Original Research

The Use of the Blood Lactate Curve to Develop Training Intensity Guidelines for the Sports of Track and Field and Cross-Country

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ABSTRACT

Int J Exerc Sci 5(2) : 148-159, 2012. The purpose of this study was to develop and field test a standardized system of training intensity guidelines for the sport of track and field/cross country, modeled after the standardized system of training intensity guidelines developed, adopted, and in use by U.S.A. Swimming. This study was quantitative and focused on the development and field-testing of standardized training intensity guidelines, based on the blood lactate curve and energy metabolism. The findings showed that as intensity increased so did participants' blood lactate concentration, heart rate, and ratings of perceived exertion. A Pearson product-moment correlation analysis between the mean values of blood lactate concentration, heart rate, and ratings of perceived exertion, and the corresponding training intensity ranges revealed significant positive correlations between mean blood lactate values ($r = 0.99$, $p < 0.001$), mean heart rate ($r = 0.96$, $p < 0.001$); and ratings of perceived exertion ($r = 0.99$, $p < 0.005$). Correlation analyses between heart rate and measures of blood lactate were positive ($r = 0.70$, $p > 0.05$), as were heart rate and ratings of perceived exertion ($r = 0.96$, $p < 0.005$). Measures of blood lactate were positively and significantly correlated to ratings of perceived exertion ($r = 0.82$, $p < 0.05$). These findings validated the training intensity guidelines model.

KEY WORDS: Heart Rate, rating of perceived exertion, running, training, swimming

INTRODUCTION

Coaches are constantly in search of new methods and tools to improve the performance abilities of the athletes they mentor (19). Despite improvements in clothing and equipment design, modern trends in nutrition and the presence of performance enhancing drugs, the major factor influencing athletic performance continues to be the effective planning of training by sport coaches (3, 10, 19).

A training program must be planned and implemented using valid and reliable training intensity indices (18, 19). Additionally, for sport coaches to make evidence-based changes in training processes, and/or determine whether athletes are complying with training prescriptions, valid and reliable measures of training intensity are essential (18, 19).

It is questionable whether or not U.S.A. track and field and cross-country coaches routinely employ valid and reliable measures to quantify training intensity (3, 11). Often, U.S.A. track and field/cross-country coaches prescribe and monitor training workload intensities according to the subjective feelings of their athletes, or erroneously associate training intensity with a specific method of training (5, 6). In addition, exercise intensity prescription based solely on measured or predicted values of maximum speed, race performance, VO_2max and/or physiological indicators, such as heart rate (HR), create a varied training stimuli, and can result in varied levels of cardiovascular and metabolic adaptation (8). This problem arises because the intensity at which disproportionate increases in blood lactate values occur is not a consistent percentage of an athlete's maximum speed, race performance, VO_2max and/or HR (8). Because of the variance stated in the previously state measures better and more reliable physiological measures of training intensity are needed (5, 7).

Accumulated data suggest that lactate performance curves provide the most valid and reliable indices of exercise intensity of prescribing guidelines for training (4). In swimming, lactate performance curves are used to delineate the metabolic continuum into standardized training intensity zones (9). This method provides U.S.A. Swimming coaches with standardized terminology that has clear meaning in common usage.

The purpose of this study was to develop and field test a standardized system of training intensity guidelines for the collegiate endurance track and field/cross country athletes. This system was modeled after the standardized system of training intensity guidelines developed, adopted and in use by U.S.A. Swimming. Therefore, this study sought to determine whether or not there was a positive correlation between blood lactate, HR, and Rate of Perceived Exertion (RPE) and the training intensity guidelines. The training intensity guidelines derived from the literature review are displayed in table 1.

Table 1. Training intensity guidelines derived from the literature review.

