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Section: Original Investigation

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Abstract

Purpose: Dietary nitrate supplementation has been reported to improve performance in kayaking and rowing exercise which mandate significant recruitment of the upper body musculature. Since the effect of dietary nitrate supplementation on swimming performance is unclear, the purpose of this study was to assess the effect of dietary nitrate supplementation on 100-m and 200-m swimming freestyle time-trial (TT) performance. **Methods:** In a double blind, randomized crossover design, ten moderately-trained swimmers underwent two separate 3-day supplementation periods, with a daily dose of either 140 mL nitrate-rich (BRJ; ~800 mg/d nitrate) or nitrate-depleted (PLA) BRJ. Following blood sampling on day 3, the swimmers performed both 200-m and 100-m freestyle swimming TTs, with 30 min recovery between trials. **Results:** Plasma nitrite concentrations was greater after BRJ relative to PLA consumption (432 ± 203 nmol/L, 111 ± 56 nmol/L, respectively, $p = 0.001$). Systolic BP was lowered after BRJ compared to PLA supplementation (114 ± 10, 120 ± 10 mmHg, respectively $p = 0.001$), but time to complete the 200-m (BRJ: 152.6 ± 14.1 s, PLA: 152.5 ± 14.1 s) and 100-m (BRJ: 69.5 ± 7.2 s, PLA: 69.4 ± 7.4 s) freestyle swimming TTs were not different between BRJ and PLA ($p > 0.05$). **Conclusion:** While 3 days of BRJ supplementation increased plasma nitrite concentration and lowered blood pressure, it did not improve 100-m and 200-m swimming TT performance. These results do not support an ergogenic effect of nitrate supplementation in moderately-trained swimmers, at least for 100-m and 200-m freestyle swimming performance.

Key words: Nitrite, exercise performance, ergogenic aid

Introduction

Dietary supplementation with inorganic nitrate (NO_3^-) has emerged as a popular nutritional intervention to enhance exercise performance. After ingestion, NO_3^- is chemically reduced to nitrite (NO_2^-), via anaerobic bacteria that populate the oral cavity, and subsequently to nitric oxide (NO) through a variety of ubiquitously expressed NO_2^- reductases [1]. NO, and associated reactive nitrogen intermediates, can exert a positive influence on numerous physiological processes that could conflate to improve exercise performance, including skeletal muscle perfusion and oxygenation, metabolism and contractility[2]. Therefore, short-term NO_3^- supplementation has been shown to improve high-intensity continuous [3,4] and intermittent [5] exercise performance during running and cycling exercise, at least in recreationally-active participants.

Although NO_3^- supplementation appears to confer ergogenic potential during running and cycling exercise in recreationally-active participants, it has been suggested that an ergogenic effect of NO_3^- supplementation in these exercise modalities is less likely in well trained individuals[2,3]. However, there is evidence that NO_3^- supplementation can improve performance in highly trained athletes in events where a large muscle mass is recruited and the upper body musculature is heavily engaged, such as kayaking [6] and rowing [7]. Compared to leg exercise, exercise efficiency, vascular conductance and muscle O_2 extraction are compromised, and acidosis and muscle sympathetic nerve activity are increased, at the same relative intensity during arm exercise [8,9]. The more acidic environment in the arm muscles during exercise might facilitate the reduction of NO_2^- to NO [10] and it has been reported that NO_3^- supplementation can improve efficiency, muscle O_2 extraction and muscle blood flow, and can lower muscle sympathetic nerve activity during arm exercise [11-13]. Collectively, these physiological enhancements in the upper body musculature might account for improved performance in trained rowers [7] and kayakers [6] after NO_3^- supplementation.

Swimming is an exercise modality that mandates significant recruitment of the upper body musculature, with the arms making a greater contribution to propulsive force than the legs [14]. Therefore, the physiological enhancements in the arm muscles that have been reported after NO_3^- supplementation [11-13] might be expected to enhance swimming performance. Moreover, swimming exercise provokes exercise-induced arterial hypoxemia [15] and since the ergogenic effect of NO_3^- supplementation appears to be more pronounced in hypoxia compared to normoxia [16], likely as a function of enhanced reduction of NO_2^- to NO [17], NO_3^- supplementation might represent an effective ergogenic aid for swimmers. In addition, swimming is accompanied by periods of dynamic apnea [18-20], with apnea duration linked to swimming performance[21]. Since there is some evidence that NO_3^- supplementation might enhance dynamic apnea performance [18-20], this might also contribute to a potential improvement in swimming performance following NO_3^- supplementation. Accordingly, swimming might produce physiological conditions that enhance the potential for an ergogenic effect following NO_3^- supplementation.

