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Original Article

The Effect of Sodium Bicarbonate Intake on Maximum Muscle Strength during High-Intensity Exercise of a Sprinter

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Abstract

Background: This study investigated the effect of sodium bicarbonate ($HCO3^-$) intake on maximum muscle strength variables during eight weeks of high-intensity exercise of a sprinter.

Methods: The study was conducted on 30 elite sprint athletes in Seoul, Republic of Korea as in 2016 with ≥3 yr of an athletic career by assigning 10 each to three groups (the control, training, and sodium bicarbonate-training combination groups [$HCO3^-$ and training group]). The training group and the $HCO3^-$ and training group participated in a high-intensity exercise program for 90 min per session, five days a week for eight weeks in total, and it involved 80%-90% heart rate max intensity increase every 2-3 weeks, and allocation of internal exercise, aquatic exercise, and hill exercise. $HCO3^-$ was provided to the $HCO3^-$ and training group, and involved an intake of 300 g of $HCO3^-$ per 1 kg body weight, once a day, 90 min prior to the high-intensity exercise program for eight weeks.

Results: $HCO3^-$ intake during high-intensity training had a positive effect on maximum muscle strength. A positive effect was observed in the $HCO3^-$ and training groups; however, the effect on maximum muscle strength was stronger in the $HCO3^-$ and training groups. In particular, the effect on maximum muscle strength was observed during extension than during flexing starting from the fourth week of the exercise program with $HCO3^-$ intake.

Conclusion: $HCO3^-$ intake during 8 weeks of high-intensity training began to have a positive effect on maximum muscle strength. Therefore, $HCO3^-$ intake during high-intensity exercise is effective in improving exercise capacity.

Keywords: High-intensity exercise; Muscle strength; Sodium bicarbonate; Sprinter

Introduction

Power and speed are decisive factors in determining the outcome of sprinting, and sprinting requires strong power within a short time and it is one of the sports that is representative of anaerobic energy metabolism that synthesises ATP without using oxygen (1-2). Thus, in the 100-, 200-, 300-, and 400-m races, the activation of adenosine triphosphate-phosphate creatine (ATP-PC) and the lactate system is important (1-2).

Research and development of ergogenic aids along with more systematic and scientific training methods is becoming diversified through the increasing interest in performance improvement (3). There are successful cases of performance improvement and field application through the oral intake or injection of biochemical nutritional ergogenic aids that directly affect the performance or through buffer and neutralising aids that reduce or remove wastes that disrupt biochemical reactions. Various aids have been used in real sports fields (1-3).

Bicarbonate, which is an alkaline and one of the pH buffers, neutralises lactic acid accumulated by anaerobic energy metabolism with high-intensity exercise and balances the acid-to-base concentration of the blood by increasing the pH (1-3). Nevertheless, there are many conflicting results regarding the theoretical effect of bicarbonate in advanced studies, making it difficult to deduce clear conclusions regarding the effect of bicarbonate intake (4-6).

A significant increase in performance in the bicarbonate intake group was reported after measuring sprint capacity through exhaustive running in 15 endurance track and field athletes (4). In addition, an improvement in the performance of the bicarbonate intake group was reported because of a repetition of various cycling intensities and rest (5). However, no effect on sports performance in the bicarbonate intake group was reported (6). Thus, there are conflicting results on the effect of bicarbonate intake.

Advanced studies have been interested in isokinetic strength measurement methods that are quantitative and accurate for muscle contraction, as muscle contraction capacity is closely related to successful sport performance (1, 2, 7). However, the advanced studies did not investigate the effect of bicarbonate intake on maximum muscle strength. Thus, the purpose of this study was to investigate the effect of bicarbonate intake on isokinetic maximum strength in sprint athletes in improving sprint performance.

