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Effects of New Zealand Black Currant Extract on Exercising Substrate Utilization and Postexercise Blood Pressure in Men and Women

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New Zealand black currant extract (NZBC) has been shown to increase fat oxidation during exercise and decrease the postexercise blood pressure in men and women. The change in fat oxidation by NZBC has also been shown to be correlated to body composition in men and women. There has never been a comparison of sex responses within the same study. Twenty-two participants (11 men and 11 women, age: 29 ± 8 years, maximal oxygen uptake: 44 ± 9 ml·kg^{-1}·min^{-1}, body fat: 18% ± 6%) had resting blood pressure measured for 2 hr (no exercise). In a double-blind, placebo-controlled (PLA), randomized crossover design, participants completed 1 hr of treadmill exercise at 50% maximal oxygen uptake with expired gas measurement, followed by 2-hr resting blood pressure measurement with 7 days of NZBC or PLA. Average fat oxidation was different between the conditions (NZBC: 0.27 ± 0.11 g/min, PLA: 0.21 ± 0.12 g/min, $p < .001$), but the response between men and women was not different. When combined, there was no relationship ($p > .05$) between body fat percentage and change in fat oxidation ($r = -.079$), with men also demonstrating no relationship ($r = -.069$), although women did demonstrate a relationship ($r = .691$, $p < .05$). In the 2-hr rest, systolic pressure delta change was larger with NZBC than PLA (no exercise vs. NZBC: −5.5 ± 5.4 mmHg vs. no exercise vs. PLA: −2.9 ± 5.1 mmHg, $p < .001$) but was not different between men and women. A 7-day intake of NZBC extract increases fat oxidation during moderate-intensity exercise and decreases postexercise blood pressure in men and women. The magnitude of change in fat oxidation in women is correlated to body fat percentage.

Keywords: anthocyanins, fat oxidation, carbohydrate oxidation, exercise, body composition

Black currant is a fruit with a high content (~590 mg/100 g) of the flavonoid anthocyanin, mostly derived from the anthocyanidins delphinidin (66.1%) and cyanidin (31.6%) in glucoside and rutinoside forms (Rothwell et al., 2013). Anthocyanins give dark pigmentation to fruits, with the amount affected by ultraviolet light (Guo et al., 2008); recent studies have examined exercise performance and physiological effects following intake of New Zealand black currant (NZBC) extract (Cook et al., 2015; Şahin et al., 2022).

Anthocyanin confers health benefits partly by anti-inflammatory and antioxidant effects (Cappellini et al., 2021; Cerletti et al., 2017). This likely results from the high delphinidin content, which, of all the anthocyanins, has the highest number of hydroxyl groups and B-ring-located hydroxyl groups, which confer intracellular radical scavenging (Yi et al., 2010). Furthermore, under conditions where cell oxidative stress and inflammation occur, such as high-intensity exercise, this may also explain why black currant extract supplementation has been shown to increase exercise performance (see reviews: Braakhuis et al., 2020; Cook & Willems, 2019; Willems & Blacker, 2022). In addition, studies have also shown positive responses from NZBC extract that would support exercise performance, such as altered cardiovascular function (Willems et al., 2015) and substrate utilization (Cook et al., 2015). Despite the radical scavenging ability of the parent anthocyanins, it is likely that metabolites are the main causes due to higher bioavailability and synergistic activity (Keane et al., 2016).

The ability to oxidize fat during exercise is important for exercise performance. During sports wherein the use of limited stored energy substrates is important, increasing fat oxidation (FATOX) could be important to preserve endogenous carbohydrate stores. For example, the ability to use fat during exercise is positively associated with performance in an Ironman Triathlon in men (Frandsen et al., 2017) and women (Vest et al., 2018). Furthermore, body composition also influences FATOX during exercise, with a higher body fat percentage increasing utilization of fat (Goodpaster et al., 2002).

Increased FATOX has been observed after 7 days of NZBC extract intake. For example, Cook et al. (2015) observed in trained men cyclists a 27% increase in FATOX (placebo [PLA]: 0.37 ± 0.15 g/min, NZBC: 0.44 ± 0.12 g/min) during 10 min of ergometer cycling at 65% VO_2max following 105 mg/day of anthocyanins. Furthermore, during 120 min of ergometer cycling at 65% VO_2max, intake of 210 mg/day of anthocyanins increased FATOX by 22% in men (control: 0.63 ± 0.2 g/min, NZBC: 0.74 ± 0.13 g/min), and Strauss et al. (2018) observed a 27% increase in women for the

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same duration and intensity of cycling (PLA: 0.34 ± 0.1 g/min, NZBC: 0.40 ± 0.07 g/min).

The magnitude of change in FATOX following NZBC extract intake may be associated with body fat percentage. For example, Şahin et al. (2022) demonstrated a correlation between body mass index and body fat percentage and the absolute change in FATOX ($R^2 = .3968$, $R^2 = .5662$, respectively) during moderate-intensity treadmill walking following 14 days of NZBC intake in recreationally active men. Similarly, Willems et al. (2022) observed that intake of 600 mg of NZBC extract capsules (210 mg anthocyanin) for 7 days increased FATOX during moderate-intensity (4.7 ± 0.4 metabolic equivalents) treadmill walking in recreationally active women, with the absolute change over PLA correlated to body mass index ($R^2 = .53$) and body fat percentage of the legs ($R^2 = .57$), arms ($R^2 = .46$), and trunk ($R^2 = .44$). However, both experiments only had single sex samples, and comparisons between men and women following NZBC intake within the same study have not been investigated. Therefore, it is unclear whether there are effects of sex and body composition in substrate utilization responses following NZBC extract intake.

NZBC extract has also influenced cardiovascular responses during exercise by increasing femoral artery diameter (Cook, Myers, Gault & Willems 2017) and the postexercise hypotension response (Shan & Cook, 2023). Similarly, the cardiovascular responses following NZBC extract intake between men and women have never been compared. It is not known whether different responses could occur, especially as women and men have been shown to have similar postexercise blood pressure responses; however, the hemodynamic determinants are different, with men having a decrease in cardiac output, whereas in women, there is a decrease in systemic vascular resistance (Queiroz et al., 2013). As a result, a men versus women comparison is important to inform guidance on intake and characteristics that could have a greater response to NZBC extract intake.

Furthermore, the responses to NZBC extract for men and women may be different. For example, following absorption, polyphenols undergo monooxygenation and are then catalyzed by phase II enzymes. Isoforms of these enzymes have differing activity in men and women (Campesi et al., 2018). Furthermore, there have been observations of sex differences in the efficacy of berry polyphenols to reduce oxidative stress. For example, oxidized low-density lipoproteins decreased to a greater extent following a high-fat meal challenge in women compared with men (women:−4.6 ± 2.7, men:−3.2 ± 3.0 U/L) following 6 weeks of 10 g daily of freeze-dried strawberry beverage consumption (~338 mg phenolic compounds—quercetin, ellagic acid, anthocyanins, catechins, and kaempferol; Burton-Freeman et al., 2010). In addition, 4 weeks of the polyphenol genistein (600 mg/kg food), an isoflavone, was shown to reduce systolic blood pressure (SBP) in women murine only (Al-Nakkash et al., 2012).

