ORIGINAL ARTICLE

The influence of bovine colostrum supplementation on exercise performance in highly trained cyclists

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Br J Sports Med 2006;40:797–801. doi: 10.1136/bjism.2006.027946

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Accepted 22 June 2006
Published Online First
6 July 2006

Purpose: The aim of this experiment was to investigate the influence of low dose bovine colostrum supplementation on exercise performance in cyclists over a 10 week period that included 5 days of high intensity training (HIT).

Methods: Over 7 days of preliminary testing, 29 highly trained male road cyclists completed a $\text{VO}_{2\text{max}}$ test (in which their ventilatory threshold was estimated), a time to fatigue test at 110% of ventilatory threshold, and a 40 km time trial (TT_{40}). Cyclists were then assigned to either a supplement ($n = 14$, 10 g/day bovine colostrum protein concentrate (CPC)) or a placebo group ($n = 15$, 10 g/day whey protein) and resumed their normal training. Following 5 weeks of supplementation, the cyclists returned to the laboratory to complete a second series of performance testing (week 7). They then underwent five consecutive days of HIT (week 8) followed by a further series of performance tests (week 9).

Results: The influence of bovine CPC on TT_{40} performance during normal training was unclear (week 7: $1 \pm 3.1\%$, week 9: $0.1 \pm 2.1\%$; mean $\pm 90\%$ confidence limits). However, at the end of the HIT period, bovine CPC supplementation, compared to the placebo, elicited a $1.9 \pm 2.2\%$ improvement from baseline in TT_{40} performance and a $2.3 \pm 6.0\%$ increase in time trial intensity ($\% \text{VO}_{2\text{max}}$), and maintained TT_{40} heart rate ($2.5 \pm 3.7\%$). In addition, bovine CPC supplementation prevented a decrease in ventilatory threshold following the HIT period ($4.6 \pm 4.6\%$).

Conclusion: Low dose bovine CPC supplementation elicited improvements in TT_{40} performance during an HIT period and maintained ventilatory threshold following five consecutive days of HIT.

Colostrum is the first milk produced by mammals after parturition and contains high concentrations of growth and immune factors essential to the physiological maturation of the newborn. Growth factors in colostrum include insulin-like growth factors and transforming growth factors and are believed to play an important role in the development of skeletal muscle,¹ gastrointestinal differentiation,² and cell repair.³

The importance of colostrum for human neonate immune system development is well recognised,⁴ and the presence of closely homologous bioactive components in bovine colostrum has led to the growing use of bovine colostrum in humans.

Limited research to date suggests that bovine colostrum supplementation enhances exercise performance and recovery.^{5–7} Bovine colostrum supplementation at 60 g/day for 8 weeks has been shown to improve repeat sprint performance,⁶ peak vertical jump power and peak cycle power,⁵ and peak running speed during a repeated bout of intense exercise.⁸ In addition, a 20 g/day dose and a 60 g/day dose over 8 weeks have both been reported to improve cycle time trial performance.⁷ Whether a smaller and hence more economical dose can enhance exercise performance is yet to be established.

As bovine colostrum has been found to improve endurance cycling performance⁷ and enhance recovery from an acute exercise session,⁸ it may benefit athletes during consecutive days of high intensity training (HIT) or competition where recovery between exercise sessions is limited. Periods of HIT among athletes have been associated with a reduction in exercise time to fatigue at 110% of anaerobic threshold,⁹ a decrease in submaximal exercise heart rate,¹⁰ and a decrease in the anaerobic threshold.¹¹ The influence of bovine colostrum on performance and recovery from consecutive HIT sessions over several days is yet to be investigated.

The primary aim of this investigation was to examine the influence of low dose (10 g/day) bovine colostrum protein concentrate (CPC) supplementation on exercise performance in highly trained cyclists during the athletes' normal training and 5 days of HIT. We hypothesised that bovine CPC would improve exercise performance during both periods.

METHODS

Subjects

Twenty nine highly trained male road cyclists volunteered to participate in the present investigation (table 1). They had been racing competitively for at least two seasons and had maintained consistent training volumes for at least 2 months prior to the study. Prior to acceptance into the study, the cyclists completed a medical history questionnaire and gave their written consent. The experimental protocol was approved by the Medical Research Ethics Committee at The University of Queensland.

