomfort or the interaction of SB with other substances that could be among the contents of some supplements. It is important for the athletes to have an ad-hoc training level to meet the high metabolic demand and neuromuscular stress generated by this event, this will ensure that the athletes complete the course and do not abandon the race at one of the obstacles. As mentioned in the protocol, the ingestion of SB must be considered as a concentration of 0.3 g•Kg^{-1} of body mass diluted in 500 mL of distilled water[7]. This dose must be ingested 30 minutes before the start of the warm-up, which should contain joint mobility, jogging and exercises that progressively increase the effort intensity.

Acknowledgements

The authors would like to thank the Military Pentathlon team of the Chilean Navy for their impartial participation in this present study.

Conflict of interests

The authors have no conflict of interest at all.

Bibliography

1. Ojeda ÁH. Evolución del Pentatlón Militar como disciplina de alto rendimiento. *Rev Mar.* 2016;5:56-9.
2. Moschopoulos AI, Albanidis E, Anastasiou A, Antoniou P. Organised military sports of the hellenic armed forces for the period 1948–1968. *Int J Hist Sport.* 2015;32:351-66.
3. Council International Military Sports. Military Penathlon Regulations. 2019. (consultado 0807/2019). Disponible en: http://www.milsport.one/sports/military-pentathlon
4. Lazăr I. Motility structure and dynamic specific efforts in obstacle course test. "Mircea cel Batran" *Nav Acad Sci Bull.* 2011;14:184-8.
5. Allen DG, Lamb GD, Westerblad H. Skeletal muscle fatigue: cellular mechanisms. *Physiol Rev*. 2008;88:287-332.
6. Cameron SL, McLay-Cooke RT, Brown RC, Gray AR, Fairbairn KA. Increased blood pH but not performance with sodium bicarbonate supplementation in elite rugby union players. *Int J Sport Nutr Exerc Metab.* 2010;20:307-21.
7. Hood VL, Tannen RL. Protection of acid–base balance by pH regulation of acid production. *N Engl J Med*. 1998;339:819-26.
8. Burke LM, Pyne DB. Bicarbonate loading to enhance training and competitive performance. *Int J Sports Physiol Perform*. 2007;2:93-7.
9. McNaughton LR, Gough L, Deb S, Bentley D, Sparks SA. Recent Developments in the Use of Sodium Bicarbonate as an Ergogenic Aid. *Curr Sports Med Rep*. 2016;15:233-44.
10. Lindh AM, Peyrebrune MC, Ingham SA, Bailey DM, Folland JP. Sodium bicarbonate improves swimming performance. *Int J Sports Med.* 2008;29:519-23.
11. Siegler JC, Marshall PWM, Bishop D, Shaw G, Green S. Mechanistic insights into the efficacy of sodium bicarbonate supplementation to improve athletic performance. *Sport Med.* 2016;2:41.
12. Carr AJ, Slater GJ, Gore CJ, Dawson B, Burke LM. Effect of sodium bicarbonate on [HCO3−], pH, and gastrointestinal symptoms. *Int J Sport Nutr Exerc Metab*. 2011;21:189-94.
13. Russell C, Papadopoulos E, Mezil Y, Wells GD, Plyley MJ, Greenway M, *et al.* Acute versus chronic supplementation of sodium citrate on 200 m performance in adolescent swimmers. *J Int Soc Sports Nutr*. 2014;11:26.
14. Maliqueo SG, Ojeda ÁH, Barrilao RG, Serrano PC. Time to fatigue on lactate threshold and supplementation with sodium bicarbonate in middle-distance college athletes. *Arch Med Deporte.* 2018;35:16-22.
15. George KP, MacLaren DPM. The effect of induced alkalosis and acidosis on endurance running at an intensity corresponding to 4 mM blood lactate. *Ergonomics.* 1988;31:1639-45.
16. Brisola GMP, Miyagi WE, da Silva HS, Zagatto AM. 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;40:931-7.
17. Joyce S, Minahan C, Anderson M, Osborne M. Acute and chronic loading of sodium bicarbonate in highly trained swimmers. *Eur J Appl Physiol.* 2012;112:461-9.
18. Miller P, Robinson AL, Sparks SA, Bridge CA, Bentley DJ, McNaughton LR. The effects of novel ingestion of sodium bicarbonate on repeated sprint ability. *J Strenght Cond Res.* 2016;30:561-8.
19. Hobson RM, Harris RC, Martin D, Smith P, Macklin B, Elliott-Sale KJ, *et al.* Effect of sodium bicarbonate supplementation on 2000-m rowing performance. *Int J Sports Physiol Perform.* 2014;9:139-44.
20. Casey A, Hughes J, Izard RM, Greeves JP. Supplement use by UK-based British Army soldiers in training. *Br J Nutr.* 2014;112:1175-84.
21. Armentano MJ, Brenner AK, Hedman TL, Solomon ZT, Chavez J, Kemper GB, *et al.* The effect and safety of short-term creatine supplementation on performance of push-ups. *Mil Med.* 2007;172:312-7.
22. McClung JP, Karl JP, Cable SJ, Williams KW, Nindl BC, Young AJ, *et al*. Randomized, double-blind, placebo-controlled trial of iron supplementation in female soldiers during military training: effects on iron status, physical performance, and mood. *Am J Clin Nutr.* 2009;90:124-31.
23. Hoffman JR, Stout JR, Harris RC, Moran DS. β-Alanine supplementation and military performance. *Amino Acids.* 2015;47:2463-74.
24. Zareyian P. Effect of sodium bicarbonate supplementation before exhaustive activity on physiological parameters of fatigue in conscripts: A study in Sanandaj, Iran. *Ann Mil Heal Sci Res.* 2015;13:62-6.