Elliott-Sale et al. (2021) highlighted the importance of including women in research to inform sex-specific guidelines. In addition, Smith et al. (2022) identified in an audit of sports nutrition research that fewer than 4% of studies conducted a comparison of men versus women within the same study. To the authors' knowledge, there have been no men versus women comparisons in one study on physiological, metabolic, and cardiovascular responses to the intake of NZBC extract.

The aim of this study was to compare metabolic responses during moderate-intensity treadmill exercise following NZBC extract intake between men and women and further examine whether postexercise blood pressure responses were similar. The study hypothesized that postexercise blood pressure responses between men and women would be similar. Furthermore, this study hypothesized that NZBC extract would increase FATOX, but the absolute change would be similarly correlated to body fat percentage in men and women.

Methods

Ethical Approval

Ethical approval was obtained from the University of Worcester's College of Business, Psychology, and Sport Research ethics panel (CBPS2122007), with procedures conducted in accordance with the ethical principles outlined by the Declaration of Helsinki (World Medical Association, 2013).

Participants

Twenty-two self-reported physically active participants (11 women) volunteered, were health screened and provided written informed consent, with characteristics presented in Table 1. To participate, participants had to be not using any dietary supplements, nonsmokers, not obese (BMI ≤ 30), and free from any metabolic health disorders. Womene participants were allowed to continue with contraception during the study—with seven reporting use. Participants' blood pressure was also categorized as high normal or below (Table 1) and confirmed in Visit 1 using the right arm, with no participant achieving a resting SBP of ≥140 mmHg and ≥90 mmHg diastolic blood pressure (DBP; Williams et al., 2018). The same arm was used for all blood pressure measurement in the remaining visits. Participants were excluded if they had cardiovascular disease, were taking medication to control blood pressure, or had musculoskeletal injuries that would be exacerbated by the testing.

Experimental Design

The experimental design has previously been described (Shan & Cook, 2023). A double-blind, PLA-controlled, randomized crossover design was used, with four laboratory visits at the same time in the morning. The air-conditioned laboratory was maintained at 20°C. Prior to all visits, participants refrained from exercise for 48 hr, alcohol for 24 hr, and caffeine on the day of the testing.

During Visit 1, height (Harpenden Wall Mounted Stadiometer), body mass (Sartorius scales), blood pressure (Omron M5-I, Omron Healthcare Ltd.), and body composition (Bodystat 1500, Bodystat Ltd.) were measured. Participants then completed an incremental motorized treadmill protocol (HP COSMOS) to 11 km/hr with expired gas measurement to determine the linear relationship between running speed and VO_2. After a 5-min rest, this was followed by a second incremental intensity protocol until voluntary termination to calculate VO_2max. Following a 20-min rest, a square wave verification protocol was performed at 110% velocity at VO_2max (vVO_2max) until voluntary termination (Poole & Jones, 2017).

In the second visit (i.e., no exercise), participants rested on a massage plinth for 120 min with blood pressure measured every 15 min. Visits 1 and 2 were separated by 72 hr. Visits 2–3 were separated by a minimum of 7 days to allow for consumption of the NZBC extract or PLA.

For 6 days prior to Visits 3 and 4, participants consumed either NZBC (CurraNZ, Health Currancy Ltd.) or PLA (microcrystalline cellulose M102) from two 300-mg identical size, shape, and color capsules. A dose–response study indicated that 600 mg for 7 days

Table 1 Men and Women Participant Characteristics

	Men ($n = 11$)	Women ($n = 11$)	Combined ($n = 22$)	p
Age (years)	32 ± 9	27 ± 7	29 ± 8	.172
Height (cm)	178 ± 7	163 ± 6*	171 ± 10	<.001
Body mass (kg)	73 ± 13	64 ± 7	69 ± 11	.060
Body mass index	23.0 ± 3.4	24.2 ± 2.1	23.6 ± 2.9	.331
Body fat (%)	13.1 ± 2.2	23.4 ± 4.7*	18 ± 6	<.001
Fat-free mass (kg)	64 ± 12	49 ± 5*	56 ± 12	<.001
Fat mass (kg)	10 ± 2	15 ± 4*	13 ± 4	<.001
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	50 ± 6	38 ± 7*	44 ± 9	<.001
VO_2max (L/min)	3.6 ± 0.5	2.5 ± 0.6*	3.0 ± 0.8	<.001
vVO_2max (km/hr)	18.5 ± 2.2	14.6 ± 1.7*	16.6 ± 2.8	<.001
RER_{max} (AU)	1.18 ± 0.08	1.20 ± 0.03	1.19 ± 0.07	.348
HR_{max} (beats/min)	185 ± 12	191 ± 13	188 ± 12	.313
Resting systolic pressure (mmHg)	120 ± 9	113 ± 11	116 ± 11	.128
Resting diastolic pressure (mmHg)	71 ± 8	72 ± 6	72 ± 7	.806
Resting mean arterial pressure (mmHg)	87 ± 7	86 ± 8	86 ± 7	.573
Resting rate pressure product	7,055 ± 1,162	6,755 ± 1,109	6,605 ± 1,808	.541
Classification of blood pressure				
Optimal (sys < 120 and dia < 80)	7	9	16	—
Normal (sys 120–129 and/or dia 80–84)	2	2	4	—
High normal (sys 130–139 and/or dia 85–89)	2	0	2	—

Note. Data are reported as mean ± SD and counts. VO_2max = maximal oxygen uptake; vVO_2max = running speed at maximal oxygen uptake; RER_{max} = maximum respiratory exchange ratio; HR_{max} = maximum heart rate; AU = arbitrary units; sys = systolic; dia = diastolic.
*Women different from men ($p < .05$).

reduced resting mean arterial pressure (MAP) in endurance-trained men, with no additional benefit of a higher dose (Cook, Myers, Gault, Edwards et al., 2017). Participants consumed a capsule in the morning and in the evening with a meal. On Day 7, participants consumed both capsules 2 hr before the testing. Each NZBC capsule contained 105 mg of anthocyanins, giving a daily intake of 210 mg of anthocyanins from the capsules. Random allocation resulted in 11 participants receiving the PLA on Visit 3 (three men and eight women). An exit survey during the Visit 4 debriefs identified that nine participants (three men and six women) correctly guessed the experimental condition order they received (41%). For the women, Visits 3 and 4 were 28 days apart to assume testing in the same phase of the menstrual cycle (Bonen et al., 1983), whereas for the men, a minimum 14-day washout between conditions was used.

For Visits 3 and 4, participants exercised at an individualized speed to elicit 50% VO_2max, with measurement of heart rate (Polar H7, Polar Electro Oy) and expired gases (Cortex Metalyzer 3B, Biophysik GmbH) and with analysis every 5 min by averaging the last 60 s of each 5-min section. Stoichiometric equations were used to calculate carbohydrate and FATOX (Jeukendrup & Wallis, 2005). Rating of perceived exertion (Borg 6–20) was recorded every 15 min. The exercise was followed by participants resting on a massage plinth for 120 min, with blood pressure measured immediately and then every 15 min. Participants consumed water ad libitum.