Materials and Methods

Participants

The subjects of this study were male and female elite sprint athletes (aged 17-19 yr) who had more than 3 yr of experience in Seoul, Republic of Korea as in 2016. In addition, 30 subjects who agreed to participate in the research had no specific disease or experience with drugs or aids, and thoroughly understood the content and process of this study were recruited. The subjects were classified into the control group (CG, n=10), training group (TG, n=10), and $HCO3^-$ and training group ($HCO3^-$+TG, n=10). This study was conducted in accordance with the principles stated in the Helsinki Declaration for studies with human subjects. All procedures were approved by Hanyang University, Korea, and informed consent was obtained from the participants and their parents. The subject characteristics are shown in Table 1.

Table 1: The physical characteristic of participants

Group	*n*	*Height (cm)*	*Weight (kg)*	*Fat (%)*	*Age (yr)*	*Career (yr)*
Control Group	10	167.01 ± 2.17	60.17 ± 4.34	12.02 ± 2.85	17.25 ± 0.46	5.00 ± 2.50
Training Group	10	172.03 ± 1.52	62.35 ± 3.08	11.40 ± 3.45	17.00 ± 0.96	4.91 ± 1.47
$HCO3^-$ + Training Group	10	170.61 ± 2.19	62.28 ± 2.59	11.31 ± 1.38	17.50 ± 0.51	5.00 ± 2.30

Results are expressed as mean ± standard deviation

Intake of bicarbonate

NaHCO3 was put into a gelatin capsule and subjects were asked to take orally the capsule with 200 ml of water to ensure easy ingestion of bicarbonate in the $HCO3^-$ and training group. It was administered once a day for a period of 8 weeks at 0.3 g (300 mg) $HCO3^-$ per 1 kg of body weight of the subject by referring to results from advanced studies that reported effectiveness in 300-mg administration per 1 kg body weight. Administration of less than 300 mg of $HCO3^-$ per 1 kg of body weight was not effective (4,8).

Table 2: High-intensity exercise training program

Interval training (Mon, Wed, Fri)	*Exercise*		*Time (90 min)*
Warm up	Jogging, stretching		20
1st exercise	Interval training 100 m × 5 set		10
1st rest	Break time		10
2nd exercise	Interval training 100 m × 5 set		10
2nd rest	Break time		10
3rd exercise	Interval training 100 m × 5 set		10
Cool down	Jogging, stretching		20
Aquatic exercise training (Tue)	Exercise		Time (90 min)
Warm up	Jogging, stretching		20
1st exercise	Underwater pitch 60 sec × 10 set		10
1st rest	Break time		10
2nd exercise	Underwater pitch 40 sec × 10 set		10
2nd rest	Break time		10
3rd exercise	Underwater pitch 20 sec × 10 set		10
Cool down	Jogging, stretching		20
Hill exercise training (Thu)	Exercise	Gradient	Time (90 min)
Warm up	Jogging, stretching		20
1st exercise	Rising hill 60 sec × 10 set	20°	10
1st rest	Break time		10
2nd exercise	Rising hill 120 sec × 5 set	15°	10
2nd rest	Break time		10
3rd exercise	Downhill 60 sec × 10 set	20°	10
Cool down	Jogging, stretching		20

High-intensity training program

The high-intensity training program in this study was conducted on the 5 d/wk for 8 weeks for the training group and $HCO3^-$ and training group. The exercise intensity was gradually increased at 80, 85, and 90% of their maximum heart rate on the 1st to 3rd, 4th to 6th, and 7th to 8th weeks, and the exercise program was diversified on each day of the week. The high-intensity exercise-training program is shown in Table 2.

Isokinetic maximum strength measurements

Isokinetic maximum strength test equipment (HUMAC NORM, Cybex, division of Lumex Inc., Ronkonkoma, NY, USA) was used to analyse the effect of $HCO3^-$ intake on isokinetic maximum strength in the high-intensity training of sprint athletes. The subjects performed light warmup exercises 10 min before the measurement, and an explanation of the measurement process and preparatory work of the measurement process were carried out to enable subjects familiarise themselves with the equipment. Isokinetic maximum strength measurement of the knee joint was conducted 5 times at 30 °/sec, 60 °/sec, 90 °/sec, and 120 °/sec load velocity, and the resting time between measurements was set to 5 min (9-10). Isokinetic maximum strength

