International Journal of Sport Nutrition and Exercise Metabolism, 2002, **12,** 349-363

Oral Bovine Colostrum Supplementation Enhances Buffer Capacity But Not Rowing Performance in Elite Female Rowers

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A randomized, double-blind, placebo controlled design was used in which 13 elite female rowers, all of whom had competed at World Championships, were supplemented with 60 g · day^{-1} of either bovine colostrum (BC; $n = 6$) or concentrated whey protein powder (WP; $n = 7$) during 9 weeks of pre-competition training. All subjects undertook the study as a group and completed the same training program. Prior to, and after 9 weeks of supplementation and training, subjects completed an incremental rowing test (ROW1) on a rowing ergometer consisting of 3 3 4-min submaximal workloads and a 4-min maximal effort (4max), each separated by a 1-min recovery period. The rowing test was repeated after a 15-min period of passive recovery (ROW2). The 4max for ROW1 provided a measure of performance, and the difference between the 4max efforts of ROW1 and ROW2 provided an index of recovery. Blood lactate concentrations and pH measured prior to exercise and at the end of each workload were used to estimate blood buffer capacity (b). Food intake was recorded daily for dietary analysis. There were no differences in macronutrient intakes ($p >$ .56) or training volumes ($p >$ .99) between BC and WP during the study period. Rowing performance (distance rowed and work done) during 4max of ROW2 was less than ROW1 at baseline ($p <$ .05) but not different between groups ($p >$ .05). Performance increased in both rows by Week 9 ($p <$ .001), with no difference between groups ($p >$ .75). However, the increase was greatest in ROW2 ($p <$ .05), such that by Week 9 there was no longer a difference in performance between the two rows in either group ($p >$ .05). b was not different between groups for ROW1 at baseline (BC 38.3 ± 5.0, WP 38.2 ± 7.2 slykes; $p >$ .05) but was higher in BC by Week 9 (BC 40.8 ± 5.9, WP 33.4 ± 5.3 slykes; $p <$ .05). b for ROW2 followed the same pattern of change as for ROW1. We conclude that supplementation with BC improves b, but not performance, in elite female rowers. It was not possible to determine whether b had any effect on recovery.

Key Words: elite subjects, nutritional supplement, lactate, pH

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Introduction

Bovine colostrum is the first milk secreted by cows after parturition and is a rich source of proteins, carbohydrates, fat, vitamins, minerals, and biologically active components such as antimicrobial molecules, immunoglobulins, and peptide growth factors (10, 14, 27). Feeding colostrum has recently been shown to increase the synthesis of myofibrillar protein in the skeletal muscle of newborn piglets (11), and bone-free lean body mass in healthy trained adults (2), suggesting that colostrum might be beneficial for improving muscular function and athletic performance. However, a previous study reported that 5 days of colostrum supplementation had no effect on vertical jump performance or recovery from exercise in speed and strength trained athletes (24). In contrast, more recent studies have shown that longer periods of colostrum supplementation (i.e., 8 weeks) are effective in improving recovery from endurance exercise in recreational runners (7) but have no effect on endurance exercise performance (2, 7). Anecdotal evidence indicates that elite athletes are taking colostrum in an effort to enhance recovery, but an improvement in the recovery of recreational runners does not necessarily imply that the same effect will be seen in elite subjects because elite performers almost certainly have a different training history and a physiological development that is closer to their genetic limits (19).