In spite of an apparent synergy between the physiological demands of swimming and the conditions to optimize the effectiveness of NO_3^- supplementation, the influence of NO_3^- supplementation on physiological and performance responses during swimming exercise is unclear [19,22,23]. Indeed, 6 days of NO_3^- supplementation has been reported to enhance the 'anaerobic threshold' and swimming economy in trained masters swimmers [23], who trained 3-4 times/week (6-7 h/week)[23], and acute NO_3^- supplementation enhanced performance in the second half of a trial comprising 8 × 21 m lengths in trained swimmers [22], who completed 3 weekly swimming training session[22]. However, 6 days of NO_3^- supplementation did not improve performance during repeated 15 m sprints in elite female water polo athletes [19] who were preparing for the 2016 Olympic Games qualification and training 7 to 8 session a week[19]. Therefore, the existing studies suggest that NO_3^- supplementation is less likely to be ergogenic for swimming performance as competitive standard and fitness status is increased, consistent with other exercise modalities[2,3]. However, since these studies did not assess the effect of NO_3^- supplementation on swimming performance over distances competed at major championships, further research is required to evaluate its potential as an ergogenic aid for moderately-trained swimmers.

The majority of studies assessing the effect of NO_3^- supplementation on time-trial performance in trained subjects have been > 6 min and have mostly revealed no effect on performance[2,3]. In contrast, NO_3^- supplementation has been reported to enhance 500 m kayaking time-trial performance, which was ~ 2 min[6]. Therefore, NO_3^- supplementation might have greater ergogenic potential during shorter duration time-trial performance tests in trained athletes, such as the 100 m and 200 m distances in swimming. Moreover, given the pronounced glycolytic energy turnover during such events, as reflected by a high post-competition BLa[24], and since the reduction of NO_2^- to NO is potented with acidosis[10], NO_3^- supplementation has the potential to be ergogenic for trained swimmers competing over the 100 m and 200 m distances. However, this has yet to be investigated.

The purpose of this study was to test the hypothesis that short-term supplementation with NO_3^- would improve 200-m and 100-m freestyle swimming performance in moderately-trained swimmers.

Methods

Participants

Ten moderately-trained university swimmers (5 males) (mean ± SD: age 22 ± 6 years, body mass 80.2 ± 14.9 kg, height 1.75 ± 0.06 m) participated in this study. All participants had at least 10 years competitive swimming experience at club standard and at least 5 years experience competing in regional and university-level competitions. Participants completed at least 3 to 4 weekly swimming training sessions (6-8 h a week). Ethical approval for this study was received from the Medicine, Dentistry and Clinical Sciences Research Ethics Committee at the University of Chester (reference no: 1256/17/OE/CSN). All participants provided written informed consent and completed health screening forms prior to participation in the study. Participants were required to record their dietary intake in the 24 h before the control trial and to repeat the same diet in the 24 h before subsequent trials. For 24 h prior to and for each of the testing days, participants were asked to refrain from high-intensity exercise, and the consumption of alcohol, caffeine, nutritional supplements and any anti-inflammatory drugs. Participants avoided antibacterial mouthwash throughout the testing period, given that it eradicates oral nitrate reducing bacteria [25]. The swimmers who participated in this study were in the middle stage of the general preparation training phase and that their training was standardized with 3 times/week, ~4000 m of swimming completed each time during the BRJ and PLA supplementation periods.

Experimental Design

Participants completed three separate visits over ten days. On the first familiarization visit, all subjects performed a 200-m front-crawl time-trial (TT) following blood sample collection and blood pressure measurement. After 30 min of passive recovery, participants completed a 100-m front-crawl TT. The data during this familiarization visit were not used for further analyses.

Following completion of this initial familiarization, participants were assigned to consume either nitrate-rich beetroot juice (BRJ) or nitrate-depleted beetroot juice (PLA) for 3-days, in a randomized, double-blind, cross-over design. A minimum washout period of 72-h separated the BRJ and PLA supplementation periods to ensure plasma NO_2^- concentration had returned to baseline[4].

