**Title: New Zealand blackcurrant does not accelerate recovery from exercise induced muscle damage following half marathon running**

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**Running head:** Blackcurrant effects on recovery following a half-marathon race

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**Abstract**

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 (EIMD). We examined whether NZBC extract supplementation enhances recovery from EIMD after a half-marathon race. Following a randomized, double-blind, independent groups design, 20 (8 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 h:min:s) ingested either two 300 mg·day$^{-1}$ capsules of NZBC extract (CurraNZ™) or a visually matched placebo (PLA), for 7-days prior to and 2-days following a half-marathon. Countermovement jump (CMJ) performance variables, urine interleukin-6 (IL-6), perceived muscle soreness and fatigue were measured pre-, post-, and at 24 h and 48 h after the half-marathon and analysed using a mixed linear model with statistical significance set a priori at $P<0.05$. The CMJ performance variables were reduced immediately post-half-marathon ($P<0.05$) with all returning to pre half-marathon by 48 h except concentric and eccentric peak force and eccentric duration, with no difference in response between groups. Creatinine corrected urine IL-6 increased 48 h post-half-marathon in the NZBC group only ($P=0.01$) and remained unchanged compared to pre half-marathon in PLA group ($P>0.05$). Perceived muscle soreness and fatigue increased immediately post-half-marathon and returned to pre half-marathon by 48 h, with no difference between groups. Supplementation with NZBC extract had no effect on recovery of CMJ variables, perceptions of muscle soreness or fatigue following a half-marathon in recreational runners, possibly because the event only induced modest EIMD.

**Keywords.** Anthocyanins, muscle damage, endurance exercise, inflammation, supplementation

## Introduction

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 (Warren et al. 1999; Clarkson & Hubal. 2002) and via indirect markers measured systemically in plasma such as creatine kinase (CK) and inflammatory cytokines (e.g. interleukin-6 (IL-6)) and muscle soreness (Hydahl & Hubal. 2014; Clarkson & Hubal. 2002).

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 by increasing reducing inflammation, lipid peroxidation and muscle function 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, e.g. 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 (eNOS) 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 to placebo (PLA), would facilitate recovery, by accelerating the return of muscle function, reducing muscle soreness and fatigue, and inhibiting the exercise-induced inflammatory cascade.

## 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, UK 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), based on Counter Movement Jump (CMJ) height we calculated (G*Power) that at 80% power, and an α of 0.05, 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. Participants completed a health history questionnaire, were non-smokers, had no known food allergies and were not taking anti-inflammatory therapies. Females completed a menstrual cycle questionnaire (Köhne et al. 2016). Participants abstained from strenuous exercise and alcohol for 48 h prior, and caffeine-containing products on the day of the half-marathon. 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 Research Ethics Committee with protocols and procedures conforming to the 2013 Declaration of Helsinki.

***Insert **Table 1** near here***

*Experimental design*

The study followed a double-blind, placebo-controlled, randomised, independent-groups study design. Groups were matched according to predicted half-marathon finish times by pairing participants with equivalent times (Howatson et al. 2009; Clifford et al. 2016). Blinding of the placebo 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 placebo capsules for each participant and labelled with a random letter. 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. Participants completed one familiarisation visit, and four experimental visits pre- and immediately post-half-marathon (in the race holding area), 24 and 48 h (laboratory) (**Figure 1**). For the familiarisation visit, participants were briefed on the study, explained all the procedures and had their height and body mass recorded. Countermovement jumps (CMJ), visual analogue scales (VAS) 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, UK) and race distance confirmed using GPS (Polar M430 GPS, Polar Electro Ltd, UK).

***Insert **Figure 1** near here***

*Half-marathon*

The half-marathon took place on 19th October 2018 in Chichester (West Sussex, UK). The course was mostly flat, across a mix of concrete terrain, grass and chalk. However, mile 4 to 8 consisted of a steep incline and decline (total route ascent: 239 m; total route descent: 232 m). At race start at 9:00, the air temperature was 8°C, humidity 81%, barometric pressure 1023 hPa, and air speed 10 mph. It remained dry and mostly overcast with intermittent sunny spells for the duration of the race.