Despite the reported physiological and performance effects of colostrum supplementation (2, 7, 11), no study has as yet been able to identify the mechanism of action of this supplement. In addition to examining the performance effects of bovine colostrum supplementation, Mero et al. (24) also examined effects on serum insulin-like growth factor I (IGF-I) concentrations, and found that 8 days of supplementation increased serum IGF-1 in a dose dependent manner. In contrast, we subsequently demonstrated that 8 weeks of supplementation had no effect on plasma IGF-1 concentrations (7). Despite the equivocal findings with respect to the effects of bovine colostrum supplementation on circulating IGF-I concentrations, Burrin et al. (9) showed that feeding colostrum to newborn animals stimulated protein synthesis in a number of tissues, including skeletal muscle, independently of changes in circulating plasma IGF-1 concentrations. More recently, it has been shown in newborn piglets that the stimulation of skeletal muscle protein synthesis caused by feeding colostrum is restricted entirely to the myofibrillar protein compartment (11) and, since IGF-I has been shown to stimulate proportional increases in myofibrillar and sarcoplasmic protein synthesis, it would seem that some component other than IGF-I is more likely to induce the increased skeletal muscle protein synthesis associated with feeding colostrum. Apart from IGF-I, colostrum contains a vast number of peptide growth factors (10, 27) and other yet-to-be-identified mitogenic factors (4), any number of which might be responsible for the effects of colostrum supplementation. Identifying the active component(s) in this supplement may therefore prove quite difficult. However, as more research findings become available, and the physiological and performance effects of colostrum supplementation become better characterized, it should be possible to better define the mechanism of action of the supplement and, consequently, to more easily identify active component(s) that might be responsible for the effects. Therefore, studies examining the effects of colostrum supplementation on exercise performance should endeavor to measure the physiological parameters underpinning these performances. More specifically, studies examining the effects of bovine colostrum on endurance exercise performance and/or recovery should at least measure oxygen uptake and blood lactate

responses to exercise, since maximal oxygen uptake ($\dot{V}O_{2max}$) is highly correlated with endurance performance (15, 32), and blood lactate accumulation during exercise is not only associated with fatigue (21) but is also an important determinant of endurance performance (16). Other physiological parameters, which are specific to particular activities, should also be measured. For example, buffer capacity (b), which reflects the ability to bind free protons, and offset reductions in pH during exercise, is elevated in rowers (23, 29), and given the strong association between acidosis and muscular fatigue (28), changes in b have the capacity to impact on rowing performance. Furthermore, since muscle proteins have been identified as a major intramuscular buffer (20, 28), and colostrum supplementation has been shown to stimulate muscle protein synthesis (8, 9, 11), it is conceivable that the mitogenic growth factors in colostrum may elevate b by stimulating muscle protein synthesis. Therefore, any studies examining the effects of bovine colostrum on rowing performance, such as the present study, should measure b.

In the present study, therefore, we sought to determine whether colostrum supplementation had any effect on rowing performance and/or recovery. We also sought to determine whether there were any effects of bovine colostrum supplementation on a number of physiological parameters related to rowing performance (i.e., $\dot{V}O_{2max}$, blood lactate, pH, and b) in an effort to identify the physiological mechanisms that might underlie any changes in performance or recovery.

Methods

Subjects

Thirteen female rowers from the South Australian Sports Institute (SASI) High Performance Rowing program, all of whom had previously competed at World Championships, volunteered to participate after providing written informed consent. The testing procedures were carried out in the Sports Physiology laboratory of SASI, which is a quality assured laboratory under the Laboratory Standards Assistance Scheme of the Australian Sports Commission (13). All experimental procedures were approved by the Human Research Ethics Committee of the University of South Australia.

Experimental Procedures

This study was conducted during a 9-week pre-competition period leading up to selection trials for National and World Championships. The study was conducted during this training period because it was the only time of year when all of the subjects were undertaking exactly the same training program and were able to train and participate in the study together as a single group. Prior to the commencement of the study, all subjects had participated in a standardized rowing training program for at least 1 month under the supervision of their coaches with minimal differences in training between the subjects. In addition, since the subjects were members of the High Performance Rowing program at SASI, under the supervision of coaches and other staff they were encouraged at all times to follow healthy dietary guidelines, and their dietary intakes were similar to those reported for other elite female athletes, including rowers (6). The only experimental manipulations imposed on the subjects beyond their normal commitments during the study period were the consumption of the appropriate dietary supplement, the recording of food intake, and the completion of a second exercise test after a short recovery period at each test session.

The study employed a double-blind, randomized, placebo-controlled, parallel design. Each subject attended the laboratory on two separate occasions (i.e., weeks 0 and 9) for testing, separated by 9 weeks of training and supplementation. All subjects followed standard dietary and exercise guidelines during the 24 hours prior to testing (12). During each visit to the laboratory, body mass and stature were assessed prior to the performance of two discontinuous, incremental rowing ergometer tests (ROW1 and ROW2) separated by a 15-min period of passive recovery, during which subjects remained seated on the ergometer. ROW1 provided a measure of rowing performance, and ROW2, although it is of itself a performance test, was used to provide an index of the extent to which subjects were able to recover during the interval between the rows. Blood lactate concentrations and pH were measured from finger-prick capillary blood samples taken during each of the two rows. Subjects began consuming the appropriate supplements, and resumed their regular training program (same training program for all subjects) on the day following the initial testing session. Food intakes were recorded daily during the 9-week study period for subsequent dietary analysis.

