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ORIGINAL RESEARCH

No Effect of New Zealand Blackcurrant Extract on Recovery of Muscle Damage Following Running a Half-Marathon

Rianne Costello, Mark E.T. Willems, and Stephen D. Myers
University of Chichester

Fiona Myers
University of Portsmouth

Nathan A. Lewis
English Institute of Sport

Ben J. Lee and Sam D. Blacker
University of Chichester

New Zealand blackcurrant (NZBC) contains anthocyanins, known to moderate blood flow and display anti-inflammatory properties that may improve recovery from exercise-induced muscle damage. The authors examined whether NZBC extract supplementation enhances recovery from exercise-induced muscle damage after a half-marathon race. Following a randomized, double-blind, independent groups design, 20 (eight women) recreational runners (age 30 ± 6 years, height 1.73 ± 0.74 m, body mass 68.5 ± 7.8 kg, half-marathon finishing time 1:56:33 ± 0:18:08 hr:min:s) ingested either two 300-mg/day capsules of NZBC extract (CurraNZ™) or a visually matched placebo, for 7 days prior to and 2 days following a half-marathon. Countermovement jump performance variables, urine interleukin-6, and perceived muscle soreness and fatigue were measured pre, post, and at 24 and 48 hr after the half-marathon and analyzed using a mixed linear model with statistical significance set a priori at $p < .05$. The countermovement jump performance variables were reduced immediately post-half-marathon ($p < .05$), with all returning to pre-half-marathon levels by 48 hr, except the concentric and eccentric peak force and eccentric duration, with no difference in response between groups ($p > .05$). Urine interleukin-6 increased 48-hr post-half-marathon in the NZBC group only ($p < .01$) and remained unchanged compared with pre-half-marathon levels in the placebo group ($p > .05$). Perceived muscle soreness and fatigue increased immediately post-half-marathon ($p < .01$) and returned to pre-half-marathon levels by 48 hr, with no difference between groups ($p > .05$). Supplementation with NZBC extract had no effect on the recovery of countermovement jump variables and perceptions of muscle soreness or fatigue following a half-marathon in recreational runners.

Keywords: Anthocyanins, endurance exercise, inflammation, supplementation

Exercise-induced muscle damage (EIMD) occurs following exercise that involves eccentric contractions (Paulsen et al., 2012). A biphasic response to EIMD is typically observed, where initially metabolic and mechanical disruptions are followed by a secondary phase initiated by a disruption in intracellular Ca^{2+} homeostasis (Howatson & van Someren, 2008). Half-marathons have been shown to cause EIMD (Duthie et al., 1990; Withee et al., 2017). The magnitude of EIMD can be assessed through direct measures of structural damage and force deficits (Clarkson & Hubal, 2002; Warren et al., 1999) and via indirect markers measured systemically in plasma, such as creatine kinase and inflammatory cytokines (e.g., interleukin-6 [IL-6]) and muscle soreness (Clarkson & Hubal, 2002; Hyldahl & Hubal, 2014).

Recently, foods and supplements that are rich in polyphenols, such as berries and fruits, have been shown to enhance exercise performance and recovery (for a review see Cook & Willems, 2018). Montmorency tart cherry juice (MCJ) has been shown to enhance recovery of muscle function and reduce inflammation and lipid peroxidation following a marathon race (Howatson et al., 2009). However, beetroot juice supplementation did not affect recovery following a marathon race (Clifford et al., 2016). The difference may be related to the profile of the polyphenolic compounds, for example, the anthocyanins. Although the precise mechanisms are not clear, it has been speculated that anthocyanins may exert their recovery benefits by upregulating endothelial nitric oxide synthase activity, thus improving blood flow to the affected tissues (Cook & Willems, 2018). New Zealand blackcurrant (NZBC) is unique due to its high anthocyanin content and has been shown to enhance exercise performance (for a review see Cook & Willems, 2018) and recovery from EIMD (Coelho et al., 2017) in laboratory settings. The effects of NZBC extract on recovery following more ecologically valid events in the field, such as a half-marathon race, are not known.

The aim of this study was to examine the effect of NZBC extract supplementation taken before and following running a half-marathon race on markers of EIMD. It was hypothesized that NZBC extract, when compared with a placebo (PLA), would facilitate recovery by accelerating the return of muscle function, reducing muscle soreness and fatigue, and inhibiting the exercise-induced inflammatory cascade.

