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

Authors: Rianne Costello[1], Mark E.T. Willems[1], Stephen D. Myers[1], Fiona Myers[2], Nathan A. Lewis[3], Ben J. Lee[1], Sam D. Blacker[1]

Institutions:

[1]Institute of Sport, University of Chichester, UK

[2] School of Biological Sciences, Faculty of Science, University of Portsmouth, Portsmouth, UK

[3]English Institute of Sport, Bath, UK

Running head: Blackcurrant effects following a half-marathon

Corresponding author:
Dr Sam Blacker Ph.D
Institute of Sport,
University of Chichester
Chichester,
PO19 6PE
United Kingdom
Email: S.Blacker@chi.ac.uk

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 levels except concentric and eccentric peak force and eccentric duration, with no difference in response between groups ($P>0.05$). 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 levels in PLA group ($P>0.05$). Perceived muscle soreness and fatigue increased immediately post-half-marathon ($P<0.01$) and returned to pre half-marathon by 48 h, with no difference between groups ($P>0.05$). 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

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 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, 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), established on Counter Movement Jump (CMJ) height we calculated (G*Power; Faul et al. 2007) 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 of Chichester 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. The 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 the start of race at 9:00, the air temperature was 8ºC, 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, United Kingdom) or two capsules of identical looking placebo capsules (2 x 300 mg microcrystalline cellulose M102; CurraNZ™, Health Currancy Ltd, Surrey, United Kingdom) 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 anthocyanins 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 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

Countermovement jumps (CMJ) were performed on a force plate (PASPORT force plate, PS-2141, PASCO Scientific, California, USA) sampling at 1000 Hz (Lake et al. 2018). 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 seconds of passive (standing) recovery. Outcome variables jump height (JH), reactive strength index modified (RSImod), time to take-off, concentric phase average peak force, net impulse, power, 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 outcome variables JH and RSImod are expressed as a percentage change from pre-half marathon to account for inter-individual variability. The coefficient of variation for the outcome variables, JH, RSImod and time to take off was 6, 9 and 6 %, respectively.

Muscle soreness and fatigue

Whilst in a 90^{o} degree squat position, participants rated their self-perceived muscle soreness and fatigue were using a 0-10 VAS, 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, mid-stream urine samples were collected into 50-mL Falcon® conical tubes. At all four time points (pre, post, 24 h post and 48 h post), urine was 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 ^{o}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, 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). 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 Bonferroni adjustment post hoc analysis. 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 levels by 24 h (97.2 ± 11.1 vs 101.6 ± 10.7 %, respectively). Apart from TTT, 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 levels in the NZBC group only (P<0.01) and remained unchanged at all time points in the placebo group compared to pre-half marathon levels (P>0.05). No time or interaction effects were present (P>0.05) (**Figure 4**).

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

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 h after the half-marathon.

The reduction in the CMJ variables (concentric phase average peak force, net impulse, 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 post-race muscle recovery. The lack of 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 to those previous ones where anthocyanin rich supplements have been provided following running exercise. Howatson et al. (2009) showed that an MCJ supplement enhanced recovery of muscle function following a marathon and observed attenuation of biomarkers of inflammation (serum C-reactive protein, CRP; IL-6 and uric acid) and oxidative stress (thiobarbituric acid reactive species, TBARS) in the 48 h following the marathon; effects that were associated with an accelerated recovery of muscle function as determined by maximal voluntary isometric contraction (MVIC). Differences in findings between the present study and Howatson et al. (2009) 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 in the present study (7-days pre, 2-days 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 was delphinidin-3-

267 rutinoside (Rothwell et al. 2013). In contrast, MCJ was provided in a juice containing 80 mg of
268 anthocyanins per day and the main anthocyanin was cyanidin-3-glucosylrutinoside (Howatson
269 et al. 2009). *In vitro* models have demonstrated that cyanidin-3-glucoside upregulates eNOS
270 activity (Edwards et al. 2015). As the main anthocyanin in NZBC is delphinidin-3-rutinoside, it
271 is possible that the cyanidin-3-glucoside in MCJ is better able to upregulate eNOS activity,
272 thus influencing blood flow through flow mediated dilation (Cook et al. 2017) during strenuous
273 exercise and reducing the susceptibility to injury (Jones et al. 2017). Further, polyphenol
274 scavenging has been purported as a potential mechanism by which, polyphenols could help
275 support redox status by dampening the oxidative stress response following EIMD (Powers &
276 Jackson, 2008). However, this notion has recently been debated with polyphenol metabolism
277 to electrophiles and a cyto-protective endogenous antioxidant response via nuclear factor
278 erythroid 2-related factor 2 (Nrf-2) signalling having been suggested as a more plausible
279 mechanism (Owens et al. 2018).
280
281 However, other studies have also reported no benefit from supplementation with nitrate-rich,
282 beetroot juice (Clifford et al. 2016) and anthocyanin-rich, bilberry juice (Lynn et al. 2018) on
283 markers of EIMD following marathon and half-marathon running, respectively. Clifford et al.
284 (2016) observed that beetroot juice supplemented for the 3-days following a marathon, was
285 unable to attenuate declines in CMJ and MVIC, and elevations in markers of inflammation,
286 (leucocytes, neutrophils, monocytes, hs-CRP, IL-1ra, IL-2, IL-4, IL-6, IL-8, IL-10,TNF-alpha
287 and interferon-γ). On the other hand, Lynn et al (2018) concluded that consumption of bilberry
288 juice 5-days prior to, on race day, and for 2-days following a half-marathon, evoked moderate
289 increases in exercise-induced muscle soreness and markers of inflammation (CRP) and
290 muscle damage (determined by creatine kinase concentrations). Similarly, the lack of benefit
291 observed may be attributable to the different supplementation strategies used (beetroot juice
292 3-days following the marathon only vs. bilberry juice 5-days prior to, on race day and 2-days
293 following the half-marathon), leading to different biological activities of the phytonutrients.
294

