PAN
Physical Activity and Nutrition | 2023;27(4):008-014

OPEN ACCESS
https://doi.org/10.20463/pan.2023.0032

Received: 2023/10/25, Revised: 2023/11/27, Accepted: 2023/11/30, Published: 2023/12/31

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Cranberry supplementation improves physiological markers of performance in trained runners

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[Purpose] Cranberries have the highest polyphenol and antioxidant capacity among fruits and vegetables and may protect against exercise-induced free radical production, consequently improving performance. This study aimed to investigate the effect of polyphenol-rich cranberry extract (CE) on time-trial performance and lactate response following exercise.

[Methods] A total of 14 trained runners were tested at i) baseline, ii) 2 h following an acute CE dose (0.7 g/kg of body mass), and iii) 4 weeks after daily supplement consumption (0.3 g/kg of body mass). At each time point, runners performed a 1500-m race followed by a 400-m race where the live vastus lateralis oxygenation changes were determined by near-infrared spectroscopy and blood lactate was measured at rest and 1 and 3 min after each trial. The Shapiro-Wilk test and repeated-measures analysis of variance were used to establish significance ($P < 0.05$).

[Results] Cranberry supplementation over 28 d improved aerobic performance during the 1500-m time trial, whereas the acute dose had no effect. More specifically, muscle reoxygenation rates were significantly faster after 28 d compared to baseline ($P = 0.04$; $\eta^2 = 0.29$), and a trend towards slower deoxygenation rate was observed ($P = 0.13$; $\eta^2 = 0.20$). Chronic CE consumption also buffered the post-exercise lactate response for the 400-m race ($P = 0.01$; $\eta^2 = 0.27$), while no effects were seen for the longer race.

[Conclusion] Our results suggest that cranberry supplementation may have ergogenic effects, as it improves physiological markers of performance during short- and long-distance running.

[Keywords] polyphenol, proanthocyanidins, NIRS, muscle oxygenation, oxygen consumption, blood lactate

INTRODUCTION

Polyphenols, including proanthocyanidins (PAC), anthocyanins, flavonols, and flavonols, are secondary plant compounds found in fruits and vegetables[1,2]. Cranberries have the highest total polyphenol content among the most consumed fruits in the American diet, and one of the highest antioxidant capacities among fruits and vegetables[3,4]. Furthermore, their polyphenol content stands out because of the high concentration in rare A-type PAC, which is believed to be the main contributor to their beneficial effects[5].

The use of dietary supplements is growing among athletes, and many are turning to natural health products to improve exercise performance[6]. Strenuous exercise significantly increases reactive oxygen species production owing to high oxidative metabolic demands[7,8]. Consequently, polyphenols may offer natural antioxidant defense against exercise-induced free radical production.

During operation, the contribution of the aerobic and anaerobic energy systems depends on the relative intensity. Blood lactate can be measured during or at the termination of exercise to provide insight into the anaerobic capacity of an athlete, and has been associated with relative performance during shorter high-intensity events, such as the 400-m and 800-m time trials (TT)[9]. Maximal oxygen consumption (VO_{2max}) testing is the gold standard for measuring aerobic capacity but is not practical for field testing. Conversely, live muscle oxygenation can be measured using near-infrared spectroscopy (NIRS), a non-invasive technique that is associated with pulmonary VO_2 and has been used in various athletic populations, such as cyclists and runners[10-12]. NIRS devices are portable and can provide muscle-specific information, such as reoxygenation metrics, which offer a reliable way to measure post-exercise recovery[13].

Previous clinical studies have demonstrated the ergogenic effects of cranberries on cycling and rowing, which are notably related to lowering inflammatory markers and buffering lactate[14,15]. To our knowledge, the effects of cranberries on running performance remain unknown. This study aimed to investigate the effect of cranberry supplementation for 28 d on performance, lactate production, and muscle oxygenation when running 1500-m (aerobic) and 400-m (anaerobic) TT.

