©Journal of Sports Science and Medicine (2009) **8**, 45-50
http://www.jssm.org

Research article

Effects of sodium bicarbonate ingestion on swim performance in youth athletes

Adam Zajac [1]✉, Jaroslaw Cholewa [1], Stanislaw Poprzecki [2], Zbigniew Waśkiewicz [3] and Jozef Langfort [2,4]
[1] Department of Sports Training, Academy of Physical Education in Katowice, Poland
[2] Department of Biochemistry, Academy of Physical Education in Katowice, Poland
[3] Department of Team Sports, Academy of Physical Education in Katowice, Poland
[4] Department of Experimental Pharmacology, Medical Research Center, Polish Academy of Sciences, Warsaw, Poland

Abstract
The purpose of this study was to evaluate the effect of oral administration of sodium bicarbonate (300 $mg \cdot kg^{-1}$ b.w.) on swim performance in competitive, (training experience of 6.6±0.6 years) youth, (15.1±0.6 years) male swimmers. The subjects completed a test trial, in a double blind fashion, on separate days, consisting of 4 x 50m front crawl swims with a 1 minute passive rest interval twice, on two occasions: after ingestion of bicarbonate or placebo, 72 hours apart, at the same time of the day. Blood samples were drawn from the finger tip three times during each trial; upon arrival to the laboratory, 60 min after ingestion of placebo or the sodium bicarbonate solution and after the 4 x 50m test, during the 1st min of recovery. Plasma lactate concentration, blood pH, standard bicarbonate and base excess were evaluated. The total time of the 4 x 50 m test trial improved from 1.54.28 to 1.52.85s, while statistically significant changes in swimming speed were recorded only during the first 50m sprint (1.92 vs. 1.97 $m \cdot s^{-1}$, $p < 0.05$). Resting blood concentration of HCO_3^- increased following the ingestion of sodium bicarbonate from 25.13 to 28.49 mM ($p < 0.05$). Sodium bicarbonate intake had a statistically significant effect on resting blood pH (7.33 vs. 7.41, $p < .05$) as well as on post exercise plasma lactate concentration (11.27 vs. 13.06 mM, $p < 0.05$)). Collectively, these data demonstrate that the ingestion of sodium bicarbonate in youth athletes is an effective buffer during high intensity interval swimming and suggest that such a procedure can be used in youth athletes to increase training intensity as well as swimming performance in competition at distances from 50 to 200 m.

Key words: Sodium bicarbonate, swimming, youth athletes, buffering capacity.

Introduction

In sport disciplines relying on speed endurance or strength endurance, anaerobic glycolysis provides the primary energy source for muscular contractions. The total capacity of the glycolytic pathway is limited by the progressive increase of acidity within the muscles, caused by the accumulation of hydrogen ions (Verbitsky et al., 1997). The increase in acidity ultimately inhibits energy transfer and the ability of the muscles to contract, forcing the athlete to decrease the intensity of exercise (Costill et al., 1984; Harrison and Thompson, 2005; McNaughton, 1992). The naturally occurring bicarbonates are the body's first line of defense against increased acidity. When the buffering capacity within the cell is exceeded, lactate and hydrogen ions diffuse outside the cells (McNaughton, 1992). It has been reasoned that increasing the body's extracellular buffering capacity, by boosting the bicarbonate reserve, will allow hydrogen ions to leave the exercising muscles at a faster rate; consequently, more hydrogen ions and lactate can be produced before the acidity within the muscle cells reaches a limiting level (Faff, 1993; Harrison and Thompson, 2005). The benefit from sodium bicarbonate supplementation would thus be a delayed onset of fatigue during anaerobic exercise (Cairns, 2006; Hollidge-Horvat et al., 2000; Thomas et al., 2005).