was measured in both knee joints, and it was measured 3 times (before high-intensity training, 4 weeks into high-intensity training, and 8 weeks into high-intensity training) to examine the degree of change over time.
The measurement position of the knee joint was determined after the subject had sat, maintained a holding grip, and stabilized the chest and thighs to minimise external force on other body areas during flexion and extension of the lower limb. In addition, the ankle was fixed with an ankle-fixing band to avoid an influence on extension and flexion. In setting the exercise range, full extension of the knee joint was set to 0 °/sec, and range of motion was set from 0 to 135 °/sec. In this study, a light warmup with submaximal capacity was performed before measurements.

Statistical analysis

Data analysis was conducted using SPSS version 18.0 (IBM Corp., Armonk, NY, USA). All results were expressed as mean ± standard deviation, and a two-way repeated measure analysis of variance was conducted to examine group differences in isokinetic maximum strength after $HCO3^-$ intake. Tukey's test was conducted as a post-hoc test. All statistical significance was set at $P<0.05$.

Results

The effect of $HCO3^-$ intake on isokinetic maximum strength in high-intensity training of sprint athletes resulting in a change of 30 °/sec is shown in Table 3.

Table 3: The change of 30 °/sec of foot by isokinetic maximum strength test

Variable		*Pre*	*4 weeks*	*8 weeks*	*Interaction (group × time)* F
Right extensor (N)	CG	140.00 ± 32.00	138.75 ± 31.39	139.50 ± 30.60	6.265**
	TG	175.00 ± 51.80	152.63 ± 55.81	197.00 ± 39.83#	
	$HCO3^-$+TG	197.00 ± 38.23#	199.00 ± 38.64#	219.25 ± 39.73##	
Right flexor (N)	CG	83.25 ± 23.12	82.75 ± 22.12	81.13 ± 20.37	8.445**
	TG	99.25 ± 26.43	102.13 ± 26.76	110.75 ± 32.98	
	$HCO3^-$+TG	102.63 ± 19.00	107.38 ± 17.03	117.75 ± 18.74#	
Left extensor (N)	CG	151.50 ± 16.02	150.37 ± 15.33	149.63 ± 15.41	7.496**
	TG	174.88 ± 62.18	182.25 ± 54.03	203.38 ± 39.70#	
	$HCO3^-$+TG	187.75 ± 35.20	197.63 ± 38.55	223.00 ± 41.17##	
Left flexor (N)	CG	83.25 ± 3.73	82.38 ± 4.63	80.63 ± 7.11	5.120*
	TG	97.13 ± 30.62	95.50 ± 25.37	102.25 ± 17.70#	
	$HCO3^-$+TG	105.25 ± 18.78	109.13 ± 19.73#	120.13 ± 20.13###	

Results are expressed as mean ± standard deviation
*$P<0.05$, **$P<0.01$; tested by two-way analysis of variance with repeated measure
#$P<0.05$, ##$P<0.01$, ###$P<0.001$; tested by Tukey post-hoc compared to control group
CG: control group; TG: training group; $HCO3^-$+TG: intake $HCO3^-$ and training group

There was a significant difference in both extension and flexion in the interaction effect among the group and time at 30 °/sec right foot maximum strength ($P<0.01$). According to the post-hoc test, $HCO3^-$+TG showed significant differences in extension before ($P<0.05$), 4 weeks into ($P<0.05$), and 8 weeks into ($P<0.01$) high-intensity training compared with the CG. $HCO3^-$ +TG showed statistical significance in flexion at 8 weeks when compared with the CG ($P<0.05$). There was statistical significance in the interaction effect among the groups in left foot maximum strength at 30 °/sec in both extension ($P<0.01$) and flexion ($P<0.05$). According to the post-hoc test, TG (P<0.05) and $HCO3^-$+TG (P<0.01) showed significance in extension after 8 weeks of high-intensity training when compared with the CG (P<0.05). $HCO3^-$+TG showed significant difference in flexion after 4 weeks (P<0.05) and 8 weeks of high-intensity training (P<0.001) compared with CG, and TG showed significant differences after 8 weeks (P<0.05).

