

Blood Lactate, Heart Rate, and Rating of Perceived Exertion in Collegiate Sprint, Middle Distance, and Long Distance Runners after 400 and 1600 Meter Runs

Taylor J. Canfield and Kathe A. Gabel

Abstract—The aim of this study was to investigate the effect of running classification (sprint, middle, and long distance) and two distances on blood lactate (BLa), heart rate (HR), and rating of perceived exertion (RPE) Borg scale ratings in collegiate athletes. On different days, runners ($n = 15$) ran 400m and 1600m at a five min mile pace, followed by a two min 6mph jog, and a two min 3mph walk as part of the cool down. BLa, HR, and RPE were taken at baseline, post-run, plus 2 and 4 min recovery times. The middle and long distance runners exhibited lower BLa concentrations than sprint runners after two min of recovery post 400 m runs, immediately after, and two and four min recovery periods post 1600 m runs. When compared to sprint runners, distance runners may have exhibited the ability to clear BLa more quickly, particularly after running 1600 m.

Keywords—Blood lactate, HR, RPE, running.

I. INTRODUCTION

BLOOD LACTATE (BLa) concentrations increase during and after various exercise intensities and durations: short heavy isokinetic exercise [1], short maximal treadmill running [2], incremental treadmill tests [3], middle-distance races [4], and isokinetic endurance exercise [1]. Hirakoba and Yunoki [5] report higher BLa concentrations in sprinters and long distance runners after participating in an incremental exercise test on a cycle ergometer. Bret, et al. [6] concluded that middle-distance runners exhibited higher lactate exchange ability when compared to sprint runners.

However, lactate removal ability was similar in these runners during passive recovery after a 1 min exercise (25.2 km h^{-1}). Since training differs for these modes of running, it is of interest to further investigate BLa responses in different classifications of runners.

Collegiate long distance runners aerobically train four to five days a week, generally running 10 – 20 miles one day, with other runs from six to nine miles, and shorter runs on pre-race day, about three to five miles, combined with limited anaerobic training, such as a fast 400m run under 1:10 pace.

Race days for long distance consist of running from 3000m to 10,000m. Middle distance runners are slightly more aerobically trained than anaerobically trained. They run five to 15 miles less per week than long distance runners. Speed days involve shorter intervals such as repeat 400m, 300m, and 200m. Middle distance runners also participate in the long runs that might be a few miles shorter than long distance runners' long runs. Middle distance races consist of any distance from 400m to 1600m. Middle distance runners may also train with long distance runners, with less total mileage and more anaerobic work on speed days. Sprint runners participate in mainly speed work; however, also run two to six miles without speed usually twice a week. These athletes generally complete interval training at distances from 50m repeats to 600m repeats and race from a 50m dash to the 400m dash during competition. Overall, anaerobically trained athletes (sprint runners) run about half the number of miles than aerobically trained athletes (long distance runners), but complete more speed work.

A preliminary study from this lab involved eight collegiate male runners, four sprint runners and four long distance runners. They had been training for three months and were in the middle of their competitive season. A baseline BLa was taken, and then runners warmed up by walking on the treadmill for 1.5 min and stretching for .5 min. After running 800m at five min mile pace, BLa samples were taken immediately after exercise, 2 min jog, and 4 min of walking.

After running 800 m and during recovery, mean BLa concentrations were higher in sprint runners (Table I).

Lactate threshold (LT) has been suggested as a determinant of endurance performance [7] and a method to monitor endurance training effects [8]. However, Papadopoulos, Doyle, and LaBudde [9] found that a single LT point could not be reliably associated with different running distances (10 km and 21.1 km). With this background, the question arises do BLa concentrations differ in trained runners who have specific training protocols and run shorter distances? The aim of this study was to investigate the effect of running classification (sprint, middle and long distance) and two distances (400m and 1600m) on blood lactate (BLa), heart rate (HR), and rating of perceived exertion (RPE) Borg scale ratings in participants while running at a set pace.

Taylor C. Canfield is a Master of Science Athletic Training candidate at Montana State University Billings, Billings, MT 59101.