Category (Abbreviation)	Intensity / Speed	Lactate (mmol/L)	Expected Heart Rate (HR)	Rating of Perceived Exertion (RPE)
Recovery (REC)	<80% of Maximum Lactate Steady Sate (MLSS)	<1	120 - 140	9
Extensive Endurance (E1)	80 to 90 % of MLSS	1 – 2.5	120 - 140	11
Intensive Endurance (E2)	90 – 95% of MLSS	2 – 3.5	140 - 160	13
MLSS (E3)	95 – 103% of MLSS	3 – 5	160 - 180	15
VO_2max (E4)	109 – 111% of MLSS	> 6	>180	17
Lactate Tolerance & Buffering (S1)	90 – 100% of max run for 1 to 3 minutes	Max	N/A	17+
Lactate Production (S2)	90 – 100% of max run for 5 to 50 seconds	N/A	N/A	N/A
Sprint (S3)	Max speed for 0.1 to 5 seconds	N/A	N/A	N/A
Economy (Econ)	Race pace or speed at which technique can be maintained	N/A	N/A	N/A

METHODS

This study employed a quantitative design and focused on the development and field testing of training intensity guidelines, the paradigm was derived from U.S.A. Swimming's standardized system of training intensity guidelines, based on the blood lactate curve. To conduct this study, three instruments were utilized: (a) an Accusport blood lactate analyzer, (b) a Polar HR monitor, and (c) the 15-point Borg rating scale of perceived exertion (RPE).

For the purpose of this study, the Accusport Lactate Meter was used to determine athlete blood lactate training intensity concentrations. The Accusport Lactate Meter has been shown to be accurate relative to standard chemistry methods. In addition, a study by Bishop (2) demonstrated that the Accusport Lactate Meter showed high single trial intra-class reliability ($r = 0.992$; $N = 73$) and high day-to-day inter-class reliability ($r = 0.96$; $N = 42$). These results indicate that the Accusport Lactate Meter is a reliable tool, which can be used to accurately and reliably determine blood lactate concentrations in the field.

In addition to blood lactate analysis, subjects were fitted with a Polar Favor T31 HR monitor prior to training intensity runs. The Polar Favor T31 HR monitor consists of a chest strap transmitter and a wristwatch receiver. This model does not keep programmed target zone information, nor does it have a stopwatch function or timers to assist the subject during test runs. The Polar Favor T31 wristwatch receiver turns on and displays the subject's heart-beats per minute once it receives a signal from the transmitter in the chest strap.

Heart rate monitors have been used since 1983 and have been shown to be accurate and valid tools for monitoring and registering HR in the field (12). A study by Seaward, et al. (20) compared the validity, stability and functionality of portable HR monitors and found that HR monitors using conventional chest strap electrodes resulted in correlation coefficient (r) values ranging from 0.998 to 0.999 when compared to direct ECG measurement of the heart in laboratory settings.

The Borg 15-point RPE scale is a category-ratio scale used to assess exertion intensity (14). The scale allows people to use numbers, ranging from 6 to 20, and associated verbal descriptors to describe and/or estimate exertion perception intensity. Research has indicated that the relationship between perceptual ratings from Borg's category-ratio scale and blood and muscle lactate accumulation have a strong positive correlation ($r = 0.78$, $p > 0.05$) (16).

Participants

This study was conducted with male and female collegiate track and field and cross-country athletes recruited from NCAA D-I intercollegiate track and field and cross-country teams at a University in the Intermountain West. Potential subjects were not allowed to participate until they had read the introductory cover letter and completed the required human subjects consent form, as required and approved by the Institution's IRB. Subjects included eight intercollegiate track and field and cross-country athletes (4 male and 4 female) who had passed the intercollegiate athletic participation physical examinations and other criteria required to be active competitive members of the University collegiate track and field/cross-country teams. All subjects were 18 years or older.

Each subject ($N = 8$) completed a demographic profile questionnaire. This questionnaire was used to gather information related to training history, current training status, and primary

Table 2. Participant sport demographics.