Costello, Willems, S.D. Myers, Lee, and Blacker are with the Institute of Sport, University of Chichester, Chichester, United Kingdom. F. Myers is with the Faculty of Science, School of Biological Sciences, University of Portsmouth, Portsmouth, United Kingdom. Lewis is with the English Institute of Sport, Bath, United Kingdom. Blacker (S.Blacker@chi.ac.uk) is corresponding author.

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Materials and Methods

Participants

Twelve healthy men and eight healthy women (Table 1) who were runners taking part in the 2018 Chichester half-marathon (Chichester, United Kingdom) volunteered to participate in the study. Based on a similar previous study focusing on recovery with a polyphenol-rich supplement following a running event (Clifford et al., 2016), established on countermovement jump (CMJ) height, we calculated (G*Power; Faul, Erdfelder, Lang, & Buchner, 2007) that, at 80% power and an α of .05, at least eight volunteers were required, to detect a group difference of 5% (using change from pre-half-marathon data; 3.5% *SD*) at any time points post the half-marathon event. The participants completed a health history questionnaire, were nonsmokers, had no known food allergies, and were not taking anti-inflammatory therapies. The females completed a menstrual cycle questionnaire (Köhne et al., 2016). The participants abstained from strenuous exercise and alcohol for 48 hr prior and caffeine-containing products on the day of the half-marathon. The participants were also asked to avoid all additional means that could affect recovery and adhere to their normal activity schedule. The study was approved by the University of Chichester Research Ethics Committee, with protocols and procedures conforming to the 2013 Declaration of Helsinki.

Experimental Design

The study followed a double-blind, PLA-controlled, randomized, independent-groups study design. The groups were matched according to predicted half-marathon finish times by pairing participants with equivalent times (Clifford et al., 2016; Howatson et al., 2009). Blinding of the PLA and supplement was carried out by an independent researcher who had no involvement with this investigation. Packets were made up with visually identical NZBC and PLA capsules for each participant and labeled with a random letter.

Table 1 Descriptive Data of the Volunteer Half-Marathon Runners in the NZBC and PLA Groups

Participant characteristics	NZBC (*n* = 10)	PLA (*n* = 10)
Age (years)	30 ± 4	29 ± 7
Sex (M/F)	6/4	6/4
Height (m)	1.72 ± 0.78	1.74 ± 0.67
Body mass (kg)	69.0 ± 8.1	68.0 ± 7.8
Estimated female menstrual cycle phase		
Luteal	3	2
Follicular	1	2
Years running	6 ± 5	11 ± 5
Average weekly mileage	12 ± 8	14 ± 7
Longest training run (miles)	11 ± 6	11 ± 6
Previous half-marathons	5 ± 3	6 ± 4
Predicted finish time (hr:min:s)	1:56:30 ± 0:15:40	1:58:18 ± 0:22:52
Actual finish time (hr:min:s)	1:58:12 ± 0:17:53	1:54:54 ± 0:18:15
Average heart rate (bpm)	166 ± 16	162 ± 27

Note. Values are presented as mean ± *SD*, *n* = 20. NZBC = New Zealand blackcurrant; PLA = placebo; M = male; F = female; bpm = beats per minute.