Studies with bicarbonate loading have employed various exercise protocols, different doses and times of ingestion. Ergogenic effects were investigated in relation to sprint and middle distance running, rowing, swimming, cycling and different forms of strength exercises. In most of them, significant improvements in performance have been recorded (Gao et al., 1988; Goldfinch et al., 1988; McNaughton, 1990; 1999; McNaughton and Cedero, 1991; Pilegaard et al., 1999; Thomas et al., 2005). There are however studies that do not show benefits of bicarbonate ingestion on performance (Cairns, 2006; Hollidge-Horvat et al., 2000). Experiments have been conducted with different doses of sodium bicarbonate, ranging from 100 to 500 mg/kg of body mass (Horswill et al., 2004; McNaughton et al., 1999). The research literature suggests that doses below 200 mg may cause elevations in blood bicarbonate but do not improve anaerobic performance. Ingesting doses greater than 300 mg does not further increase alkalosis, thus most scientists suggest this dose (McNaughton et al., 1999). The time allowed between ingestion and exercise has also varied from 30 to 150 min in endurance exercise and may had an effect on the alkalotic state achieved prior to exercise (Horswill et al., 2004; McNaughton, 1992; McNaughton et al., 1999; Parry-Billings and MacLaren, 1986). In well trained athletes performance benefits following bicarbonate ingestion are most often observed in single bouts of anaerobic exercise, lasting from 60 to 240s however ergogenic benefits of bicarbonate ingestion were also registered in short duration repeated sprints or resistance exercises, yet during final few repetitions or in the last trials of an exercise protocol (Bishop et al., 2004).

In swimming, athletes begin intensive training between the age of 9 and 11 (Denadai et al., 2000) and child, youth as well as adult athletes usually take part in

Received: 28 July 2008 / Accepted: 19 November 2008 / Published (online): 01 March 2009

the same training regime. Almost all studies with buffering substances have been conducted on adult athletes or untrained male and female adults (Cairns, 2006; McNaughton, 1990; McNaughton et al., 1999; Thomas et al., 2005). Since no data is available on the effects of bicarbonate ingestion in youth athletes, we decided to investigate whether the ingestion of sodium bicarbonate brought beneficial effects on buffering capacity and swim performance in youth swimmers.

Methods

Subjects

A group of eight, well trained competitive youth male swimmers took part in the experiment. All subjects were informed of the nature of the study and possible side effects, and the parents of all the subjects gave their written consent for participation. The project was approved by the Ethics Committee for Scientific Research at the Academy of Physical Education in Katowice. The evaluation of biological development of the adolescent swimmers (Tanner's scale) confirmed that all of the subjects were post puberty.

The basic physical characteristics of the subjects were: (Mean ± SD) age 15.1 ± 0.4 years, body mass 56.1 ± 1.2 kg, height 1.66 ± 0.03 m, training experience 6.6±0.6 years. The research was conducted in the pre-competitive period of an annual training cycle. During this period all swimmers trained approximately 25 h per week, including 2.5 h of strength training on land. The average volume of swim training equaled 69.5 km per week.

Protocol

Each subject completed two test trials consisting of 4 x 50 m front crawl swims with a 1 min passive rest interval between each sprint. The subjects were instructed to swim as fast as possible during each 50 m swim. The two test trials were conducted in a double blind fashion on separate days, 72 hours apart at the same time of the day. One week before and during the experiment the swimmers were placed on a mixed, isocaloric diet which included 60% carbohydrate, 20% protein and 20% fat. The average caloric value of the diet was calculated from a 3 day (2 weekdays and 1 weekend day) diet diary which was analyzed by a computer program (Dieta 2, Warsaw, Poland). The subjects arrived in the laboratory in a 3 h post-absorptive state. The pre-trial meals were standardized for all athletes and consisted of carbohydrates (70%), fat (20%) and protein (10%). During the first trial, four randomly chosen swimmers were given a 500 ml solution containing 300 mg of sodium bicarbonate ($NaHCO_3$) per kg of body mass while the other four athletes received a placebo solution containing an equimolar dose of sodium chloride NaCl (Van Montfoort et al., 2004). The solutions were sugar free and fruit flavored. All subjects reported similar taste of the experimental and placebo treatment solution. In the second trial the order was reversed.