Question	Participant							
	1	2	3	4	5	6	7	8
What is your intercollegiate eligibility status?	Other	Junior	Freshman	Other	Sophomore	Sophomore	Junior	Senior
What is your sex?	Female	Female	Female	Female	Male	Male	Male	Male
What is your age group?	Over 22 years old	19 to 20 years old	17 to 18 years old	Over 22 years old	19 to 20 years old	21 to 22 years old	21 to 22 years old	21 to 22 years old
How many seasons were you an interscholastic (middle school and/or junior high and high school) track and field and/or cross-country athlete?	10 to 12	7 to 9	10 to 12	10 to 12	4 to 6	4 to 6	10 to 12	10 to 12
How many seasons have you been a collegiate track and field and/or cross-country athlete?	8 or more	1 to 3	1 to 3	4 to 6	1 to 3	1 to 3	8 or more	4 to 6
How would you classify your current level of conditioning?	High	High	High	High	Moderate	High	High	Moderate
What phase of the training season are you currently in?	Preparatory Phase	Preparatory Phase	Preparatory Phase	Preparatory Phase	Preparatory Phase	Preparatory Phase	Preparatory Phase	Off Season
In the past 4 weeks, on average, how many hours per week do you spend training for your sport?	12 to 14 hours	9 to 11 hours	12 to 14 hours	15 to 17 hours	18 or more hours	18 or more hours	9 to 11 hours	12 to 14 hours
What sport area do you generally compete in?	Endurance Events	Endurance Events	Endurance Events	Multi Events	Endurance Events	Endurance Events	Endurance Events	Endurance Events

event competition area (i.e., endurance, sprints, or field/multi-events). See table 2.

Procedures

Subjects were asked to run a 30-minute time trial (T-30) to determine their Maximal Lactate Steady State (MLSS). The T-30 time trial, like all subsequent test runs, was run on a 200 meter indoor track. Olbrecht et al. (17) originally designed the T-30 as a non-invasive predictor of the MLSS in swimmers. However, McGhee et al. (15) also later demonstrated the T-30 to be an effective non-invasive predictor of MLSS for land athletes who run. Following completion of the T-30 time trial, relative values of the speed at MLSS were used to approximate the training intensities associated with the development of aerobic power, extensive and intensive aerobic endurance training (which is commonly used for the maintenance and/or development of aerobic capacity), and recovery training. Subjects were then asked to complete one 30-minute run on a 200-meter indoor track at each of the predicted velocities.

Each of the test runs took place 2 days apart. This allowed for the 24 to 36 hours that may be needed to restore muscle glycogen stores following such an exercise exertion (18). In the case of unavailability of the indoor track, the run was scheduled for the following day, thus all test runs were completed with the same track conditions. To provide additional time for glycogen restoration and guard against the possibility of over-training, the test runs progressed from low intensity to high intensity. Therefore, the first test run was a T-30 pace which, as stated, was used to determine each subject's speed at MLSS. The second test run was completed at the

Table 3. Correlation between relative % of MLSS and participant blood lactate, heart Rate and RPE means.

Variable	Training Intensity Range (N = 40)	Blood Lactate (N = 40)	Heart Rate (N = 40)	Rating of Perceived Exertion (N = 40)
Training Intensity Guidelines (Relative % of MLSS)	1.00	.99**	.96**	.99**
Blood Lactate (Mean)		1.00	.70Ns	.82*
Heart Rate (Mean)			1.00	.96**
Rating of Perceived Exertion (Mean)				1.00

Ns = not significant ($p > .05$), $^{*}p < .05$, $^{**}p < .001$
Note: N = 40 derived from 8 subjects X 5 test runs (one at each training intensity)

predicted speed of recovery training (70 to 80% of MLSS). The third test run was completed at the predicted speed of extensive endurance training (80 to 90% of MLSS). The fourth test run was completed at the predicted speed of intensive endurance training (to 95% of MLSS). The final test run was completed at the predicted speed of aerobic power training (107-110% of MLSS).

Immediately after each test run micro-capillary blood lactate samples were taken, HR values were identified, and subjects were asked to rate their perceived level of exertion using the Borg 15-point RPE scale.

Statistical analysis
Quantitative data were analyzed descriptively and a bivariate correlational statistical analysis was employed to indicate the association between the relative values of the MLSS derived from subjects' running paces as prescribed by the training intensity guidelines developed for this study (i.e., aerobic power training, intensive and extensive endurance training, and recovery training) and the training intensity subject data. To address the primary purpose of the study, the mean of the highest blood lactate, HR, and RPE values for each training intensity zone were identified following each test run. Using the statistics program SPSS, a Pearson product-moment correlation analysis was then run between each of these mean values and the corresponding training intensity range means was computed. An alpha of 0.05 was used to determine statistical significance.