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METHODS

Participants

A total of 14 trained endurance athletes (8 males and 6 females) were recruited from local varsity cross-country teams and running clubs. All athletes were 18–40 years old and performed at least 5 h of endurance training per week. Table 1 lists the participants' basic characteristics. The exclusion criteria were as follows: (i) smoking or vaping, (ii) use of ergogenic aids or drugs, (iii) injuries or physical limitations that could impair proper running mechanics, and (iv) cardiovascular or metabolic disease. The protocol (#30016555) was approved by the Human Research Ethics Committee of Concordia University. All participants signed a consent form before the start of the study.

Table 1. Participants Characteristics.

Variable	Mean (SD)
Age (years)	28 (6)
Height (cm)	169.4 (8.1)
Weight (kg)	62 (8.1)
Status	
Elite	5
Competitive	7
Recreative	2
Event	
Cross-Country	7
Half Marathon	2
Marathon	2
Other	3
Berry Consumption	
Low	7
Moderate	3
High	4

Study Design

The study utilized a repeated-measures design with case-control matching, comprising three separate visits during which athletes performed a 1500-m TT followed by a 400-m TT. The athletes were instructed to perform their pre-race warm-up before testing. A 10-min static break was provided between the two TTs to ensure full recovery. Each athlete completed an online health questionnaire before their first visit, which included questions related to their health, dietary habits, exercise, and history of injury. Baseline measurements were obtained during the first visit (baseline). At the second visit, 1 week after baseline, participants consumed an acute dose of CE 2 h before testing (SD-CE). The third visit was conducted 28 d after CE consumption to test for chronic effects (28-CE). The tests were performed on a local 200-m indoor track. Figure 1 shows the breakdown of the study population. The discontinuation of participation was not related to any aspect of the supplementation or testing protocols.

Dietary Intervention

The athletes were instructed to maintain their usual diet throughout the study period and on the testing days to avoid confounding factors. Table 1 presents information on berry consumption that we collected. CE comprised a lab-grade freeze-dried powder containing 7.2–10% PACs (Fruit D'Or Inc., Villeroy, QC). The participants were instructed to keep the supplement in a cool, dry place away from sunlight, as per the manufacturer's recommendations. In preparation for their second visit, the participants consumed an acute dose representing 0.7 g/kg of body mass, 1–3 h before testing. For chronic testing, a dose representing 0.3 g/kg of body mass was consumed daily for 28 d.

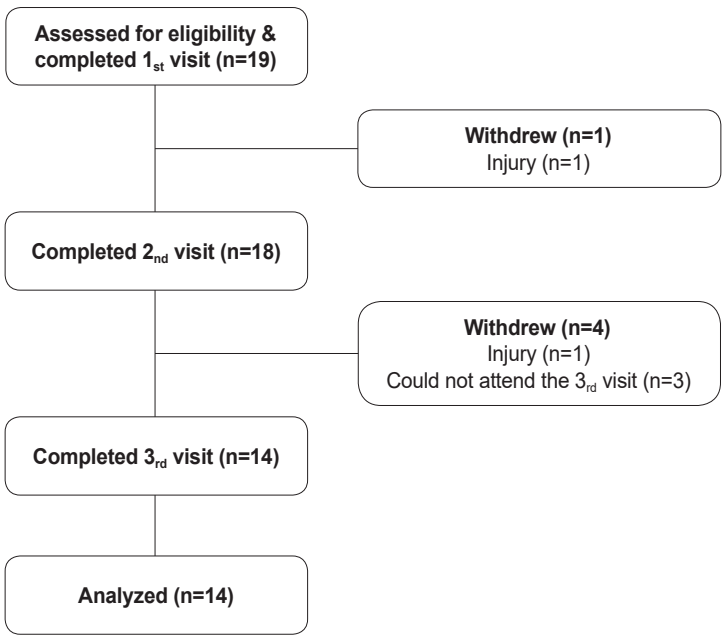

Figure 1. Consort diagram breakdown of the subject population from recruitment to data analysis.