*Supplementation protocol*

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

*Dietary intake*

For ecological validity, participants maintained their habitual diet prior to and post- the half-marathon (Bowtell & Kelly. 2019) and recorded their 72 h dietary intake in food diaries which were analysed (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 three months from the Phenol Explorer database (Neveu et al. 2010). The intake of anthocyanin was calculated as

159 the sum of the consumption frequency of each anthocyanin containing food, multiplied by
160 the content of the anthocyanin content for the portion sizes.
161
162 *Indices of muscle function*
163 Countermovement jumps (CMJ) were performed on a force plate (PASPORT force plate,
164 PS-2141, PASCO Scientific, California, USA) sampling at 1000 Hz (Lake et al. 2018).
165 Participants were instructed to jump as high and as fast as possible, without specific
166 information on squat depth to avoid altering natural jump patterns (Jidovtseff et al. 2014).
167 Three maximal efforts were performed, separated by 30 seconds of passive (standing)
168 recovery. Outcome variables; jump height (JH), reactive strength index modified (RSImod),
169 time to take-off (TTT), concentric phase average peak force, net impulse, power, duration
170 and eccentric phase average peak force, net impulse, displacement (braking phase),
171 duration are reported (Gathercole et al. 2015). Neuromuscular variables are expressed
172 relative to body mass and outcome variables JH and RSImod are expressed as a
173 percentage change from pre-half marathon to account for inter-individual variability. The
174 Coefficient of Variation (CV) for the outcome variables, JH, RSImod and TTT was 6, 9 and 6
175 %, respectively.
176
177 *Muscle soreness and fatigue*
178 Whilst in a 90$^{o}$ degree squat position, participants rated their self-perceived muscle soreness
179 and fatigue were using a 0-10 VAS, where 0 represented “no soreness” and 10 represented
180 “extreme soreness” and 0 represented “no fatigue” and 10 represented “extreme fatigue”,
181 respectively (Jakeman et al. 2017).
182
183 *Urine sampling, handling and biochemical analysis*
184 Second evacuation, mid-stream urine samples were obtained into 50 mL Falcon® conical
185 tubes. At all 4 time points (pre half-marathon, post half-marathon, 24 h and 48 h), urine was
186 collected and kept on ice for no more than 2 h prior to being centrifuged at 1000 *g* for 10

minutes. The urine was subsequently stored in 2 mL aliquots at -80 ºC 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, UK). Normal reference ranges for this assay are reported at < 3 pg/mL. The urine intra- and inter-assay precision determined by CV 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 post-race 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 V8 (Graphpad software, San Diego, California). Dependent variables (CMJ, VAS and IL-6 analyses) were analysed using a mixed linear model with two independent group levels (NZBC vs. PLA) and four repeated measures time points (pre, post, 24 and 48 h post). Homoscedasticity plots were used to check homogeneity of variance for all variables and any violations of the assumption were corrected using the Greenhouse-Geisser adjustment. In order to control for the false discovery rate and correct for multiple comparisons, three families of hypothesis were tested according to the procedures of Benjamini and Hochberg (1995); (1) CMJ outcome and performance variables; (2) Self perceptual muscle soreness and fatigue; and (3) Creatinine corrected urine IL-6 concentrations; as post-hoc procedure. The alpha level for statistical significance was set at 0.05 a priori. All data are reported as mean ± SD for $n$ = 10 for each group, unless otherwise stated.

**Results**

Half-marathon finish times did not differ between groups ($P$=0.67). Average energy intake (KJ) in the day before the half-marathon until the cessation of the study did not differ between groups ($P$=0.90) nor did the proportions coming from carbohydrate ($P$=0.51),

protein (*P*=0.36) or fat (*P*=0.63). Habitual anthocyanin intake did not differ between groups (*P*=0.99) (**Table 2**).