Supplements

After being tested at Week 0, subjects were randomly allocated to the consumption of 60 g · day^{-1} of concentrated bovine colostrum protein powder (BC; intact™, Numico Research Australia Pty. Ltd., Adelaide, Australia) or a concentrated whey protein powder placebo (WP; Alacen, New Zealand Milk Products Australia, Rowville, Australia). All supplements were provided in pre-weighed 20-g sachets, and the subjects mixed and consumed the contents of one sachet with their morning meal and two sachets with their evening meal. The contents of each sachet were mixed with 85 ml of warm water and 40 ml of milk, shaken vigorously, then chilled before drinking. The taste and color of the two supplements were indistinguishable.

Body Mass and Stature

Body mass was measured using electronic digital scales (Mettler, TE, Greifensee, Switzerland), with the subjects clothed only in a rowing suit. Stature was measured by the stretch stature method (26), using a custom-made stadiometer fitted with a metal tape (Lufkin, North Carolina, USA) and a right-angled headboard.

Rowing Tests

The two rowing tests undertaken at each testing session were performed on a rowing ergometer (Concept IIc, Concept II, Inc., Morrisville, USA) with the damper lever set at two for lightweight and three for heavyweight rowers, in order to best replicate the drag forces of rowing on water (17). Each test consisted of three 3 4-min submaximal workloads, separated by 1-min rest intervals, and a final 4-min maximal effort (4max). A 15-min period of passive recovery was allowed before the test was repeated. The resistances for the three submaximal workloads were calculated according to a modified form of a commonly used rowing test protocol (17) and were based on each subject's best time for a race simulation test performed over 2000-m during the 2 months proceeding study commencement. In brief, the average 500-m pace of the 2000-m race simulation time plus 4 s was calculated, then an

additional 30, 18, and 6 s was added to give target times per 500 m for the first, second, and third submaximal workloads, respectively.

Expired Air

Throughout each rowing test, subjects' breathed through a face mask (Hans Rudolph, 7900 series, Kansas City, MO) fitted with a two-way non-rebreathing valve (Hans Rudolph 2700, Kansas City, MO). A pre-calibrated large flow turbine transducer (Morgan Mark 2 ventilation meter, Kent, England) was attached to the inspiratory port to measure ventilatory volumes. Expired air was collected into a 2.6-L mixing chamber (Sportech, Canberra, Australia) from which dried gas was sampled continuously (~500 ml · min^{-1}) and passed to an oxygen analyzer (Ametek S-3A/I, Pittsburgh, PA) and a carbon dioxide analyzer (Ametek CD-3A, Pittsburgh, PA), both of which had been calibrated prior to each test with commercially-produced alpha grade gas mixtures of known oxygen and carbon dioxide composition (BOC Gases, Adelaide, Australia). The electrical outputs from the gas analyzers and ventilation meter were integrated using a personal computer system, which calculated the necessary ventilatory variables as 1-min averages using a customized application that was written using commercially available software (Labview, National Instruments, TX). The values for oxygen uptake ($\dot{V}O_2$) and carbon dioxide output ($\dot{V}CO_2$) averaged over the final minute of each workload were recorded as the measured values.

Blood Samples

Finger-prick blood samples were collected prior to the commencement of rowing exercise, at the end of each submaximal workload, and immediately after each 4max test for determination of blood lactate concentrations and pH. Blood lactate concentrations were measured using an automated lactate analyzer (Model YSI 1500 Sport, Yellow Springs, OH), and pH was measured using an automated blood gas analysis system (Ciba-Corning 865, Essex, England).

Blood Buffer Capacity (b)

b was estimated from the relationship between the blood lactate concentration and pH using linear regression analysis and was defined as the increase in blood lactate concentration corresponding to a decrease in pH of 1.0 unit (30, 33). b was expressed in units called "slykes" (mmol · L^{-1} · pH unit). Reliability trials for the determination of b in rowers were not undertaken for this study, but blood lactate and pH measurements taken from 8 recreational runners who performed two incremental treadmill exercise tests separated by 2 days revealed that the determination of b has a typical error of measurement (TEM) of 6.3 slykes, or 16%. This is considered a worst estimate of the reproducibility of b, since it is likely that the TEM would be lower in elite performers such as rowers used in the present study, due to their greater skill and familiarity with the test procedures.