The fluid was ingested over a 15 min period, 90 min before the start of the test trial. All subjects were interviewed regarding gastrointestinal distractions following sodium bicarbonate ingestion. None of the participants reported serious gastrointestinal distractions. After ingesting the solution the athletes were allowed to rest quietly for 60 min prior to testing. Before the time trials the swimmers performed a specific warm-up, which also allowed to maintain the acid-base balance at an appropriate level by stimulating the buffering capacity (Beedle et al., 2007; Poprzecki et al., 2007). The warm up procedure included continuous swimming over 300 m with moderate intensity (HR= 140-150 bts·min^{-1}), stretching and 3 x 25m swims with high intensity. The time of the swim trials was recorded electronically, and the average swim speed in m/s was calculated.

Blood samples were drawn from the finger tip 3 times during each trial; upon arrival to the laboratory (pre ingestion), 60 min after ingestion of placebo or the bicarbonate solution (post ingestion) and during the 1st min of recovery (post exercise). Plasma lactate (LA) concentration was determined enzymatically using commercial kits (Boehringer Diagnostika, Mannheim, Germany). Blood pH, standard bicarbonate (SB) and base excess (BE) were measured using a 168pH Blood-Gas Analyzer (Ciba-Corning, Basel, Switzerland). The intra and interassay coefficients of variation for lactate were 3.2 and 8.9% respectively.

Statistical analysis

All results are presented as mean values and standard deviations (SD). The data was analyzed using parametric statistics following confirmation of a normal distribution by repeated Kolmogorov-Smirnov tests. To evaluate the effects of sodium bicarbonate intake on swim performance and chosen biochemical variables a two-way ANOVA for repeated measures (trial, measurements over time) was used, followed by the Tukey's post hoc test for paired observations to determine the significance of differences. Statistical significance was accepted at $p \leq 0.05$.

Results

The swimming speed of each 50 m time trial is presented in Figure 1. The results of the ANOVA ($F_{(2.28)}$=5.63, $p < 0.05$) indicate a significant effect of sodium bicarbonate ingestion on swimming performance in youth athletes during the 4 x 50 m front crawl test protocol. Post hoc tests reveal a statistically significant difference in swimming speed only in the first 50m sprint (1.92 vs. 1.97 m·s^{-1}, $p < 0.01$). In trials 3 and 4 swimming speed was higher after bicarbonate ingestion, yet these differences were statistically insignificant. There was a significant difference in the completion time of the 4 x 50 m swim protocol between the control and experimental trials (1.54.28 vs. 1.52.85 min, $p < 0.001$).

Pre and post ingestion as well as post exercise values of acid-base equilibrium variables (HCO_3^-, BE, pH) are displayed in Figure 2 and 3. The results of ANOVA indicated a significant effect of sodium bicarbonate ingestion on blood concentration of bicarbonates ($F_{(2.28)}$ = 18.06 $p < 0.01$, Figure 2). The post hoc analysis indicated no differences in the pre ingestion and post exercise state, while a significant difference between the control and experimental trial was observed in the post ingestion state (25.13 vs. 28.49 mM, $p < 0.001$). When considering

