

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

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14 **Running head:** Blackcurrant effects following a half-marathon

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29 **Abstract**

30 New Zealand blackcurrant (NZBC) contains anthocyanins, known to moderate blood flow and
31 display anti-inflammatory properties that may improve recovery from exercise-induced muscle
32 damage (EIMD). We examined whether NZBC extract supplementation enhances recovery
33 from EIMD after a half-marathon race. Following a randomized, double-blind, independent
34 groups design, 20 (8 women) recreational runners (age 30 ± 6 years, height 1.73 ± 0.74 m,
35 body mass 68.5 ± 7.8 kg, half-marathon finishing time $1:56:33 \pm 0:18:08$ h:min:s) ingested
36 either two $300 \text{ mg} \cdot \text{day}^{-1}$ capsules of NZBC extract (CurraNZ™) or a visually matched placebo
37 (PLA), for 7-days prior to and 2-days following a half-marathon. Countermovement jump
38 (CMJ) performance variables, urine interleukin-6 (IL-6), perceived muscle soreness and
39 fatigue were measured pre-, post-, and at 24 h and 48 h after the half-marathon and analysed
40 using a mixed linear model with statistical significance set a priori at $P < 0.05$. The CMJ
41 performance variables were reduced immediately post-half-marathon ($P < 0.05$) with all
42 returning to pre half-marathon by 48 h levels except concentric and eccentric peak force and
43 eccentric duration, with no difference in response between groups ($P > 0.05$). Urine IL-6
44 increased 48 h post-half-marathon in the NZBC group only ($P < 0.01$) and remained unchanged
45 compared to pre half-marathon levels in PLA group ($P > 0.05$). Perceived muscle soreness and
46 fatigue increased immediately post-half-marathon ($P < 0.01$) and returned to pre half-marathon
47 by 48 h, with no difference between groups ($P > 0.05$). Supplementation with NZBC extract had
48 no effect on the recovery of countermovement jump variables and perceptions of muscle
49 soreness or fatigue following a half-marathon in recreational runners.

50

51 **Keywords.** Anthocyanins, endurance exercise, inflammation, supplementation

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57 **Introduction**

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

67

68 Recently, foods and supplements that are rich in polyphenols such as berries and fruits have
69 been shown to enhance exercise performance and recovery (for a review see Cook & Willems.
70 2018). Montmorency tart cherry juice (MCJ) has been shown to enhance recovery of muscle
71 function and reduce inflammation and lipid peroxidation following a marathon race (Howatson
72 et al. 2009). However, beetroot juice supplementation did not affect recovery following a
73 marathon race (Clifford et al. 2016). The difference may be related to the profile of the
74 polyphenolic compounds, e.g. the anthocyanins. Although the precise mechanisms are not
75 clear, it has been speculated that anthocyanins may exert their recovery benefits by
76 upregulating endothelial nitric oxide synthase (eNOS) activity, thus improving blood flow to the
77 affected tissues (Cook & Willems, 2018). New Zealand blackcurrant (NZBC) is unique due to
78 its high anthocyanin content and has been shown to enhance exercise performance (for a
79 review see Cook & Willems, 2018) and recovery from EIMD (Coelho et al. 2017) in laboratory
80 settings. The effects of NZBC extract on recovery following more ecologically valid events in
81 the field, such as a half-marathon race, are not known.

82

83 The aim of this study was to examine the effect of NZBC extract supplementation taken before
84 and following running a half-marathon race on markers of EIMD. It was hypothesized that

85 NZBC extract, when compared to placebo (PLA), would facilitate recovery, by accelerating the
86 return of muscle function, reducing muscle soreness and fatigue, and inhibiting the exercise-
87 induced inflammatory cascade.

88

89 **Materials and methods**

90 *Participants*

91 Twelve healthy men and eight healthy women (**Table 1**) who were runners taking part in the
92 2018 Chichester Half-Marathon, Chichester, UK volunteered to participate in the study. Based
93 on a similar previous study focusing on recovery with a polyphenol-rich supplement following
94 a running event (Clifford et al. 2016), established on Counter Movement Jump (CMJ) height
95 we calculated (G*Power; Faul et al. 2007) that at 80% power, and an α of 0.05, at least eight
96 volunteers were required to detect a group difference of 5% (using change from pre-half
97 marathon data) (3.5% SD) at any time points post the half-marathon event. Participants
98 completed a health history questionnaire, were non-smokers, had no known food allergies
99 and were not taking anti-inflammatory therapies. Females completed a menstrual cycle
100 questionnaire (Köhne et al. 2016). Participants abstained from strenuous exercise and alcohol
101 for 48 h prior, and caffeine-containing products on the day of the half-marathon. Participants
102 were also asked to avoid all additional means that could affect recovery and adhere to their
103 normal activity schedule. The study was approved by the University of Chichester Research
104 Ethics Committee with protocols and procedures conforming to the 2013 Declaration of
105 Helsinki.