Supplementation

During the two 3-day supplementation periods, participants consumed 2 × 70 mL/day of concentrated nitrate-rich (~8 mmol/day nitrite) or nitrate-depleted beetroot juice (Beet It, James White Drinks Ltd., Ipswich, UK). Participants ingested a 70 mL shot in the morning (~9 am) and evening (~9 pm) over the first 2 days of supplementation. On the final day of supplementation, 2 × 70 mL shots were ingested together 3 h prior to the 200-m TT.

Simulated swimming time trials

All trials were completed in the same swimming pool with a depth, length, width and water temperature of 1-3 m, 25-m, 12.5-m, and 28 °C respectively, with trials performed at the same time of day for each condition (~12 pm). The swimming performance tests consisted of 200-m and 100-m front crawl swimming distances using a protocol adopted from Lindh et al. [26] to provide a closer simulation of a real swimming competition situation. Each subject completed a standardized low-to-moderate intensity warm-up (~25 min) before each trial. Ten minutes following the warm-up, a 200-m freestyle TT was performed. After completing the 200-m TT, the subjects recovered in a seated position for 30 min and were only allowed to drink water, which was recorded and precisely replicated on the subsequent trial. Following the recovery, a 100-m freestyle TT was performed. Participants completed the TTs individually (with no other competitors present). All TTs were commenced with a diving start from diving blocks and were timed with a stopwatch.

Measurements

Upon arrival at the laboratory and following 10 min of rest, supine blood pressure (BP) of the brachial artery was measured four times using an automated sphygmomanometer (Dinamap Pro, GE Medical Systems, Tampa, FL). The mean of the measurements was calculated and used for analysis. Subsequently, a venous blood sample (~4 mL) was collected into a lithium-heparin tube. Samples were then centrifuged at 1160 g and 4°C for 10 min (hettich® 320 centrifuge, Canada). Plasma was subsequently aliquoted and stored in labelled tubes at -80°C for later analysis of the nitrite concentration using a modification of the chemiluminescence technique as previously described [4]. Capillary blood lactate concentration (BLa) was also measured using a lactate analyzer (Lactatepro©, Japan) from finger pinprick samples. BLa was measured prior to the warm up, and immediately before and after the 200-m and 100-m freestyle swimming performance trials.

Statistical analysis

Paired samples *t*-tests were employed to test for differences between the BRJ and PLA supplements in 100-m and 200-m swimming performance, plasma nitrite concentration and blood pressure. A two-way (supplement × time) repeated-measures ANOVA was employed to assess blood lactate responses following PLA and BRJ supplementation. Where the ANOVA revealed a significant effect, paired samples t-tests were utilised using Fisher LSD to define the origin of any potential effect. Statistical significance was set at $p < 0.05$, and all data were analyzed using SPSS 23.0 (IBM Corp., Armonk, NY), and are presented as mean ± SD.

Results

Plasma nitrite and blood pressure

The plasma nitrite concentration was increased after BRJ (432 ± 203 $nmol \cdot L^{-1}$) compared to PLA (111 ± 56 $nmol \cdot L^{-1}$) supplementation ($p = 0.001$; figure 1).

Systolic BP was lowered by 5 % after BRJ supplementation compared to PLA (114 ± 10, 120 ± 10 mmHg, respectively $p = 0.001$). However, diastolic BP was not different after BR (65 ± 7 mmHg) compared to PLA (66 ± 7 mmHg) supplementation ($p > 0.05$; figure 2).

200-m and 100-m swimming time-trials

There was no difference in 200-m freestyle swimming TT performance following BRJ (152.6 ± 14.1 s) and PLA (152.5 ± 14.1 s) supplementation ($p > 0.05$; figure 3). There was also no difference in 100-m freestyle swimming TT performance following BRJ (69.5 ± 7.1 s) and PLA (69.4 ± 7.3 s) supplementation ($p > 0.05$; figure 3).

Blood lactate concentration

The two-way ANOVA demonstrated no significant main effect for supplement ($p > 0.05$) or no supplement × time interaction effect ($p > 0.05$) for BLa.