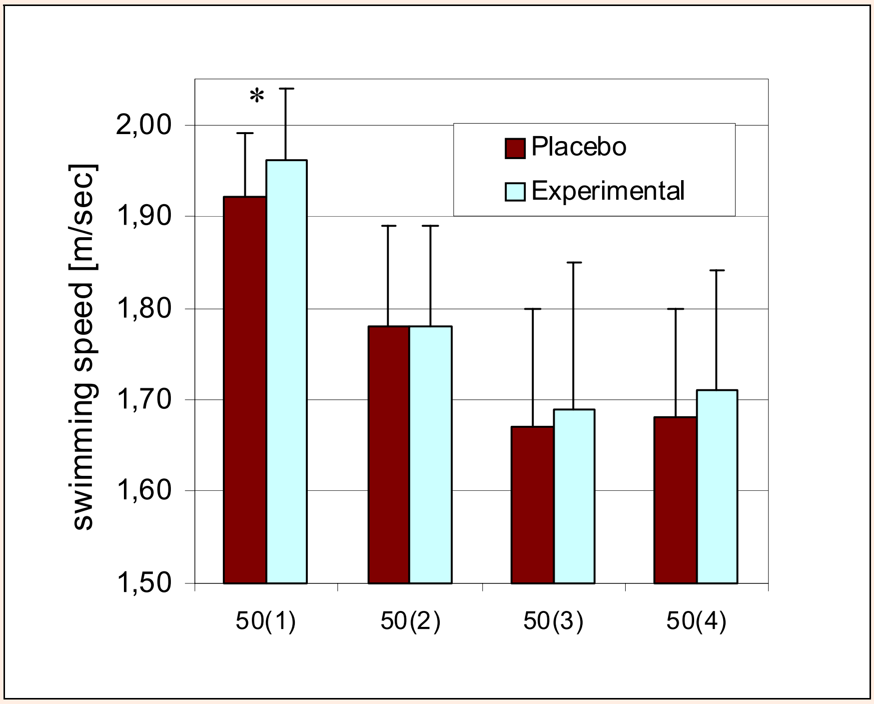

Figure 1. A comparison of subsequent 50m front crawl swims for the control and experimental trials.
* statistically significant difference between swimming speed of the first 50m sprint ($p < 0.01$)

base excess, it must be indicated that bicarbonate intake resulted in higher values in the post ingestion state and lower ones immediately after exercise, yet these changes were not significant. The ingestion of bicarbonate had a statistically significant effect on blood pH ($F_{(2.28)} = 10.02$, $p < 0.01$, Figure 3). Sixty minutes after the ingestion of sodium bicarbonate, blood pH in the experimental trial was significantly higher in comparison to the placebo trial (7.41 vs. 7.33, $p < 0.01$).

The results of the ANOVA also revealed a significant effect of sodium bicarbonate ingestion on plasma lactate concentration ($F_{(2.28)} = 17.81$, $p < 0.001$) which only appeared in the 1st minute after exercise cessation(13.06 vs. 11.27 mmol·l^{-1}, $p < 0.001$). No changes in LA concentration occurred in the pre- and post ingestion states ($p > 0.05$).