106

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

108

109 *Experimental design*

110 The study followed a double-blind, placebo-controlled, randomised, independent-groups study
111 design. Groups were matched according to predicted half-marathon finish times by pairing
112 participants with equivalent times (Howatson et al. 2009; Clifford et al. 2016). Blinding of the
113 placebo and supplement was carried out by an independent researcher who had no
114 involvement with this investigation. Packets were made up with visually identical NZBC and
115 placebo capsules for each participant and labelled with a random letter. Each participant in a
116 matched pair was randomly assigned to one of the letters and provided with that packet of
117 capsules. The blinding codes were revealed following data analysis. The participants
118 completed one familiarisation visit, and four experimental visits pre- and immediately post-
119 half-marathon (in the race holding area), 24 and 48 h (laboratory; **Figure 1**). For the
120 familiarisation visit, participants were briefed on the study, explained all the procedures and
121 had their height and body mass recorded. Countermovement jumps (CMJ), visual analogue
122 scales (VAS) for muscle soreness and fatigue and a urine sample were completed in this order
123 during each experimental visit. Heart rate was collected during the half-marathon (Polar Team
124 2, Polar Electro Ltd, UK) and race distance confirmed using GPS (Polar M430 GPS, Polar
125 Electro Ltd, UK).

126

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

128

129 *Half-marathon*

130 The half-marathon took place on 19th October 2018 in Chichester (West Sussex, UK). The
131 course was mostly flat, across a mix of concrete terrain, grass and chalk. However, mile 4 to
132 8 consisted of a steep incline and decline (total route ascent: 239 m; total route descent: 232

133 m). At the start of race at 9:00, the air temperature was 8°C, humidity 81%, barometric
134 pressure 1023 hPa, and air speed 10 mph. It remained dry and mostly overcast with
135 intermittent sunny spells for the duration of the race.

136

137 *Supplementation protocol*

138 Participants ingested two capsules of NZBC extract (2 x 300 mg CurraNZ™) each containing
139 105 mg of anthocyanins (CurraNZ™, Health Currancy Ltd, Surrey, United Kingdom) or two
140 capsules of identical looking placebo capsules (2 x 300 mg microcrystalline cellulose M102;
141 CurraNZ™, Health Currancy Ltd, Surrey, United Kingdom) with breakfast every morning for 7-
142 days and 2-days following the half-marathon. On the morning of the half-marathon,
143 participants consumed their supplement 2 h prior to starting the race. This supplementation
144 regime was based on previous work where anthocyanins peak in systemic circulation ~2 h
145 after ingestion (Matsumoto et al. 2005). Full compliance with intake was achieved. Blinding
146 was not broken until after analysis was completed and a follow-up questionnaire revealed 40%
147 of participants accurately guessed which supplementation they received.

148

149 *Dietary intake*

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

158

159 *Indices of muscle function*

160 Countermovement jumps (CMJ) were performed on a force plate (PASPORT force plate, PS-
161 2141, PASCO Scientific, California, USA) sampling at 1000 Hz (Lake et al. 2018). Participants
162 were instructed to jump as high and as fast as possible, without specific information on squat
163 depth to avoid altering natural jump patterns (Jidovtseff et al. 2014). Three maximal efforts
164 were performed, separated by 30 seconds of passive (standing) recovery. Outcome variables
165 jump height (JH), reactive strength index modified (RSI_{mod}), time to take-off, concentric
166 phase average peak force, net impulse, power, duration and eccentric phase average peak
167 force, net impulse, displacement (braking phase) and duration are reported (Gathercole et al.
168 2015). The neuromuscular variables are expressed relative to body mass and outcome
169 variables JH and RSI_{mod} are expressed as a percentage change from pre-half marathon to
170 account for inter-individual variability. The coefficient of variation for the outcome variables,
171 JH, RSI_{mod} and time to take off was 6, 9 and 6 %, respectively.

172

173 *Muscle soreness and fatigue*

174 Whilst in a 90° degree squat position, participants rated their self-perceived muscle soreness
175 and fatigue were using a 0-10 VAS, where 0 represented *no soreness* and 10 represented
176 *extreme soreness* and 0 represented *no fatigue* and 10 represented *extreme fatigue*,
177 respectively (Jakeman et al. 2017).