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Muscle Oxygenation

NIRS monitors (Moxy monitors, 5th generation; Fortiori Design, Minnesota, USA) were used to assess changes in muscle oxygenation by utilizing four wavelengths of near-infrared light (680, 720, 760, and 800 nm), with a source-detector spacing of 12.5 and 25.0 mm[16]. Because oxygenated and deoxygenated hemoglobin have different absorbance spectra, they reflect light differently. Consequently, the Moxy device can report changes in both the total tissue hemoglobin concentration ([THb]) and oxygenated hemoglobin expressed as a percentage of the total hemoglobin (SmO_2).

Skinfold measurements were performed at the location of the right vastus lateralis, 10 cm above the patella, using skinfold calipers (Harpenden, UK). For the data to be considered viable, the skinfold measurements should be less than half the distance between the emitter and detector. The NIRS device was placed on the right vastus lateralis muscle and secured using medical tape and HypaFix. The black self-adhesive tape was wrapped around the leg to ensure no movement of the device and to block any extraneous light. The raw SmO_2 and [THb] signals were collected at a frequency of 0.5 Hz with data smoothing performed by the Moxy software. The deoxyhaemoglobin concentration ([HHb]), representing muscle O_2 extraction, was computed from SmO_2 and [THb] using the following equation:

(i) $SmO_2 = 100 \times [O_2Hb]/[THb]$, and
(ii) $[THb] = [O_2Hb] + [HHb]$.[17]

Baseline SmO_2 and [THb] were computed as a 2-min average when athletes sat still, before the 1500-m TT. Peak deoxygenation (SmO_{2min}) was calculated for both TTs as the lowest 5-s SmO_2 average minus the baseline SmO_2. Deoxygenation and reoxygenation rates were calculated as the linear regression of the first 12 s of each TT and the first 12 s following the completion of each TT, respectively[16].

Blood Lactate

Blood was collected from the non-dominant hand using a finger prick with a portable lactometer (Lactate Plus, Nova Biomedical, Waltham, MA, USA). The finger was cleaned using 70% ethanol wipes and soapy water on the fingertip and blood collection was done using disposable lancets. Blood lactate was collected before the 1500-m TT to obtain a baseline measurement (< 2 mmol/L) and at 1- and 3-min marks after each TT.

Data Analysis

A Shapiro-Wilk test of normality was performed for each parameter. Repeated-measures analysis of variance (RMANOVA) was performed for the TT, lactate, and NIRS data, and the Bonferroni post-hoc test was used when statistical significance was detected. Effect sizes are reported as partial eta squared, where: $\eta^2 \leq 0.06$ = small effect; η^2 between 0.06 and 0.13 = medium effect; $\eta^2 \geq 0.14$ = large effect. Repeated measures correlation (rmcorr) was performed to investigate the relationship among running time, lactate production, and peak muscle deoxygenation[18,19]. All data are presented as means ± standard deviation. Data were analyzed using SPSS version 29. Figures were created using R studio version 2023.06.1. Before all the analyses, the significance level was set at 0.05.

RESULTS

Table 2 presents a summary of these data. CE consumption for 28 d demonstrated a trend toward improving running times for the 1500-m TT ($P = 0.10$; $\eta^2 = 0.15$), but not for the 400-m TT ($P = 0.39$; $\eta^2 = 0.07$). Although not statistically significant, the faster running time during the 1500m

Table 2. Summary of results for the performance metrics.

Variable	Group	Mean (SD)	η^2	p-value
Time Trials (s)				
1500m	Baseline	321.36 (45.34)		
	SD-CE	322.24 (43.96)	**0.15**¥	0.10
	28-CE	307.93 (30.69)		
400m	Baseline	73.47 (10.99)		
	SD-CE	73.82 (10.21)	0.07	0.39
	28-CE	70.4 (7.76)		
Muscle Oxygenation Metrics				
Baseline SmO_2 (%)	Baseline	81.8 (6.8)		
	SD-CE	79.8 (8.2)	**0.2**¥	0.14
	28-CE	80.4 (8.4)		
Baseline THb (AU)	Baseline	12.5 (0.5)		
	SD-CE	12.4 (0.4)	0.03	0.71
	28-CE	12.5 (0.4)		
1500m				
Deoxy Rate (%/s)	Baseline	-4.6 (2.6)		
	SD-CE	-4.8 (1.5)	**0.2**¥	0.13
	28-CE	-4.1 (1.8)		