Incremental Intensity Oxygen–Speed Relationship

The incremental treadmill protocol in Visit 1 allowed the relationship between VO_2max and speed to be established. Starting at 5 km/hr and 1% incline, the protocol increased by 1 km/hr every 4 min until 11 km/hr was reached. Expired gases were averaged for the last 60 s of each stage and combined with VO_2max and vVO_2max, and relationship analysis allowed calculation of the speed required for 50% VO_2max.

Maximal Intensity Treadmill Protocol and Verification of VO_2max

The protocol commenced at 7 km/hr for women and 8 km/hr for men on a 1% incline, increasing by 1 km/hr every minute until voluntary termination. The square wave protocol commenced at 7 km/hr for 2 min before increasing to 110% vVO_2max until voluntary termination. Participants were verbally encouraged throughout and had no real-time feedback. The highest VO_2 obtained in both protocols was determined from 15-breath averaging, with 18 participants demonstrating a plateau of < 2.1 $ml \cdot kg^{-1} \cdot min^{-1}$ in VO_2 between the last two speed increments. The square wave protocol confirmed that there was no additional increase in VO_2 with the additional speed. Only two participants achieved a higher VO_2 in the verification protocol (step: 43.8 ± 8.6, verification: 42.1 ± 8.2 $ml \cdot kg^{-1} \cdot min^{-1}$, $p = .002$).

Blood Pressure

For all blood pressure measurements within this study, participants rested supine on a massage plinth with back angle set to 45°, without the use of electronic devices or books. The sphygmomanometer cuff (Omron M5-I, Omron Corporation) was placed around the upper arm approximately 2 cm above the brachial artery. The Omron M5-I has passed the validation recommendation of the

international protocol of the European Society of Hypertension, with a device–observer difference of 0.2 ± 3.6 mmHg for SBP and 0.2 ± 3.9 mmHg for DBP against the mercury sphygmomanometer technique (Omboni et al., 2007). Two measurements were taken and the lowest SBP and DBP recorded. MAP was calculated by:

$$MAP = DBP + [(SBP - DBP) \div 3].$$

Statistical Analysis and Calculations

Data were analyzed using SPSS (version 27.0) and GraphPad (version 9.4.1, GraphPad Software). An a priori power analysis indicated that a sample size of 22 was required to determine a within–between interaction of a 25% increase in FATOX between the PLA and NZBC in the men and women (Willems et al., 2022), with a high statistical power (G*Power: $1-\beta = 0.08$, $\alpha = .05$). Data were assessed using Shapiro–Wilk test for normality. Condition (i.e., NZBC vs. PLA vs. no exercise), sex (men vs. women), time, and interaction effects were analyzed with a repeated-measures analysis of variance. Specificity was checked using Mauchly's test, and if violated, Greenhouse–Geisser correction was applied. Post hoc analysis was completed with Bonferroni corrected comparisons. Delta change (Δ) for the 120-min average blood pressure changes was also calculated for PLA and NZBC against the no exercise condition. The fat and carbohydrate oxidation following intake of PLA was subtracted (i.e., absolute change) from the oxidation rate with intake of NZBC extract (i.e., Δ FATOX and Δ CHOOX). Respiratory exchange ratio was calculated as the ratio between the carbon dioxide produced and oxygen consumed. Cohen's *d* effect size (Cohen, 1988) was calculated with interpretation as < 0.2 trivial, 0.2–0.49 small, 0.5–0.69 moderate, and >0.8 large. Data are presented as mean ± *SD*.

Results

Rate of Perceived Exertion

For the 1-hr treadmill run at 50% VO_2max, there was a change over time for rate of perceived exertion ($p < .001$) but no difference between the conditions or interactions between condition and sex, time and sex, or condition and time ($p > .05$).

Metabolic Responses During Exercise

For the 1-hr treadmill run at 50% VO_2max, participants exercised at 6.8 ± 1.1 km/hr, and there was a difference in the speed between men (7.5 ± 1.1 km/hr, $p < .001$) and women (6.0 ± 0.4 km/hr, $p < .001$). However, there was no difference in average relative intensity for NZBC and PLA between men (NZBC: 51.7 ± 6.1% VO_2max, PLA: 49.5 ± 6.9% VO_2max, $p = .109$) and women (NZBC: 52.1 ± 6.9% VO_2max, PLA: 52.9 ± 9.2% VO_2max, $p = .109$).

For the absolute VO_2, there was a change over time ($p = .036$) but no effect of condition or interactions ($p > .05$). The change over time was also observed for relative VO_2 ($p = .010$), economy ($p = .006$), and minute ventilation ($p < .001$), with no interactions or condition differences. The volume of carbon dioxide demonstrated no time, condition, or sex effects ($p > .05$). Heart rate changed over time ($p = .002$) and over time between sex ($p < .001$) (Table 2).

Respiratory exchange ratio demonstrated a change over time ($p < .001$) and a difference between the conditions ($p < .001$), with no interactions between condition and sex ($p = .700$), time and condition ($p = .102$), and time and sex ($p = .539$). Combined respiratory exchange ratio was different ($p < .05$) at 5, 10, 15, 20, 25, 30, 35, 50, and 60 min of exercise (Figure 1A). Responses for men and women are presented in Figure 1B and 1C.

The FATOX demonstrated an effect on condition ($p < .001$) and time ($p < .001$), but there were no interactions of condition and sex ($p = .225$), time and sex ($p = .349$), or condition and time ($p = .610$). Post hoc comparisons between conditions indicated differences ($p < .05$) at 5 ($d = 0.588$), 10 ($d = 0.577$), 15 ($d = 0.518$), 20 ($d = 1.134$), 25 ($d = 0.542$), 30 ($d = 0.932$), 35 ($d = 0.912$), 50 ($d = 0.520$), 55 ($d = 0.572$), and 60 min ($d = 0.588$) (Figure 1D). Responses for men and women are presented in Figure 1E and 1F.

Average FATOX for men and women during the exercise was different between the conditions (NZBC: 0.27 ± 0.11 g/min, PLA: 0.21 ± 0.12 g/min, $p < .001$, $d = 0.859$), but the responses between men (NZBC: 0.27 ± 0.11 g/min, PLA: 0.19 ± 0.11 g/min, $p = .012$, $d = 0.921$) and women (NZBC: 0.26 ± 0.12 g/min, PLA: 0.22 ± 0.14 g/min, $p = .014$, $d = 0.899$) were not different ($p = .078$).