Experimental overview

All testing was completed in the Exercise Physiology Laboratory at The University of Queensland. The investigation was double blind and placebo controlled. Cyclists completed 1 week of familiarisation testing that consisted of a $\text{VO}_{2\text{max}}$ test (in which their ventilatory threshold was estimated), a time to fatigue test at 110% of ventilatory threshold (TTF), and a 40 km time trial (TT_{40}). The tests were repeated the following week (in the same order) and the data from this week used as baseline measures (that is, $\text{VO}_{2\text{max}}$ 1, TTF₁, $\text{TT}_{40}1). Following 5 weeks of supplementation and regular training, the cyclists returned to the laboratory to complete another series of performance tests (that is, $\text{VO}_{2\text{max}}$$

Abbreviations: CPC, colostrum protein concentrate; HIT, high intensity training; TT_{40} , 40 km time trial; VT, ventilatory threshold

Table 1 Athlete characteristics

	Bovine CPC (n = 14)	Placebo (n = 15)
Age (years)	29 (7)	27 (6)
Weight (kg)	75.1 (8.1)	77.6 (7.4)
Height (cm)	180.3 (5.2)	179.4 (4.1)
VO _{2max} (ml/kg/min)	68.8 (4.7)	69.3 (5.8)
Peak power output (W)	446 (43)	461 (34)
Training volume (km/week)	463 (110)	422 (70)

Data are presented as means (SD).

2, TT_{F2}, TT₄₀₂). At the start of week 8, cyclists undertook five consecutive days of HIT (which included a 40 km time trial, that is, TT₄₀₃). This was followed by a further series of performance tests in week 9 (that is, VO_{2max} 3, TTF₃, TT₄₀₄) and, after 2 days of rest, a final TTF test (TTF₄) (fig 1). Cyclists avoided all strenuous physical activity for 24 h prior to each of the tests.

Diet and training diary

During the trial cyclists completed a daily diary that sought information on training and quality of sleep, as well as daily food and fluid intake. Dietary records were analysed using computer software (Foodworks, Xyris, Brisbane, Australia) that calculated daily average macro- and micronutrient intakes. Cyclists refrained from taking any dietary supplements 1 month prior to and for the duration of the study. Training diaries provided information on total number of training kilometres and total training time per week. This was further expressed in five categories of training intensity (category 1: <75% ventilatory threshold; category 2: 75–85% ventilatory threshold; category 3: 85–95% ventilatory threshold; category 4: 95–105% ventilatory threshold; category 5: >105% ventilatory threshold).

VO_{2max} test

Height (cm) and weight (kg) were measured when the cyclists first arrived at the laboratory. Then, following a warm up at a self selected pace for 5 min, the cyclists completed a progressive exercise test to fatigue as described in Laursen *et al.*¹² The test commenced at an initial workload of 100 W; workload thereafter increased by 15 W (30 W/min) until volitional fatigue. Oxygen consumption was calculated with an online data acquisition and analysis program (South Australian Sports Institute, Adelaide, Australia). Ventilatory

threshold was established during the VO_{2max} test and was defined as the point at which a first clear breakpoint in the VE/VCO₂ was observed.¹³

Time to fatigue test

Following a self selected warm up, the cyclists rode an electronically braked cycle ergometer at a power output corresponding to 110% of their ventilatory threshold until they were no longer able to maintain pedal revolutions greater than 60 rpm. Performance time was blinded to the athlete during the TTF and revealed to them on completion of the test.

Laboratory simulated 40 km time trial

Cyclists were instructed to abstain from physical activity for 24 h before each test and to arrive at the laboratory well hydrated and fasted (for a period of 8 h). The cyclists rode their own road bicycle mounted to a stationary windtrainer (Cyclosimulator CS-1000, CatEye, Boulder, CO) as described in Laursen *et al.*¹⁴ Performance time was blinded to the athlete during the TT₄₀ and revealed to them on completion of the ride. Cyclists were allowed to consume water ad libitum during exercise; intake was monitored and recorded. Expired air was collected for 3 min periods at 5, 20, and 35 km and heart rate was recorded every 15 s (Vantage NV, Polar Electro Oy, Kempele Finland).