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Variable	Group	Mean (SD)	η²	p-value
Peak Deoxy (Δ%)	Baseline	-59.9 (12,5)		
	SD-CE	-61.3 (6.8)	0.07	0.55
	28-CE	-57.6 (20.7)		
Mean SmO_2 (%)	Baseline	30.0 (11.4)		
	SD-CE	28.2 (6.8)	0.02	0.82
	28-CE	28.4 (14.0)		
400m				
Deoxy Rate (%/s)	Baseline	-5.1 (2.6)		
	SD-CE	-4.8 (1.1)	0.005	0.95
	28-CE	-5.0 (2.3)		
Peak Deoxy (Δ%)	Baseline	-63.6 (15.0)		
	SD-CE	-68.2 (8.2)	0.01	0.90
	28-CE	-63.4 (21.2)		
Mean SmO_2 (%)	Baseline	27.3 (9.6)		
	SD-CE	26.6 (9.5)	0.01	0.89
	28-CE	26.0 (11.5)		

Mean data expressed as means ± SD. Repeated measures ANOVA p-levels and partial ETA squared (η²) listed for each variable. ¥ represents a large effect size (η² ≥ 0.14); * represents p<0.05. *SmO_2* muscle oxygen saturation, *THb* total hemoglobin, *Deoxy* muscle deoxygenation.

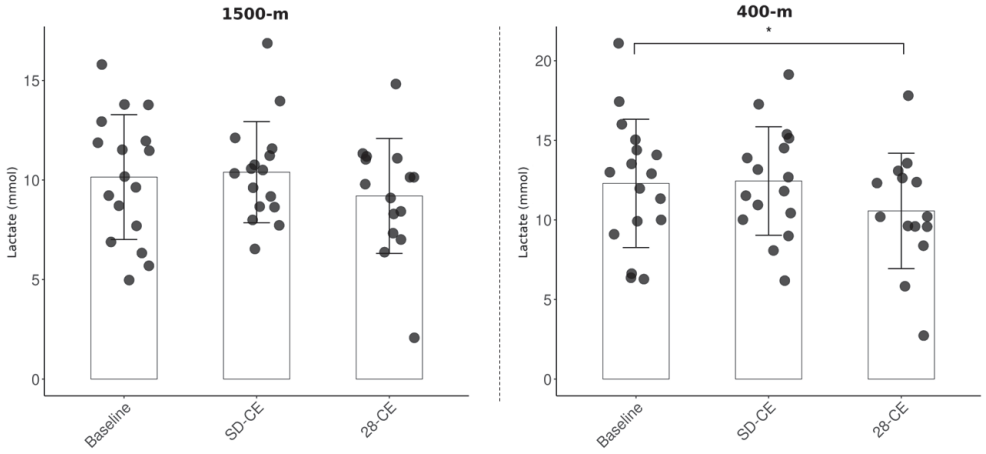

Figure 2. Post-exercise lactate response following the 1500-m and 400-m time trials. * p < 0.05.