Kathe A. Gabel is the Department Chair and Professor in Health & Human Performance Department at Montana State University Billings, Billings, MT, 59101 USA (phone: 406-657-2370; fax: 406-657-2399; email: kgabel@msubillings.edu).

II. MATERIALS AND METHODS

A. Participants

Male collegiate track athletes classified as sprint, middle distance and long distance runners were purposively recruited to participate in this study. Fifteen runners volunteered, signed consent forms that listed procedures, potential risks and benefits as approved by local Departmental review, and recorded their competitive personal records (PR). Following International Society of Advanced Kinanthropometry (ISAK) guidelines [10], two body mass and two stretch stature estimates were measured and recorded. Two running distances (400m and 1600m) were used in testing runners for BLA concentrations, HR, and Borg RPE. All 15 participants were able to complete the 400m in 75 seconds or a 5 min mile pace; however, only 10 out the 15 participants completed the 1600m run at the same 5 min mile pace. Two out of the four sprinters, five middle distance runners, and three out of the six long distance runners were able to complete five min and distance of 1600 m.

For the final ten runners, mean body mass of sprint runners was 74 kg and height was 1.81 m, with middle distance runners averaging 69 kg and 1.83 m, and long distance runners weighing on average 66 kg and standing 1.77 m. All runners had a history of track competition and experience with running.

B. Procedures

Testing was done within a two week period during which participants ran the 400m the first week, and completed the 1600m run during the second week. After a 1.5 min 8 mph jog, one min of dynamic stretching, and .5 min jog, all participants ran on a treadmill for a 75 sec 400m run or 5 min 1600m run followed with a 2 min recovery jog (6 mph) and a 2 min recovery walk (3 mph).

A *Polar Wearlink* HR monitor and FT1 display watch were used for estimating HR, and the traditional Borg scale of 6 to 20 was used for participants' reference RPE. The HR monitor was tested before assessing each participant, with back up equipment of the same model available in case of monitor failure. When the post-run blood sample was obtained, a post-run HR reading was taken. After each test run, participants were asked to rate their RPE on the traditional Borg scale of 6 to 20.

C. Blood Lactate Measurement and Analysis

Dry chemistry was used to estimate BLA concentrations. A lactate meter (*NovaBiomedical Lactate Plus*) and a minimum of four lactate strips (*NovaLactate Plus* strips) were used per runner each test session. Before each test session, lactate meters were tested with designated back up meters and strips were available in case of failure. Lactate control values were also recorded using *Nova Lactate Plus* control solutions.

TABLE I
BLA CONCENTRATIONS PRE AND POST EXERCISE IN LONG DISTANCE AND SPRINT RUNNERS IN PRELIMINARY STUDY (N=8)

Time	Long distance runners (n=4) BLA (mmol L ⁻¹)	Sprint runners (n=4) BLA (mmol L ⁻¹)	Significance p value
Baseline	1.5 ± 0.4	1.6 ± 0.3	.639
Post exercise	8.0 ± 1.8	11.4 ± 2.0*	.046
2 min recovery	6.8 ± 1.4	12.3 ± 2.1*	.004
4 min recovery	5.3 ± 1.5	9.9 ± 2.5*	.018

*= p<.05 Results are presented with means ± standard deviations

Before baseline BLA samples were taken, each participant washed his hands for one min, rested in a seated position, while his left index finger was sanitized and prepped by a technician. After the finger was pricked with a lancet, the first blood was wiped away before a lactate strip was used to sample blood. Baseline BLA levels were recorded. As a baseline BLA sample was taken by one technician, a second technician recorded the resting HR from the HR monitor. Immediately after the test run, participants stepped off the treadmill. Another BLA sample was taken from the left index finger, after thorough sterilization to eliminate sweat lactate contamination. At the same time, a post exercise HR reading was recorded. Two more BLA samples were taken during active recovery, specifically after a 2 min jog and 2 min walk.

D. Statistical Analysis

All statistical analyses were performed using the *Statistical Package for Social Sciences*, version 18 (SPSS, Inc., Chicago, IL, USA). Standard statistical methods were used to calculate means, standard deviations, and standard errors. Independent sample t tests (two tailed test) were used to assess differences

between the two types of athletes. Assumption of homogeneity of variance was tested using Levines Test of Equality of Variance. Magnitude of differences was assessed by Effect Size (ES) and the scale proposed by Cohen [11].