Supplements

After baseline performance testing, cyclists were randomly assigned to one of two groups. Cyclists in one group ingested 10 g whey protein (placebo) per day while cyclists in the other group ingested 10 g Intact bovine CPC (Numico Research Australia, SA, Australia) per day mixed with 50 ml water and 100 ml skim milk. The period of supplementation was 8 weeks and 1 day and both cyclists and experimenters were blinded to the treatment. The composition of the various bovine colostrum supplements available differs widely. Most published trials relating to bovine colostrum supplementation in athletes have used Intact CPC^{7,8} which is a standardised, low heat, low fat, low lactose colostrum powder containing 20% IgG and retains both casein and whey proteins.

High intensity training

Following the testing in week 7, cyclists completed five consecutive days of HIT. All training sessions involved

Figure 1 Experimental overview. The first week of testing involved a VO_{2max} test, a 40 km time trial (TT₄₀), and a time to fatigue test at 110% of ventilatory threshold (TTF). These tests were repeated in weeks 7 and 9. Following 5 weeks of normal training (weeks 2–6) and 1 week of repeat testing (week 7), the cyclists performed five consecutive days of high intensity training (HIT) that included a TT₄₀ on the fifth day (TT₄₀₃). After the final week of testing (week 9), cyclists performed a final TTF test (week 10).

exercise at or above ventilatory threshold. The first day of HIT involved 20×1 min efforts at peak power output with 2 min recovery at 50 W in between each effort. Training on day 2 involved 60 min cycling at 100% ventilatory threshold (comparable to TT₄₀ intensity). Day 3 involved 12×30 s sprints at 175% of peak power output with 4.5 min cycling at 50 W in between sprints. HIT on day 4 involved 30 min cycling at 80% of ventilatory threshold followed by 45 min at 100% ventilatory threshold. On the final day of HIT, cyclists performed another TT₄₀ (TT₄₀₃).

Statistical analysis

All performance variables were log transformed to reduce non-uniformity of error. The effects of bovine CPC were expressed as the difference in the mean percent change between the bovine CPC and placebo group.¹⁵ To determine if the true effect of bovine CPC was beneficial or harmful, the precision of estimate was expressed as 90% confidence limits.¹⁵ If the effect of benefit and harm were both greater than 5%, the true effect was expressed as unclear. The smallest worthwhile improvement for performance measures was calculated to be half the coefficient of variation for that measure.¹⁶ Worthwhile improvements were considered to be 0.65% for TT₄₀¹⁴ and 5% for TTF. Worthwhile improvements in physiological variables were considered as: TT₄₀ intensity (% VO_{2max}), 5%; ventilatory threshold, 5%¹⁷; peak power output, 1.8%¹²; VO_{2max}, 2.1%.¹² Differences between groups for total training time, training kilometres, training intensity, and nutrient intake were analysed with an 8 (week 3 to week 10)×2 (group) ANOVA using SPSS version 10.0 for Windows (SPSS, Chicago, IL). $p < 0.05$ was accepted as being statistically significant. When a significant main effect was found, differences between training weeks were determined using a Bonferroni post hoc analysis.

RESULTS

Total training kilometres, total training time, and training intensity were not different between groups over the 10 week period ($p > 0.05$). Total training time (in minutes) spent in heart rate categories 4 and 5 significantly increased during the HIT period (week 8) for both the placebo (category 4: $190 \pm 14\%$, $p < 0.01$; category 5: $75 \pm 44\%$, $p < 0.03$) and bovine CPC groups (category 4: $160 \pm 49\%$, $p < 0.001$; category 5: $81 \pm 25\%$, $p < 0.001$) when compared to the same 5 day training period for week 7.

The average energy and macronutrient intake of cyclists in the placebo group was similar to those of the bovine CPC group ($p > 0.05$). For the placebo group, average daily macronutrient intake was: carbohydrate 56%, protein 20%, and fat 24%; and energy intake was 10 673 kJ. For the bovine CPC group, average daily macronutrient intake was: carbohydrate 55%, protein 23%, and fat 22%; and energy intake was 10 572 kJ.