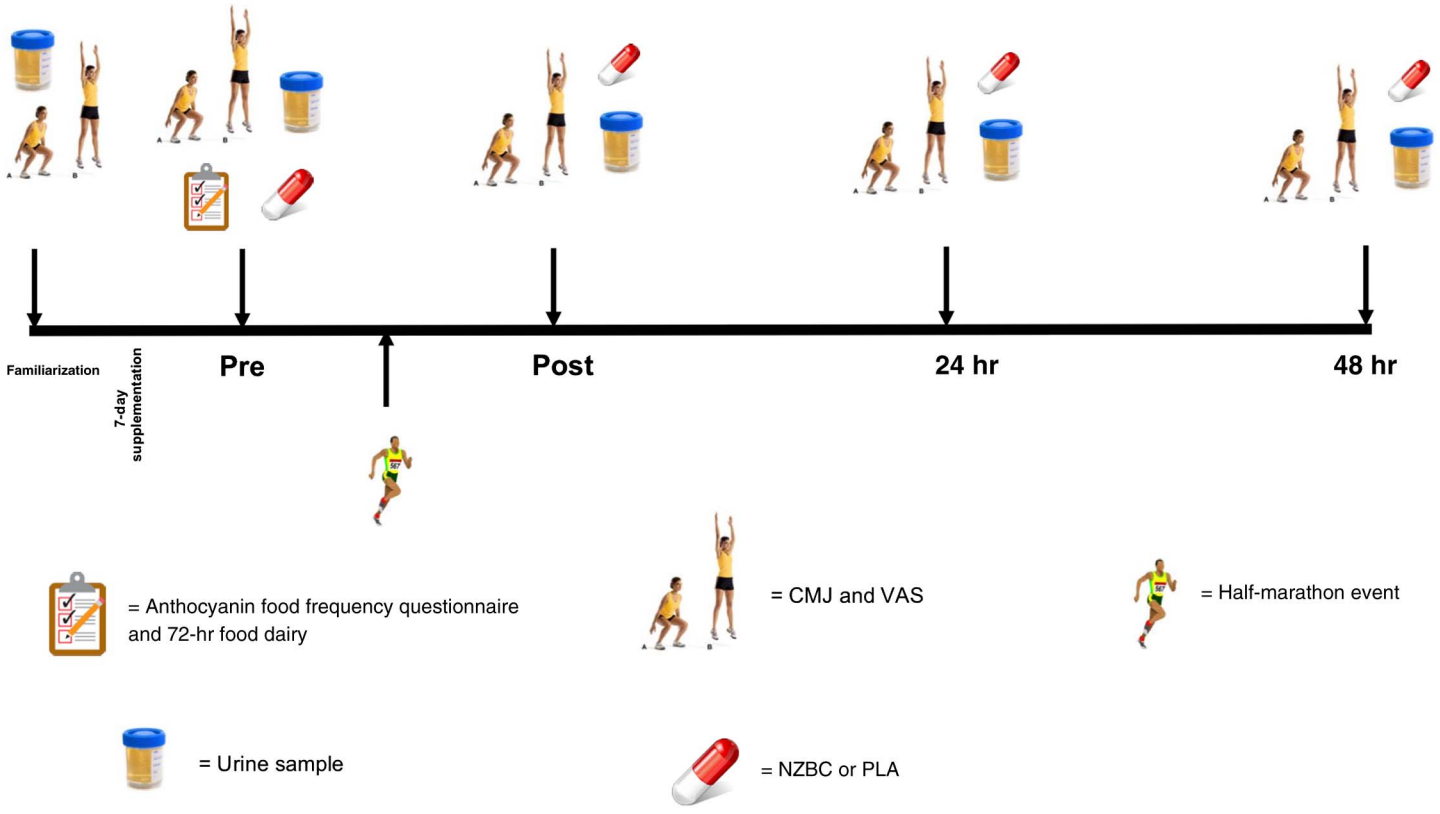

Figure 1 — Study design. CMJ = countermovement jump; VAS = visual analog scales; NZBC = New Zealand blackcurrant; PLA = placebo.

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Each participant in a matched pair was randomly assigned to one of the letters and provided with that packet of capsules. The blinding codes were revealed following data analysis. The participants completed one familiarization visit and four experimental visits: pre- and immediately post-half-marathon (in the race holding area), 24 hr, and 48 hr (laboratory; Figure 1). For the familiarization visit, the participants were briefed on the study, explained all the procedures, and had their height and body mass recorded. The CMJ, visual analog scales for muscle soreness and fatigue, and a urine sample were completed in this order during each experimental visit. Heart rate was collected during the half-marathon (Polar Team 2; Polar Electro Ltd., Warwick, United Kingdom) and race distance was confirmed using GPS (Polar M430 GPS; Polar Electro Ltd.).

Half-Marathon

The half-marathon took place on October 19, 2018, in Chichester (West Sussex, United Kingdom). The course was mostly flat, across a mix of concrete terrain, grass, and chalk. However, miles 4–8 consisted of a steep incline and decline (total route ascent: 239 m; total route descent: 232 m). At the start of the race at 9:00, the air temperature was 8 °C, humidity 81%, barometric pressure 1,023 hPa, and air speed 10 miles/hr. It remained dry and mostly overcast, with intermittent sunny spells for the duration of the race.

Supplementation Protocol

The participants ingested two capsules of NZBC extract (2 × 300 mg CurraNZ™), each containing 105 mg of anthocyanins (CurraNZ™; Health Currancy Ltd., Surrey, United Kingdom), or two capsules of identical-looking PLA capsules (2 × 300-mg microcrystalline cellulose M102; CurraNZ™) with breakfast every morning for 7 days and 2 days following the half-marathon. On the morning of the half-marathon, the participants consumed their supplement 2 hr prior to starting the race. This supplementation regime was based on previous work, where anthocyanins peak in systemic circulation ~2 hr after ingestion (Matsumoto et al., 2005). Full compliance with intake was achieved. Blinding was not broken until after the analysis was completed, and a follow-up questionnaire revealed that 40% of the participants accurately guessed which supplementation they had received.