Discussion

The principal original findings of this study were that 3-days of BRJ juice supplementation, which increased plasma nitrite concentration and lowered systolic blood pressure, did not enhance 200-m or 100-m swimming TT performance in moderately-trained swimmers. These findings contrast with our experimental hypothesis and do not support short-term BRJ supplementation as an ergogenic intervention for moderately-trained freestyle swimmers over 100-m and 200-m.

Compared to the PLA condition, plasma nitrite concentration was 289% higher in the BRJ condition. This result is consistent with numerous previous studies [16], including the study by Jonvik et al. [4,19] in elite female water polo athletes. Therefore, the BRJ intervention was successful at increasing the circulating reservoir for O_2-independent NO generation by a magnitude that has previously been shown to enhance performance [4].

In addition to an increase in plasma nitrite concentration, short-term BRJ supplementation lowered systolic BP (6 mmHg) in young moderately-trained swimmers. However, there was no reduction in diastolic BP after BRJ supplementation compared to PLA supplementation. A lowering of blood pressure after BRJ ingestion is consistent with previous reports [4,27], with the mechanisms that underpin this effect likely to be multifaceted, but are largely believed to be NO-mediated [28]. The magnitude of BP reduction in the current study is likely to be of clinical relevance [29,30].

Despite increasing the circulating plasma nitrite concentration and by extension the potential for O_2-indepenent NO generation, BRJ supplementation did not improve 200-m or 100-m swimming performance in moderately-trained swimmers in the current study. These findings are consistent with recent reports that BRJ supplementation did not improve overall performance in a 168 m trial in trained swimmers [22] or repeated 15 m sprints in elite female water polo athletes [19]. However, since the 168 m TT was performed in a 21 m swimming pool rather than a traditional 25 m or 50 m pool, and since 168 m is not an appropriate competition distance, the physiological demands of the trial assessed by Pinna et al. [22] would have differed compared to 100-m and 200-m swimming races. To overcome this limitation, a simulation test which was adapted from a previous protocol [26], was applied in the present study to more closely reflect a real competition situation. Therefore, our findings significantly extend previous observations by testing the ergogenic potential of BRJ supplementation over competition-specific race distances. Since no effect of BRJ supplementation was observed for either short- or middle-distance swimming performance, our results imply that BRJ supplementation does not appear to provide an ergogenic effect for trained swimmers, at least over these distances. However, since the performance tests in the current study, and the previous study by Lowings et al.[22] , were in the region of 1-3 min, we cannot exclude the possibility that BRJ supplementation could be ergogenic for swimming events where the completion time is less than or greater than 1-3 min.

Practical Applications

Collectively, the findings of the present study and other recent publications [19,22] do not support BRJ supplementation as a nutritional ergogenic aid for trained swimmers, at least up to distances of 200-m, but are in accord with the notion that BRJ supplementation is less likely to be ergogenic in well trained athletes [2]. However, since we did not measure plasma nitrite concentration prior to the 100-m bout, which occurred 30 min following completion of the 200-m bout, and since plasma nitrite concentration declines during intense exercise [5], we cannot exclude the possibility that the plasma nitrite declined to a concentration that was too low to elicit an ergogenic effect in the 100-m TT and that BRJ supplementation could have been ergogenic in the 100-m TT if this had been completed without a prior maximal 200-m bout. Similarly, since aspects of endurance performance might be improved to a greater extent after prolonged compared to short-term BRJ supplementation [27], improved swimming performance could have been observed if we had extended the supplementation window. Finally, since the TTs were hand timed in the current study and the error of such a method is likely to be higher than electronic timing methods, small performance changes may have been missed, especially during exercise over a short duration. Use of electronic timing pads is recommended to overcome this limitation. Therefore, further research is required to assess the potential ergogenic effects of BRJ supplementation in swimmers.

Conclusions

In conclusion, 3-days of dietary supplementation with nitrate-rich beetroot juice increased plasma nitrite concentration and lowered BP but did not benefit middle (200-m) and short-distance (100-m) freestyle swimming performance in moderately-trained swimmers. These findings do not support short-term supplementation with nitrate-rich beetroot juice as a nutritional ergogenic aid for trained swimmers, at least for the 100-m and 200-m freestyle events.

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Authorship

The study was designed by OZ, CN, MM and SB. Data were collected, analysed, and subsequently interpreted by OZ, CN, MM and SB. Manuscript preparation, including drafting of the article and manuscript revisions, was undertaken by OZ, CN, MM and SB. All authors approved the final version of the article.