Training

All subjects completed the same on-water and dry-land training programs under the supervision of their coach during the study period (see Tables 1 and 2). The work

intensities of the on-water rowing training were divided into six categories based on measurements of the lactate threshold (LT) and anaerobic threshold (AT) determined during a seven-stage progressive rowing ergometer test to exhaustion, which was conducted as part of the subjects' routine physiological assessment in the 2 months prior to study commencement (17). LT was defined as the point on the lactate-workload curve (third order polynomial) where the blood lactate concentration reached a level of 0.4 mmol · L^{-1} above the minimum recorded lactate reading then continued to rise (17). AT was determined using a modified D-max method (17). The training intensities, actual time spent, and percentages of time spent at each of the six training intensities during the study period are included in Table 1. The dry-land training consisted of a strength-plyometric training program performed three times per week, with four sessions completed every 4th week. The specific exercises, number of sets, and number of repetitions performed, are described in Table 2. No subjects missed any training sessions during the study period.

Nutrition

All subjects consumed their normal diet throughout the study and kept a daily food diary for subsequent computerized analysis (SERVE Dietary Analysis Software, M.H. Williams, Adelaide, South Australia) of energy and macronutrient (i.e., carbohydrate, fat, and protein) intakes. Apart for the dietary supplements that were consumed as part of the experimental protocol, no other amino acid supplements, creatine monohydrate, or sport supplements were used by the athletes during the study phase.

Statistical Procedures

Student's *t* test was used to compare group means for age, stature, mass, and dietary intakes. Linear regression was used to determine relationships between variables

Table 1 Breakdown of Rowing On-Water Training Program

Training intensity	Time spent (%)	Minutes per week
Below LT	45.7	496
Between LT and LT-AT	29.3	318
Between LT-AT and AT	14.2	153
At AT	5.0	54
Above AT	3.8	41
Anaerobic work at or above race pace	2.0	22
Total	100.0	1084

Note. LT, lactate threshold (rise in LA of 0.4 mmol · L^{-1} above minimum); AT, anaerobic threshold (modified D-max method); LT-AT, midway distance between LT and AT.

Table 2 Exercises and Number of Sets and Repetitions Performed During Strength-Plyometric Training Sessions Three Times Per Week and Four Times Every 4th Week

Exercise	Sets	Repetitions
Lower body		
Single leg press*†	4	6 (each leg)
Smith squat machine*†	4	6
Chin-ups†	4	6
Box jumps—explosive rebound (box-floor-box)	4	10
Box jumps—controlled concentric contraction (box-floor)	4	10
Upper body		
Bench press*†	4	6
Single arm bench pulls*†	4	6 (each arm)
Swiss ball		
Front bridge with alternate leg raise	4	10 (each side)
Pilates crunch	4	10
Supine hip extension	4	10
Supine hip extension with arms adducted	4	10

Note. *Performed at 65% 1RM; †performed with controlled eccentric phase and explosive concentric phase.

where appropriate. To determine the effects of the treatment, time of measurement, and their interactions on the dependant measures, univariate analysis of variance (ANOVA) with repeated measures was used. One factor was the treatment group (i.e., BC or WP), and the other factors (with repeated measures) were the time of measurement of the dependant variable (i.e., Weeks 0 and 9), the rowing protocol (i.e., ROW 1 or ROW 2) and, where appropriate, the workloads of the rowing protocol. Where ANOVA showed a statistically significant main effect, pair-wise comparisons were made using Tukey's HSD for unequal sample sizes (Spjotvoll & Stoline test). The data obtained pre-exercise and from the three submaximal workloads of the rowing protocol were analyzed separately from the data for the 4max tests, except in so far as all pH and blood lactate values were used for calculation of b. Statistical significance was set at an a level of $p < .05$. All data values cited in the text, and shown in tables and figures, represent means ± standard deviation (*SD*).

Results

Age, Stature, and Mass

There was no difference in age (BC 20.7 ± 4.2 years, WP 20.6 ± 2.3 years; $p = .94$), stature (BC 177.3 ± 3.4 cm, WP 173.5 ± 4.1 cm; $p = .11$) or body mass (BC 70.7 ± 6.9 kg, WP 68.7 ± 5.5 kg; $p = .57$) between the two groups at Week 0, and neither stature ($p = .33$) nor body mass ($p = .90$) changed in either group during the study period.