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**). Large inter-individual variability was present due to four participant's data skewing the NZBC group average. 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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Conflict of interest The authors declare no conflict of interest.

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460 **Table 1** Descriptive data of the volunteer Half-Marathon runners in the NZBC and placebo
461 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

462 Values are mean ± SD, *n* = 20.

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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·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^{-1})	153 ± 122	172 ± 81

472 **Table 3.** Indices of muscle function and damage for both New Zealand blackcurrant and
473 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 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

Values are mean ± SD, *n* = 10 per group. #Time*Supplement interaction (*P*=0.02). *Main effect of time but not statistically significant when Bonferroni correction applied (*P*>0.05). **Elevated above pre-half marathon at immediately post (time effect, *P*<0.05*)*. ***Elevated above pre-half marathon immediately post, 24 and 48 h post (time effect, *P*<0.05) No other group or interaction effects observed (*P*>0.05). NZBC, New Zealand blackcurrant; PLA, placebo.

481 **Figure legends**
482

483 **Figure 1**. Study design.

484

485 **Figure 2a 2b, 3 a and 3b and 4 -** 2a. Percentage change from pre half-marathon in
486 countermovement jump (CMJ) height and post half-marathon (*pre to post; $P < 0.01$). 2b.
487 Percentage change from pre half-marathon in reactive strength index modified (RSImod) and
488 post half-marathon (*pre to post; $P < 0.01$). 3a. Muscle soreness ratings pre and post half-
489 marathon (*pre to post; $P < 0.01$). 3b. Muscle fatigue ratings pre and post half-marathon (*pre
490 to post; $P < 0.01$). 4. Interleukin-6 urine concentrations with creatinine correction pre and post
491 half-marathon (**pre to 48 h; $P<0.01$). Values are mean ± SD ($n = 10$ per group for **2a, 2b, 3a,**
492 **3b** and **4**).
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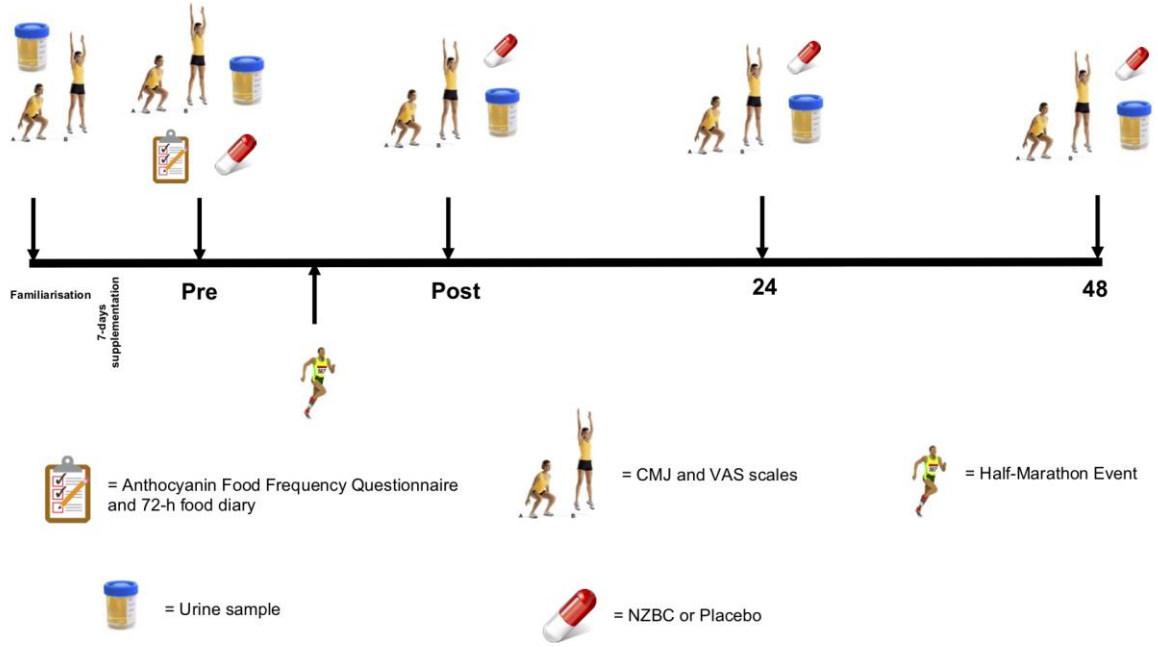

