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Dietary nitrate supplementation improves sprint and high-intensity intermittent running performance

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ABSTRACT

The influence of dietary nitrate (NO_3^-) supplementation on indices of maximal sprint and intermittent exercise performance is unclear.

Purpose: To investigate the effects of NO_3^- supplementation on sprint running performance, and cognitive function and exercise performance during the sport-specific Yo-Yo Intermittent Recovery level 1 test (IR1).

Methods: In a double-blind, randomized, crossover study, 36 male team-sport players received NO_3^--rich (BR; 70 mL·day^{-1}; 6.4 mmol of NO_3^-), and NO_3^--depleted (PL; 70 mL·day^{-1}; 0.04 mmol NO_3^-) beetroot juice for 5 days. On day 5 of supplementation, subjects completed a series of maximal 20-m sprints followed by the Yo-Yo IR1. Cognitive tasks were completed prior to, during and immediately following the Yo-Yo IR1.

Results: BR improved sprint split times relative to PL at 20 m (1.2%; BR 3.98 ± 0.18 vs. PL 4.03 ± 0.19 s; $P < 0.05$), 10 m (1.6%; BR 2.53 ± 0.12 vs. PL 2.57 ± 0.19 s; $P < 0.05$) and 5 m (2.3%; BR 1.73 ± 0.09 vs. PL 1.77 ± 0.09 s; $P < 0.05$). The distance covered in the Yo-Yo IR1 test improved by 3.9% (BR 1422 ± 502 vs. PL 1369 ± 505 m; $P < 0.05$). The reaction time to the cognitive tasks was shorter in BR (615 ± 98 ms) than PL (645 ± 120 ms; $P < 0.05$) at rest but not during the Yo-Yo IR1. There was no difference in response accuracy.

Conclusions: Dietary NO_3^- supplementation enhances maximal sprint and high-intensity intermittent running performance in competitive team sport players. Our findings suggest that NO_3^- supplementation has the potential to improve performance in single-sprint or multiple-sprint (team) sports.

1. Introduction

Nitric oxide (NO) is a gaseous signaling molecule that regulates several physiological processes that are important to exercise performance, including vasodilation, mitochondrial respiration and skeletal muscle contractility [49,51]. NO can be generated through the nitric oxide synthase (NOS)-catalysed oxidation of L-arginine and through the O_2-independent, one-electron reduction of nitrite (NO_2^-). The reduction of NO_2^- to NO is enhanced in hypoxia and acidosis [33,52] and, since contracting skeletal muscles become increasingly hypoxic and acidic during exercise, NOS activity may be reduced and NO_2^- reduction may become an increasingly important source of NO during exercise [34]. Increasing plasma [NO_2^-] via NO_3^- supplementation has been reported to improve muscle oxygenation [4,36], muscle metabolic efficiency [3,16,32] and contractile function [13,20,21], and to improve endurance exercise capacity at least in participants that are not highly trained [4,11,30].

Recent evidence suggests that NO_3^- supplementation has the potential to preferentially enhance physiological responses in type II (fast-twitch), compared to type I (slow-twitch), skeletal muscle [25]. Indeed, increased calcium handling proteins and contractile force has been observed in type II, but not type I, mouse skeletal muscle after NO_3^- supplementation [21]. In addition, NO_3^- supplementation increased hind limb blood flow during exercise in rats,

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with this additional bulk blood flow being selectively directed towards type II muscle fibres [17]. Human studies suggest that NO_3^- supplementation can increase evoked explosive force production [20] and maximal voluntary power production [13] in the knee extensors, and can increase maximal sprint cycling power output [44] and 180 m sprint running performance [45]. However, while these findings suggest that NO_3^- supplementation has the potential to improve sprinting performance, the effects of NO_3^- supplementation on sprint running performance over short distances that reflect those exhibited during team sports match-play (10–20 m [47,48]); have yet to be investigated.

The activity pattern during team sports, such as football, rugby and hockey, is characterised by short-duration bouts of high-intensity exercise interspersed with brief recovery periods [47]. Since this pattern of high-intensity intermittent exercise is associated with significant type II muscle recruitment [29] and, since NO_3^- supplementation can enhance physiological processes in type II muscle [17,21], NO_3^- supplementation has the potential to enhance team-sport-specific high-intensity intermittent exercise performance. Consuming a very large NO_3^- dose (29 mmol) over 36 h prior to exercise was shown to improve performance during the Yo-Yo intermittent recovery level 1 test (Yo-Yo IR1; [59]), a well-established and ecologically valid test widely used to mimic the high-intensity running bouts of football match-play [6]. Performance can also be improved in short-duration intermittent cycling sprints after supplementation with a large NO_3^- dose (~8–13 mmol NO_3^- per day, over 3–7 days; [50,61]), but not with acute consumption of a small NO_3^- dose (~5 mmol NO_3^- per day; [35]). However, the effects of short-term supplementation with a moderate NO_3^- dose on performance during a team-sport-specific intermittent performance test (i.e., a supplementation procedure that has been shown to be effective at improving continuous endurance exercise performance [3,4,30,53]), remains to be determined.

