The Decline in Excess Post-exercise Oxygen Consumption in Response to Dietary Nitrate is Eliminated with Concurrent Caffeine Intake

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Abstract

Introduction: Dietary nitrate has been shown to reduce submaximal oxygen consumption (VO2), but less is known about the changes to excess post-exercise oxygen consumption (EPOC). In contrast, caffeine intake increases both exercise VO2 and EPOC. Minimal research has reported on the combined effects of dietary nitrate/caffeine on exercise and post-exercise metabolism. Hypothesis: Caffeine will elevate exercise VO2 and EPOC while dietary nitrate will attenuate the change in exercise VO2 and EPOC. **Methods**: Seven healthy individuals participated in a double-blind, placebo controlled, crossover experiment. The first of five visits consisted of a maximal volume of oxygen consumption (VO2max) treadmill test. Prior to visit 2 – 5, participants consumed either a dietary nitrate (~12.4 mmol, NIT) or placebo nitrate supplement (PLN) combined with either a caffeine (3 mg/kg, CAF) or placebo caffeine (PLC) dose. Supplements were consumed on each of 4 days and the final dose of NIT or PLN and CAF or PLC were consumed 2.5 and 1-hr pre-exercise, respectively. Visits 2 – 5 consisted of a 30-min treadmill run at ~65% VO2max followed by a 60-min seated recovery. During exercise, VO2 and heart rate (HR) were measured continuously. During recovery, EPOC, HR, and peripheral (SBP/DBP) and aortic (cSBP/cDBP) blood pressure (via pulse wave analysis) were measured every 20 min. A linear mixed effects model analysis was performed to determine how each supplementation influenced each dependent variable. Treatments (NIT+CAF, CAF+PLN, NIT+PLC, PLN+PLC) and exercise timepoints (10, 20, 30 min) and recovery timepoints (20, 40, and 60 min post-exercise) served as fixed factors. If $p<0.05$, post-hoc pairwise comparisons were performed. **Results**: Exercise VO2 ($p=0.450$) and HR ($p=0.622$) were not different between treatments at any timepoint. However, EPOC was different between treatments ($p<0.001$); NIT+PLC (4.0±0.6 ml/kg/min) was significantly lower than NIT+CAF (4.7±0.7 ml/kg/min, $p<0.001$),CAF+PLN (4.6±0.7 ml/kg/min $p=0.001$), and PLN+PLC (4.7±0.8 ml/kg/min, $p=0.001$). Recovery PLN+PLC brachial SBP (117±8 mmHg) was significantly lower than NIT+CAF (122+7 mmHg, $p=0.041$), CAF+PLN (123+9 mmHg, $p=0.003$), and NIT+PLC (122+6 mmHg, $p=0.013$). Recovery treatment differences were found for cSBP ($p=0.005$); PLN+PLC (104+7 mmHg) was significantly lower than CAF+PLN (109+9 mmHg, $p=0.001$), and NIT+PLC (108+7 mmHg, $p=0.013$), but not NIT+CAF (107+7mmHg, $p=0.063$). Recovery HR was elevated in PLN+PLC (91+14 bpm) compared to CAF+PLN (86+15 bpm, $p=0.029$) and NIT+PLC (86+12 bpm, $p=0.002$). **Conclusion**: A modest dose of caffeine (3 mg/kg) did not elevate exercise VO2 or EPOC. Dietary nitrate reduced EPOC and elevated peripheral and aortic SBP in recovery. When caffeine was consumed alongside nitrate, the decrease in EPOC was abolished. Dietary nitrate alone may not be advised to those seeking additional workout caloric expenditure.

Methods

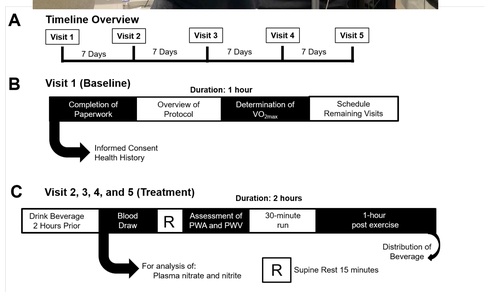

FIGURE 1— Schematic timeline: Trials 1-5. Beverage and caffeine consumption random counterbalanced placebo, dietary nitrate, and caffeine.

Results

Table 1 — Participant Demographics

Sex	Number	Age (years)	HT (cm)	Mass (kg)	BMI
Male	3	30.3 ± 9.5	174.1 ± 4.8	76.7 ± 13.2	25.3 ± 4.3
Female	4	20.8 ± 3.1	166.7 ± 9.7	63.3 ± 9.0	22.7 ± 1.2

Mean ± SD. Height, HT (cm); Body Mass Index, BMI (kg/m^2)