Rowing Tests

The distances rowed and mechanical work done during the three submaximal workloads of ROW 1 and ROW 2 were not different between the two groups ($p > .23$) or between Weeks 0 and 9 ($p > .18$). The distances rowed and the mechanical work done during 4max of ROW 1 and ROW 2 at Weeks 0 and 9 are shown in Figures 1 and 2, respectively.

There were no differences in the $\dot{V}O_2$ response to submaximal exercise between the two groups during ROW 1 or ROW 2, or between Weeks 0 and 9 ($p > .56$). There was no difference in the peak $\dot{V}O_2$ achieved during 4max of ROW 1 at Week 0 between the two groups (BC 3.7 ± 0.3 L · min^{-1}, WP 3.6 ± 0.3 L · min^{-1}; $p = .65$) and peak $\dot{V}O_2$ had not changed in either group by Week 9 ($p = .12$). There was no difference in the peak $\dot{V}O_2$ achieved during 4max of ROW 2 between the groups at week 0 (BC 3.6 ± 0.3 L · min^{-1}, WP 3.6 ± 0.2 L · min^{-1}; $p = .65$), and these values were not different from those achieved during ROW 1 ($p = .99$). However, by Week 9, peak $\dot{V}O_2$ during 4max of ROW 2 had increased ($p = .002$) in both groups (BC 0.3 ± 0.2 L · min^{-1}, WP 0.1 ± 0.1 L · min^{-1}), such that it was significantly higher than during ROW 1 ($p = .03$) but was still not different between groups (BC 3.8 ± 0.3 L · min^{-1}, 3.7 ± 0.2 L · min^{-1}; $p = .23$).

Blood Lactate, pH, and Buffer Capacity (b)

The blood lactate concentrations achieved during the rowing tests are reported in Table 3, and the pH values are reported in Table 4. The data for b is presented in Figure 3. There was no relationship between the change in b and the changes in distance rowed (BC, $r^2 = 0.23$, $p = .34$; WP, $r^2 = 0.02$, $p = .74$) or mechanical work done (BC, $r^2 = 0.19$, $p = .38$; WP, $r^2 = 0.04$, $p = .66$) during 4max of ROW 1 in either group. Similarly, there was no relationship between these same parameters for ROW2 (distance rowed BC, $r^2 = 0.03$, $p = .79$; WP, $r^2 = 0.18$, $p = .35$; mechanical work done BC, $r^2 = 0.02$, $p = .81$; WP, $r^2 = 0.15$, $p = .39$).

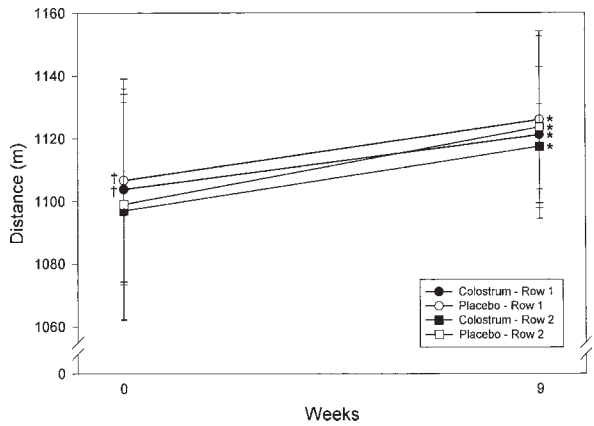

Figure 1 — Distance rowed by elite female rowers during 4-min maximal efforts of ROW 1 and ROW 2 prior to and after 9 weeks of training and supplementation with concentrated bovine colostrum protein powder ($n = 6$) or a concentrated whey protein powder placebo ($n = 7$). Values are means ± *SD*. *$p < .001$, significantly different from week 0. †$p < .05$, significantly different from ROW 2.

