Short Communication

The effects of sodium bicarbonate supplementation on a soccer specific conditioning test in division III soccer players

Jason M. Cholewa, David J. Grannis, Daniel A. Jaffe, Lucas Guimarães-Ferreira,
Tracy D. Matthews, Vincent J. Paolone

Objectives: This study investigated the performance enhancing effects of bicarbonate ingestion on soccer specific performance.
Design: A randomized and double-blinded study.
Methods: Division III collegiate male soccer players ($N = 7$) participated in the study. Participants ingested either an alkaline treatment (.3 g/kg $NaHCO_3$) or placebo (cornflower) 60 min prior to exercise on two separate testing sessions spaced 7 days apart. Distance to fatigue in the Yo-Yo Intermittent Recovery Test Level 2 was used to assess performance. Capillary blood was sampled pre-ingestion (PE), 60 min post ingestion (PI), exhaustion (EX), following 15 min of recovery (RC) and analyzed for lactate ($[La^-]$) and pH.
Results: No significant ($p > .05$) differences between conditions existed for performance. A significant ($p < .05$) main effect was found for $[La^-]$: values at EX were significantly greater than PE, PI, and RC; however, no interaction ($p > .05$) existed between time and condition. pH values at PE and PI were significantly greater than EX and RC in both conditions; however, pH was significantly ($p < .05$) greater at PI than PE in treatment but not placebo.
Conclusion: Bicarbonate ingestion increased extracellular buffering capacity but does not appear to enhance shuttle run performance in Division III soccer players.
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Key words: Blood lactate ■ buffering ■ performance ■ glycolysis ■ alkalosis

INTRODUCTION

The activity patterns of soccer require athletes to perform repeated bouts of high speed sprints randomly interspersed with periods of jogging or walking. Although the maximal-intensity sprinting interval is only 4-7 s in duration[1], the energy demands of soccer are supplied predominately via non-oxidative glycolysis with muscle pH decreasing to 6.80 and blood lactate (La^-) reaching levels as high as 12 mmol/L during match play.[2]

Ingestion of 0.3 g/kg of sodium bicarbonate ($NaHCO_3$) 90 min prior to exercise has been shown to increase plasma pH and bicarbonate concentrations ($[HCO_3^-]$).[3] Elevated plasma $[HCO_3^-]$ widens the intracellular/extracellular pH gradient, facilitating the efflux of La^- and hydrogen ions (H^+) out of the muscle cell, and thereby attenuates the decrease in intramuscular pH.[4] Because elevated intramuscular $[H^+]$ reduces ATP supply by inhibiting phosphofructokinase[5], induced metabolic alkalosis has been suggested improve performance during high-intensity exercise by defending against H^+-induced decreases in glycolytic enzymatic function.[6] In support of this hypothesis, induced metabolic alkalosis has been reported to increase blood lactate by 26-28% following high-intensity-intermittent exercise.[7,8]

Previous studies have used time motion analysis reports to develop cycle ergometry-based tests that emulate the metabolic demands of team-sports in order to investigate the ergogenic potential of induced metabolic alkalosis. The tests most typically described in the literature contain repeated bouts (≤ 20) of short duration (≤ 6 s) sprints separated by incomplete (60-90 s) periods of low-intensity (40-60% VO_{2PEAK}) active recovery.[9] Price et al.[8] investigated the effects of $NaHCO_3$ ingestion on ten 3 min cycle ergometry exercise blocks consisting of one 14 s maximal sprint per block. Compared to the power output during the first sprint, decreases in power output over the subsequent 9 sprints were attenuated with $NaHCO_3$ ingestion. Similarly, Bishop and Claudius[10] reported induced metabolic alkalosis increased the work completed and power output during the final 18 min of two 36-min periods of intermittent high-intensity cycle ergometry.