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References

1. Lundberg JO, Weitzberg E. NO generation from inorganic nitrate and nitrite: Role in physiology, nutrition and therapeutics. *Archives of pharmacal research.* 2009;32(8):1119-1126.

2. Jones AM. Dietary nitrate supplementation and exercise performance. *Sports medicine.* 2014;44(1):35-45.

3. Porcelli S, Ramaglia M, Bellistri G, et al. Aerobic fitness affects the exercise performance responses to nitrate supplementation. *Medicine and science in sports and exercise.* 2014:1-34.

4. Wylie LJ, Kelly J, Bailey SJ, et al. Beetroot juice and exercise: pharmacodynamic and dose-response relationships. *Journal of Applied Physiology.* 2013;115(3):325-336.

5. Wylie LJ, Mohr M, Krustrup P, et al. Dietary nitrate supplementation improves team sport-specific intense intermittent exercise performance. *European journal of applied physiology.* 2013;113(7):1673-1684.

6. Peeling P, Cox GR, Bullock N, Burke LM. Beetroot juice improves on-water 500 m time-trial performance, and laboratory-based paddling economy in national and international-level kayak athletes. *International journal of sport nutrition and exercise metabolism.* 2015;25(3):278-284.

7. Hoon MW, Jones AM, Johnson NA, et al. The effect of variable doses of inorganic nitrate-rich beetroot juice on simulated 2000-m rowing performance in trained athletes. *International journal of sports physiology and performance.* 2014;9(4):615-620.

8. Calbet J, Gonzalez-Alonso J, Helge J, et al. Central and peripheral hemodynamics in exercising humans: leg vs arm exercise. *Scandinavian journal of medicine & science in sports.* 2015;25:144-157.

9. Kang J, Robertson RJ, Goss FL, et al. Metabolic efficiency during arm and leg exercise at the same relative intensities. *Medicine and science in sports and exercise.* 1997;29(3):377-382.

10. Modin A, Björne H, Herulf M, Alving K, Weitzberg E, Lundberg J. Nitrite-derived nitric oxide: a possible mediator of 'acidic–metabolic'vasodilation. *Acta physiologica Scandinavica.* 2001;171(1):9-16.

11. Richards JC, Racine ML, Hearon CM, et al. Acute ingestion of dietary nitrate increases muscle blood flow via local vasodilation during handgrip exercise in young adults. *Physiological reports.* 2018;6(2).

12. Craig JC, Broxterman RM, Smith JR, Allen JD, Barstow TJ. Effect of dietary nitrate supplementation on conduit artery blood flow, muscle oxygenation, and metabolic rate during handgrip exercise. *Journal of Applied Physiology.* 2018.

13. Notay K, Incognito AV, Millar PJ. Acute beetroot juice supplementation on sympathetic nerve activity: A randomized, double-blind, placebo-controlled proof-of-concept study. *American Journal of Physiology-Heart and Circulatory Physiology.* 2017;313(1):H59-H65.

14. Morouço PG, Marinho DA, Izquierdo M, Neiva H, Marques MC. Relative contribution of arms and legs in 30 s fully tethered front crawl swimming. *BioMed research international.* 2015;2015.

15. Spanoudaki S, Maridaki M, Myrianthefs P, Baltopoulos P. Exercise induced arterial hypoxemia in swimmers. *Journal of sports medicine and physical fitness.* 2004;44(4):342.

16. Kelly J, Vanhatalo A, Bailey SJ, et al. Dietary nitrate supplementation: effects on plasma nitrite and pulmonary O2 uptake dynamics during exercise in hypoxia and normoxia. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology.* 2014;307(7):R920-R930.

17. Castello PR, David PS, McClure T, Crook Z, Poyton RO. Mitochondrial cytochrome oxidase produces nitric oxide under hypoxic conditions: implications for oxygen sensing and hypoxic signaling in eukaryotes. *Cell metabolism.* 2006;3(4):277-287.

18. Engan HK, Jones AM, Ehrenberg F, Schagatay E. Acute dietary nitrate supplementation improves dry static apnea performance. *Respiratory physiology & neurobiology.* 2012;182(2):53-59.