Compared to baseline (TT₄₀₁), and relative to placebo, bovine CPC supplementation improved mean TT₄₀ performance for all TT₄₀ (TT₄₀₂, TT₄₀₃, and TT₄₀₄) (table 2). While the effect of bovine CPC on TT₄₀₂ and TT₄₀₄ was unclear ($1.4 \pm 2.5\%$ and $2.7 \pm 1.22\%$, respectively; mean $\pm$ confidence limits), supplementation provided a likely benefit for TT₄₀ performance at the end of the HIT period (TT₄₀₃ v TT₄₀₁) ($1.7 \pm 1.3\%$) (fig 2). There was an even greater effect of bovine CPC on TT₄₀₃ performance for cyclists performing baseline time trials faster than 54 min (equivalent to national level 40 km time trial time¹⁸), with a mean $3.3 \pm 2.3\%$ difference between groups. This represented a very likely improvement in TT₄₀₃ following bovine CPC supplementation with 0% chance of harm and 98% chance of benefit. Figure 2 shows that those who supplemented with bovine CPC, with the exception of four cyclists, either maintained or improved

their TT₄₀ performance following five consecutive days of HIT. While the bovine CPC group improved mean TT₄₀ performance at the end of the HIT period, there were no differences between the placebo and bovine CPC groups for TT₄₀₄, which was faster than TT₄₀₃ for both groups (placebo: -90 ± 45 s; bovine CPC: -34 ± 32 s). Heart rate during TT₄₀₃ was reduced from TT₄₀₂ for the placebo group, while bovine CPC provided a possible benefit to maintain TT₄₀ HR at the end of the HIT period (placebo: $-3.23 \pm 1.61\%$; bovine CPC: $-0.26 \pm 1.45\%$) (table 2). Bovine CPC was also associated with a possible benefit (increase) in TT₄₀ intensity, expressed as a percentage of VO_{2max}, following 5 weeks of supplementation (TT₄₀₂) ($4.4 \pm 3.7\%$) and at the end of the HIT period (TT₄₀₃) ($3.6 \pm 2.2\%$). Despite an increase in TT₄₀ intensity in the placebo group at the end of the HIT period ($2.7 \pm 4.9\%$), TT₄₀ performance was slower (3 ± 52 s).

Both the placebo and bovine CPC groups experienced an increase in TTF from baseline (TTF₁) to week 10 (TTF₄) (placebo: TTF₁ = 416 ± 83 s, TTF₄ = 491 ± 129 s; bovine CPC: TTF₁ = 455 ± 133 s, TTF₄ = 504 ± 163 s). However, the effect of a 10 g/day dose of bovine CPC on TTF performance was unclear (table 2).

The influence of bovine CPC supplementation on VO_{2max} and peak power output over the experimental period was trivial (table 3). However, bovine CPC provided a possible benefit to maintain ventilatory threshold 3–4 days following the HIT period ($3.6 \pm 5.9\%$): the placebo group experienced a mean 14.6% ($\pm 19.2\%$) decrease in ventilatory threshold, while the bovine CPC group experienced a mean 2.2% increase ($\pm 15.7\%$) (table 3).

DISCUSSION

The present data show that low dose bovine CPC supplementation provides a worthwhile improvement in TT₄₀ performance following a period of HIT. In addition, there was a possible benefit of bovine CPC to enhance TT₄₀ intensity and prevent a decrease in submaximal heart rate during HIT. Bovine CPC supplementation also provided a possible benefit to minimise fatigue and/or enhance recovery

Figure 2 Individual change in TT₄₀₃ performance from baseline. TT₄₀₁ was completed at baseline (prior to the supplementation period), while TT₄₀₃ was performed on the last of the five consecutive days of HIT.