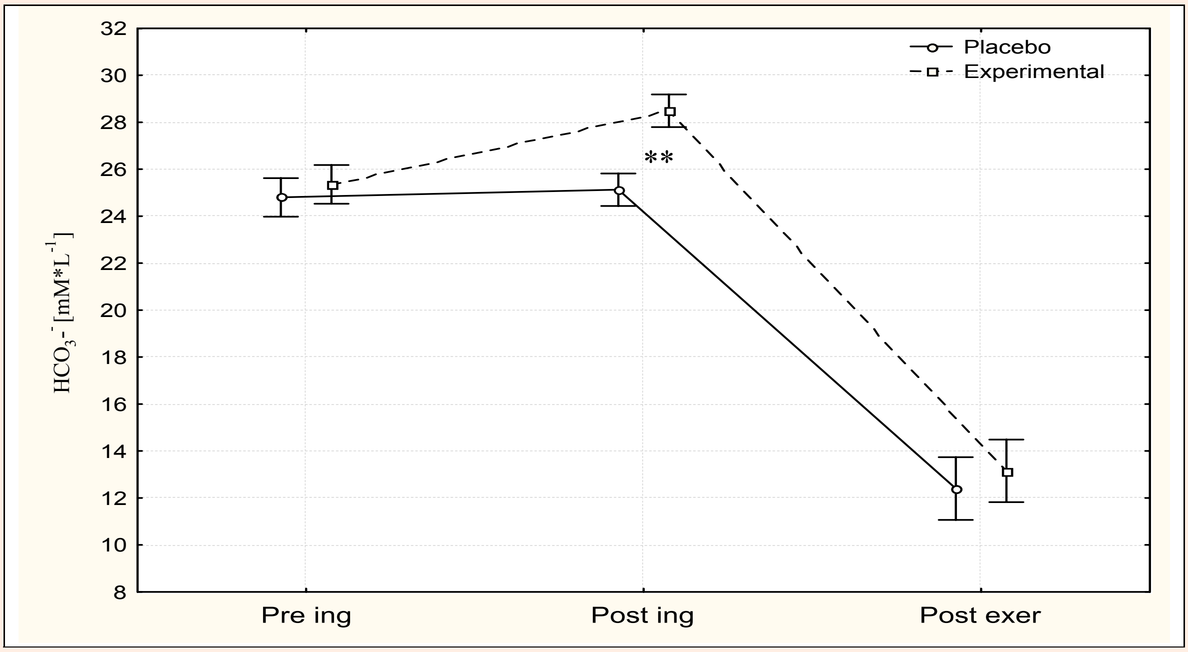

Figure 2. Blood bicarbonate (HCO_3^-) levels in the pre and post ingestion as well as post exercise states for the placebo and experimental trials. ** statistically significant difference in the post ingestion state between the placebo and sodium bicarbonate trial ($p < 0.001$).

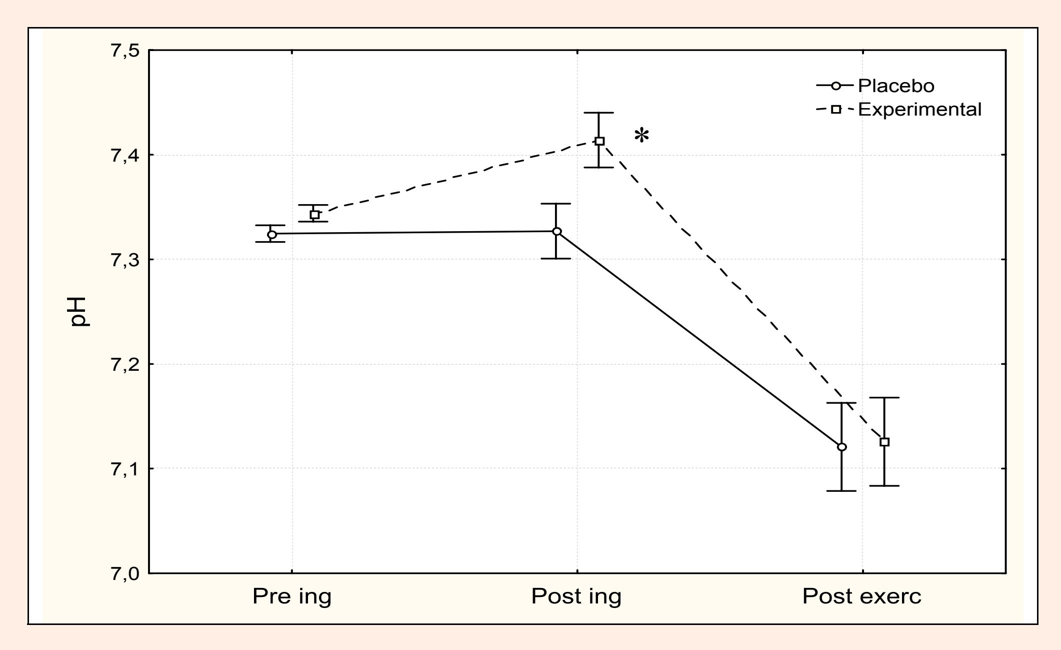

Figure 3. Blood pH levels in the pre and post ingestion as well as post exercise states for the placebo and experimental trials.
* statistically significant difference in the post ingestion state between the placebo and sodium bicarbonate trial ($p < 0.001$).

Discussion

There is a growing body of evidence to suggest that induced metabolic alkalosis in adults improves performance in repeated short duration sprints, in single effort prolonged sprints and in prolonged intermittent exercise of high intensity (Hollidge-Horvat, 2000; McNaughton 1992; Parry-Billings and MacLaren, 1986). Recently obtained results indicate that sodium bicarbonate supplementation can also improve 200 m freestyle performance time in elite male competitors (Lindh et al., 2008). In the present study, we extended these findings, showing that the ingestion of sodium bicarbonate is an effective means during high intensity swimming, which improves performance in well-trained youth athletes. This was evidenced in the present study by significant improvement of swim speed of the first 50 m sprint as well as the total time of the 4 x 50 m swimming test protocol following sodium bicarbonate ingestion (Figure 1). Furthermore, evidence in favor of beneficial effects of sodium bicarbonate intake include, significantly elevated blood bicarbonates and higher blood pH in the post-ingestion state, (Figure 2, 3) as well as elevated plasma lactate concentration after exercise. It is therefore sensible to postulate that the elevation of buffering capacity following bicarbonate intake can be also used in practice in youth athletes to increase training intensity and swimming performance in competition at distances from 50 to 200 m in which energy production relies to a significant extent on the glycolytic pathway within working muscle cells (Cairns, 2006; McNaughton, 1992).