Similarly, carbohydrate oxidation demonstrated an effect on condition ($p = .002$) and time ($p < .001$), but there were no interactions of condition and sex ($p = .192$), time and sex ($p = .305$), or condition and time ($p = .896$). There were differences ($p < .05$) at 20 ($d = –0.888$), 30 ($d = –0.477$), 40 ($d = –0.467$), 50 ($d = –0.466$), 55 ($d = –0.456$), and 60 min ($d = –0.536$) (Figure 1G). Responses for men and women are presented in Figure 1H and 1I. Combined average carbohydrate oxidation for men and women during the exercise was different between the conditions (NZBC: 1.32 ± 0.44 g/min, PLA: 1.43 ± 0.49 g/min, $p = .002$, $d = –0.762$), but the responses between men (NZBC: 1.64 ± 0.33 g/min, PLA: 1.80 ± 0.38 g/min, $p = .011$, $d = –0.935$) and women (NZBC: 0.99 ± 0.23 g/min, PLA: 1.06 ± 0.27 g/min, $p = .0892$) were not different ($p = 0.197$).

Fat and Carbohydrate Oxidation Responses to Body Composition

When combined, there was no relationship ($p > .05$) between body fat percentage, fat-free mass, and fat mass following NZBC for Δ FATOX ($r = –.079$, $r = .141$, and $r = .012$, respectively; Figure 2A) and Δ CHOOX ($r = .199$, $r = –.044$, and $r = .232$, respectively; Figure 2B). For men, there was also no relationship ($p > .05$) between body fat percentage, fat-free mass, and fat mass for Δ FATOX ($r = –.069$, $r = .039$, and $r = .029$, respectively; Figure 2A) and Δ CHOOX from NZBC ($r = –.071$, $r = .076$, and $r = .029$, respectively; Figure 2B). However, for women, there was a relationship between body fat percentage and Δ FATOX ($r = .691$, $p = .019$; Figure 2C) but no relationship ($p > .05$) between fat-free mass and fat mass for Δ FATOX ($r = –.429$ and $r = .538$, respectively). There was no relationship ($p > .05$) between body fat percentage, fat-free mass, and fat mass for Δ CHOOX in women from NZBC ($r = .14$, $r = .440$, and $r = .158$, respectively; Figure 2D).

Blood Pressure Responses

For the 120-min blood pressure measurement, SBP demonstrated an effect on time ($p = .005$), condition ($p < .001$), and interaction of time and condition ($p = .002$). There was no interaction of sex and time ($p = .719$) or condition and sex ($p = .159$). Post hoc comparisons indicated that NZBC was different from PLA ($p = .004$, $d = 0.32$) at 15 min. At 30 min, no exercise was different from NZBC ($p = .005$, $d = 0.51$), with NZBC also different from PLA ($p = .019$, $d = 0.25$). At 45 min, no exercise was different from NZBC ($p = .029$, $d = 0.49$). At 60 min, no exercise was different

Table 2 Volume of Oxygen Uptake and Carbon Dioxide Produced, Heart Rate, Economy, and Minute Ventilation During 60 min of Treadmill Exercise Following Placebo and NZBC Extract in Men and Women

	Time (min)											
	5	10	15	20	25	30	35	40	45	50	55	60
VCO_2 (L/min)												
Combined NZBC	1.41 ± 0.40	1.42 ± 0.41	1.44 ± 0.41	1.42 ± 0.40	1.44 ± 0.41	1.43 ± 0.40	1.42 ± 0.41	1.41 ± 0.41	1.40 ± 0.41	1.41 ± 0.39	1.39 ± 0.39	1.39 ± 0.38
Combined PLA	1.37 ± 0.38	1.40 ± 0.36	1.43 ± 0.37	1.40 ± 0.36	1.39 ± 0.39	1.40 ± 0.38	1.40 ± 0.39	1.40 ± 0.38	1.40 ± 0.37	1.38 ± 0.35	1.39 ± 0.37	1.38 ± 0.35
Men NZBC	1.71 ± 0.26	1.73 ± 0.31	1.74 ± 0.32	1.71 ± 0.31	1.72 ± 0.35	1.71 ± 0.33	1.72 ± 0.32	1.72 ± 0.30	1.70 ± 0.31	1.69 ± 0.31	1.67 ± 0.32	1.67 ± 0.28
Men PLA	1.60 ± 0.35	1.64 ± 0.29	1.71 ± 0.24	1.63 ± 0.31	1.63 ± 0.34	1.64 ± 0.33	1.65 ± 0.36	1.65 ± 0.33	1.66 ± 0.26	1.63 ± 0.28	1.67 ± 0.24	1.65 ± 0.17
Women NZBC	1.10 ± 0.25	1.12 ± 0.24	1.14 ± 0.23	1.12 ± 0.24	1.16 ± 0.23	1.14 ± 0.22	1.11 ± 0.22	1.10 ± 0.22	1.10 ± 0.23	1.12 ± 0.21	1.11 ± 0.21	1.10 ± 0.23
Women PLA	1.13 ± 0.24	1.17 ± 0.24	1.15 ± 0.24	1.17 ± 0.24	1.14 ± 0.26	1.16 ± 0.25	1.15 ± 0.23	1.15 ± 0.24	1.13 ± 0.25	1.14 ± 0.22	1.12 ± 0.24	1.11 ± 0.26
VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)†												
Combined NZBC	22.6 ± 4.8	22.6 ± 5.0	22.7 ± 4.7	22.5 ± 4.7	22.9 ± 5.0	23.0 ± 5.1	23.0 ± 5.0	22.9 ± 5.1	22.7 ± 5.0	23.0 ± 4.8	22.8 ± 4.7	22.7 ± 4.5
Combined PLA	21.9 ± 4.8	22.0 ± 4.4	22.5 ± 4.6	22.0 ± 4.6	21.9 ± 4.7	22.3 ± 4.8	22.6 ± 5.0	22.6 ± 4.9	22.7 ± 4.6	22.4 ± 4.5	22.7 ± 4.6	22.8 ± 4.7
Men NZBC	25.6 ± 3.7	25.7 ± 4.3	25.5 ± 4.2	25.4 ± 4.0	25.7 ± 4.8	26.1 ± 5.0	26.1 ± 4.6	26.1 ± 4.6	25.7 ± 4.5	25.7 ± 4.5	25.5 ± 4.5	25.5 ± 3.9
Men PLA	23.8 ± 5.3	23.9 ± 4.5	24.9 ± 4.1	24.0 ± 4.8	24.1 ± 4.6	24.5 ± 4.9	24.7 ± 5.4	24.8 ± 4.9	25.1 ± 4.1	24.6 ± 4.4	25.3 ± 3.9	25.6 ± 3.7
Women NZBC	19.6 ± 3.8	19.5 ± 3.6	19.9 ± 3.4	19.7 ± 3.5	20.1 ± 3.4	19.9 ± 3.1	20.0 ± 3.4	19.7 ± 3.4	19.7 ± 3.6	20.2 ± 3.3	20.2 ± 3.3	20.0 ± 3.3
Women PLA	20.0 ± 3.7	20.1 ± 3.7	20.1 ± 3.7	20.0 ± 3.6	19.7 ± 3.6	20.0 ± 3.6	20.4 ± 3.7	20.5 ± 3.9	20.4 ± 4.0	20.2 ± 3.5	20.1 ± 3.7	20.0 ± 4.0
VO_2 (L/min)†												
Combined NZBC	1.55 ± 0.42	1.55 ± 0.43	1.56 ± 0.41	1.55 ± 0.41	1.57 ± 0.43	1.57 ± 0.43	1.58 ± 0.43	1.58 ± 0.44	1.57 ± 0.44	1.58 ± 0.42	1.57 ± 0.41	1.57 ± 0.42
Combined PLA	1.50 ± 0.39	1.51 ± 0.36	1.54 ± 0.37	1.51 ± 0.38	1.51 ± 0.40	1.53 ± 0.39	1.55 ± 0.41	1.55 ± 0.40	1.56 ± 0.37	1.53 ± 0.37	1.56 ± 0.38	1.56 ± 0.38
Men NZBC	1.84 ± 0.30	1.85 ± 0.33	1.84 ± 0.33	1.83 ± 0.31	1.85 ± 0.37	1.86 ± 0.36	1.88 ± 0.35	1.88 ± 0.35	1.86 ± 0.36	1.85 ± 0.35	1.84 ± 0.36	1.84 ± 0.34
Men PLA	1.71 ± 0.37	1.72 ± 0.31	1.79 ± 0.28	1.73 ± 0.34	1.75 ± 0.35	1.76 ± 0.36	1.78 ± 0.39	1.79 ± 0.37	1.80 ± 0.29	1.77 ± 0.31	1.81 ± 0.27	1.83 ± 0.22
Women NZBC	1.27 ± 0.30	1.26 ± 0.29	1.28 ± 0.27	1.27 ± 0.29	1.29 ± 0.27	1.28 ± 0.27	1.29 ± 0.28	1.28 ± 0.29	1.27 ± 0.30	1.30 ± 0.27	1.30 ± 0.27	1.29 ± 0.29
Women PLA	1.29 ± 0.29	1.29 ± 0.28	1.29 ± 0.28	1.29 ± 0.28	1.27 ± 0.29	1.29 ± 0.28	1.31 ± 0.28	1.32 ± 0.29	1.32 ± 0.29	1.30 ± 0.27	1.30 ± 0.28	1.29 ± 0.30