***Insert **Table 2** near here***

*Indices of muscle function*

Countermovement jump (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, eccentric net impulse) showed a main effect of time (*P*<0.01), indicating muscle damage after the half-marathon (**Figures 2a, 2b; Table 3**). Relative to pre-half marathon, 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 had returned to pre half-marathon values by 24 h (97.2 ± 11.1 vs 101.6 ± 10.7 %, respectively). No group or interaction effects were present at any time point for any of the CMJ outcome or neuromuscular variables (all *P*>0.05) (**Table 3**).

***Insert **Table 3** near here***

*Muscle soreness and fatigue*

Muscle soreness and fatigue both showed a main effect of time (*P*=0.01 and *P*=0.01, respectively) (**Figures 3a, 3b**). However, no group or interaction effects were present at any time point for muscle soreness or fatigue (*P*>0.05).

*Inflammatory cytokine response*

At 48 h after the half-marathon, IL-6 urine concentrations corrected to creatinine increased compared to pre-half marathon in the NZBC group only (time effect; *P*=0.01) and remained unchanged at all time points in the placebo group compared to pre-half marathon (*P*>0.05). No group or interaction effects were present (*P*>0.05) (**Figure 4**).

243

244 ***Insert **Figure 2a, 2b, 3a, 3b, 4** near here***

245

246

247 **Discussion**

248 This is the first study to investigate the effect of NZBC extract supplementation on recovery
249 from EIMD following a half-marathon running race. However, contrary to our hypothesis,
250 NZBC extract did not affect the recovery of muscle function, reduce muscle soreness or
251 attenuate the acute inflammatory response in the 48 h after the half-marathon.
252
253 The reduction in the CMJ variables (concentric phase average peak force, net impulse,
254 average power and eccentric phase average peak force and average duration) immediately
255 and in the days after the half-marathon running race demonstrated that the event caused
256 EIMD. However, the similar response for each condition over time indicates that NZBC
257 extract did not affect post-race muscle recovery. The lack of observable difference between
258 groups may be due to the half-marathon race only inducing modest changes in all of the
259 CMJ outcome and neuromuscular variables. Future research could investigate whether
260 NZBC extract is able to modulate declines in contractile properties following exercise with a
261 greater effect on EIMD.
262
263 The results of the present study are in contrast to those previous ones where anthocyanin
264 rich supplements have been provided following running exercise. Howatson et al. (2009)
265 showed that a MCJ supplement enhanced recovery of muscle function following a marathon
266 and observed attenuation of biomarkers of inflammation (serum C-reactive protein, CRP; IL-
267 6 and uric acid) and oxidative stress (thiobarbituric acid reactive species, TBARS) in the 48
268 h following the marathon; effects that were associated with an accelerated recovery of
269 muscle function as determined by maximal voluntary isometric contraction (MVIC).
270 Differences in findings between the present study and Howatson et al. (2009) may be
271 attributable to the different anthocyanins in each supplement, the mode of delivery (capsules
272 vs. juice) and the exercise protocol (half-marathon vs marathon). Supplements were
273 provided before and after the half-marathon both in in the present study (7-days pre, 2-days
274 post), and by Howatson et al. (2009) (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 is 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 is cyanidin-3-glucosylrutinoside (Howatson et al. 2009). *In vitro* models have demonstrated that cyanidin-3-glucoside upregulates eNOS 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 eNOS 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). Further, 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 cyto-protective endogenous antioxidant response via Nrf-2 signalling 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 the 3-days following a marathon, was unable to attenuate declines in CMJ and MVIC, and elevations in markers of inflammation, (leucocytes, neutrophils, monocytes, hs-CRP, IL-1ra, IL-2, IL-4, IL-6, IL-8, IL-10,TNF-alpha and interferon-$\gamma$). 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 (CRP) 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 CK were attenuated in the recovery period with NZBC. Compared to the present study, differences in exercise protocol (half-marathon vs. repeated isolated forearm flexor exercise), techniques used to quantify EIMD (CMJ vs. MVIC) 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 (Sugama et al. 2013; Mrakic-Sposta et al. 2015). However, there was no increase in IL-6 immediately post and 24 after the half-marathon for either PLA or NZBC (**Figure 4**), however, large inter-individual variability was present. These data suggest that IL-6 is unlikely to have 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 h 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 participants were not provided with standardised meals prior to and immediately following the half-marathon event. As the participants appeared to have low habitual carbohydrate intake compared to the recommended guidelines of 6-10 g/kg/d (Thomas et al. 2016), it is possible that this may have influenced our results. Future research should look to implement standardised meals to ensure that