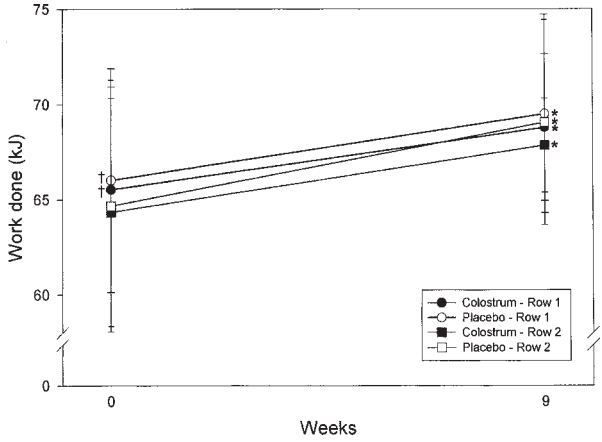

Figure 2 — Mechanical work done by elite female rowers during 4-min maximal efforts of ROW 1 and ROW 2 prior to and after 9 weeks of training and supplementation with concentrated bovine colostrum protein powder (n = 6) or a concentrated whey protein powder placebo (n = 7). Values are means ± *SD*. *p < .001, significantly different from week 0. †p < .01, significantly different from ROW 2.

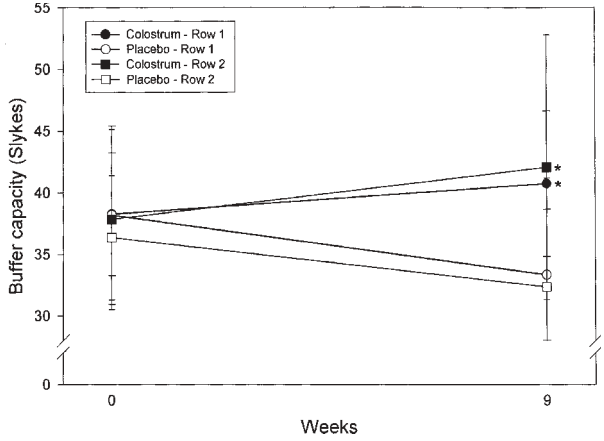

Figure 3 — Buffer capacity prior to and after 9 weeks of training and supplementation with concentrated bovine colostrum protein powder (n = 6) or a concentrated whey protein powder placebo (n = 7) in elite female rowers. Values are means ± *SD*. *p = .03, significantly different from Placebo.

Dietary Analysis

There were no differences in the mean daily energy intakes (p = .78) or macronutrient intakes (p > .46) between the two groups during the study period (see Table 5).

Discussion

This study demonstrated that supplementation of a group of elite female rowers with bovine colostrum during 9 weeks of training significantly enhanced b but did not

Table 3 Blood Lactate Concentrations (mmol · L^{-1}) Prior to Exercise At the End of Each Submaximal Workload and After a 4-Min Maximal Rowing Test for ROW 1 and ROW 2 Before and After 9 Weeks of Training and Oral Supplementation With Concentrated Bovine Colostrum Protein Powder (*n* = 6) or a Concentrated Whey Protein Powder Placebo (*n* = 7)

	Week 0				Week 9			
	Colostrum		Placebo		Colostrum		Placebo	
Variable	Row 1	Row 2	Row 1	Row 2	Row 1	Row 2	Row 1	Row 2
Pre-exercise	1.26 ± 0.43[e]	5.99 ± 2.49[f]	1.31 ± 0.31[e]	6.43 ± 1.73	1.36 ± 0.28[e]	7.02 ± 2.61	1.42 ± 0.49[e]	6.14 ± 1.63[a]
Submaximal workload 1	1.11 ± 0.21[e]	2.63 ± 1.64[b]	1.12 ± 0.27[e]	3.18 ± 1.40[b]	0.91 ± 0.09[e]	3.12 ± 1.14[b]	1.29 ± 0.52[e]	3.34 ± 1.31[b]
Submaximal workload 2	1.05 ± 0.20	1.61 ± 0.79[b]	1.15 ± 0.38	1.80 ± 1.02[b,c]	1.12 ± 0.28[e]	2.05 ± 1.19[b]	1.01 ± 0.32[e]	1.88 ± 0.73[b,c]
Submaximal workload 3	2.93 ± 0.20[c,d]	3.26 ± 0.90[b,c,d]	2.84 ± 1.04[b,d,f]	3.14 ± 1.40[b,d,f]	3.31 ± 1.03[b,c,d]	2.63 ± 0.69[b]	2.03 ± 0.68[d]	2.42 ± 0.90[b,c]
Maximal rowing test	8.34 ± 2.40[f]	7.98 ± 2.10[f]	8.77 ± 1.79[f]	8.67 ± 1.75[f]	9.50 ± 2.34	9.77 ± 3.19	9.03 ± 2.24	9.15 ± 1.58

Note. Values are means ± *SD*.
[a]$p < .001$ Colostrum versus Placebo. [b]$p < .05$ different from pre-exercise. [c]$p < .05$ different from submaximal workload 1. [d]$p < .05$ different from submaximal workload 2. [e]$p < .05$ different from Row 2. [f]$p < .05$ different from Week 9.