(continued)

Table 2 *(continued)*

	Time (min)											
	5	10	15	20	25	30	35	40	45	50	55	60
Economy ($ml \cdot kg^{-1} \cdot km^{-1}$)†												
Combined NZBC	199 ± 28	199 ± 26	200 ± 25	198 ± 25	201 ± 25	202 ± 25	202 ± 26	202 ± 28	200 ± 27	203 ± 26	201 ± 26	201 ± 25
Combined PLA	191 ± 28	193 ± 25	198 ± 26	193 ± 27	192 ± 26	195 ± 27	198 ± 29	199 ± 28	200 ± 28	197 ± 25	200 ± 27	201 ± 31
Men NZBC	202 ± 20	203 ± 20	203 ± 20	201 ± 20	203 ± 23	206 ± 25	206 ± 22	208 ± 26	203 ± 22	205 ± 25	202 ± 24	203 ± 21
Men PLA	185 ± 26	187 ± 17	197 ± 22	188 ± 24	190 ± 22	192 ± 24	193 ± 28	195 ± 24	199 ± 22	194 ± 22	201 ± 26	204 ± 30
Women NZBC	195 ± 34	194 ± 32	197 ± 29	196 ± 30	200 ± 29	198 ± 27	199 ± 29	196 ± 29	196 ± 32	201 ± 28	201 ± 29	198 ± 28
Women PLA	198 ± 30	199 ± 30	199 ± 31	199 ± 30	195 ± 30	199 ± 30	202 ± 30	203 ± 33	202 ± 34	200 ± 28	200 ± 30	198 ± 34
Heart rate (beats/min)†,#												
Combined NZBC	124 ± 12	125 ± 12	124 ± 12	126 ± 13	127 ± 15	128 ± 14	130 ± 16	131 ± 17	131 ± 17	132 ± 17	133 ± 17	132 ± 18
Combined PLA	124 ± 15	126 ± 14	128 ± 14	127 ± 14	127 ± 13	128 ± 13	129 ± 13	129 ± 13	131 ± 14	132 ± 15	133 ± 15	132 ± 16
Men NZBC	123 ± 16	124 ± 16	124 ± 16	128 ± 18	130 ± 20	131 ± 19	134 ± 21	135 ± 23	136 ± 22	137 ± 23	137 ± 23	137 ± 23
Men PLA	123 ± 18	125 ± 17	130 ± 19	129 ± 19	130 ± 18	130 ± 19	131 ± 19	132 ± 18	134 ± 19	135 ± 20	136 ± 20	137 ± 21
Women NZBC	125 ± 10	125 ± 8	124 ± 7	123 ± 8	124 ± 9	125 ± 8	127 ± 9	126 ± 9	127 ± 12	128 ± 8	129 ± 9	127 ± 10
Women PLA	126 ± 14	127 ± 11	126 ± 8	125 ± 8	125 ± 8	126 ± 7	127 ± 5	127 ± 7	128 ± 6	129 ± 7	129 ± 8	128 ± 9
V_E (L/min)†												
Combined NZBC	41.9 ± 9.4	44.2 ± 10.6	44.5 ± 9.6	44.5 ± 10.3	46.1 ± 10.9	46.3 ± 12.0	46.2 ± 11.3	46.2 ± 11.6	45.9 ± 11.5	46.6 ± 10.8	46.7 ± 11.0	46.8 ± 11.2
Combined PLA	42.3 ± 9.7	44.0 ± 9.1	45.2 ± 9.3	44.9 ± 9.1	45.2 ± 10.8	45.4 ± 10.3	45.8 ± 10.5	46.1 ± 10.0	46.0 ± 10.3	46.1 ± 9.8	46.4 ± 10.3	47.1 ± 10.7
Men NZBC	47.1 ± 9.4	49.6 ± 11.2	49.6 ± 9.5	49.6 ± 11.1	51.5 ± 12.0	52.0 ± 13.4	52.1 ± 12.5	52.4 ± 12.6	51.8 ± 12.6	51.8 ± 11.7	52.3 ± 12.0	52.8 ± 10.4
Men PLA	47.8 ± 10.5	48.6 ± 9.8	51.0 ± 8.9	49.4 ± 10.0	50.7 ± 11.2	50.9 ± 10.9	51.1 ± 11.3	51.4 ± 10.1	51.6 ± 9.4	51.0 ± 10.3	52.1 ± 9.6	53.3 ± 8.2
Women NZBC	36.7 ± 5.9	38.8 ± 6.9	39.4 ± 6.8	39.4 ± 6.6	40.6 ± 6.4	40.5 ± 7.1	40.4 ± 6.1	39.9 ± 6.4	40.1 ± 6.7	41.4 ± 6.8	41.2 ± 6.6	40.8 ± 8.7
Women PLA	36.8 ± 4.6	39.3 ± 5.5	39.5 ± 5.4	40.3 ± 5.3	39.7 ± 7.2	39.9 ± 6.2	40.5 ± 6.3	40.7 ± 6.7	40.4 ± 8.0	41.2 ± 6.6	40.8 ± 7.8	40.8 ± 9.3

Note. All measures collected following 7 days of supplementation with NZBC extract or PLA during treadmill exercise. Data are reported as mean ± *SD* from 22 participants (11 women, 11 men). NZBC = New Zealand black currant; PLA = placebo; V_E = minute ventilation; VO_2max = maximal oxygen uptake; VCO_2 = volume of carbon dioxide.
†Significant effect for time ($p < .05$). #Significant interaction between time and sex ($p < .05$).