Field based team-sports require athletes to perform bipedal locomotion, not cycle ergometry[11,12] therefore, a running-based test of multiple sprints would strengthen the ecological validity when assessing the effects of $NaHCO_3$ ingestion on soccer performance.[13] Gaitanos et al.[14] reported no significant differences between $NaHCO_3$ ingestion and placebo in power output dur-

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From the Department of Kinesiology, Recreation and Sport Studies, Coastal Carolina University, Conway, SC, USA (J.M.C.), Department of Physical Education, Wellness and Sport Studies, Gardner-Webb University, Boiling Springs, NC, USA (D.J.G.), Center for Physical Development Excellence, Department of Physical Education, United States Military Academy, West Point, NY, USA (D.A.J.), Muscle Physiology and Human Performance Research Group, Center of Physical Education and Sports, Federal University of Espirito Santo, Vitoria, ES, Brazil (L.G-F.), and Exercise Science and Sport Studies Department, Springfield College, Springfield, MA (T.D.M., V.J.P.)
Communicated by Takashi Abe, PhD
Correspondence to Dr. Jason M. Cholewa, Department of Kinesiology, Recreation and Sport Studies, Coastal Carolina University, Conway, SC 29526, USA. Email: jcholewa@coastal.edu

ing 10 × 6 s non-motorized treadmill sprinting. Treadmill-based tests, however, do not involve eccentric muscle actions, such as the changing of directions that occurs during team-sport competitions.[15] The exclusion of directional change results in a reduced energy demand, variations in motor unit recruitment patterns, and thence are not accurate representations of match play.[15] Furthermore, the performance in unidirectional sprint tests has been shown to be poorly correlated with sprinting tests involving changes of direction.[16]

The Yo-Yo Intermittent Recovery Test level 2 (Yo-Yo IR2) was developed to tax the non-oxidative glycolytic energy system while also demanding an energy contribution via aerobic respiration. Krustrup et al.[17] investigated the physiological and metabolic responses elicited during the Yo-Yo IR2 testing protocol. Mean and peak heart rates (87% and 98%, respectively), muscle pH (6.80) and blood La^- at exhaustion (11.5 mmol/l) were similar to those recorded previously during soccer matches.[18] Because the physiological and metabolic responses of the Yo-Yo IR2 are representative of intense match play, the Yo-Yo IR2 is an appropriate tool in evaluating the ability of an athlete to perform and recover from high intensity intermittent exercise.[2]

$NaHCO_3$ ingestion has been shown to attenuate the development of fatigue during prolonged high-intensity intermittent exercise.[7,8,10] Currently, there is limited research examining the effects of $NaHCO_3$ ingestion during sport-specific field tests. The purpose of this study was to examine the effects of $NaHCO_3$ ingestion on an intermittent running protocol consisting of the metabolic and movement demands similar to those observed during a soccer match on collegiate male soccer players. We hypothesized that $NaHCO_3$ ingestion will increase plasma pH and blood lactate, and increase distance to fatigue.

METHODS

All methods and procedures were approved by the Springfield College Institutional Review Board prior to data collection.

Participants

Seven male varsity soccer players (height: 177.3 ± 7 cm; weight: 74.8 ± 10.3 kg; VO_{2PEAK}: 59.2 ± 5.0 ml/kg-min) were recruited from a Division III college in Western Massachusetts following consent from the Athletic Department. Participants were between 18 and 22 years of age and were required to pass the collegiate athletic physical which screens for gastrointestinal disorders, cardiovascular conditions that may have placed them in serious risk upon exertion, spinal injuries, and injuries to the lower body which have occurred within 1 year of participating in the study. Participants that did not pass the athletic physical requirement were excluded from the study. All participants were required to thoroughly read and sign the informed consent. Trials were carried out at the same time each day, within a 10 day period, with at least 72 hours separating trials. Prior to all data collection visits, participants were familiarized with assessment protocols.

Dietary Standardization and Training

Participants were required to keep a food diary documenting all foods and fluids (including details of the volume, type, and mass) consumed the day prior to and day of the initial visit. Participants received a copy of this food diary and were instructed consume the exact same foods on the day prior to and day of testing in order to maintain nutritional status. Participants were required to refrain from ingesting any anti-acid or performing exercise 24 and 48 hr prior to testing, respectively. In addition, participants were provided with a list of beverages and foods containing caffeine and were required to abstain from caffeine or alcohol consumption 48 hr prior to testing. Additionally, participants were asked to refrain from consuming any food or beverages (except water) 4 hr prior to testing and were required to complete all testing wearing the same foot wear.