Dietary Intake

For ecological validity, the participants maintained their habitual diet prior to and post the half-marathon (Bowtell & Kelly, 2019) and recorded their 72-hr dietary intake in food diaries, which were analyzed (Nutritics Ltd., Dublin, Ireland) for carbohydrate, fat and protein, and total energy intake. The habitual anthocyanin food frequency questionnaire recorded the amount and frequency of anthocyanin-containing foods eaten within the last 3 months from the Phenol-Explorer database (Neveu et al., 2010). The intake of anthocyanin was calculated as the sum of the consumption frequency of each anthocyanin-containing food, multiplied by the content of the anthocyanin content for the portion sizes.

Indices of Muscle Function

The CMJ were performed on a force plate (PASPORT force plate, PS-2141; PASCO Scientific Inc., Roseville, CA) sampling at 1000 Hz (Lake et al., 2018). The participants were instructed to jump as high and as fast as possible, without specific information on squat depth to avoid altering natural jump patterns (Jidovtseff et al., 2014). Three maximal efforts were performed, separated by 30 s of passive (standing) recovery. Outcome variables jump height (JH), reactive strength index modified (RSImod), time to takeoff, concentric phase average peak force, net impulse, power, and duration, and eccentric phase average peak force, net impulse, displacement (braking phase), and duration are reported (Gathercole et al., 2015). The neuromuscular variables are expressed relative to body mass, and the outcome variables JH and RSImod are expressed as a percentage change from pre-half-marathon levels to account for interindividual variability. The coefficient of variation for the outcome variables JH, RSImod, and time to takeoff was 6%, 9%, and 6%, respectively.

Muscle Soreness and Fatigue

While in a 90° squat position, the participants rated their self-perceived muscle soreness and fatigue using 0–10 visual analog scales, where 0 represented *no soreness* and 10 represented *extreme soreness* and 0 represented *no fatigue* and 10 represented *extreme fatigue*, respectively (Jakeman et al., 2017).

Urine Sampling, Handling, and Biochemical Analysis

Second evacuation, midstream urine samples were collected into 50-ml Falcon® conical tubes. At all four time points (pre, post, 24 hr post, and 48 hr post), urine was collected and kept on ice for no more than 2 hr prior to being centrifuged at 1,000*g* for 10 min. The urine was subsequently stored in 2-ml aliquots at −80 °C and thawed on the morning of the analysis. Urinary IL-6 concentration was determined in duplicate using a quantitative sandwich enzyme immunoassay ELISA technique (Quantikine; R&D Systems Europe Ltd., Abingdon, United Kingdom). Normal reference ranges for this assay are reported at <3 pg/ml. The urine intra- and interassay precision determined by coefficient of variation was 4%. Urinary cytokine levels were expressed as ratios of IL-6 to creatinine (pg/mg creatinine) to avoid dilution effects, to be able to compare results from different participants, and to standardize the samples in light of differences in postrace hydration status. Urine creatinine was measured using a colorimetric assay (CR510; Randox, County Antrim, Northern Ireland).

Data Analysis

Statistical analyses were completed using GraphPad Prism (version 8.0; GraphPad Software, Inc., San Diego, CA). The dependent variables (CMJ, visual analog scales, and IL-6 analyses) were analyzed using a mixed linear model with two independent group levels (NZBC vs. PLA) and four repeated-measures time points (pre, post, 24 hr post, and 48 hr post). The Shapiro–Wilks test was used to check homogeneity of variance for all variables, and any violations of the assumption were corrected using the Greenhouse–Geisser adjustment. Significant main effects or interactions were assessed using the Bonferroni adjustment post hoc analysis. The alpha level for statistical significance was set at .05 a priori. All data are reported as mean ± *SD* for $n = 10$ for each group, unless otherwise stated.

Results

The half-marathon finish times did not differ between groups ($p = .67$). The average energy intake (in kilojoules) in the day before the half-marathon until the cessation of the study did not differ between

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groups ($p = .90$), nor did the proportions coming from carbohydrate ($p = .51$), protein ($p = .36$), or fat ($p = .63$). Habitual anthocyanin intake did not differ between groups ($p = .99$; Table 2).