The ability to make quick and accurate decisions whilst simultaneously performing high-intensity running exercise is a key determinant of team sport performance. It has been reported that acute low dose (~5 mmol) NO_3^- ingestion can increase resting brain blood flow and improve resting cognitive performance [57], and that NO_3^- supplementation (12.8 mmol NO_3^- per day for 7 days) can improve reaction time to cognitive tasks during prolonged intermittent sprint-cycling [50]. However, the effect of NO_3^- supplementation on cognitive performance during an exercise test that simulates the movement patterns of team sport match-play has not been investigated.

The purpose of this study was to assess the effects of NO_3^- supplementation on team-sport-specific exercise performance variables and cognitive function before, during and after a Yo-Yo IR1 test. We hypothesised that, compared to a placebo supplement, NO_3^- supplementation would: 1) improve sprint running performance; and 2) improve exercise and cognitive performance during a Yo-Yo IR1 test.

2. Methods

2.1. Subjects

Thirty-six male team-sport players from local football, rugby and hockey teams (mean ± SD: age 24 ± 4 years, height 1.80 ± 0.07 m, body mass 80 ± 10 kg) volunteered to participate. The subjects trained (5–10 h per week) and participated regularly in university and local league competitions. None of the subjects were supplementing their diet with any putative ergogenic aid for 6 months prior to the start of the study. Following an explanation of the experimental procedures, associated risks, potential benefits and likely value of possible findings, subjects gave their written informed consent to participate. The study was approved by the Institutional Research Ethics Committee and conformed to the code of ethics of the Declaration of Helsinki.

2.2. Experimental design

Subjects initially visited the laboratory to be screened and familiarized to the testing procedures. This included the Yo-Yo intermittent recovery level 1 test (Yo-Yo IR1) until task failure, 20 m sprint efforts and the computer-based cognitive tasks. The total distance covered in the Yo-Yo IR1 test was used to calculate the subject's 75% distance which served as a time-point for cognitive assessment in the experimental visits. In a double-blind, randomized, crossover design, subjects were then assigned to receive NO_3^--rich beetroot juice (BR) and a NO_3^--depleted beetroot juice (PL) for 5 days with a wash-out period of 7 days separating the two supplementation periods. On day 5 of each supplementation period, subjects completed the experimental protocol.

Experimental visits were scheduled at the same time of day (±2 h). Subjects were instructed to record their diet during the 24 h preceding the first experimental visit and to repeat this prior to the second visit. They were not specifically asked to refrain from the consumption of high-NO_3^- foods. Subjects were also instructed to arrive at the laboratory ≥3 h post-prandial, having avoided strenuous exercise and the consumption of alcohol in the 24 h preceding, and caffeine in the 8 h preceding, each experimental visit. For the duration of the study, subjects were asked to refrain from taking other dietary supplements, and also to avoid using antibacterial mouthwash as this inhibits the reduction of NO_3^- to NO_2^- in the oral cavity by eliminating commensal bacteria [18].

2.3. Supplementation

Following the initial screening and familiarization visit, subjects were allocated to receive concentrated NO_3^--rich beetroot juice (BR; beetroot juice; ~6.4 mmol of NO_3^- per 70 mL; Beet it, James White Drinks Ltd., Ipswich, UK) or NO_3^--depleted beetroot juice placebo (PL; placebo beetroot juice; ~0.04 mmol NO_3^- per 70 mL; Beet it, James White Drinks Ltd., Ipswich, UK) in a double-blind, randomized, crossover design. Subjects consumed 1 × 70 mL of their allocated supplement each day for 5 days and recorded the timing of each supplement. Consumption of each supplement was communicated to the research team via text or email. Compliance to the supplementation regimen was also assessed via questionnaires during each experimental visit. On the day of each experimental visit, subjects consumed 1 × 70 mL of their allocated daily supplement 2.5 h prior to arriving at the laboratory and commencing the exercise tests.

2.4. Exercise protocol

All exercise tests were performed indoors on a wooden surface on running lanes 2 m wide and 20 m long. During experimental visits, subjects first completed five running sprints from a stationary start as quickly as possible over a distance of 20 m. Each sprint was separated by a period of 30 s walking recovery. Subjects began each sprint with the left foot positioned on a starting jump mat (Smartspeed, Fusion Sports, Australia). A timing gate system (Smartspeed, Fusion Sports, Australia) positioned at 0, 5, 10 and 20 m provided a randomly timed (between 1 and 4 s) flashing light and buzzer sound as stimuli to start each sprint. Reaction time to the stimuli, as well as 5, 10 and 20 m split times were recorded. Following a 5-min period of passive recovery, participants completed the Yo-Yo IR1 test until failure. The Yo-Yo IR1 test