Experimental Design

All testing was conducted indoors on a synthetic surface. Participants reported to the Springfield College Human Performance Laboratory on three separate occasions. On the first visit participants reported to the lab where pre-exercise nude body mass and height were measured. Participants then proceeded to the field house and performed the 1 min multi-stage 20 m shuttle run (Beep test) in order to predict VO_{2PEAK}. Leger and Gadoury[19] demonstrated the Beep test was a valid ($r = 0.90$, SEE = 4.7) tool in predicting the VO_{2PEAK} of adults above the age of 18 years. The Beep test required participants to run between two parallel lines spaced 20 m apart at a beginning speed of 9 km/h. The speed was then increased 0.5 km/h every 1 min by a pacing disk emitting a series of sound signals until volitional exhaustion, or when the subject missed the turning sound signal on three consecutive shuttles. The maximum speed reached during the test was recorded and represented the maximal aerobic speed (MAS). Participants ran in groups of no more than 4 to simulate competition and ensure maximal effort as described by Ramsbottom, Brewer, and Williams.[20] VO_{2PEAK} was calculated using the following equation[21]: $SP - \dot{V}O_{2PEAK} = -27.4 + (6.0 * MAS)$.

On subsequent visits, participants reported to the human performance laboratory 90 min prior to testing and ingested either the alkaline treatment ($NaHCO_3$; 0.3 g/kg) or a placebo (corn flower) in an equal quantity of unmarked capsules. Water was provided *ad libitum*. Treatments were administered randomized and double blind. Ingestion of 0.3 g/kg $NaHCO_3$ was previously reported to improve anaerobic performance without causing gastrointestinal discomfort.[7,8,10] Following 60 min of quite rest participants proceeded to the field house where they completed a 5 min aerobic warm up (45% VO_{2PEAK}) and 5 min of dynamic stretching, and then rested for 10 min prior to performing the Yo-Yo IR2 test (Figure 1). The Yo-Yo IR2 consists of repeated two 20 m shuttle runs at progressively increasing speeds (Figure 2). The subject starts at cone 2, sprints 20 m to cone 3, turns and sprints 20 m back to cone 2. The subject was then provided 5 m to stop at the end of the shuttle (cone 1) and each shuttle run was separated by 10 s of passive recovery. The speed was controlled by prerecorded audio beeps from a laptop computer. The test was terminated when the subject failed to complete the shuttle on two consecutive attempts before time expires. The distance and time to fatigue were recorded and represented the performance results. Krustrup et al.[17] showed that the Yo-Yo IR2 test to be reliable ($r = 0.97$) and sensitive (CV = 10.4%). Bangsbo, Iaia, and Krustrup[22] reported a significant correlation between Yo-Yo IR2 test performance and peak running intensity during a soccer match.

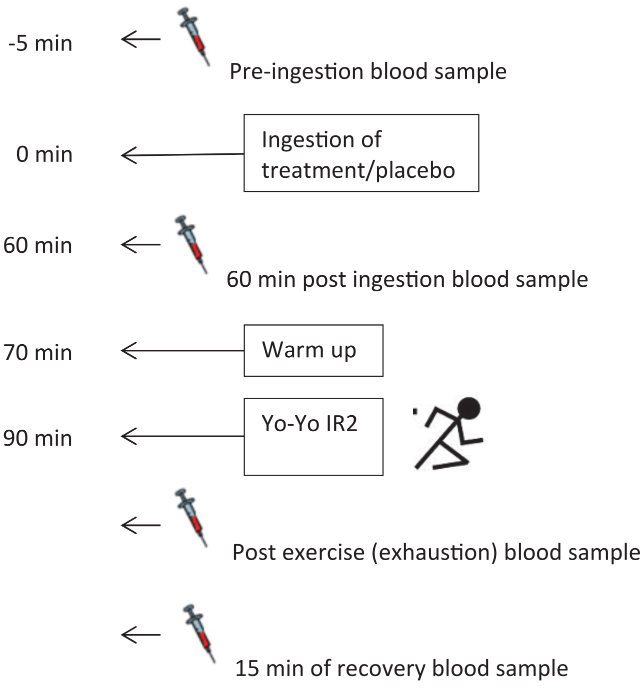

Figure 1 Schematic detailing the experimental design.

Figure 2 Schematic detailing the Yo-Yo Intermittent Recovery Test Level 2.