494
495 Figure 1

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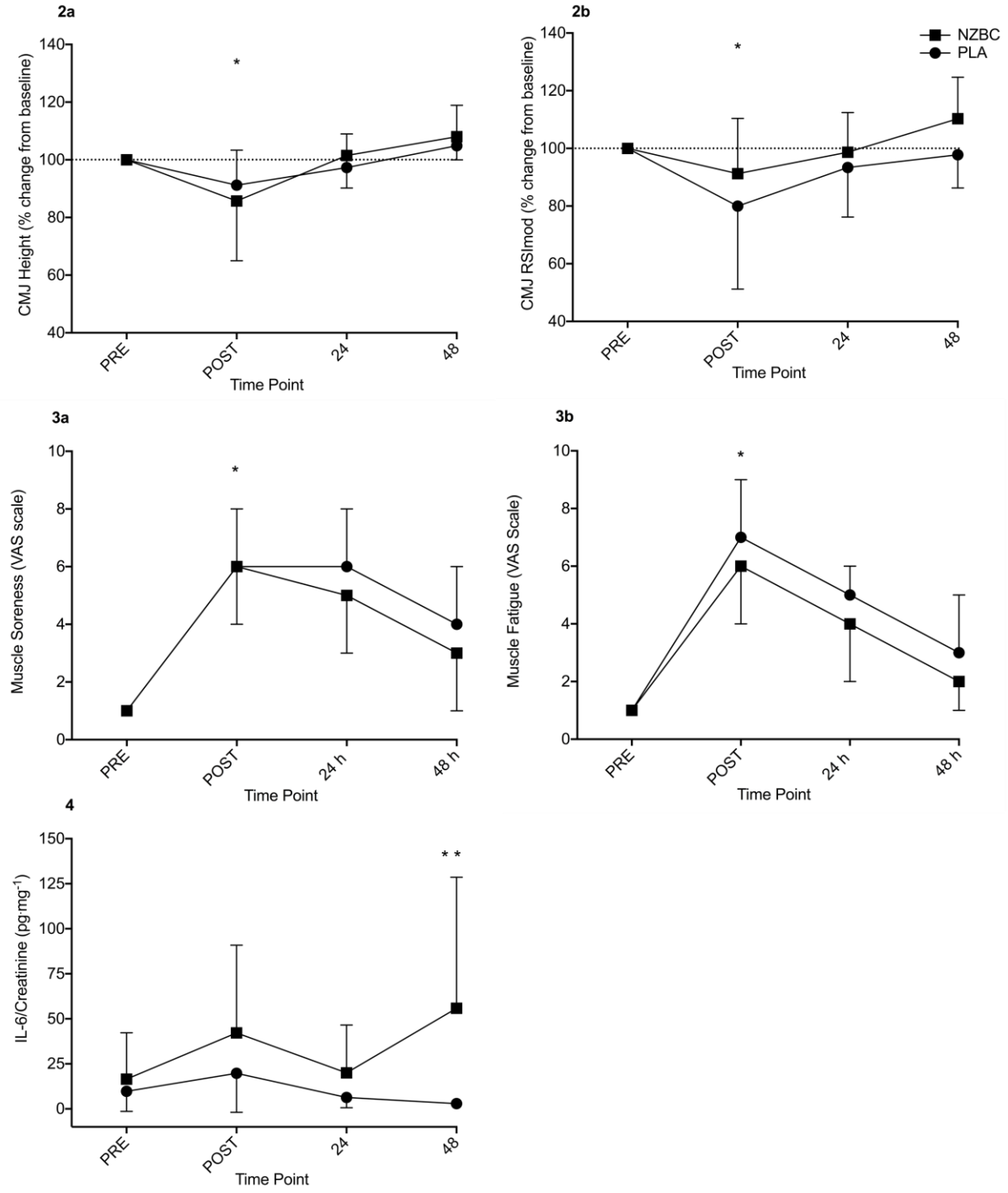
2a
CMJ Height (% change from baseline)
140
120
100
80
60
40
*
PRE
POST
24
48
Time Point
2b
CMJ RSImod (% change from baseline)
NZBC
PLA
*
Time Point
3a
Muscle Soreness (VAS scale)
10
8
6
4
2
0
*
PRE
POST
24 h
48 h
Time Point
3b
Muscle Fatigue (VAS Scale)
*
Time Point
4
IL-6/Creatinine (pg·mg-1)
150
125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

497