The effect of $HCO3^-$ intake on isokinetic maximum strength in high-intensity training of sprint athletes, resulting in a change at 60 °/sec, is shown in Table 4.

Table 4: The change of 60 °/sec of foot by isokinetic maximum strength test

Variable		*Pre*	*4 weeks*	*8 weeks*	*Interaction (group × time)* F
Right extensor (N)	CG	136.75 ± 30.68	136.50 ± 31.30	136.25 ± 29.23	9.992**
	TG	173.13 ± 37.98	175.25 ± 34.66	183.00 ± 26.88#	
	$HCO3^-$+TG	170.88 ± 35.15	164.50 ± 37.55	194.75 ± 36.35##	
Right flexor (N)	CG	80.50 ± 14.55	80.75 ± 15.28	80.88 ± 14.59	5.926*
	TG	99.25 ± 23.28	101.25 ± 24.65	106.50 ± 29.95	
	$HCO3^-$+TG	98.00 ± 17.38	100.50 ± 16.18	106.13 ± 13.24	
Left extensor (N)	CG	145.00 ± 15.64	143.36 ± 15.68	143.00 ± 13.80	7.451**
	TG	162.75 ± 50.99	169.88 ± 43.57	183.88 ± 36.81#	
	$HCO3^-$+TG	179.38 ± 31.94	185.88 ± 33.01#	197.88 ± 36.12##	
Left flexor (N)	CG	80.75 ± 13.68	79.00 ± 12.67	76.88 ± 9.85	8.104**
	TG	97.13 ± 23.33	96.75 ± 22.50	101.88 ± 20.79#	
	$HCO3^-$+TG	102.13 ± 20.05	104.25 ± 17.61#	111.38 ± 18.04##	

Results are expressed as mean ± standard deviation
*P<0.05, **P<0.01; tested by two-way analysis of variance with repeated measure
#P<0.05, ##P<0.01; tested by Tukey post-hoc compared to control group
CG: control group; TG: training group; $HCO3^-$+TG: intake $HCO3^-$ and training group

At 60 °/sec right foot maximum strength, the interaction effect by group and time showed statistical significance in both extension (P<0.01) and flexion (P<0.05). According to the post-hoc test TG (P<0.05) and $HCO3^-$+TG (P<0.01) showed statistical significance in extension after 8 weeks compared with the CG. Statistical significance was observed in both extension (P<0.01) and flexion (P<0.01) in the interaction effect within the groups and time at 60 °/sec left foot maximum strength. According to the post-hoc test, $HCO3^-$+TG showed statistical significance in extension after 4 weeks (P<0.05) and 8 weeks (P<0.01), and TG showed statistical significance after 8 weeks (P<0.05) compared with CG. $HCO3^-$+TG showed statistical significance in flexion after 4 weeks (P<0.05) and after 8 weeks (P<0.01), and TG levels were significantly higher after 8 weeks (P<0.05) compared with the CG.

The effect of $HCO3^-$ intake on isokinetic maximum strength in high-intensity training of sprint athletes, resulting in a change at 90 °/sec, is shown in Table 5.

At 90 °/sec right foot maximum strength, the interaction effect by group and time showed statistical significance in both extension (P<0.05) and flexion (P<0.01). According to the post-hoc test $HCO3^-$+TG showed statistical significance in extension after 4 weeks (P<0.05) and 8 weeks (P<0.01) of high-intensity training, and TG showed statistical significance after 8 weeks (P<0.05) compared with the CG. $HCO3^-$+TG showed statistical significance in flexion after 8 weeks (P<0.05) compared with the CG. At 90 °/sec left foot maximum strength, interaction effect by group and time showed statistical significance in both extension (P<0.01) and flexion (P<0.01). According to the post-hoc test, TG

(*P*<0.05) and $HCO3^-$+TG (*P*<0.01) showed statistical significance in extension after 8 weeks of high-intensity training when compared with the CG. TG showed statistical significance after 8 weeks of high-intensity training and $HCO3^-$+TG showed statistical significance after 4 weeks (*P*<0.01) and 8 weeks (*P*<0.001) compared with the CG.