Table 4 Blood pH Prior to Exercise At the End of Each Submaximal Workload and After a 4-Min Maximal Rowing Test for ROW 1 and ROW 2 Before and After 9 Weeks of Training and Supplementation With Concentrated Bovine Colostrum Protein Powder (n = 6) or a Concentrated Whey Protein Powder Placebo (n = 7)

	Week 0				Week 9			
	Colostrum		Placebo		Colostrum		Placebo	
Variable	Row 1	Row 2	Row 1	Row 2	Row 1	Row 2	Row 1	Row 2
Pre-exercise	7.39 ± 0.02[b]	7.29 ± 0.07	7.38 ± 0.05[b]	7.27 ± 0.06	7.42 ± 0.02[b]	7.30 ± 0.04	7.39 ± 0.02[b]	7.27 ± 0.05
Submaximal workload 1	7.40 ± 0.02	7.39 ± 0.03[a]	7.39 ± 0.03	7.36 ± 0.04[a]	7.41 ± 0.02	7.38 ± 0.02[a]	7.39 ± 0.03[b]	7.36 ± 0.03[a]
Submaximal workload 2	7.40 ± 0.02	7.40 ± 0.01[a]	7.40 ± 0.02	7.39 ± 0.03[a]	7.40 ± 0.02	7.40 ± 0.01[a]	7.40 ± 0.02	7.40 ± 0.03[a]
Submaximal workload 3	7.36 ± 0.01	7.37 ± 0.02[a]	7.36 ± 0.02	7.36 ± 0.04[a]	7.37 ± 0.02[a]	7.38 ± 0.01[a]	7.37 ± 0.02	7.38 ± 0.03[a]
Maximal rowing test	7.21 ± 0.06	7.23 ± 0.07	7.19 ± 0.06	7.20 ± 0.07	7.19 ± 0.06	7.20 ± 0.06	7.16 ± 0.06	7.17 ± 0.05

Note. Values are means ± *SD*.
[a]$p < .05$ different from pre-exercise. [b]$p < .05$ different from Row 2.

Table 5 Dietary Intakes of Elite Female Rowers During 9 Weeks of Training and Supplementation With Concentrated Bovine Colostrum Protein Powder (n = 6) or a Concentrated Whey Protein Powder Placebo (n = 7)

Variable	Colostrum	Placebo
Mean daily energy intake (kJ · day^{-1})	9465 ± 1918	9771 ± 1965
Carbohydrate as % daily energy intake	52.4 ± 2.7	51.2 ± 4.4
Protein as % daily energy intake	23.3 ± 1.8	23.3 ± 2.5
Fat as % daily energy intake	23.1 ± 2.6	24.4 ± 5.3
Protein intake as g · kg bm · day^{-1}	1.85 ± 0.28	1.97 ± 0.32

Note. Values are means ± *SD.*

improve rowing performance. By the end of the study, both groups of subjects rowed the same distance and performed the same mechanical work during the second rowing test (ROW2) as during the first rowing test (ROW1), indicating that they had completely recovered from ROW1 during the intervening 15-min rest period. It was not possible therefore to determine whether bovine colostrum supplementation had any effect on recovery in these athletes.