19. Jonvik KL, Van Dijk J-W, Senden JM, Van Loon LJ, Verdijk LB. The Effect of Beetroot Juice Supplementation on Dynamic Apnea and Intermittent Sprint Performance in Elite Female Water Polo Players. *International journal of sport nutrition and exercise metabolism.* 2017:1-20.

20. Patrician A, Schagatay E. Dietary nitrate enhances arterial oxygen saturation after dynamic apnea. *Scandinavian journal of medicine & science in sports.* 2017;27(6):622-626.

21. Maglischo EW. *Swimming fastest.* Human Kinetics; 2003.

22. Lowings S, Shannon OM, Deighton K, Matu J, Barlow MJ. Effect of Dietary Nitrate Supplementation on Swimming Performance in Trained Swimmers. *International Journal of Sport Nutrition and Exercise Metabolism.* 2017:1-24.

23. Pinna M, Roberto S, Milia R, et al. Effect of beetroot juice supplementation on aerobic response during swimming. *Nutrients.* 2014;6(2):605-615.

24. Bonifazi M, Martelli G, Marugo L, Sardella F, Carli G. Blood lactate accumulation in top level swimmers following competition. *The Journal of sports medicine and physical fitness.* 1993;33(1):13-18.

25. Govoni M, Jansson EÅ, Weitzberg E, Lundberg JO. The increase in plasma nitrite after a dietary nitrate load is markedly attenuated by an antibacterial mouthwash. *Nitric Oxide.* 2008;19(4):333-337.

26. Lindh A, Peyrebrune M, Ingham S, Bailey D, Folland J. Sodium bicarbonate improves swimming performance. *International Journal of Sports Medicine.* 2008;29(06):519-523.

27. Vanhatalo A, Bailey SJ, Blackwell JR, et al. Acute and chronic effects of dietary nitrate supplementation on blood pressure and the physiological responses to moderate-intensity and incremental exercise. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology.* 2010;299(4):R1121-R1131.

28. Carlström M, Lundberg JO, Weitzberg E. Mechanisms underlying blood pressure reduction by dietary inorganic nitrate. *Acta Physiologica.* 2018:e13080.

29. Omar S, Webb A, Lundberg J, Weitzberg E. Therapeutic effects of inorganic nitrate and nitrite in cardiovascular and metabolic diseases. *Journal of internal medicine.* 2016;279(4):315-336.

30. Palmer AJ, Bulpitt CJ, Fletcher AE, et al. Relation between blood pressure and stroke mortality. *Hypertension.* 1992;20(5):601-605.