Indices of Muscle Function

The CMJ outcome variables (JH and RSImod) and neuromuscular variables (concentric average relative peak force, concentric net impulse, concentric average power, eccentric average relative peak force, and eccentric net impulse) showed a main effect of time ($p < .01$), indicating muscle damage after the half-marathon (Figure 2a and 2b; Table 3). Relative to pre-half-marathon levels, JH and RSImod decreased to a similar extent in the NZBC and PLA groups immediately post-half-marathon (91.3 ± 11.5% vs. 85.6 ± 19.5%, respectively) and returned to the pre-half-marathon values by 24 hr (97.2 ± 11.1% vs. 101.6 ± 10.7%, respectively). Apart from time to takeoff, no group or interaction effects were present at any time point for any of the CMJ outcome or neuromuscular variables (all $ps > .05$; Table 3).

Table 2 Absolute and Relative to Body Mass Average Daily Macronutrient Intake Prior to and for 2 Days Following the Half-Marathon and Habitual Anthocyanin Intake as Indicated From the Anthocyanin Food Frequency Questionnaire

Nutritional component	NZBC	PLA
Total energy intake (kJ)	9,091 ± 3,319	8,903 ± 2,198
(kJ·kg body mass^{-1})	133 ± 46	134 ± 38
Carbohydrate (g)	226 ± 73	249 ± 68
(g·kg body mass^{-1})	3.3 ± 1.1	3.8 ± 1.1
Protein (g)	107 ± 37	92 ± 23
(g·kg body mass^{-1})	1.6 ± 0.5	1.4 ± 0.4
Fat (g)	93 ± 46	84 ± 23
(g·kg body mass^{-1})	1.3 ± 0.6	1.3 ± 0.4
Habitual anthocyanin intake (mg/day)	153 ± 122	172 ± 81

Note. Values are presented as mean ± *SD*, $n = 10$ per group. NZBC = New Zealand blackcurrant; PLA = placebo.

Muscle Soreness and Fatigue

Muscle soreness and fatigue both showed a main effect of time ($p < .01$ and $p < .01$, respectively; Figure 3a and 3b). However, no group or interaction effects were present at any time point for muscle soreness or fatigue ($p > .05$).

Inflammatory Cytokine Response

At 48 hr after the half-marathon, IL-6 urine concentrations corrected to creatinine increased compared with pre-half-marathon levels in the NZBC group only ($p < .01$) and remained unchanged at all time points in the PLA group compared with pre-half-marathon levels ($p > .05$). No time or interaction effects were present ($p > .05$; Figure 4).

Discussion

This is the first study to investigate the effect of NZBC extract supplementation on recovery from EIMD following a half-marathon running race. However, contrary to our hypothesis, NZBC extract did not affect the recovery of muscle function, reduce muscle soreness, or attenuate the acute inflammatory response in the 48 hr after the half-marathon.

The reduction in the CMJ variables (concentric phase average peak force, net impulse, and average power, and eccentric phase average peak force and average duration) immediately and in the days after the half-marathon running race demonstrated that the event caused EIMD. However, the similar response for each condition over time indicates that NZBC extract did not affect postrace muscle recovery. The lack of an observable difference between groups may be due to the half-marathon race only inducing modest changes in all of the CMJ outcome and neuromuscular variables. Future research could investigate whether NZBC extract is able to modulate declines in contractile properties following exercise with a greater effect on EIMD.

The results of the present study are in contrast with the previous ones where anthocyanin-rich supplements were provided following running exercise. Howatson et al. (2009) showed that an MCJ supplement enhanced the recovery of muscle function following a marathon and observed an attenuation of biomarkers of