b reflects the ability to resist decreases in pH in response to increases in proton load by binding free protons, and can be estimated during exercise from the change in lactate corresponding to a decrease in pH of 1.0 unit (30, 33). Although, the majority of studies have estimated b during exercise from the relationship between changes in muscle lactate concentrations and muscle pH (30, 34), because the present study was conducted in elite athletes during the immediate period leading up to National and World Championship selection trials, a less invasive technique was required to avoid any interference with the subjects' training. Consequently, estimations of b were obtained from the relationship between changes in blood lactate and pH (5, 33). Unlike measurements of muscle b, which only assesses the effect of muscle buffer systems, the estimation of b from blood measurements represents the sum effect of both muscle and blood buffer systems. It is not possible therefore, to distinguish between muscle and blood buffering effects individually when estimating b from blood measures alone. However, irrespective of whether b is assessed in muscle or blood during exercise, this variable is calculated from the relationship between changes in lactate concentration and changes in pH, and it is therefore an assumption that lactic acid is the sole source of H^+ during exercise. Although a reported 94% of H^+ produced during exercise originates from the production of lactic acid (20), the hydrolysis of ATP also produces H^+ (20, 28), and therefore differences in ATP hydrolysis have the potential to confound estimates of b during exercise regardless of whether they are determined in muscle tissue or in blood. In the present study, the mechanical work performed during the rowing tests was the same for both groups at Week 0 and, although both groups performed more work during the 4max of both rows at Week 9, there was no difference in the amount of work performed between the two groups. Therefore, since ATP hydrolysis provides the energy for muscle contraction, and the work done did not differ between the two

groups, the rates of ATP hydrolysis and the resultant H^+ loads resulting from this hydrolysis should have been similar in both groups at Weeks 0 and 9, making between-group comparisons of b valid. On the other hand, because the mechanical work done during 4max increased in both groups from Week 0 to Week 9, the H^+ load from ATP hydrolysis would also have increased, which would serve to reduce pH independently of any increase in lactic acid accumulation and lead to an underestimation of b. Therefore, it is likely that b at Week 9 represented an underestimation of the true b relative to values at Week 0 for both groups. Such underestimation could account for the apparent fall in b in the WP group from Week 0 to Week 9, whilst at the same time masking the true magnitude of the increase in b in the BC group. Nevertheless, given that between-group comparisons of b should still be valid, the present data indicate that 9 weeks of bovine colostrum supplementation provided subjects with a b that was on average 7.4 slykes (22%) greater than subjects taking the placebo. Our worst estimate of the reproducibility of blood b was 6.3 slykes (16%), which suggests that the greater b in the colostrum group may be a real effect caused by consumption of the colostrum supplement.

Although previous studies have documented physiological or performance effects of colostrum supplementation (2, 7, 8, 11, 18, 24), none have been able to determine the mechanism by which this supplement elicits these effects. However, the finding of an enhancement of b in the present study may provide some insight into a potential mechanism, since Hofman et al. (18) showed that bovine colostrum supplementation increased repeat sprint ability (RSA) in elite field hockey players, and RSA correlates highly with blood b in these athletes (5). Although there are a number of intramuscular (bicarbonate, creatine phosphate, inorganic phosphates, proteins, protein-bound histidine residues, carnosine and anserine; 20, 28) and extracellular (bicarbonate, plasma proteins and inorganic phosphate) buffers (3), we did not measure these in the present study and are therefore unable to determine which buffering system(s) were affected by the colostrum supplement. Nevertheless, increases in muscle b have been attributed to the growth of fast-twitch relative to slow-twitch muscle fibers (22), due to increased protein accretion (30, 34). Therefore, since bovine colostrum contains a high concentration of mitogenic hormones and growth factors compared to mature milk (10, 14, 27) and these non-nutritive factors have been shown to increase the synthesis of skeletal muscle contractile protein (11), it is tempting to speculate that in the present study, a non-nutritive component(s) of the colostrum supplement may have increased the synthesis of skeletal muscle contractile protein, particularly in fast-twitch muscle fibers, thereby increasing intramuscular protein content and b. If bovine colostrum supplementation particularly affects fast-twitch muscle fibers in such a manner, this might also explain why colostrum supplementation did not improve rowing performance in the present study, or endurance running performance in previous studies (2, 7), because these activities are predominantly aerobic in nature (15, 25, 31), and improvements in performance would rely predominantly on adaptations in slow-twitch rather than fast-twitch muscle fibers (1, 35, 36). Future studies should examine changes in buffer systems and muscle fiber type characteristics resulting from bovine colostrum supplementation.

In conclusion, this study demonstrated that 9 weeks of supplementation with bovine colostrum during training enhanced b but had no effect on performance in elite female rowers. The mechanism by which the supplement increased b was not identified, and future studies should address the mode of action of this supplement.

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Acknowledgments

This work was supported by a grant from Numico Research (Australia) Pty. Ltd., Adelaide, Australia.