optimal intake of macronutrients prior to exercise are met. Further, 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 recreational runners. However, the present study suggests that NZBC supplementation has no effect on 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.
- Utilising 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 jump height.

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482

**Table 1** Descriptive data of the volunteer Half-Marathon runners in the NZBC and placebo groups

| Participant Characteristics | NZBC (n = 10) | Placebo (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 (h:min:s) | 1:56:30 ± 0:15:40 | 1:58:18 ± 0:22:52 |
| Actual finish time (h:min:s) | 1:58:12 ± 0:17:53 | 1:54:54 ± 0:18:15 |
| Average Heart Rate (bpm) | 166 ± 16 | 162 ± 27 |

Values are mean ± SD, *n* = 20.

**Table 2** Absolute and relative to body mass average daily intake macronutrient intake prior to and for the 2-day following the half-marathon and habitual anthocyanin intake as indicated from the anthocyanin food frequency questionnaire (n = 10 per group, Mean ± SD).

| Nutritional component | NZBC | Placebo |
|---|---|---|
| Total energy intake (kJ) | 9091 ± 3319 | 8903 ± 2198 |
| (kJ·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$^{-1}$) | 153 ± 122 | 172 ± 81 |

496

497 **Table 3.** Indices of muscle function and damage for both New Zealand blackcurrant and
498 placebo groups before and following Half-Marathon race

| **CMJ variable** | **Pre Half-Marathon** | **Post Half-Marathon** | **24 h post Half-Marathon** | **48 h post Half-Marathon** |
|---|---|---|---|---|
| Time to take off (s)# | | | | |
| 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 average 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 average 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** |

499

500 Values are mean ± SD, *n* = 10 per group. #Time*Supplement interaction (*P*=0.02). *Elevated
501 above pre-half marathon immediately post half-marathon (time effect, *P*<0.05); **Elevated above
502 pre-half marathon 48 h after half-marathon (time effect, *P*=0.03*)*. NZBC, New Zealand
503 blackcurrant; PLA, placebo.

504

505

506 **Figure legends**
507

508 **Figure 1**. Study design.

509

510 **Figure 2a 2b, 3 a and 3b and 4 -** 2a. Percentage change from pre half-marathon in
511 countermovement jump (CMJ) height and post half-marathon (*pre to post; *P* = 0.01). 2b.
512 Percentage change from pre half-marathon in reactive strength index modified (RSImod)
513 and post half-marathon (*pre to post; *P* = 0.01). 3a. Muscle soreness ratings pre and post
514 half-marathon (*pre to post; p = 0.01). 3b. Muscle fatigue ratings pre and post half-marathon
515 (*pre to post; *P* = 0.01). 4. Interleukin-6 urine concentrations with creatinine correction pre
516 and post half-marathon (**pre to 48 h; *P* = 0.01). Values are mean ± SD (*n* = 10 per group
517 for **2a, 2b, 3a, 3b** and **4**).