Of interest is the fact that similar sodium bicarbonate ingestion in adult athletes as applied in our study, raises blood pH up to 7.48, increases resting blood bicarbonate levels to 32-36 mM and maintains anaerobic glycolysis at a rate which results in plasma post exercise lactate concentrations of 22-28 mM (Gaul et al., 1995; Parry-Billings and MacLaren, 1986; Thomas et al., 2005). In our subjects the considered acid-base balance variables and lactate concentration were also affected significantly by the intake of sodium bicarbonate and the occurred changes revealed a similar pattern to that reported for adult athletes, yet the effects were less pronounced. The lower LA production seen in our study after high intensity exercise is not surprising, because it is a well documented fact that children and youth, whether trained or untrained have a significantly smaller anaerobic capacity than adults (Hebestreit et al., 1996). This is explained, at least partially, by lower activity of muscle glycolytic enzymes (Inbar and Bar-Or, 1986). This is in accordance with studies which show that lactate production during exercise and changes in glycolytic enzyme activity in both human and animals become increasingly more effective with age (Berg et al., 1986; Billat et al., 2003; Denadai et al., 2000). It was reported that in boys, plasma norepinephrine levels were positively correlated with testosterone levels (Rowland et al., 1996). These findings suggested that glycolytic performance of youth athletes was partially depended on hormonal status and might be attributed to maturity-related differences.

While lower glycolytic capacity and the restricted reliance on high threshold motor units during intensive exercise in immature subjects (Inbar and Bar-Or, 1986) may fully account for lower LA production seen in our study, the cause of diminished plasma sodium bicarbonate concentration remains to be investigated and explained. However, based on data available in literature, a few possible mechanisms may be taken into account for HCO_3^- down regulation. Ratel et al. (2002) suggested that the limited decline in pH may be due to a different time course of regulation of arterial pCO_2 by a greater ventilation compensatory response in children. In this regard, an important finding is that children breathe more during exercise to eliminate a given amount of CO_2 (Nagano et al., 1998) which in turn leads to a lower arterial pCO_2 set point (Armon et al., 1991; Cooper et al., 1987). Additionally, aforementioned studies also showed that in children arterial pCO_2 increased with age while the ratio of alveolar pCO_2 to VO_2 decreased at the ventilatory anaerobic threshold.

Conclusion

In conclusion, the intake of sodium bicarbonate in youth swimmers can significantly increase work capacity during short, intensive interval training. At the same time, acute ingestion of sodium bicarbonate before competition can improve swimming sprint performance at 50 m. This is most likely due to increased buffering capacity. The risk of gastrointestinal side effects, although not seen in our subjects, cannot be ignored, yet pre competition experimentation may decrease the chance of its occurrence or the severity.

References

Armon, Y., Cooper, D.M. and Zanconato, S. (1991) Maturation of ventilatory responses to 1 minute exercise. *Pediatric Research* **29**, 362-368.

Beedle, B.B. and Mann, C.L. (2007) A comparison of two warm-ups joint range of m-otion. *Journal of Strength and Conditioning Research* **21(3)**, 776-779.

Berg, A., Kim, S. and Keul, J. (1986) Skeletal muscle enzyme activities in healthy young subjects. *International Journal of Sports Medicine* **7**, 236-239.

Billat, V., Sirvent, P., Py, G., Koralsztein, J. and Mercier, J. (2003) The concept of maximal lactate steady state: a bridge between biochemistry, physiology and sport science. *Sports Medicine* **33**, 407-426.