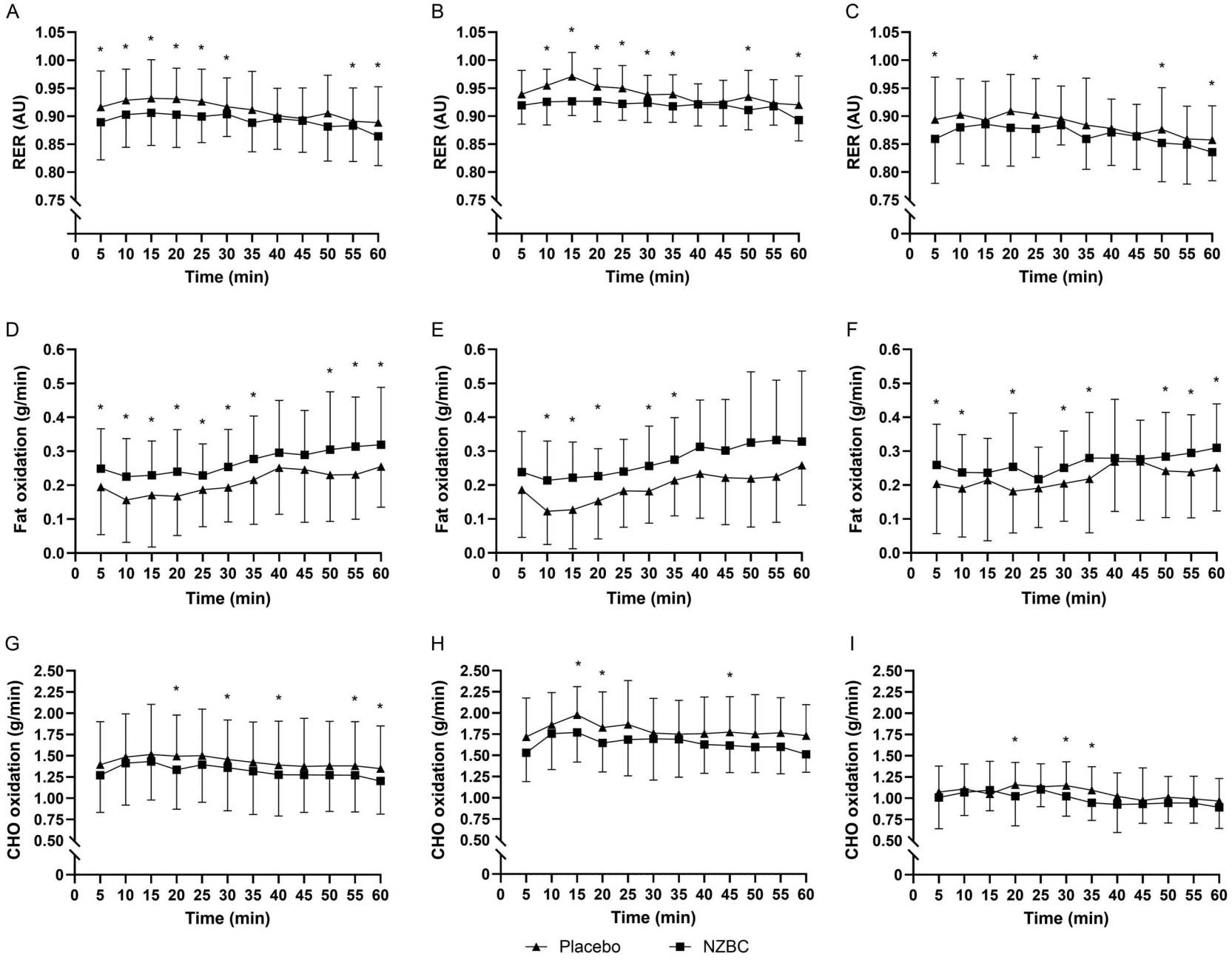

Figure 1 — (A) Combined RER, (B) men RER, (C) women RER, (D) combined fat oxidation, (E) men fat oxidation, (F) women fat oxidation, (G) combined carbohydrate oxidation, (H) men carbohydrate oxidation, and (I) women carbohydrate oxidation following 7-days NZBC extract or PLA during 60 min of treadmill exercise at 50% VO_2max in men and women (n = 22, 11 men and 11 women). Data are presented as mean ± *SD*. RER = respiratory exchange ratio; NZBC = New Zealand black currant extract; VO_2max = maximal rate of oxygen uptake. *NZBC extract different ($p < .05$) from placebo.

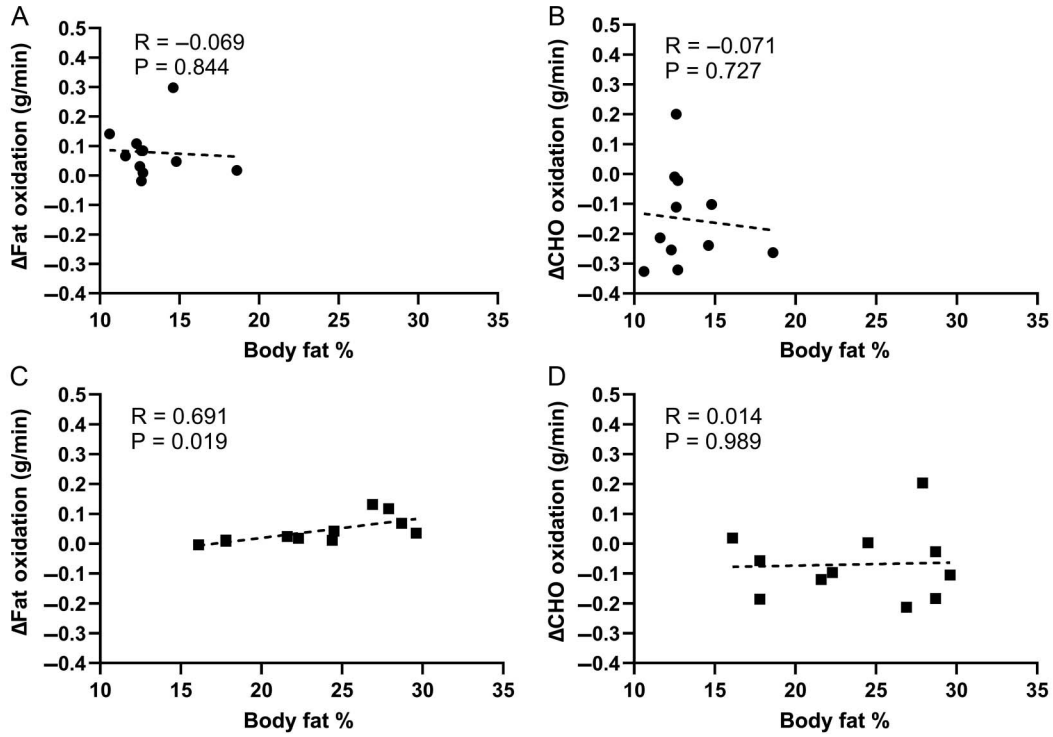

Figure 2 — (A) Men Δ FATOX, (B) men Δ CHOOX, (C) women Δ FATOX, and (D) women Δ CHOOX responses following NZBC extract against body fat percentage. Δ FATOX = delta change of fat oxidation; Δ CHOOX = delta change of carbohydrate oxidation; NZBC = New Zealand black currant extract.