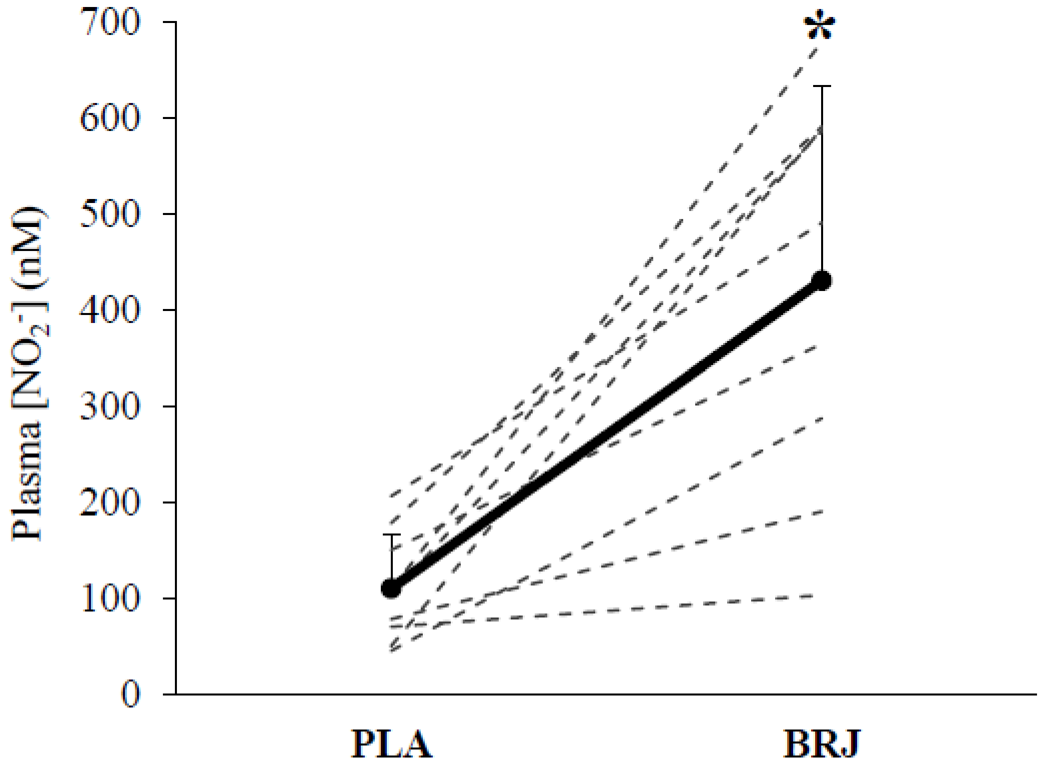

Figure 1: Group mean (SD) and individual plasma nitrite concentration (NO2-) responses after 3-days dietary nitrate or placebo supplementation are shown in the black and dashed lines, respectively. Plasma NO2- was elevated following nitrate supplementation compared to placebo supplementation ($p < 0.05$)

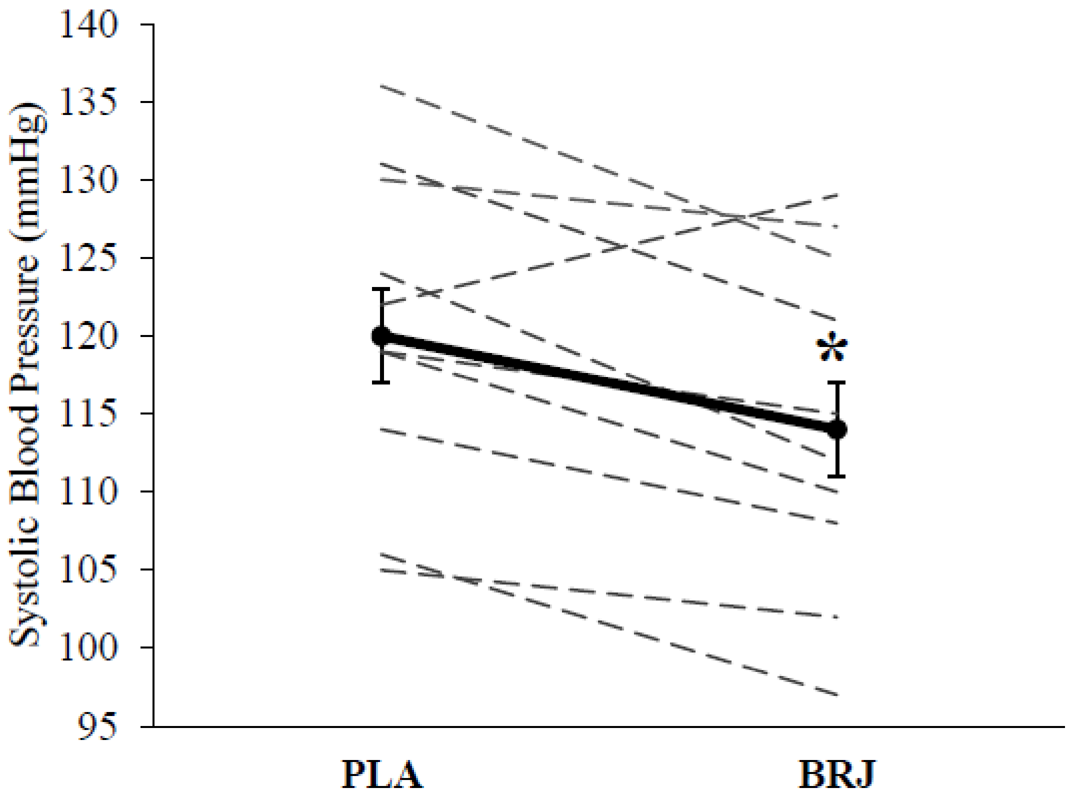

Figure 2: Group mean (SD) and individual systolic blood pressure responses after 3-days dietary nitrate or placebo supplementation are shown in the black and dashed lines, respectively. Systolic blood pressure was lowered following nitrate supplementation compared to placebo supplementation ($p < 0.05$)