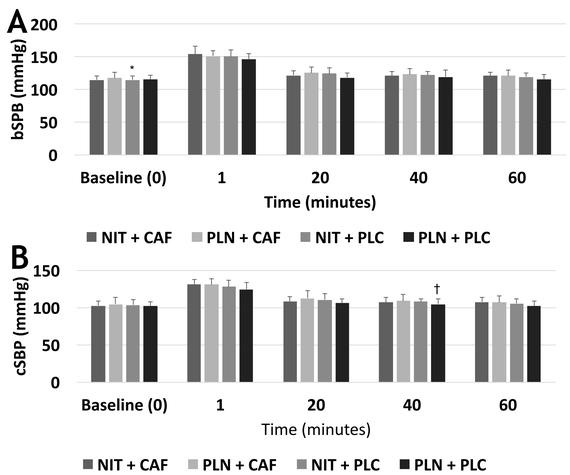

FIGURE 2— Mean ± SD brachial systolic blood pressure and central systolic blood pressure throughout each treatment. Panel A) Brachial systolic blood pressure (bSBP, mmHg), at baseline, 20, 40, and 60minutes post-exercise. Panel B) Central systolic blood pressure (bDBP, mmHg), at rest, 20, 40, and 60 minutes post-exercise. * PLN+PLC was significantly lower than all other treatments ($p<0.05$) † PLN+PLC was significantly lower than CAF+PLN and NIT+PLC but not NIT+CAF ($p=0.005$)

Purpose

The purpose of this study was to determine the combined effects of caffeine and dietary nitrate on exercise VO2 and EPOC.

Statistical Analysis

All statistical analysis was performed in SPSS v25.0. A linear mixed effects model analysis was performed for each dependent variable. Treatment (NIT+CAF, PLN+CAF, NIT+PLC, PLN+PLC) and Timepoint (20 minutes post-exercise, 40 minutes post-exercise, 60 minutes post-exercise) served as fixed factors. The two-way interaction between Treatment and Timepoint was included in the model. Participant served as a random factor. For each dependent variable, models were created using various repeated measures covariance structures. The model which produced the lowest Akaike's Information Criterion (AIC) was considered to be the best fitting model. If the two-way interaction was not significant, it was removed from the model. *Post-hoc* pairwise comparisons were performed if any parameter within the model was statistically significant ($p<0.05$).

Results

Table 2 — Mean Heart Rate Post-Exercise

	NIT + CAF	PLN + CAF	NIT + PLC	PLN + PLC
Baseline (Rest)	64.4 ± 10.1	62.0 ± 9.1	63.9 ± 9.9	62.9 ± 7.0
1	120.1 ± 23.1	119.8 ± 19.8	118.9 ± 21.3	123.1 ± 21.1
20	94.1 ± 16.3	94.5 ± 13.0	91.1 ± 14.7	98.0 ± 16.0
40	86.1 ± 15.8	84.5 ± 16.0	85.8 ± 11.7	89.3 ± 12.2
60	80.0 ± 18.6	79.9 ± 12.6	82.0 ± 10.4	84.5 ± 12.3

Mean ± SD. nitrate, NIT (12.4 mmol/day); caffeine, CAF (3 mg/kg), placebo nitrate, PLN; placebo caffeine, PLC

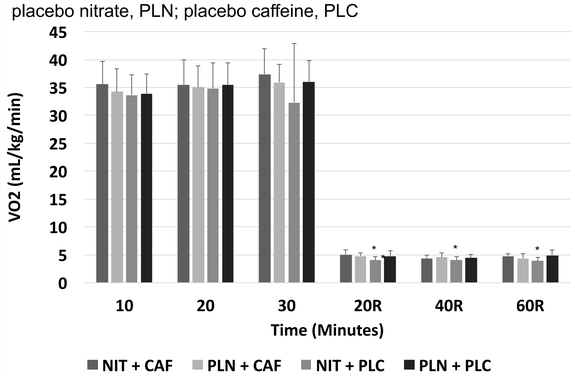

FIGURE 3— Mean ± SD VO2 (mL/kg/min) during exercise at timepoints 10, 20, and 30 minutes and after exercise at timepoints 20, 40, and 60 minutes post, throughout each treatment. *NIT+PLC was significantly lower than all other treatments ($p<0.001$)

Discussion

Dietary nitrate has been shown to reduce submaximal oxygen consumption (VO_2) and caffeine intake increases both exercise

VO_2 and EPOC. A modest dose of caffeine (3 mg/kg) did not elevate exercise VO_2 or EPOC. Dietary nitrate reduced EPOC and elevated peripheral and aortic SBP in recovery. When caffeine was consumed alongside nitrate, the decrease in EPOC was abolished. Dietary nitrate alone may not be advised to those seeking additional workout caloric expenditure.

Relevant References

Carriker CR, Vaughan RA, VanDusseldorp TA, Johnson KE, Beltz NM, McCormick JJ, Cole NH, Gibson AL. Nitrate-containing beet juice reduces oxygen consumption during submaximal exercise in low but not high aerobically fit runners. *Journal of Exercise Nutrition and Biochemistry*, 20(4): 27-34. 2016. doi:10.20463/jenb.2016.0029

Glaister M, Pattison JR, Muniz-Pumares D, Patterson SD, Foley P. Effects of dietary nitrate, caffeine, and their combination on 20-km cycling time trial performance. *The Journal of Strength and Conditioning Research*, 29(1), 165-174. 2015. doi:10.1519

Lane SC, Hawley JA, Desbrow B, Jones AM, Blackwell JR, Ross ML, Zemski AJ, Burke LM.
Single and combined effects of beetroot juice and caffeine supplementation on cycling time trial performance. *Applied Physiology, Nutrition, and Metabolism*, 39(9): 1050-1057. 2014 doi:10.1139

Oskarsson J, McGawley K. No individual or combined effects of caffeine and beetroot-juice supplementation during submaximal or maximal running. *Applied Physiology, Nutrition, and Metabolism*, 43(7): 697-703. 2018. doi:10.1139

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