Bishop, D., Edge, J., Davis, C. and Goodman, C. (2004) Induced metabolic alkalosis affects muscle metabolism and repeated-sprint ability. *Medicine and Science in Sports and Exercise* **36**, 807-813.

Cairns, S.P. (2006) Lactic acid and exercise performance. *Sports Medicine* **36**, 279-289.

Cooper, D.M., Kaplan, M.R., Baungarten, L., Weiler-Ravell, D., Whipp, B.J. and Wasserman, K. (1987) Coupling of ventilation and CO_2 production during exercise in children. *Pediatric Research* **21,** 568-572.

Costill, D., Verstappen, F., Kuipers, H., Janssen, E. and Fink. W. (1984) Acid-base balance during repeated bouts of exercise: Influence of HCO_3^-. *International Journal of Sports Medicine* **5**, 228-231.

Denadai, B.S., Greco, C. and Teixeira, M. (2000) Blood lactate response and critical speed in swimmers aged 10-12 years of different standards. *Journal of Sports Sciences* **18**, 779-784.

Faff, J. (1993) Can the work capacity be improved by inducing pre-exercise alkalosis? *Biology of Sport* **10**, 127-141.

Gao, J., Costill, D., Horswill, C. and Park, S.H. (1988) Sodium bicarbonate ingestion improves performance in interval swimming. *European Journal of Applied Physiology and Occupational Physiology* **58**, 171-174.

Gaul, C.A., Docherty, D. and Cicchini, R. (1995) Differences in anaerobic performance between boys and men. *International Journal of Sports Medicine* **167**, 451-455.

Goldfinch, J., McNaughton, L. and Davies, P. (1988) Induced metabolic alkalosis and its effects on 400m racing time. *European Journal Applied Physiology and Occupational Physiology* **57**, 45-48.

Harrison, A. and Thompson, K. (2005) Ergogenic aids: sodium bicarbonate. *Peak Performance* **219**, 9-10.

Hebestreit, H., Meyer, F., Htay, H., Heigenhauser G. and Bar-Or, O. (1996) Plasma metabolites, volume and electrolytes following 30s high intensity exercise in boys and men. *European Journal Applied Physiology and Occupational Physiology* **72**, 563-569.

Hollidge-Horvat, M., Parolin, M., Wong, D. and Jones, N.L. (2000) Effect of induced metabolic alkalosis on human skeletal muscle metabolism during exercise. *American Journal of Physiology Endocrinology and Metabolism* **278**, 316-329.

Horswill, C.A., Costill, D., Fink, W., Flynn M., Kirwan, J., Mitchell, J. and Houmard, J. (2004) Influence of sodium bicarbonate on sprint performance. *Medicine and Science in Sports and Exercise* **36**, 1239-1243.

Inbar, O. and Bar-Or, O. (1986) Anaerobic characteristics in male children and adolescents. *Medicine and Science in Sports and Exercise* **18**, 264-269.

Lindh, A.M., Peyrebrune, M.C., Ingham, S.A., Bailey, D.M. and Folland, J.P. (2008) Sodium bicarbonate improves swimming performance. *International Journal of Sports Medicine* **29,** 519-523.

McNaughton, L.R. (1990) Sodium citrate and anaerobic performance: Implications of dosage. *European Journal Applied Physiology and Occupational Physiology* **61**, 292-297.

McNaughton, L.R. (1992) Sodium bicarbonate ingestion and its effects on anaerobic exercise of various durations. *Journal of Sports Sciences* **10**, 425-435.

McNaughton, L.R. (1999) Bicarbonate ingestion: effects of dosage on 60s cycle ergometry. *European Journal Applied Physiology and Occupational Physiology* **80**, 333-336.

McNaughton, L.R. and Cedaro, R. (1991) The effect of sodium bicarbonate on rowing ergometer performance in elite rowers. *Australian Journal of Science and Medicine in Sport* **23**, 66-69.

McNaughton, L.R., Dalton, B. and Palmer, G. (1999) Sodium bicarbonate can be used as an ergogenic aid in high intensity, competitive cycle ergometry of 1h duration. *European Journal Applied Physiology and Occupational Physiology* **80**, 64-69.