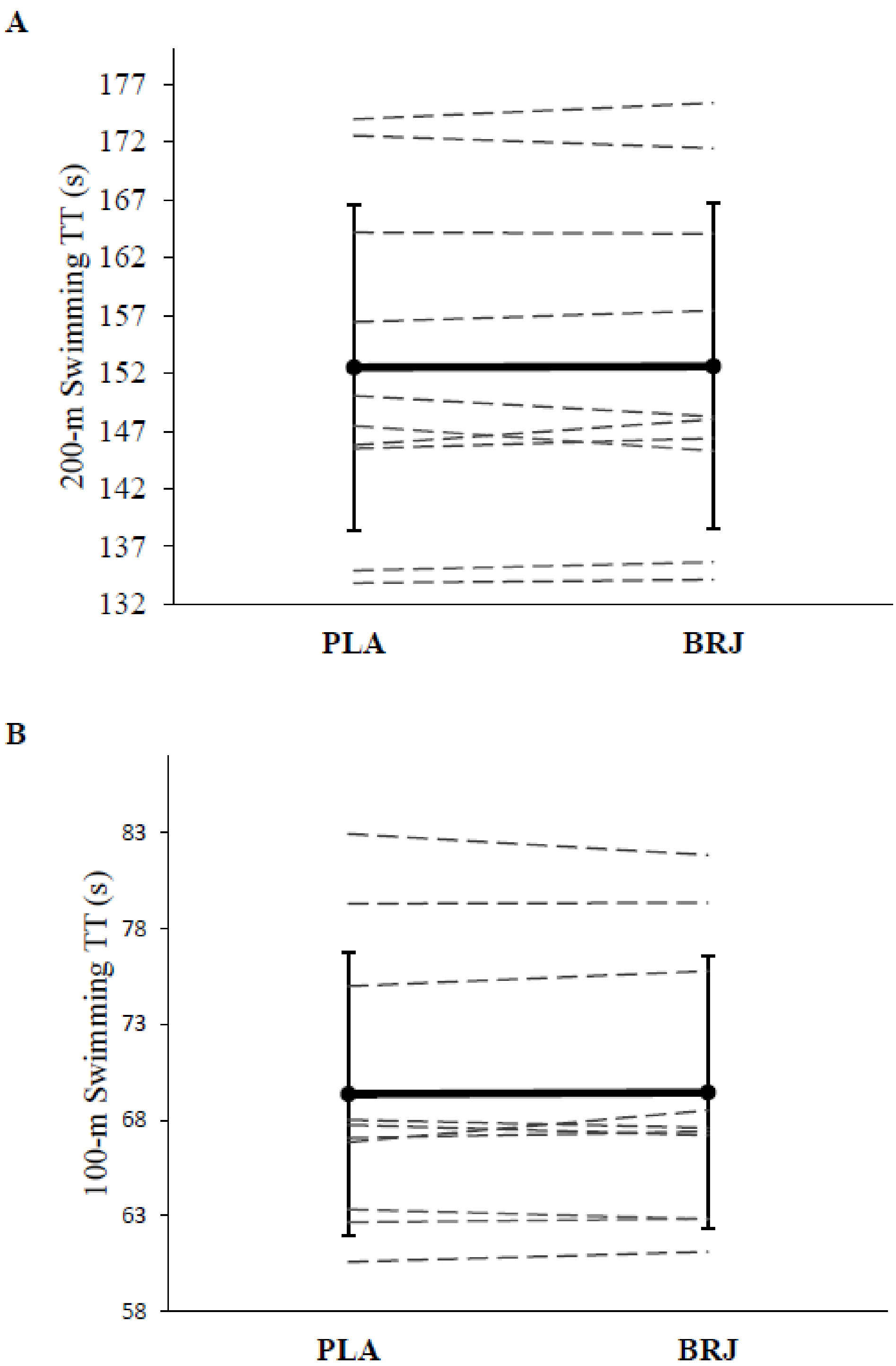

Figure 3: Group mean (SD) and individual 200-m swimming time trial (*A*) and 100-m swimming time trial (*B*) responses after 3-days dietary nitrate or placebo supplementation are shown in the black and dashed lines, respectively. There was no difference in 200-m and 100-m swimming time-trial performances between nitrate supplementation and placebo supplementation ($p > 0.05$).