III. RESULTS

No significant difference was found in BLA concentrations (mmol L⁻¹) between sprint and distance runners immediately after running 400m, $t(1.06) = 1.57$, $p = .351$, (equal variances not assumed). However, after the 400m 2 min recovery, BLA concentrations (mmol L⁻¹) were significantly higher in sprint runners ($M = 5.2$, $S.D. = 1.7$), than distance runners ($M = 3.0$, $S.D. = 0.8$). Means were significantly different, $t(8) = 2.9$, $p = .021$. A medium-large effect size ($r = .71$) indicated a meaningful difference. However, after 4 min into recovery after the 400 m run, difference in BLA concentration approached, but did not reach, significance $t(8) = 2.10$, $p = .069$ (See Table II).

TABLE II
BLA CONCENTRATIONS COLLECTED BEFORE AND AFTER 400M AND 1600M RUNS FROM COLLEGIATE SPRINT RUNNERS (N=2) AND DISTANCE RUNNERS (N=8)

Distance and Time		Sprint runners	Distance runners	Significance
		BLa (mmol L ⁻¹)	BLa (mmol L ⁻¹)	
400 m	Baseline	1.3 ± 0.2	1.3 ± 0.3	p value
	Post exercise	6.6 ± 2.3	4.1 ± .8	.839
	2 min	5.2 ± 1.7	3.0 ± .8*	.351
	recovery			.021
	4 min	3.3 ± 1.1	2.2 ± .6	.069
1600 m	recovery			
	Baseline	1.4 ± 0.5	1.5 ± 0.3	.557
	Post exercise	14.5 ± 3.5	8.8 ± 1.9*	.010
	2 min	12.7 ± 3.0	7.6 ± 2.0*	.018
	recovery			
	4 min	11.3 ± 1.5	5.7 ± 1.9*	.005
	recovery			

*= p<.05 Results are presented with means ± standard deviations.

BLa concentrations were significantly higher immediately after the 1600m run in sprint runners ($M = 14.5$, $S.D. = 3.5$), as compared to distance runners ($M = 8.8$, $S.D. = 1.9$). Means were significantly different $t(8) = 3.33$, $p = .01$ and effect size was large ($r = .76$). This trend continued during the 1600m 2 min recovery with BLa concentrations significantly higher in sprinters ($M = 12.7$, $S.D. = 3.0$) than distance runners ($M = 7.6$, $S.D. = 2.0$). Means were significantly different, $t(8) = 2.97$, $p = .018$ and effect size was medium-large ($r = .72$). During the 1600m 4 min recovery, BLa concentrations of distance runners ($M = 5.7$, $S.D. = 1.9$) continued to decrease as compared to significantly higher BLa concentrations in sprint runners ($M = 11.3$, $S.D. = 1.5$). Means were significantly different $t(8) = 3.86$, $p = .005$. Effect size was large ($r = .86$).

In general, the faster the athletes' PR in the 1600m, the lower the BLa levels appeared. For example, the runner possessing the fastest PR (4 min 16 sec) also had the lowest BLa (6.2 mmol L^{-1}) after the 1600 m run, and the runner who had the slowest PR (5 min 10 sec) had the highest BLa (17 mmol L^{-1}) after the 1600 meter run.

For both 400m and 1600m tests, no significant difference was observed in the runners' post HR. After the 400m, sprint runners averaged 165 bpm for their post HR, while distance runners posted an average of 167 bpm. The difference was not significant $t(8) = -0.247$, $p > .05 = .811$. A small effect size was found, ($r = .087$) indicating that a larger sample size would not change the significance. After the 1600m run, sprint runners averaged 175 bpm, while the distance runners had an average HR of 179 bpm. The difference was not significant $t(8) = -.643$, $p > .05 = .538$ and a small effect size ($r = .22$) was estimated.