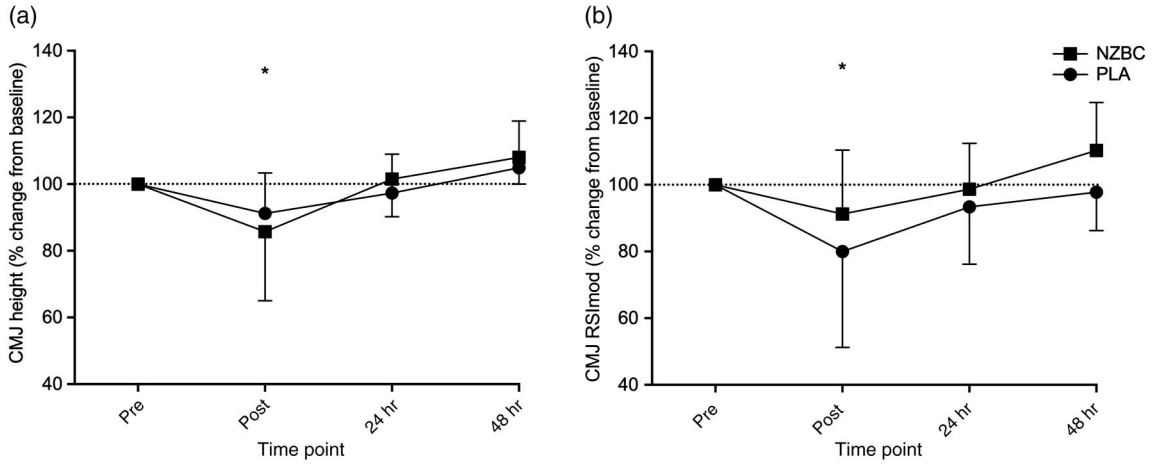

Figure 2 — (a) Percentage change from pre-half-marathon in CMJ height and post-half-marathon (*pre to post; $p < .01$). (b) Percentage change from pre-half-marathon in RSImod and post-half-marathon (*pre to post; $p < .01$). Values are presented as mean ± *SD* ($n = 10$). RSImod = reactive strength index modified; CMJ = countermovement jump; NZBC = New Zealand blackcurrant; PLA = placebo.

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Table 3 Indices of Muscle Function and Damage for Both NZBC and PLA Groups Before and Following Half-Marathon Race

CMJ variable	Pre-half-marathon	Post-half-marathon	24-hr post-half-marathon	48-hr post-half-marathon
Time to take off (s)[a]				
NZBC	0.96 ± 0.12	1.03 ± 0.20	0.95 ± 0.13	0.91 ± 0.11
PLA	0.93 ± 0.17	0.98 ± 0.16	1.02 ± 0.17	1.03 ± 0.19
Concentric phase peak force (N·kg)*				
NZBC	11.32 ± 1.56	10.40 ± 1.72	10.16 ± 2.02	10.51 ± 1.99
PLA	11.33 ± 3.34	10.32 ± 2.07	10.05 ± 2.04	10.03 ± 2.27
Concentric phase net impulse (Ns·kg)*				
NZBC	2.06 ± 0.36	1.94 ± 0.28	2.02 ± 0.32	2.10 ± 0.31
PLA	2.06 ± 0.33	1.87 ± 0.28	2.06 ± 0.25	2.13 ± 0.27
Concentric phase average power (W·kg)*				
NZBC	20.06 ± 4.31	17.98 ± 3.35	18.99 ± 4.04	19.83 ± 3.66
PLA	19.81 ± 4.03	16.64 ± 3.29	20.68 ± 6.56	19.78 ± 4.39
Concentric phase average duration (s)				
NZBC	0.32 ± 0.05	0.32 ± 0.06	0.33 ± 0.06	0.32 ± 0.05
PLA	0.33 ± 0.06	0.33 ± 0.06	0.34 ± 0.07	0.33 ± 0.07
Eccentric phase peak force (N·kg)				
NZBC	10.16 ± 2.16	7.12 ± 1.14***	7.99 ± 1.41***	8.42 ± 1.68***
PLA	10.79 ± 3.56	6.49 ± 1.30***	7.24 ± 1.73***	7.97 ± 2.56***
Eccentric phase net impulse (Ns·kg)				
NZBC	1.01 ± 0.26	0.89 ± 0.20**	0.94 ± 0.23	0.98 ± 0.20
PLA	1.06 ± 0.20	0.77 ± 0.13**	0.83 ± 0.16	0.91 ± 0.15
Eccentric phase displacement, braking phase (m)*				
NZBC	0.21 ± 0.03	0.26 ± 0.05	0.24 ± 0.05	0.23 ± 0.04
PLA	0.30 ± 0.17	0.29 ± 0.08	0.27 ± 0.06	0.30 ± 0.10
Eccentric phase average duration (s)*				
NZBC	0.21 ± 0.03	0.26 ± 0.05	0.24 ± 0.05	0.23 ± 0.04
PLA	0.25 ± 0.06	0.29 ± 0.08	0.27 ± 0.06	0.30 ± 0.10

Note. Values are presented as mean ± *SD*, $n = 10$ per group. NZBC = New Zealand blackcurrant; PLA = placebo.
[a]Time × Supplement interaction ($p = .02$).
*Main effect of time, but not statistically significant when Bonferroni correction applied ($p > .05$). **Elevated above pre-half-marathon levels at immediately post (time effect, $p < .05$). ***Elevated above pre-half-marathon levels immediately post, 24 hr post, and 48 hr post (time effect, $p < .05$). No other group or interaction effects observed ($p > .05$).