Table 5: The change of 90 °/sec of foot by isokinetic maximum strength test

Variable		*Pre*	*4 weeks*	*8 weeks*	*Interaction (group × time)* F
Right extensor (N)	CG	130.75 ± 22.66	130.50 ± 23.78	130.50 ± 14.39	5.069*
	TG	158.37 ± 39.85	162.00 ± 36.23	173.63 ± 26.98#	
	$HCO3^-$+TG	165.00 ± 33.73	170.25 ± 32.75#	188.63 ± 36.62##	
Right flexor (N)	CG	79.00 ± 15.06	78.63 ± 14.58	78.25 ± 14.48	8.623**
	TG	95.88 ± 23.57	96.63 ± 24.12	101.38 ± 24.41	
	$HCO3^-$+TG	100.38 ± 21.71	102.38 ± 20.18	110.63 ± 22.11#	
Left extensor (N)	CG	137.50 ± 14.39	135.36 ± 12.78	133.88 ± 10.80	6.761**
	TG	155.75 ± 48.89	159.87 ± 44.16	173.25 ± 32.18#	
	$HCO3^-$+TG	163.13 ± 33.85	171.13 ± 33.91	188.75 ± 30.99##	
Left flexor (N)	CG	75.25 ± 12.38	74.13 ± 11.65	71.63 ± 11.83	8.985**
	TG	89.75 ± 21.65	92.75 ± 19.26	99.50 ± 16.85##	
	$HCO3^-$+TG	97.00 ± 18.76	100.75 ± 16.24##	108.88 ± 16.09###	

Results are expressed as mean ± standard deviation
*P<0.05, **P<0.01; tested by two-way analysis of variance with repeated measure
#P<0.05, ##P<0.01, ###P<0.001; tested by Tukey post-hoc compared to control group
CG: control group; TG: training group; $HCO3^-$+TG: intake $HCO3^-$ and training group

The effect of $HCO3^-$ intake on isokinetic maximum strength in high-intensity training of sprint athletes, resulting in a change at 120 °/sec, is shown in Table 6. At 120 °/sec right foot maximum strength, interaction effect by group and time showed statistical significance in both extension (*P*<0.01) and flexion (*P*<0.05). According to the post-hoc test, $HCO3^-$+TG showed statistical significance in extension after 8 weeks of high-intensity training (*P*<0.01) compared with the CG. TG showed statistical significance in flexion after 4 weeks, and $HCO3^-$+TG showed statistical significance before (*P*<0.05), after 4 weeks (*P*<0.05), and 8 weeks (*P*<0.05) of high-intensity training. At 120 °/sec left foot maximum strength, interaction effect by group and time showed statistical significance in both extension (*P*<0.05) and flexion (*P*<0.001). According to the post-hoc test, $HCO3^-$+TG showed statistical significance after 8 weeks (*P*<0.01) compared with the CG. TG showed statistical significance in flexion after 4 weeks (*P*<0.05) and 8 weeks (*P*<0.01) of high-intensity training, and $HCO3^-$+TG showed statistical significance after 4 weeks (*P*<0.01) and 8 weeks (*P*<0.001).

Discussion

Winning a sprint race is determined by explosive strength, power, and speed (1-3). Research and development of ergogenic aids have diversified along with an interest in improving performance. Particularly, bicarbonate, which is used to remove lactic acid produced from anaerobic exercise, is not an aid or a drug, but a buffer with a lower side effect. It is legal and therefore it has been used in the sports field previously and currently. However, verification of the effectiveness of bicarbonate intake for anaerobic athletes has not been well established. Thus, this study investigated the effect of bicarbonate intake on isokinetic maximum strength in sprint athletes in improving sprint performance.