178

179 *Urine sampling, handling and biochemical analysis*

180 Second evacuation, mid-stream urine samples were collected into 50-mL Falcon® conical
181 tubes. At all four time points (pre, post, 24 h post and 48 h post), urine was collected and kept
182 on ice for no more than 2 h prior to being centrifuged at 1000 g for 10 minutes. The urine was
183 subsequently stored in 2-mL aliquots at -80 °C and thawed on the morning of the analysis.
184 Urinary IL-6 concentration was determined in duplicate using a quantitative sandwich enzyme
185 immunoassay ELISA technique (Quantikine, R&D Systems Europe Ltd., Abingdon, UK).
186 Normal reference ranges for this assay are reported at < 3 pg/mL. The urine intra- and inter-

187 assay precision determined by CV was 4 %. Urinary cytokine levels were expressed as ratios
188 of IL-6 to creatinine (pg/mg creatinine) to avoid dilution effects, to be able to compare results
189 from different participants, and to standardize the samples in light of differences in post-race
190 hydration status. Urine creatinine was measured using a colorimetric assay (CR510, Randox,
191 County Antrim, Northern Ireland).

192

193 *Data analysis*

194 Statistical analyses were completed using GraphPad Prism V8 (Graphpad software, San
195 Diego, California). Dependent variables (CMJ, VAS and IL-6 analyses) were analysed using
196 a mixed linear model with two independent group levels (NZBC vs. PLA) and four repeated
197 measures time points (pre, post, 24 and 48 h post). The Shapiro-Wilks test was used to check
198 homogeneity of variance for all variables and any violations of the assumption were corrected
199 using the Greenhouse-Geisser adjustment. Significant main effects or interactions were
200 assessed using Bonferroni adjustment post hoc analysis. The alpha level for statistical
201 significance was set at 0.05 a priori. All data are reported as mean \pm SD for $n = 10$ for each
202 group, unless otherwise stated.

203

204 **Results**

205 Half-marathon finish times did not differ between groups ($P=0.67$). Average energy intake (KJ)
206 in the day before the half-marathon until the cessation of the study did not differ between
207 groups ($P=0.90$) nor did the proportions coming from carbohydrate ($P=0.51$), protein ($P=0.36$)
208 or fat ($P=0.63$). Habitual anthocyanin intake did not differ between groups ($P=0.99$) (**Table 2**).

209

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

211

212 *Indices of muscle function*

213 Countermovement jump (CMJ) outcome variables (JH and RSI_{mod}) and neuromuscular
214 variables (concentric average relative peak force, concentric net impulse, concentric average

215 power, eccentric average relative peak force, eccentric net impulse) showed a main effect of
216 time ($P<0.01$), indicating muscle damage after the half-marathon (**Figures 2a, 2b; Table 3**).
217 Relative to pre-half marathon, JH and RSImod decreased to a similar extent in the NZBC and
218 PLA groups immediately post half-marathon (91.3 ± 11.5 vs 85.6 ± 19.5 %, respectively) and
219 had returned to pre half-marathon levels by 24 h (97.2 ± 11.1 vs 101.6 ± 10.7 %, respectively).
220 Apart from TTT, no group or interaction effects were present at any time point for any of the
221 CMJ outcome or neuromuscular variables (all $P>0.05$) (**Table 3**).

222

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

224

225 *Muscle soreness and fatigue*

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

229

230 *Inflammatory cytokine response*

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

235

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

237

238

239 **Discussion**

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

244

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

253

254 The results of the present study are in contrast to those previous ones where anthocyanin rich
255 supplements have been provided following running exercise. Howatson et al. (2009) showed
256 that an MCJ supplement enhanced recovery of muscle function following a marathon and
257 observed attenuation of biomarkers of inflammation (serum C-reactive protein, CRP; IL-6 and
258 uric acid) and oxidative stress (thiobarbituric acid reactive species, TBARS) in the 48 h
259 following the marathon; effects that were associated with an accelerated recovery of muscle
260 function as determined by maximal voluntary isometric contraction (MVIC). Differences in
261 findings between the present study and Howatson et al. (2009) may be attributable to the
262 different anthocyanins in each supplement, the mode of delivery (capsules vs. juice) and the
263 exercise protocol (half-marathon vs marathon). Supplements were provided before and after
264 the half-marathon both in in the present study (7-days pre, 2-days post), and by Howatson et
265 al. (2009) (5-days pre, 3 days post). The NZBC in the present study was provided in capsules
266 containing 210 mg of anthocyanins per day, and the main anthocyanin was delphinidin-3-

267 rutinoid (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

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

304

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

315

316 A limitation of the present study was that participants were not provided with standardised
317 meals prior to and immediately following the half-marathon event. As the participants
318 appeared to have low habitual carbohydrate intake compared to the recommended guidelines
319 of 6-10 g/kg/d (Thomas et al. 2016), it is possible that this may have influenced our results.
320 Future research should look to implement standardised meals to ensure that optimal intake of
321 macronutrients prior to exercise are met. Further, participants were permitted to maintain their
322 habitual anthocyanin intake in an effort to increase the ecological validity of the findings.