Table 2 Effect of bovine CPC (relative to placebo) on mean changes in performance and physiological variables over the experimental period

	Mean change (%)	Confidence limits (%)	Chances that the true effect has substantial...		
			Benefit (%)	Harm (%)	Practical assessment
Performance measure					
TT ₄₀ 1 v TT ₄₀ 2	-1	3.1	59	18	Unclear
TT ₄₀ 1 v TT ₄₀ 3	-1.9	2.2	83	3	Benefit likely
TT ₄₀ 1 v TT ₄₀ 4	-0.1	2.1	29	32	Unclear
TTF ₁ v TTF ₂	-2.9	9.3	7	35	Unclear
TTF ₁ v TTF ₃	-0.04	12.7	23	26	Unclear
TTF ₁ v TTF ₄	-5.2	15.7	12	52	Unclear
Physiological variables					
TT ₄₀ 1 HR v TT ₄₀ 2 HR	0.4	3.5	11	5	Unclear
TT ₄₀ 1 HR v TT ₄₀ 3 HR	2.5	3.7	41	1	Benefit possible
TT ₄₀ 1 HR v TT ₄₀ 4 HR	0.6	2.8	8	2	Benefit unlikely
TT ₄₀ 1 VO ₂ v TT ₄₀ 2 VO ₂	5.2	5.8	52	0	Benefit possible
TT ₄₀ 1 VO ₂ v TT ₄₀ 3 VO ₂	2.3	6	22	2	Benefit possible
TT ₄₀ 1 VO ₂ v TT ₄₀ 4 VO ₂	-0.6	6.8	8	14	Unclear

Confidence limits (%): add and subtract this number to the mean effect to obtain the 90% confidence limits for the true difference. TT₄₀, 40 km time trial; TTF, time to fatigue. TT₄₀1 was completed at baseline (prior to the supplementation period). TT₄₀2 was performed following 5 weeks of supplementation, TT₄₀3 was performed on the last of the five consecutive days of HIT, and TT₄₀4 was performed during the last week of performance testing (week 10).

*Qualitative analysis of effects that were beneficial or harmful assessed as: <1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99%, very likely; and >99% almost certain.¹⁵

by maintaining ventilatory threshold 3–4 days following the HIT period.

Bovine CPC supplementation, when compared to the placebo, provided a likely benefit for TT₄₀ performance at the end of a 5 day period of HIT. Improvements in time trial performance in already highly trained athletes following HIT are smaller than improvements in performance observed with untrained to moderately trained individuals following training.^{19–20} For highly trained athletes, a worthwhile improvement in performance is considered to be half of the coefficient of variation for that measure.¹⁶ The 1.65% improvement in TT₄₀ for the bovine CPC group following HIT can be considered a small but worthwhile improvement as in our laboratory the coefficient of variation for TT₄₀ performance following familiarisation is $0.9 \pm 0.7\%$.¹⁴

The placebo group experienced a slight decrease in TT₄₀3 performance from baseline, despite an increase in exercise intensity. Ronsen and colleagues²¹ have reported an increase in VO₂ at the same submaximal exercise intensity when cyclists are fatigued from a prior bout of exercise, which may be the result of an increase in fat oxidation as a result of depleted muscle glycogen concentrations.²¹ The placebo group also experienced a decrease in average TT₄₀ HR at the end of the HIT period, which may indicate greater fatigue when compared to the bovine CPC group. Declines in submaximal HR have also been reported by Verde *et al*²² and Lehmann *et al*¹⁰ following a period of intensified training, which has been associated with a decrease in performance.

Although the present data limit speculation as to the mechanism/s responsible for the improvements in TT₄₀ performance for the bovine CPC group at the end of a 5 day HIT period, energy availability may have been enhanced. Increased muscle glycogen levels during normal training do not

improve 1 h cycling performance²³ or 45 min cycling performance (at an average intensity of 82% VO_{2max}).²⁴ However, during repeated days of high intensity exercise, enhanced muscle glycogen content may prevent and/or delay fatigue.^{25–26} Research has previously found that colostrum feeding in newborn calves increases plasma glucose concentrations and is associated with enhanced gluconeogenesis rate limiting enzymes pyruvate carboxylase and phosphoenolpyruvate carboxykinase.²⁷ Colostrum also contains IGF-1 which has been found to enhance glucose uptake by skeletal muscle, independent of changes in GLUT-4 protein.²⁸ Whether bovine CPC improves muscle glycogen resynthesis during periods of intense training warrants investigation.