Similar conclusions were found for the post run RPE. No significant difference was observed for RPE Borg after the 400m or 1600 m runs. After the 400m, both sprint and distance runners averaged 13 on the Borg scale. Following the 1600m, an average of RPE rating of 15 was noted by sprint runners, while distance runners indicated a 14.5 RPE. The difference was not significant, $t(8) = .605$, $p > .05 = .887$ and a small effect size ($r = .209$) was estimated.

IV. DISCUSSION

The main finding of the present study was that training classification of collegiate runners is associated with BLa concentration when running 1600m at a set pace. This was less apparent during the shorter 400m distance run at the same pace. It is relatively well known that endurance training attenuates BLa accumulation during exercise [12], which is supported in this study. It also supports the concept that athletes with a low aerobic capacity exhibit a higher increase of lactate at the same absolute load than those with a higher aerobic capacity [13].

During intense exercise, the rate of lactate production may surpass the rate of lactate clearance from the blood; hence, increasing the BLa concentration. This typically depends on exercise intensity, duration, and mode. Hirvonen, Nummela, Rusko, Rehunen, and Harkonen [14] reported increasing BLa concentrations (100m = 3.4 ± 0.4 , 200m = 6.3 ± 0.7 , and after 400 m = 10.8 ± 0.7) (mmol L^{-1}) that were associated with increasing distance during a 400 m sprint completed by six male sprinters and middle distance runners. In the present study, all runners averaged higher BLa levels after running 1600m ($M = 11.6 \text{ mmol L}^{-1}$) as compared to the post-run 400m values ($M = 5.3 \text{ mmol L}^{-1}$) at a 5 min mile pace. In comparison, a faster pace (sprint) could possibly explain higher BLa levels of the post 400m BLa in the Hirvonen, Nummela, Rusko, Rehunen, and Harkonen [14] study.

BLa concentrations have also been associated with performance. Ferri, et al. [3] concluded that end-of-exercise blood lactate accumulation was an important predictor of the best performance in national level 1500m runners. BLa concentrations of $12.7 \pm 2.4 \text{ mmol L}^{-1}$ were reported for eight elite 1500m runners who completed an incremental treadmill test. In this case, the BLa estimates were positively correlated with time to exhaustion, i.e. higher levels were associated with the best 1500m race time. This would be interesting to investigate BLa levels in collegiate middle distance runners when engaged in a race pace to compare to national level athletes.

Bergman, et al. [15] found that nine weeks of leg cycle endurance training decreased whole body and leg lactate production and increased clearance by active muscle at

moderate intensity workloads. In the present study, the effect of endurance training was supported by the endurance-trained distance runners regularly exhibiting lower BLA concentrations than the sprint runners. With little difference between results of the middle and long distance runners, data were designated as endurance-trained.

Hirakoba and Yunoki [5] previously reported higher BLA concentrations (mmol L^{-1}) in six sprinters (10.18 ± 1.53) when compared to nine long distance runners (8.10 ± 1.61) during recovery from an incremental exercise test on a cycle ergometer. Although different blood chemistry methods and modes of exercise were used, these values are somewhat comparable to the present study's 1600m BLA 2 min recovery results: sprint runners exhibited $12.7 \pm 3 \text{ mmol L}^{-1}$ BLA, while distance runners presented $7.6 \pm 2 \text{ mmol L}^{-1}$ values.

Although limitations of the present study include small sample size and lack of aerobic ($\text{VO}_{2\text{max}}$) assessment, results provide a relatively easy protocol by which collegiate coaches of distance runners could use to monitor training and performance of their athletes throughout the season. As athletes progress throughout their college career, BLA records could be monitored and related to race success and training changes. For researchers, longitudinal records of BLA concentrations of runners could be helpful to assess and relate to other physiological variables associated with different training protocols. Overall, a relatively simple 1600m run at a set pace in conjunction of BLA collection could provide valuable information to athletes, coaches, and researchers.

V. CONCLUSION

In conclusion, collegiate distance runners exhibited lower BLA concentrations than sprint runners after two min of recovery from a 400m run, and immediately after a 1600m run, in addition to 2 and 4 min recovery periods associated with 1600m runs. When compared to sprint runners, distance runners appeared to exhibit ability to clear BLA more quickly, particularly after running 1600m. Runners did not differ in HR or RPE Borg rating after running the two distances. Present findings have applications for coaches of distance runners. It may be beneficial to initiate the simple assessment of BLA concentration during a 1600m run (5 min mile pace) regularly throughout the season to monitor performance and effect of training, particularly of middle distance runners.