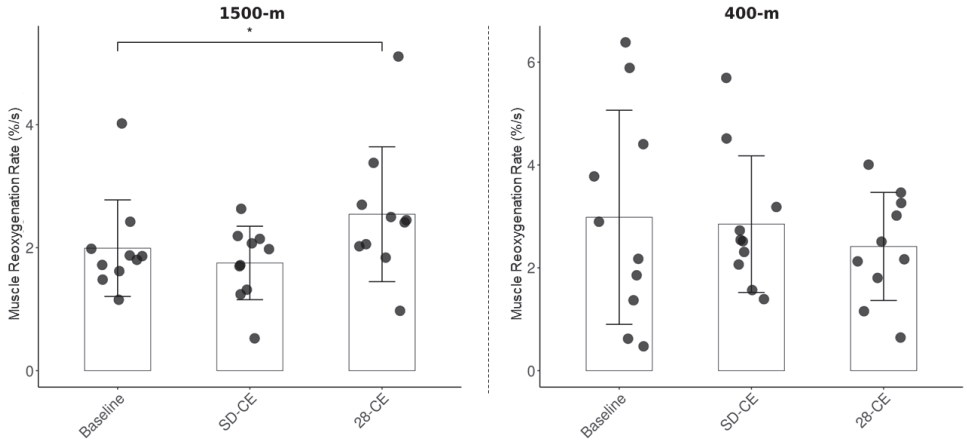

Figure 3. Peak muscle deoxygenation during the 1500-m and 400-m time trials. * p < 0.05.

TT translated to a 1.5% mean increase in running speeds. Baseline lactate levels were the same at all time points (P = 0.27; η² = 0.11). CE significantly buffered the lactate peak at 1 min post-run for the 400-m TT (P = 0.01; η² = 0.27), but not for the 1500-m TT (P = 0.33; η² = 0.08) (Figure 2).

There was no effect of CE supplementation on baseline SmO_2 (P = 0.14; η² = 0.2) or THb (P = 0.71; η² 0.2) between the three conditions, although a trend towards a lower SmO_2

was observed in the acute dose condition. For the 1500-m TT NIRS data, the muscle reoxygenation rate was significantly faster in the CE-28 condition compared to the baseline ($P = 0.04$; $\eta^2 = 0.29$) (Figure 3). Furthermore, a trend towards a slower deoxygenation rate was observed ($P = 0.13$; $\eta^2 = 0.20$). Peak muscle deoxygenation was similar across all time points ($P = 0.55$; $\eta^2 = 0.07$). For the 400-m TT, no differences were observed for the deoxygenation rate ($P = 0.95$; $\eta^2 = 0.005$), the reoxygenation rate ($P = 0.66$; $\eta^2 = 0.05$), or the peak deoxygenation ($P = 0.90$; $\eta^2 = 0.01$). There were no statistically significant effects of SD-CE on any test parameters.

A correlation between lactate production and running time was observed during the 400-m TT ($P = 0.02$; $r_{rm} = -0.43$) but not for the 1500-m TT ($P = 0.91$; $r_{rm} = 0.02$). Conversely, there was an association between peak muscle deoxygenation and running time for the 1500-m TT ($P = 0.07$; $r_{rm} = 0.40$) but not for the 400-m TT ($P = 0.38$; $r_{rm} = 0.21$). When comparing the relationship between lactate production and peak muscle deoxygenation, we observed only weak associations at both 1500 m ($P = 0.12$; $r_{rm} = 0.27$) and 400 m ($P = 0.28$; $r_{rm} = 0.26$).

When each parameter was normalized to sex, training status, main event, and berry consumption, no statistically significant differences or trends were observed (data not shown).

DISCUSSION

The main finding of this study was that cranberry supplementation for 28 d appeared to improve running speed as well as aerobic performance in trained runners during a 1500-m TT. More specifically, the muscle reoxygenation rates were significantly faster and were accompanied by enhanced running times. The faster time to completion of the 1500-m TT was associated with a 1.5% increase in speed, which is important for competitive runners. For the 400-m TT, CE buffered the post-exercise lactate response, although it did not affect the other parameters.

Few studies have examined the effects of cranberries and cranberry polyphenols on exercise performance. Our results for the acute dose are consistent with the findings of previous animal studies[20,21], in which cranberry did not improve running performance. Similarly, Skarpanska et al. found that 6 weeks of CE supplementation did not affect the 2000-m rowing TT or post-exercise lactate response, which agrees with our findings[14]. Conversely, an acute cranberry and grape seed extract dose lowered the lactate response following a 3 km cycling TT[15]. We observed a similar effect in the 400-m TT, but not during the 1500-m TT. The different testing modalities (running vs. cycling) could explain why such results were observed in a longer cycling TT, as it has been shown that submaximal and maximal cycling requires higher muscular power output, which produces blood lactate concentrations that are larger as compared to running[22].