from NZBC ($p < .001$, $d = 0.67$), with NZBC also different from PLA ($p < .001$, $d = 0.37$). At 75 min, no exercise was different from NZBC ($p < .001$, $d = 0.73$) and PLA ($p = .007$, $d = 0.43$). At 90 min, no exercise was different from NZBC ($p < .001$, $d = 0.86$) and PLA ($p = .003$, $d = 0.60$), with NZBC also different from PLA ($p = .043$, $d = 0.22$). At 105 min, no exercise was different from NZBC ($p < .001$, $d = 0.77$) and PLA ($p = .001$, $d = 0.61$). At 120 min, no exercise was different from NZBC ($p < .001$, $d = 0.62$), with NZBC also different from PLA ($p = .014$, $d = 0.35$) (Figure 3A).

The DBP was different over time ($p = .003$) but not different between conditions or with any interactions ($p > .05$) (Figure 3D).

The MAP was different over time ($p < .001$), between the conditions ($p = .002$), and with an interaction between time and condition ($p = .017$), with no interaction of condition and sex ($p = .163$) or time and sex ($p = .355$). At 45 min, no exercise was different from NZBC ($p = .031$, $d = 0.48$). At 60 min, no exercise was different from NZBC ($p = .026$, $d = 0.50$), with NZBC also different from PLA ($p = .029$, $d = 0.42$). At 75 min, no exercise was different from NZBC ($p < .001$), with NZBC also different from PLA ($p = .006$, $d = 0.67$). At 90 min, no exercise was different from NZBC ($p = .006$. $d = 0.64$). At 120 min, no exercise was different from NZBC ($p = .025$, $d = 0.58$), with NZBC also different from PLA ($p = .019$, $d = 0.43$) (Figure 3G). Men and women blood pressure responses are presented in Figure 3B, 3C, 3E, 3F, 3H, and 3I.

The Δ SBP was larger following NZBC than PLA (no exercise vs. NZBC: −5.5 ± 5.4 mmHg; no exercise vs. PLA: −2.9 ± 5.1 mmHg, $p < .001$, $d = –0.817$), with no difference in responses between men ($p = .123$) and women ($p = .149$). There was also the same response for Δ DBP (no exercise vs. NZBC: −2.5 ± 5.4 mmHg vs. no exercise vs. PLA: −0.9 ± 6.9 mmHg; $p = .013$, $d = –0.581$), with no difference in responses between the men ($p = .185$) and women ($p = .276$). As a result, the Δ MAP was also larger following NZBC (no exercise vs. NZBC: −3.5 ± 4.7 vs. no exercise vs. PLA: −1.4 ± 5.4; $p = .011$, $d = –0.598$), with no differences between men ($p = .106$) and women ($p = .245$).

Discussion

This study observed that blood pressure following 60 min of treadmill exercise at 50% VO_2max was decreased with NZBC extract, and these responses were similar in men and women. During the exercise, NZBC extract increased FATOX for men and women with a large effect; however, only women demonstrated a relationship between body fat percentage and magnitude of change in FATOX.

Substrate Utilization During Exercise

The increased FATOX following NZBC extract in the present study supports previous observations (Cook et al., 2015; Cook, Myers, Gault, Edwards et al., 2017; Şahin et al., 2022; Shan & Cook, 2023; Strauss et al., 2018; Willems et al., 2022). The novelty in the present study was that the presence of a cohort of men and women allowed direct comparison of responses in men and women, with women demonstrating a strong relationship between body fat percentage and magnitude of change of FATOX but not men.

Willems et al. (2022) demonstrated that FATOX increases during treadmill walking following NZBC extract intake in women were correlated to body composition of the trunk. Similarly, Şahin et al. (2022) demonstrated a correlation between body fat percentage and the absolute change in FATOX with NZBC extract in men in moderate-intensity treadmill walking.

The comparison of men and women is important, and this study found no relationship ($R = –0.079$) when analyzed together ($n = 22$); however, when separate ($n = 11$), the relationships between body fat