REFERENCES

- [1] B. Y. L. Kouassi, A. Duvallet, and M. Rieu, "Muscle lactate and isokinetic testing: middle-distance runners versus participants in recreational sports," *Isokinetics Exerc. Sci.*, vol. 4, no. 1, pp. 8-12, 1994.
- [2] N. Fujitsuka, T. Yamamoto, T. Ohkuwa, M. Saito, M., and M. Miyamura, "Peak blood lactate after short periods of maximal treadmill running," *Eur. J. Appl. Physiol.*, vol. 48, pp. 289-296, 1982.
- [3] A. Ferri, S. Adamo, A. La Torre, M. Marzorati, D. J. Bishop, and G. Miserocchi, "Determinants of performance in 1,500-m runners," *Eur. J. Appl. Physiol.*, vol. 112, no. 8, pp. 3033-3043, 2012.
- [4] J. R. Lacour, E. Bouvat, and J. C. Barthelemy, J. C., "Post-competition blood lactate concentrations as indicators of anaerobic energy expenditure during 400-m and 800-m races," *Eur. J. Appl. Physiol.*, vol. 61, pp. 172-176, 1990.
- [5] K. Hirakoba and T. Yunoki, "Blood lactate changes during isocapnic buffering in sprinters and long distance runners," *J. Physiol. Anthropol.*, vol. 21, no. 3, pp. 143-149, 2002.
- [6] C. Bret, L. Messonnier, J. M. NouckNouck, H. Freund, A. B. Dufour, and J. R. Lacour, "Difference in lactate exchange and removal abilities in athletes specialised in different track running events (100 to 1500m)," *Int. J. Sports Med.*, vol. 24, pp. 108-113, 2003.
- [7] S. Kumagai, L. Tanaka, U. Matsuura, A. Matsuzaka, K. Hirakoba, and K. Asano, "Relationships of the anaerobic threshold with the 5 km, 10 km, and 10 mile races," *Eur. J. Appl. Physiol.*, vol. 49, pp. 13-23, 1982.
- [8] E. F. Coyle, "Integration of the physiological factors determining endurance performance ability," *Exerc. Sport Sci. Rev.*, vol. 23, pp. 25-63, 1995.
- [9] C. Papadopoulos, J. A. Doyle, and B. D. LaBudde, "Relationship between running velocity of 2 distances and various lactate parameters," *Int. J. Sports Physiol. Perf.*, vol. 1, pp. 270-283, 2006.
- [10] M. Marfell-Jones, T. Olds, A. Stewart and J. E. Lindsay Carter. *International Standards for Anthropometric Assessment*. Australia: ISAK, 2006.
- [11] J. Cohen, "A power primer," *Psychol. Bull.*, vol. 112, no. 1, pp. 155-159, 1992.
- [12] H. S.-H. McCrae, S. C. Dennis, A. N. Bosch, and T. D. Noakes, "Effects of training on lactate production and removal during progressive exercise in humans," *J. Appl. Physiol.*, vol. 72, no. 5, pp. 1649-1656, 1992.
- [13] R. T. Withers, "Anaerobic work at submaximal relative workloads in subjects of high and medium fitness," *J. Sports Med.*, vol. 17, pp. 17-24, 1977.
- [14] J. Hirvonen, A. Nummela, H. Rusko, S. Rehuman, and M. Harkonen, "Fatigue and changes of ATP, creatine phosphate, and lactate during the 400-m sprint," *Can. J. Spt. Sci.*, vol. 17, no. 2, pp. 141-144, 1992.
- [15] B. C. Bergman, E. E. Wolfel, G. E. Butterfield, G. D. Lopaschuk, G. A. Casazza, M. A. Horning, and G. A. Brooks, "Active muscle and whole body lactate kinetics after endurance training in men," *J. Appl. Physiol.*, vol. 87, no. 5, pp. 1684-1696, 1999.