This is the first study to evaluate the effect of cranberries on muscle oxygenation using an NIRS device, although a few studies have used the same technique to examine the effects of polyphenols from other sources. Similar to our observations, a study on flavonol-rich dark chocolate supplementation for 2 weeks found no effect on baseline muscle oxygenation and peak muscle deoxygenation[23]. Conversely, studies on Montmorency cherry supplementation have shown higher baseline muscle oxygenation, but no effect during a moderate- or severe-intensity exercise bout[24,25]. Similarly, polyphenol supplementation for 7 d was not sufficient to affect any muscle oxygenation metric during a 4-km cycling TT[26]. When looking at the maximal muscle deoxygenation during exercise, a study on the polyphenols mangiferin and luteolin found that they significantly lowered muscle O_2 levels during a 30-s Wingate test after consumption for 48 h and 15 d, which they attributed to an improved ability of the muscle to extract oxygen[27], conversely to what we observed. No studies have evaluated the muscle deoxygenation and reoxygenation rates after cranberry supplementation.

Several studies have investigated the effects of polyphenols from sources other than cranberries on exercise performance. A recent systematic review of randomized controlled trials by Sommerville et al. examined the effect of polyphenol supplementation (minimum of 7 d) on exercise performance in healthy individuals[28]. They measured performance as the total power output calculated from either time trial or time to exhaustion testing and concluded that supplementation with polyphenols improved exercise performance moderately but warranted further investigation to determine the optimal dose[29]. Half of the studies (n = 7) included in the meta-analysis used quercetin, which demonstrated greater effects on performance, notably peak power production[29]. Interestingly, cranberries contain 20–30 mg of quercetin per 100 g fresh weight[30], which may have played a role in our results. The duration, treatment, and supplement dosage also differed from those used in the aforementioned meta-analyses. The mean daily polyphenol content was 688 ± 478 mg and the supplementation period varied from 7 to 56 d. For our study, 0.3 g/kg of body weight/day was administered for 28 d, which represents a mean of 1,664 mg of PACs daily, based on our participants' average body weight, which was 62.0 kg. The notable discrepancy in dosages and polyphenol types across the studies provided a trivial means of comparison.

We also observed a moderate correlation between lactate production and running time for the 400-m TT as well as between peak muscle deoxygenation and running time for the 1500m TT. These results are in agreement with previous findings[8,9] and attest to the quality of the data collected. Furthermore, these correlations indicate better oxygen extraction by the muscle, resulting in less lactate production and greater deoxygenation. With further stratification of our data based on participant sex, training status, main event, and berry consumption, we observed no statistically significant differences or trends.

Some of the limitations of this study were that a placebo powder was not developed, and the plasma polyphenol levels were not measured. The cranberry extract powder used

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had a unique formula enriched in polyphenols, making it hydrophobic, chalky in texture, and tart in taste. Therefore, it was not possible to formulate a placebo powder with the same appearance and taste. If we had been able to measure the plasma polyphenol levels in our participants, we could have gathered some insight into the bioavailability of cranberry polyphenols as well as a direct measure of the compliance of each participant. Future studies should seek to develop a viable placebo for this cranberry supplement and perform blood tests to examine its bioavailability.

In summary, these results show that CE supplementation for 28 d, but not enough to lower the time to completion, improved physiological markers of performance that may help postpone the onset of muscle fatigue during both a 400-m TT and a 1500-m TT.

ACKNOWLEDGEMENTS

We thank all the participants who volunteered to participate in this study and completed their three visits as well as the full supplementation protocol. We also thank SM, AL, and KM for their help with data collection. Finally, we thank Fruit d'Or Inc. for supplying the cranberry extract. Apart from this donation, the study was not financially supported by Fruit d'Or Inc., any other company, or organization. The authors declare no conflict of interest.

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