Blood Sampling and Analysis

Fingertip arterialized capillary blood samples were collected for analysis of La^- and pH. Samples were collected pre ingestion, 60 min post ingestion, at exhaustion, and 15 min into the recovery period after the test. The fingertip was first sterilized and then pierced with a 2 mm retractable lancet (BD Medical, New Jersey, USA). The first drop was removed and then 50-100 µL was collected in a glass capillary tube and immediately analyzed for La^- (Accusport Lactate Analyzer; Boeringer Mannheim, Castle Hill, Australia) and pH (pH Meter; Hanna Instruments, Rhode Island, USA).

Statistical Analysis

A 2 × 4 Repeated Measures Factorial ANOVA was computed to determine if mean differences or interactions existed between treatment conditions and time. Blood was sampled and analyzed for pH and La^- at pre ingestion, 1 hr post ingestion, at exhaustion, and 15 min into recovery. Mauchly's Test of Sphericity was used to determine if homogeneity of variance was present. If Mauchly's Test for Sphericity was violated, the Greenhouse-Geisser statistic was used. For significant main effects for time, pairwise comparisons were computed. Paired samples t test was used to determine if a significant difference existed for distance or time to fatigue between conditions. All statistical analyses were analyzed using SPSS v.19 (IBM, New York, USA) and a p value of less than 0.05 was accepted as statistical significance.

RESULTS

Blood Parameters

Plasma pH and [La^-] between conditions at pre-ingestion, 60 min post ingestion, exhaustion, and following 15 min of recovery are presented in Table 1. A non-significant ($p = 0.08$) interaction trend existed between condition and time for plasma pH (Figure 3). *Post hoc* analysis with paired samples t test revealed that plasma pH was significantly ($p < .05$) greater at 60 min post ingestion than pre-ingestion in $NaHCO_3$ but not placebo. A significant main effect ($p < 0.05$) of time existed for pH: exhaustion and 15 min recovery times were significantly ($p < .05$) less than pre-ingestion or 60 min post ingestion.

Table 1 Plasma pH and lactate between conditions at 4 different time points.

Condition	pH (± *sd*)	Lactate (± *sd*) mmol/L
$NaHCO_3$		
Pre-Ingestion	7.40 (0.01)	2.09 (0.95)
60 min Post Ingestion	7.42 (0.01)*	2.67 (0.74)
Exhaustion	7.26 (0.03)	8.29 (2.43)
15 min Recovery	7.38 (0.02)	4.80 (2.42)
Placebo		
Pre-Ingestion	7.39 (0.02)	2.70 (0.93)
60 min Post Ingestion	7.39 (0.02)	3.27 (0.89)
Exhaustion	7.26 (0.03)	7.66 (2.10)
15 min Recovery	7.38 (0.02)	4.21 (1.60)

Note: * significantly greater than pre-ingestion.

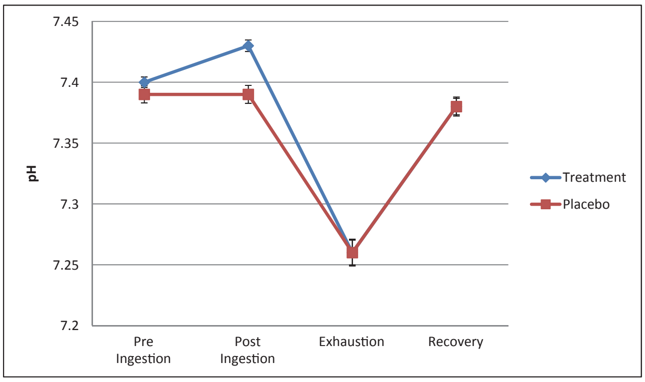

Figure 3 Line graph for pH values from pre ingestion, post ingestion, exhaustion, and 15 min into recovery between conditions.

No significant interaction ($p > 0.05$) existed between condition and time for plasma [La⁻]; however, a main effect was found. Mean [La⁻] values 60 min post ingestion was significantly less ($p < 0.05$) than exhaustion and recovery. [La⁻] values at exhaustion were also significantly greater ($p < 0.05$) than recovery.

Performance

Yo-Yo IR2 test results are presented in Table 2. There were no significant differences between placebo and $NaHCO_3$ for distance or time to fatigue.