518

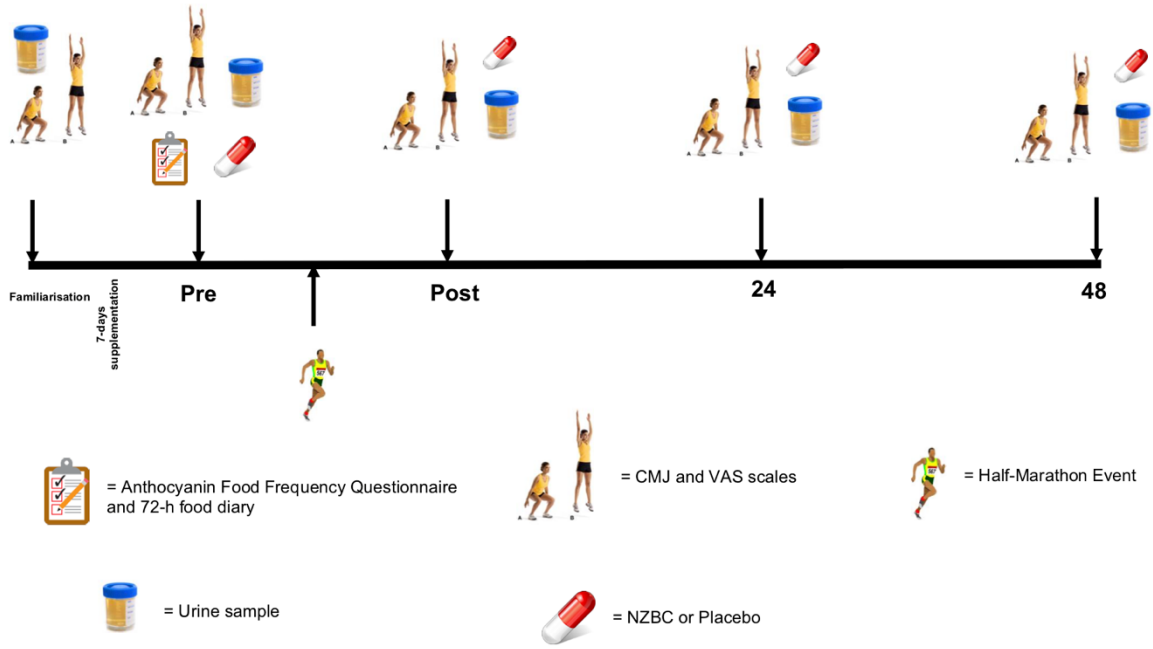
519
520 **Figure legends**
521

522 **Figure 2**. Study design.

523

524 **Figure 2a 2b, 3 a and 3b and 4 -** 2a. Percentage change from pre half-marathon in
525 countermovement jump (CMJ) height and post half-marathon (*pre to post; *P* = 0.01). 2b.
526 Percentage change from pre half-marathon in reactive strength index modified (RSImod)
527 and post half-marathon (*pre to post; *P* = 0.01). 3a. Muscle soreness ratings pre and post
528 half-marathon (*pre to post; p = 0.01). 3b. Muscle fatigue ratings pre and post half-marathon
529 (*pre to post; *P* = 0.01). 4. Interleukin-6 urine concentrations with creatinine correction pre
530 and post half-marathon (**pre to 48 h; *P* = 0.01). Values are mean ± SD (*n* = 10 per group
531 for **2a, 2b, 3a, 3b** and **4**).
532

1


Familiarisation
7-days supplementation
Pre
Post
24
48
= Anthocyanin Food Frequency Questionnaire and 72-h food diary
= CMJ and VAS scales
= Half-Marathon Event
= Urine sample
= NZBC or Placebo