Table 6: The change of 120 °/sec of foot by isokinetic maximum strength test

Variable		*Pre*	*4 weeks*	*8 weeks*	*Interaction (group × time)* F
Right extensor (N)	CG	129.75 ± 16.20	130.00 ± 16.27	129.63 ± 17.15	10.318***
	TG	148.63 ± 31.61	151.25 ± 29.28	158.88 ± 24.53	
	$HCO3^-$+TG	155.75 ± 30.97	160.88 ± 31.03	178.25 ± 37.42##	
Right flexor (N)	CG	74.75 ± 9.27	74.00 ± 10.17	73.50 ± 10.24	5.792*
	TG	93.63 ± 20.33	94.63 ± 21.33#	94.88 ± 21.76	
	$HCO3^-$+TG	96.00 ± 16.97	97.38 ± 17.20#	98.63 ± 29.51#	
Left extensor (N)	CG	129.25 ± 12.10	129.00 ± 11.02	128.50 ± 8.52	3.876*
	TG	145.63 ± 24.57	146.75 ± 38.82	158.55 ± 33.84	
	$HCO3^-$+TG	157.88 ± 32.43	164.38 ± 33.54	175.88 ± 34.04##	
Left flexor (N)	CG	71.50 ± 12.52	70.25 ± 11.82	68.38 ± 10.81	18.916***
	TG	90.88 ± 18.88	93.25 ± 18.19#	97.25 ± 16.99##	
	$HCO3^-$+TG	89.38 ± 21.70	92.75 ± 20.41#	103.63 ± 18.17###	

Results are expressed as mean ± standard deviation
*P<0.05, ***P<0.001; tested by two-way analysis of variance with repeated measure
#P<0.05, ##P<0.01, ###P<0.001; tested by Tukey post-hoc compared to control group
CG: control group; TG: training group; $HCO3^-$+TG: intake $HCO3^-$ and training group

As a result of the change in isokinetic maximum strength of the left and right extension and flexion at 30, 60, 90, and 120 °/sec after bicarbonate intake in this study, $HCO3^-$+TG showed significance in extension at each angle after 4 weeks of high-intensity training.. The results of this study were consistent with the results of advanced studies that reported more improvement in extensor strength (11-13). The extensors showed a significant improvement in maximum strength because the quadriceps has a higher muscle mass than the hamstring, and it is linked to a later release of fatigue substances (14). Nevertheless, the above advanced studies did not examine changes according to bicarbonate intake. Bicarbonate intake during repetitive high-intensity training within 60 sec improves 42% of sport performance and muscle contraction power (15), and a significant increase in isokinetic maximum strength after intake of bicarbonate could not be expected in less-than-moderate intensity aerobic exercise, but it was effective in short-term high-intensity anaerobic exercise (8). The results of this study were consistent with those of advanced studies, and participation in anaerobic exercise with long-term bicarbonate intake with regard to changes in isokinetic maximum strength showed an improvement effect after 4 weeks. This result is assumed to be because bicarbonate intake is regarded as one of the factors that maintain high-intensity exercise performance, effectively removes body waste that deteriorates muscle contraction, and rapidly aids in recovery from fatigue, resulting in maintenance of high-intensity strength exercise performance over a certain period.

There were some limitations with our study. First, the participants were limited to sprinters even though there are many other athletes who require sodium bicarbonate intake, such as weightlifters, and wrestlers. Future studies should recruit participants from various sports fields. In addition, the male subjects were recruited from Seoul, Republic of Korea; therefore, it is difficult to generalise findings to every Korean sprinter. Further, a small number of participants (n=30) participated in this study. However, it is difficult to recruit subjects, especially for an 8-week high-intensity exercise program with sodium bicarbonate intake. Future studies should recruit more subjects to confirm various aspects of the results.

Conclusion

The effect of $HCO3^-$ intake during high-intensity training on maximum strength in sprint athletes was positive in the training group and $HCO3^-$ +training group; however, the $HCO3^-$ and training group showed larger improvement in maximum strength. In particular, the $HCO3^-$ and training group after $HCO3^-$ intake showed a higher improvement in maximum strength in extension than flexion after 4 weeks of high-intensity training.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors declare that there is no conflict of interest.

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