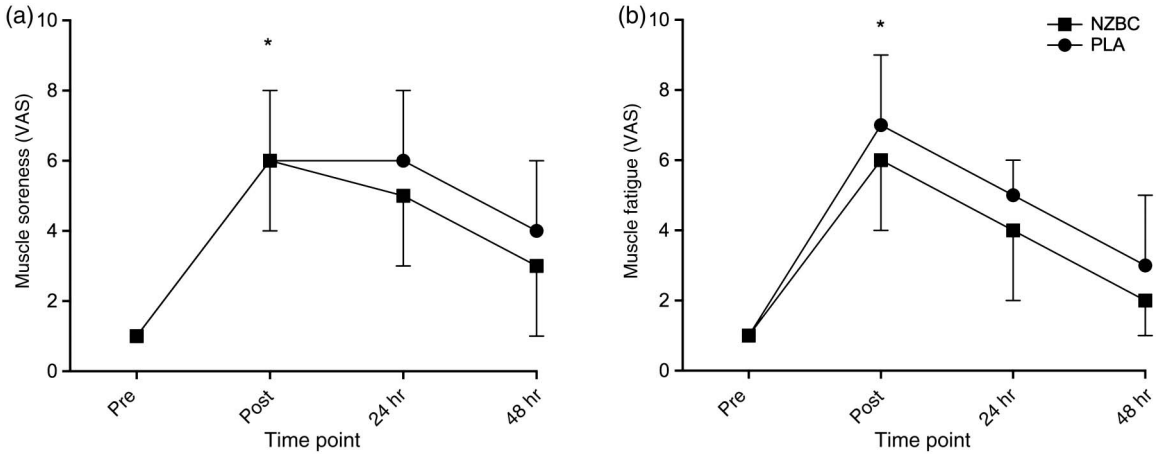

Figure 3 — (a) Muscle soreness ratings pre and post half-marathon (*pre to post; $p < .01$). (b) Muscle fatigue ratings pre and post half-marathon (*pre to post; $p < .01$). Values are presented as mean ± *SD* ($n = 10$ per group). VAS = visual analog scale; NZBC = New Zealand blackcurrant; PLA = placebo.

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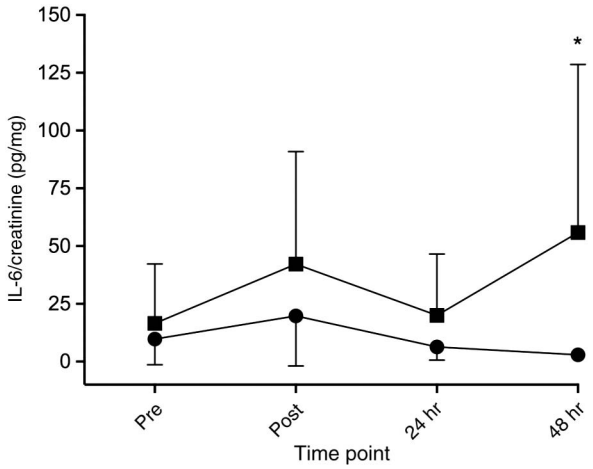

Figure 4 — IL-6 urine concentrations with creatinine correction pre and post half-marathon (*pre to 48 hr; $p < .01$). Values are presented as mean ± *SD* ($n = 10$ per group). IL-6 = interleukin-6; NZBC = New Zealand blackcurrant; PLA = placebo.

inflammation (serum C-reactive protein, IL-6, and uric acid) and oxidative stress (thiobarbituric acid reactive species) in the 48 hr following the marathon, effects that were associated with an accelerated recovery of muscle function as determined by maximal voluntary isometric contraction. The differences in the findings between the present study and Howatson et al.'s (2009) study may be attributable to the different anthocyanins in each supplement, the mode of delivery (capsules vs. juice), and the exercise protocol (half-marathon vs. marathon). Supplements were provided before and after the half-marathon, both in the present study (7 days pre, 2 days post) and in Howatson et al.'s (2009) study (5 days pre, 3 days post). The NZBC in the present study was provided in capsules containing 210 mg of anthocyanins per day, and the main anthocyanin was delphinidin-3-rutinoside (Rothwell et al., 2013). In contrast, MCJ was provided in a juice containing 80 mg of anthocyanins per day, and the main anthocyanin was cyanidin-3-glucosylrutinoside (Howatson et al., 2009). In vitro models have demonstrated that cyanidin-3-glucoside upregulates endothelial nitric oxide synthase activity (Edwards et al., 2015). As the main anthocyanin in NZBC is delphinidin-3-rutinoside, it is possible that the cyanidin-3-glucoside in MCJ is better able to upregulate endothelial nitric oxide synthase activity, thus influencing blood flow through flow-mediated dilation (Cook et al., 2017) during strenuous exercise and reducing the susceptibility to injury (Jones et al., 2017). Furthermore, polyphenol scavenging has been purported as a potential mechanism by which polyphenols could help support redox status by dampening the oxidative stress response following EIMD (Powers & Jackson, 2008). However, this notion has recently been debated, with polyphenol metabolism to electrophiles and a cytoprotective endogenous antioxidant response via nuclear factor erythroid 2-related factor 2 (Nrf-2) signaling having been suggested as a more plausible mechanism (Owens et al., 2018).