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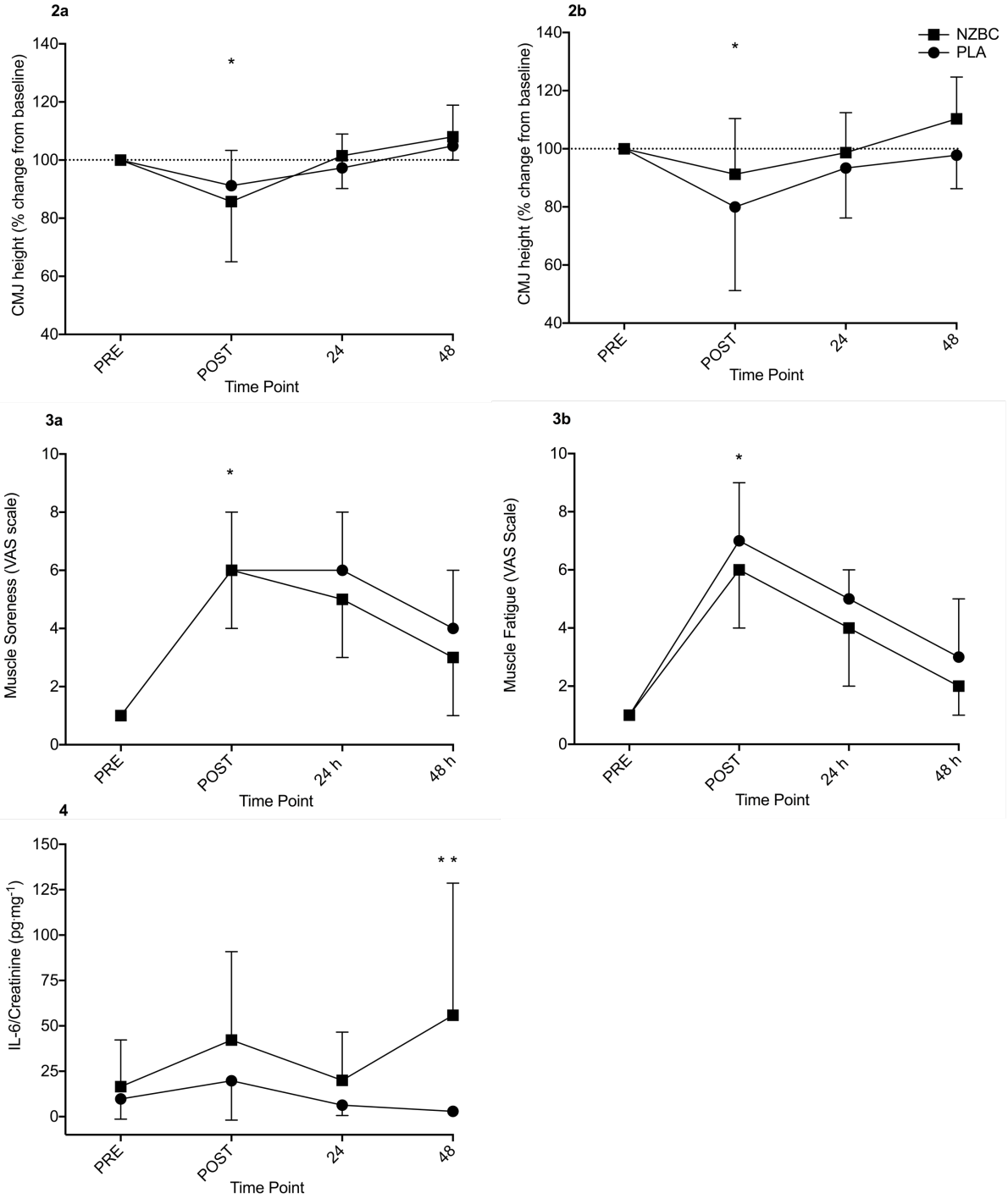
2a
CMJ height (% change from baseline)
140
120
100
80
60
40
*
PRE
POST
24
48
Time Point
2b
NZBC
PLA
CMJ height (% change from baseline)
*
PRE
POST
24
48
Time Point
3a
Muscle Soreness (VAS scale)
10
8
6
4
2
0
*
PRE
POST
24 h
48 h
Time Point
3b
Muscle Fatigue (VAS Scale)
*
PRE
POST
24 h
48 h
Time Point
4
IL-6/Creatinine (pg·mg-1)
150
125
100
75
50
25
0
* *
PRE
POST
24
48
Time Point