Nagano,Y., Baba, R., Kuraishi, K., Yasuda, T., Ikoma, M., Nishibata, K., Yokota, M. and Nagashima, M. (1998) Ventilatory control during exercise in normal children. *Pediatric Research* **43**, 704-707.

Parry-Billings, M. and MacLaren, D. (1986) The effects of sodium bicarbonate and sodium citrate ingestion on anaerobic power during intermittent exercise. *European Journal Applied Physiology and Occupational Physiology* **55**, 524-529.

Pilegaard, H., Domino, K., Noland, T., Juel, C., Hellsten, Y., Halestrap, A.P. and Bangsbo, J. (1999) Effect of high intensity training on lactate/H^+ transport capacity in human skeletal muscle. *The American Journal of Physiology* **276**, 255-261.

Poprzecki, S., Zajac, A., Wower, B. and Cholewa, J. (2007) The affects of warm-up and the recovery interval priori to exercise on anaerobic power and amid-base balance In man. *Journal of Human Kinetics* **18**, 15-28.

Ratel, S., Duche, P., Hennegrave, E., Van Praagh, E. and Bedu, M. (2002) Acid-base balance during repeated cycling sprints in boys and men. *Journal of Applied Physiology* **92**, 479-485.

Rowland, T.W., Maresh, C.M., Charkoudian, P.M., Vanderburgh, P.M. and Castellani, J.W., Armstrong, L.E. (1996) Plasma norepinephrine responses to cycle exercise in boys and men. *International Journal of Sports Medicine* **17**, 22-26.

Thomas, C., Perrey, S., Lambert, K., Hugon, G., Mornet, D. and Mercier, J. (2005) Monocarboxylate transporters, blood lactate removal after supramaximal exercise, and fatigue indexes in humans. *Journal of Applied Physiology* **98**, 804-809.

Van Montfoort, M., Van Dieren, L., Hopkins, W. and Shearman, J.P. (2004) Effects of ingestion of bicarbonate, citrate, lactate and chloride on sprint running. *Medicine Science in Sports and Exercise* **36**, 1239-1243.

Verbitsky, O., Mizrahi, J., Levin, M. and Isakov, E. (1997). Effect of ingested sodium bicarbonate on muscle force, fatigue, and recovery. *Journal of Applied Physiology* **83,** 333-337**.**

Key points

- Sodium bicarbonate is an effective ergogenic aid, also in youth athletes.
- Sodium bicarbonate intake improves swimming sprint performance.
- Sodium bicarbonate intake increases resting blood pH and bicarbonate level.

AUTHORS BIOGRAPHY

Adam ZAJAC
Employement
Prof. Academy of Physical Education in Katowice,. Poland. Department of Sports Training.
Degree
PhD
Research interests
Strength training, sports nutrition, exercise physiology
E-mail: a.zajac@awf.katowice.pl

Jaroslaw CHOLEWA
Employement
Academy of Physical Education in Katowice Poland. Department of Sports Training.
Degree
PhD
Research interests
Youth sports, development of motor abilities.
E-mail: j.cholewa@awf.katowice.pl

Stanislaw POPRZECKI
Prof. Academy of Physical Education in Katowice,. Poland. Department of Biochemistry.
Degree
PhD
Research interests
Biochemical markers of overtraining, sports nutrition, hormones and exercise.
E-mail: s.poprzecki@awf.katowice.pl

Zbigniew WASKIEWICZ
Prof. Academy of Physical Education in Katowice,. Poland. Department of Team Sports.
Degree
PhD
Research interests
Motor development, sports nutrition, skills and coordination.
E-mail: z.waskiewicz@awf.katowice.pl

Jozef LANGFORT
Prof. Medical Research Center, Polish Academy of Sciences, Warsaw, Poland. Department of Pharmacology.
Degree
PhD
Research interests
Exercise physiology, neurotransmitters, antioxidants.
E-mail: langfort@cmdik.pan.pl

✉ **Adam Zajac**
Academy of Physical Education, 40-064 Katowice, Mikołowska 72A, Poland