However, other studies have also reported no benefit from supplementation with nitrate-rich, beetroot juice (Clifford et al., 2016) and anthocyanin-rich, bilberry juice (Lynn et al., 2018) on markers of EIMD following marathon and half-marathon running, respectively. Clifford et al. (2016) observed that beetroot juice supplemented for 3 days following a marathon was unable to attenuate declines in CMJ and maximal voluntary isometric contraction, and elevations in markers of inflammation (leucocytes, neutrophils, monocytes, high-sensitivity C-reactive protein, IL-1ra, IL-2, IL-4, IL-6, IL-8, IL-10, TNF-alpha, and interferon-γ). On the other hand, Lynn et al. (2018) concluded that consumption of bilberry juice 5 days prior to, on race day, and for 2 days following a half-marathon evoked moderate increases in exercise-induced muscle soreness and markers of inflammation (C-reactive protein) and muscle damage (determined by creatine kinase concentrations). Similarly, the lack of benefit observed may be attributable to the different supplementation strategies used (beetroot juice 3 days following the marathon only vs. bilberry juice 5 days prior to, on race day, and 2 days following the half-marathon), leading to different biological activities of the phytonutrients.

Using a different exercise model, Coelho et al. (2017) examined the effect of NZBC extract on recovery from EIMD induced by 60 maximal eccentric contractions of the biceps brachii in 13 healthy young women. No effects on muscle function and plasma IL-6 were reported, but muscle soreness and serum creatine kinase were attenuated in the recovery period with NZBC. Compared with the present study, differences in exercise protocol (half-marathon vs. repeated isolated forearm flexor exercise), techniques used to quantify EIMD (CMJ vs. maximal voluntary isometric contraction), and participant characteristics (mixed men and women vs. women only) between the present study and Coelho et al. (2017) are all factors that could provide a potential explanation for these equivocal findings.

Urinary IL-6 has previously been observed to increase following long-distance running events (Mrakic-Sposta et al., 2015; Sugama et al., 2013). However, there was no increase in IL-6 immediately post and 24 hr after the half-marathon for either PLA or NZBC (Figure 4). Large interindividual variability was present due to the data of four participants skewing the NZBC group average. These data suggest that IL-6 is unlikely to have a significant role in the secondary damage process in the days after a half-marathon in recreational runners. The increase in urine IL-6 observed at 48 hr in the NZBC only could be indicative of the known anti-inflammatory role of the cytokine. However, this is purely speculative without a broader range of biomarkers indicative of pro- and anti-inflammation and oxidative stress response to compare with (Owens et al., 2018).

A limitation of the present study was that the participants were not provided with standardized meals prior to and immediately following the half-marathon event. As the participants appeared to have low habitual carbohydrate intake compared with the recommended guidelines of 6–10 $g \cdot kg^{-1} \cdot day^{-1}$ (Thomas et al., 2016), it is possible that this may have influenced our results. Future research should look to implement standardized meals to ensure that the optimal intake of macronutrients prior to exercise are met. Furthermore, the participants were permitted to maintain their habitual anthocyanin intake in an effort to increase the ecological validity of the findings. However, it is possible that, by increasing ecological validity, we may have limited our ability to detect any meaningful benefit of NZBC extract supplementation on recovery.

In conclusion, NZBC extract supplementation for 7 days prior to and 2 days following a half-marathon does not affect the recovery of muscle function, muscle soreness and fatigue, or markers of inflammation in recreational half-marathon runners.

Novelty Statement

- This is the first study where NZBC extract supplementation has been assessed for its potential as a recovery aid in an ecologically valid setting following half-marathon running in

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recreational runners. However, the present study suggests that NZBC supplementation has no effect on the recovery of EIMD parameters in recreational runners following a half-marathon.

Practical Applications

- NZBC did not improve the recovery of markers of EIMD following a half-marathon event, but no negative effects of supplementation were found.
- Utilizing CMJ neuromuscular variables provides greater insight and sensitivity into how participants may adopt a different CMJ strategy following half-marathon running, potentially highlighting aspects of relevance to real-world sporting performance that may be masked when only considering variables such as JH.

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