Research has previously found improvements in sprint and endurance running performance following bovine CPC supplementation at 8 weeks but not at 4 weeks.^{6–8} Somewhat consistent with this, the present study found the influence of bovine CPC on TT₄₀ performance was unclear following 5 weeks of supplementation during normal training. However, in contrast, the effect on TT₄₀ performance during normal training following 8 weeks of supplementation was also unclear. The disparate findings of enhanced performance in our previous work⁷ and an unclear influence on TT₄₀ performance during normal training in the present study may be related to differences in the TT protocol used (2 h and 2.8 kJ/kg v 40 km in the present study) and fasting state. It is also possible that the smaller dose (10 g) of bovine CPC used in the present study may not have been sufficient to elicit the same improvements in performance during normal training periods as those reported by our group previously.⁷ It remains to be seen if a 10 g dose improves short duration (approximately 13 min) time trial performance following 2 h of submaximal endurance performance.

Table 3 VO_{2max}, peak power output (PPO), and ventilatory threshold (VT) over the experimental period

	VO _{2max} 1 test		VO _{2max} 2 test		VO _{2max} 3 test	
	Bovine CPC	Placebo	Bovine CPC	Placebo	Bovine CPC	Placebo
VO _{2max} (l/min)	4.94 (0.52)	5.22 (0.4)	4.99 (0.65)	5.3 (0.54)	4.93 (0.52)	5.2 (0.44)
PPO (W)	442 (36)	455 (27)	445 (40)	453 (34)	448 (37)	462 (38)
VT (l/min)	4.13 (0.42)	4.48 (0.47)	4.10 (0.55)*	4.41 (0.63)	4.12 (0.48)†	4.26 (0.4)

Data are presented as means (SD).

*Possible benefit of bovine CPC from baseline to week 8; †possible benefit of bovine CPC from week 7 to week 9.

What is already known on this topic

- Colostrum is the first milk produced by mammals after parturition and contains high concentrations of growth and immune factors
- Bovine colostrum supplementation at 60 g/day enhances repeat running and cycling performance during normal training periods

The five consecutive days of HIT were sufficient to induce short term fatigue in the placebo group, as evidenced by a decrease in ventilatory threshold. This is consistent with the findings of others,^{11–29} and it remains to be determined how bovine CPC, as shown in the present study, prevented the same degree of fatigue following HIT period. Cyclists in both groups seemed to have recovered from any residual fatigue resulting from the HIT period in 6–7 days; TT₄₀ performance for both groups during the final week was faster than the TT₄₀ completed at the end of the HIT period.

In contrast to the TT₄₀ data, the influence of bovine CPC on TTF at 110% of the cyclists' ventilatory threshold was unclear. Both groups improved their TTF over the experimental period, however, there were no differences between the bovine CPC and placebo group. Previous literature has suggested that time to fatigue is a more sensitive marker of fatigue or over reaching than changes in VO_{2max}.⁹ We hypothesised that we would observe a decrease in TTF in the placebo group, compared to the bovine CPC, in the week following the HIT period. While the placebo group experienced a decrease in ventilatory threshold 3–4 days following the HIT period, TTF performance, 5–6 days following the HIT period, remained unchanged. Cyclists in the placebo group may have recovered from any residual fatigue from the HIT period within 5–6 days.¹² It is also possible that the mechanism responsible for improved TT₄₀ performance is not associated with improvements in shorter duration exercise above threshold.

In summary, low dose bovine CPC supplementation was associated with a worthwhile improvement in TT₄₀ performance and a reduction in fatigue following a 5 day HIT period. In addition, compared to placebo data, bovine CPC supplementation prevented a decrease in ventilatory threshold 3–4 days following the HIT period. The mechanism(s) for the observed performance improvements and reduction in fatigue following bovine CPC supplementation remain to be determined.

ACKNOWLEDGEMENTS

We are grateful for the dedication and commitment of the cyclists who took part in the present study.

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Competing interests: this work was funded in part by Numico Research Australia, Oakden, SA, Australia

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What this study adds

- Bovine colostrum supplementation at 10 g/day enhances cycling performance during high intensity training
- Bovine colostrum supplementation at 10 g/day prevents a decrease in ventilatory threshold following a period of high intensity training

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