323 However, it is possible that by increasing ecological validity we may have limited our ability to
324 detect any meaningful benefit of NZBC extract supplementation on recovery.

325

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

329

330 **Novelty statement**

- 331 • This is the first study where NZBC extract supplementation has been assessed for its
332 potential as a recovery aid in an ecologically valid setting following half-marathon
333 running in recreational runners. However, the present study suggests that NZBC
334 supplementation has no effect on recovery of EIMD parameters in recreational runners
335 following a half-marathon.

336

337 **Practical applications**

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

344

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359

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361

362

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459

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.

463

464

465
 466 **Table 2** Absolute and relative to body mass average daily intake macronutrient intake prior to
 467 and for the 2-day following the half-marathon and habitual anthocyanin intake as indicated
 468 from the anthocyanin food frequency questionnaire (n = 10 per group, Mean \pm SD).

469

Nutritional component	NZBC	Placebo
Total energy intake (kJ)	9091 \pm 3319	8903 \pm 2198
(kJ·kg body mass ⁻¹)	133 \pm 46	134 \pm 38
Carbohydrate (g)	226 \pm 73	249 \pm 68
(g·kg body mass ⁻¹)	3.3 \pm 1.1	3.8 \pm 1.1
Protein (g)	107 \pm 37	92 \pm 23
(g·kg body mass ⁻¹)	1.6 \pm 0.5	1.4 \pm 0.4
Fat (g)	93 \pm 46	84 \pm 23
(g·kg body mass ⁻¹)	1.3 \pm 0.6	1.3 \pm 0.4
Habitual anthocyanin intake (mg·day ⁻¹)	153 \pm 122	172 \pm 81

470

471

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

474

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

480

481 **Figure legends**

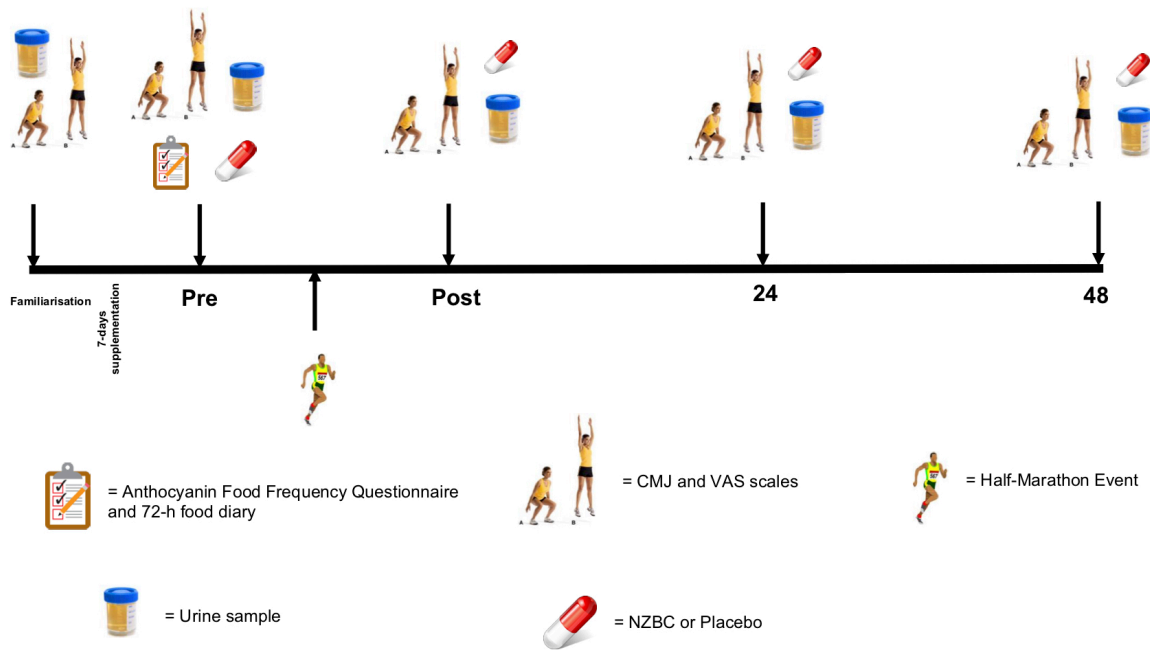
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483 **Figure 1.** Study design.

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 \pm SD ($n = 10$ per group for **2a, 2b, 3a,**
492 **3b and 4**).

493



494
 495 Figure 1
 496