DISCUSSION

This is the first study to investigate the effects of $NaHCO_3$ ingestion on a field-based conditioning test in soccer players. The major findings of the present study were that although $NaHCO_3$ increased post ingestion pH, it did not attenuate fatigue nor improve glycolytic energy production. To the author's knowledge, only one other study has examined the effects of $NaHCO_3$ ingestion on high-intensity intermittent running involving changes in direction. Similar to the results of this study, Cameron et al.[23] found $NaHCO_3$ ingestion increased blood pH but did improve repeat sprint ability in trained rugby athletes.

According to Yaseen and Thomas[24] metabolic alkalosis is defined as a blood pH in excess of 7.42. In the present study the mean pH of the $NaHCO_3$ and control group was 7.423 and 7.39, respectively. The difference in pH values in the treatment group between pre-ingestion and 1 hr post-ingestion (0.032) is similar to the differences in pH values reported by other researchers investigating the effects of induced metabolic alkalosis via $NaHCO_3$ ingestion.[25-27] Additionally, all except one subject had a post ingestion pH of greater than 7.42, indicating that $NaHCO_3$ ingestion did induce metabolic alkalosis and presumably enhanced extracellular buffering capacity.

We hypothesized that $NaHCO_3$ ingestion would attenuate the drop in plasma pH with exercise; however, no difference between treatments for post exercise blood pH values were found. The post exercise pH values in the present study are similar to the results reported by Gaitanos et al.[14] when the researchers investigated the effects of induced metabolic alkalosis on non-motorized treadmill sprinting. The researchers observed a non-significant 2% improvement in work performed and no significant differences in post exercise pH values. In contrast, Siegler and Hirsher[27] reported a significant improvement in boxing performance without observing significant differences between conditions in post exercise pH. Most researchers who have reported significant differences in performance, however, also observed significant differences in post exercise pH values. Price et al.[8] observed a significant mean difference of 0.08 pH units greater in the alkaline group following prolonged high intensity intermittent cycle sprinting. Similarly, other researchers have reported significant differences of 0.07 to 0.09 pH units greater in the treatment group in conjunction with improved performance. The blood post exercise pH values in this study ranged from 7.06 to 7.21 and 7.14 to 7.38 in the placebo and treatment groups, respectively, and presumably represent a high degree of H^+ translocation out of the muscle cell.[3,10]

At the cessation of fatiguing high intensity exercise, intramuscular [La⁻] and [H^+] are greater than the blood. Following approximately 8-12 min of passive recovery the ratios are equal and thereafter concentrations are less in muscle than blood. In addition, the decrease in intramuscular [La⁻] and [H^+] is almost entirely the result of metabolite translocation across the sarcolemma, and not local La⁻ oxidization.[28] According to Bangsbo et al.[22] blood [La⁻] peak 5-8 min into the recovery period following the performance of the Yo-Yo IR2. Therefore, if $NaHCO_3$ ingestion improves performance via enhanced metabolite translocation, significant differences in recovery levels of blood La⁻ and H^+ should exist between conditions. Participants in the present study attained an 8.2% greater post exercise blood lactate concentration in $NaHCO_3$. Mean post exercise La⁻ levels were 8.29 and 7.66 mmol/L in the treatment and control conditions, respectively; however, this difference was not statistically significant. Additionally, there were no significant differences between conditions in La⁻ and H^+ following 15 min of recovery. Thus, it is possible participants may not have generated enough metabolites to benefit from metabolic alkalosis and/or the degree of alkalosis induced was insufficient to improve metabolite translocation.

The treatment group achieved a 12.4% (149 m) greater distance to fatigue than the placebo group; however, this difference was not statistically significant due to a high inter-indi-

Table 2 Distance and time to fatigue between conditions.

Condition	Distance to Fatigue (± *sd*) m	Time to Fatigue (± *sd*)
$NaHCO_3$	1349 (620)	8:38 (1:51)
Placebo	1200 (513)	7:59 (1:35)

Note: * significantly greater than pre-ingestion.