25. Durnin J, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness : measurements on 481 men and women aged from 16 to 72 years. *Br J Nutr.* 1974;32:77-97.
26. Ojeda ÁH, Contreras-Montilla O, Maliqueo SG, Jorquera-Aguilera C, Fuentes-Kloss R, Barrilao RG. Efectos de la suplementación aguda con beta-alanina sobre una prueba de tiempo límite a velocidad aeróbica máxima en atletas de resistencia. *Nutr Hosp.* 2019;36:698-705.
27. Siegler JC, Midgley AW, Polman RCJ, Lever R. Effects of various sodium bicarbonate loading protocols on the time-dependent extracellular buffering profile. *J Strength Cond Res.* 2010;24:2551-7.
28. Van Montfoort MCE, Van Dieren L, Hopkins WG, Shearman JP. Effects of ingestion of bicarbonate, citrate, lactate, and chloride on sprint running. *Med Sci Sport Exerc.* 2004;36:1239-43.
29. Jones RL, 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.
30. Saunders B, Sale C, Harris RC, Sunderland C. Sodium bicarbonate and high-intensity-cycling capacity: variability in responses. *Int J Sports Physiol Perform.* 2014;9:627-32.
31. Billat LV. Use of blood lactate measurements for prediction of exercise performance and for control of training. *Sport Med*. 1996;22:157-75.
32. Farber HW, Schaefer EJ, Franey R, Grimaldi R, Hill NS. The endurance triathlon: metabolic changes after each event and during recovery. *Med Sci Sports Exerc.* 1991;23:959-65.
33. Junior AHL, de Salles Painelli V, Saunders B, Artioli GG. Nutritional strategies to modulate intracellular and extracellular buffering capacity during high-intensity exercise. *Sport Med.* 2015;45:71-81.
34. Galloway SDR, Maughan RJ. The effects of induced alkalosis on the metabolic response to prolonged exercise in humans. *Eur J Appl Physiol Occup Physiol.* 1996;74:384-9.
35. Wang J, Qiu J, Yi L, Hou Z, Benardot D, Cao W. Effect of sodium bicarbonate ingestion during 6 weeks of HIIT on anaerobic performance of college students. *J Int Soc Sports Nutr.* 2019;16(1):18.
36. Siegler JC, Gleadall-Siddall DO. Sodium bicarbonate ingestion and repeated swim sprint performance. *J Strength Cond Res*. 2010;24:3105-11.
37. Sparks A, Williams E, Robinson A, Miller P, Bentley DJ, Bridge C, *et al*. Sodium bicarbonate ingestion and individual variability in time-to-peak pH. *Res Sport Med.* 2017;25:58-66.
38. Gough LA, Deb SK, Sparks AS, McNaughton LR. The reproducibility of blood acid base responses in male collegiate athletes following individualised doses of sodium bicarbonate: a randomised controlled crossover study. *Sport Med.* 2017;47:2117-27.
39. Freis T, Hecksteden A, Such U, Meyer T. Effect of sodium bicarbonate on prolonged running performance: A randomized, double-blind, cross-over study. *PLoS One.* 2017;12:e0182158.
40. Delextrat A, Mackessy S, Arceo-Rendon L, Scanlan A, Ramsbottom R, Calleja-Gonzalez J. Effects of three-day serial sodium bicarbonate loading on performance and physiological parameters during a simulated basketball test in female university players. *Int J Sport Nutr Exerc Metab.* 2018;28:547-52.