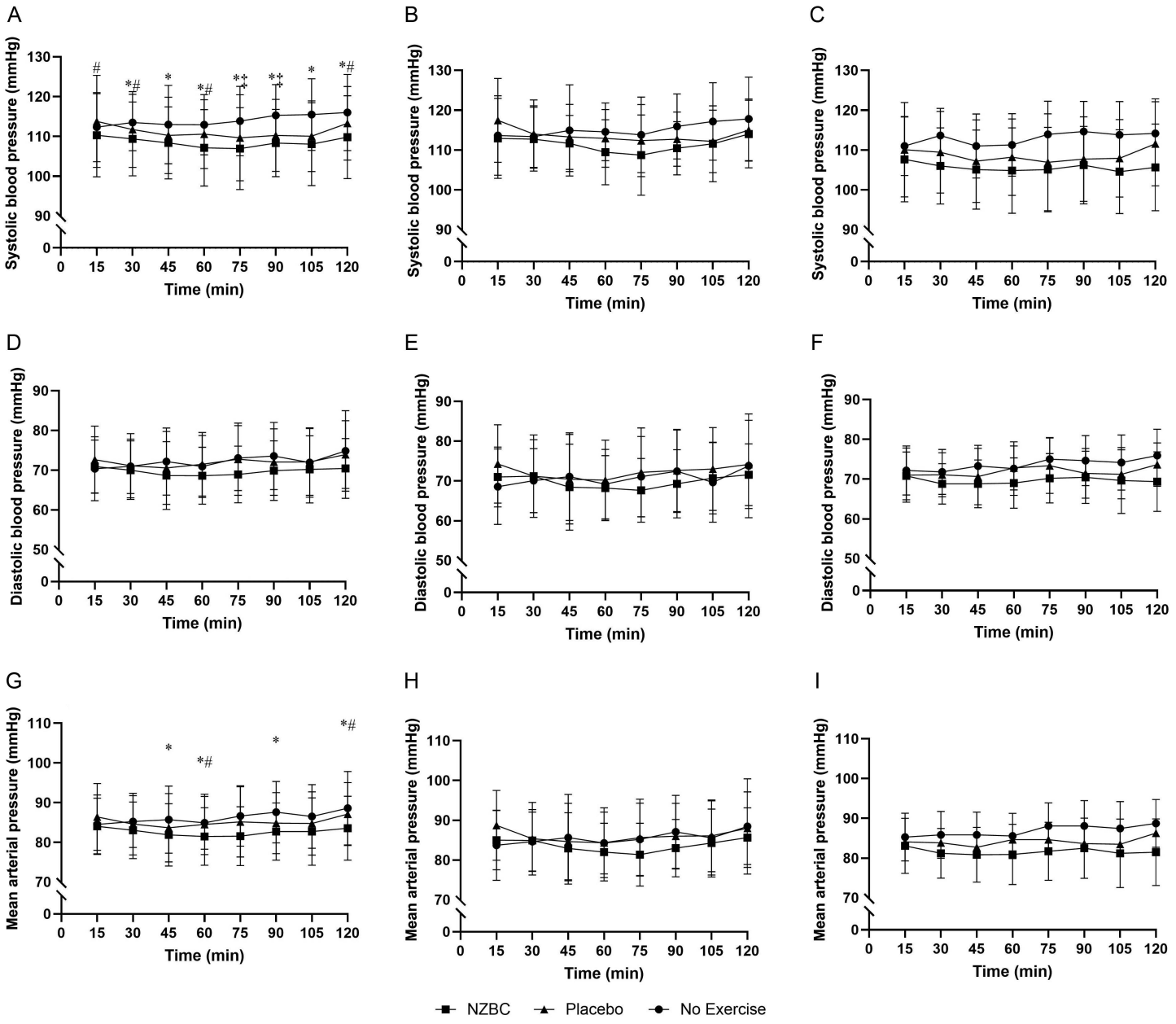

Figure 3 — (A) Combined systolic, (B) men systolic, (C) women systolic, (D) combined diastolic, (E) men diastolic, (F) women diastolic, (G) combined mean arterial pressure, (H) men mean arterial pressure, and (I) women mean arterial pressure in the no exercise condition and 120 min following exercise with NZBC extract or placebo. *No exercise different from NZBC extract; ‡no exercise different from placebo. #NZBC extract different from placebo. NZBC = New Zealand black currant extract.

percentage and magnitude of change in women become apparent. Factors pertaining to individuals responding or not responding are important for implementation of a supplement. Previous observations demonstrate variability in FATOX to NZBC extract, with women demonstrating higher responses. For example, Willems et al. (2022) observed that increased FATOX by NZBC extract in untrained physically active women ranged from 10%–66%, and Cook, Myers, Gault, Edwards et al. (2017) observed responses from 0%–44% in men cyclists (unpublished analysis). The mechanisms for the findings in the present study are not known but may relate to fat transport and metabolism. For example, women have greater FAT/CD36 in comparison with men at all levels of training (Kiens et al., 2004) and a higher ratio of maximal FATOX rate to fat-free mass (Randell et al., 2017). Therefore, these differences may explain the results observed in the present study. However, it should be recognized that a limitation was that there was no control for menstrual cycle status, phase, and use of contraception, and this should be implemented in future investigations.

Blood Pressure Responses

The larger decrease in postexercise blood pressure with NZBC extract repeats a previous observation (Shan & Cook, 2023), with a similar Δ SBP of −5.5 mmHg. However, to the authors' knowledge, this is the first study to compare responses between men and women, with no differences observed.

A consideration of this study is that blood pressure measurements were taken for 120 min following exercise under laboratory conditions in participants without hypertension. Postexercise blood pressure decrements can last for 24 hr in hypertensive men and women (Wallace et al., 1997), and it is not known whether the effects of NZBC extract on postexercise blood pressure also last for this duration or in free-living conditions. Furthermore, blood pressure reductions following physical activity are greatest in those with higher resting blood pressure (Pescatello et al., 2018). Therefore, it is also unclear whether NZBC extract-induced postexercise decrements would also work in those who are prehypertensive or hypertensive, and this should be examined in the future. Furthermore, there was no dietary control used within this study except caffeine and alcohol. Micronutrients such as sodium (Huang et al., 2020) are known to influence blood pressure; therefore, future studies must control this.

Similar to Shan and Cook (2023), the present study measured resting blood pressure in Visit 2 for 120 min with no exercise. Therefore, the SBP differences between the PLA and no exercise condition at 75, 90, and 105 min (Figure 3A) demonstrate that the exercise duration and intensity was sufficient to generate a decrease in blood pressure. The NZBC extract generated a greater decrease in blood pressure above the PLA condition with differences at 15, 30, 60, 90, and 120 min. However, the mechanisms are unclear and may be caused by an anthocyanin-induced increase in nitric oxide availability and arterial vasodilation. For example, in vitro observations demonstrate cyanidin-3-glucoside to increase the gene expression of nitric oxide synthase (Xu et al., 2004) and enter vascular endothelia smooth cells (Ziberna et al., 2012). However, to the authors' knowledge, there are no in vivo studies in humans that demonstrate a causal link between plasma anthocyanins or metabolites and arterial vasodilation. It should also be recognized that this study was powered to examine the metabolic changes between men and women and may be underpowered to detect sex differences in postexercise blood pressure.

Conclusions

A 7-day intake of NZBC extract increased FATOX during 60 min of moderate-intensity treadmill exercise in men and women, with the magnitude of responses correlated to body fat percentage in women but not in men. In the 120 min postexercise, NZBC extract caused a larger blood pressure decrement than PLA, and this response was not different between men and women.

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Nontechnical Summary

New Zealand Black currant extract (NZBC) is rich in the polyphenol anthocyanin and has recently been researched for its effects upon exercise performance and related physiological responses.

These responses include increasing the amount of fat used during exercise and lowering of blood pressure after exercise in men and women. The effect of NZBC on fat use during exercise has also been linked to body composition. However, no previous research has directly compared the responses of men and women within the same study.

In this study, 22 participants (11 men and 11 women, average age 29 years) had their resting blood pressure measured for 2 hr without exercise. They then took part in a double-blind, placebo-controlled trial wherein they exercised on a treadmill for an hour at moderate intensity, followed by 2 hr of resting blood pressure measurement. This was done after taking NZBC extract or a placebo for 7 days before. Participants also had their body composition measured.

The results showed that average fat usage was higher with NZBC compared with the placebo, but there was no difference between men and women.

Examining the men and women data together, there was no relationship between body fat percentage and usage of fat during exercise. However, when examining just the women, there was a relationship between body fat percentage and change in fat usage exercise so that those with a higher body fat percentage had a larger increase in fat usage during the exercise.

In the 2-hr rest period following the exercise, participants' blood pressure decreased. The drop in blood pressure was greater with NZBC than with the placebo, but again, there was no difference between men and women.

In summary, taking NZBC for 7 days increases fat usage during moderate-intensity exercise and lowers postexercise blood pressure in both men and women. The change in fat usage during exercise in women is related to their body fat percentage.