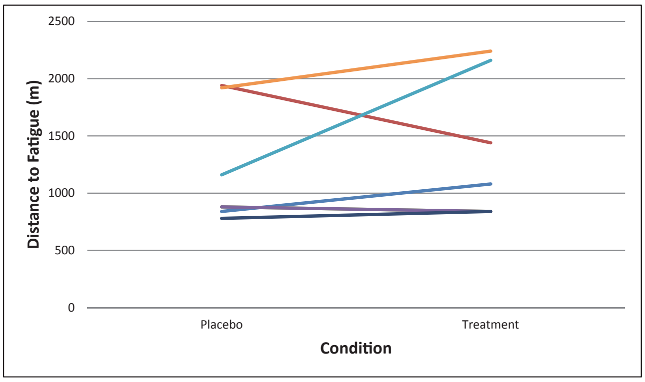

Figure 4 Individual line graph comparing changes in distance to fatigue between conditions per subject ($N = 7$).

vidual variability (Figure 4). Four of the seven subjects performed better with $NaHCO_3$ ingestion, two subjects experienced a small drop in performance, and one subject performed considerably worse. While this dramatic reduction in performance may have impacted the ability to detect statistical significance, it underlines the importance of an individualized experimental based approach with bicarbonate ingestion to determine optimal dosage, timing, and reactions prior to its use as an ergogenic in competition.

In contrast, other researchers have reported significant improvements in performance following $NaHCO_3$ ingestion.[7,8,10] Part of the variance in results reported by researchers investigating the effects of induced metabolic alkalosis on anaerobic performance may be attributed to differences in subject training status.[29] Cameron et al.[23] reported $NaHCO_3$ ingestion did not improve performance in elite rugby players performing a sport specific conditioning test. Several other researchers have also reported that $NaHCO_3$ ingestion in highly trained athletes did not improve performance.[25,30] Collegiate soccer players were recruited for this study because: soccer players regularly perform running with sharp changes in direction, the in season soccer training program is comprised of a high volume of high intensity interval training and thus the athletes would be expected to have highly developed glycolytic capacities[31], the protocol used was designed specifically to test the anaerobic fitness of soccer players[22], and, group homogeneity should result in lower within group variability during repeated measures. According to Bangsbo et al.[22] the mean distance to fatigue in the Yo-Yo IR2 by moderate-elite soccer players is 1100 m. In the present study, the grand mean for distance to fatigue was 1275 m. In addition, participants in the present study had a mean VO_{2PEAK} of 59.14 ml/kg-min, which is similar to values reported by Young et al.[31] for professional Australian Rules Football players. Thus, the participants in the present study may be considered highly trained.

Sprint trained athletes, such as those competing in team-sports, have significantly greater levels of the intramuscular buffer carnosine and higher total buffer capacity than endurance athletes or healthy controls.[32,33] In addition, Bishop, Lawrence, and Spencer[34] reported significant correlations between repeat-sprint ability and the blood buffering capacity of an athlete. Since the ability to buffer H^+ developed by sprint trained athlete may already be near maximal capacity, increasing blood buffer concentrations beyond physiological levels may not effectively increase metabolite translocation during intense exercise. Therefore, $NaHCO_3$ ingestion may not considerably enhance high-intensity anaerobic exercise performance in highly sprint trained athletes.

A potential limitation in the present study may have been the small sample size recruited. A total of 17 participants were initially recruited and completed the Beep test; however, eight participants dropped out. Nine participants completed the first Yo-Yo IR2 trial; however, only the results of the seven participants who completed all three sessions were used in the analysis. Gastrointestinal distress and academic commitments were the most cited reasons behind subject attrition. The major concern with a small sample size is that statistical power is reduced; thus, a larger sample size would have increased the ability to detect treatment effects. In addition, a high within subject variance in distance to fatigue was found. The high variance recorded reduces the ability of the repeated measures t-test to detect a statistical significance.

CONCLUSION

Ingestion of 0.3 g/kg $NaHCO_3$ one hour prior to exercise increased extracellular buffering capacity but did not enhance shuttle run performance in Division III soccer players. Additionally, the high inter-individual variability in performance and reports of GI distress in this study compared to others[7,8,10] highlights to athletes and coaches the importance of experimenting with doses and timing in practice to determine individual responses to $NaHCO_3$ prior to using it as a potential ergogenic aid in competition. Given that many team-sport games are decided in the final minutes, future research is needed to examine the effects of induced metabolic alkalosis on sport specific skill performance following fatiguing exercise.

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