RESULTS

As might be anticipated, as intensity increased so did subjects' blood lactate concentration, HR and RPE. The correlation analysis between the mean values of blood lactate concentration, HR, and RPE and the corresponding training intensity ranges revealed significant positive correlations between mean blood lactate values ($r = 0.99$, $p < 0.001$), mean HR ($r = 0.96$, $p <$

0.001), and RPE ($r = 0.99$, $p < 0.001$) across all training intensity guideline levels. Correlation analyses between HR and blood lactate concentrations were positive ($r = 0.70$, $p > 0.05$) as were HR and RPE ($r = 0.96$, $p < 0.005$). Blood lactate concentrations were also positively and significantly correlated to RPE ($r = 0.82$, $p < 0.05$). Table 3 displays the Pearson correlation between relative % of MLSS and participant blood lactate, HR and RPE Means.

DISCUSSION

The findings of this study, while limited in terms of sample size and the associated ability to generalize broadly, addressed the purpose of the study. Ultimately, these findings are important because they: (a) contribute to the empirical body of knowledge in terms of the application and utility of training intensity guidelines in the sports of track and field/cross-country; (b) demonstrated the development and confirmed the validity of training intensity guidelines for collegiate endurance track and field/cross country athletes (modeled after training intensity guidelines developed, adopted and in use by U.S. A. Swimming), culminating in a user-friendly (coach-ready) training intensity guidelines model, inclusive of track and field/cross-country training, set guidelines, seasonal applications and sport periodization examples; and (c) provide an inquiry model from which further study can be engaged.

Subject means and individual blood lactate concentrations, HR and RPE were also compared to blood lactate concentrations. HR and RPE values reported in the literature, as appropriate for each training intensity zone identified in this study. The implications of these findings are discussed below.

Similarly to other studies, the current findings showed that there was a positive and statistically significant correlation between blood lactate and training pace intensity ($r = .99$, $p < .001$). In addition, four of the five mean blood lactate values were within the specified blood lactate value ranges associated with the training intensity zones. The exception was the mean blood lactate value for the recovery training zone (1.12 mmol/L), which exceeded the predicted blood lactate value by 0.22 mmol/L.

Although the mean blood lactate value for the recovery training zone exceeded the predicted value, it was very similar to the blood lactate value obtained at similar intensities from a 2000 study by Urhausen, et al. (22). The recovery training zone in this study was defined as any intensity below 80% of an individual's MLSS pace. In that study, subjects ran 10 kilometers at 70, 80, 90, 95, and 100% of their MLSS, and reported mean blood lactate values of 1.54, 1.67, 2.67, 3.53, and 5.67 respectively. In addition, the training intensity zone model developed and used by U.S.A. Swimming indicates that training carried out within the recovery training intensity zone should produce blood lactate values of 0 to 2 mmol/L. This suggests that the predicted blood lactate range associated with the recovery training zone may need to be adjusted for the sports of track and field/cross country, to accommodate minor rises in blood lactate values following low intensity work.

Fixed HR ranges like those used in this study, have the advantage of being easy for coaches to understand and prescribe to athletes. The results of this study indicated that there was a positive and statistically significant correlation between HR and the level of intensity ($r = .96$, $p < .001$). Even so, most of the individual HRs, as well as the group mean HR at each of the sub-maximal intensity zones were in excess of the fixed HR ranges predicted from the literature (3, 13).

These consistently high HRs may have occurred for several reasons, the most relevant of which may be the application of a swim-specific training model to running. Generally, an individual exercising on land will have a higher HR than a person swimming (e.g., the specific gravity and horizontal position of the body in swimming, as well as immersion in a cooling medium—water, result in less physiologic stress during exercise) (14). Heart rates are approximately 10 to 15 beats per minute (bpm) lower while swimming than running. While related research indicates that a HR measure elicited from water-based aerobic exercise equates to an oxygen consumption (VO_2) value that is equivalent to the VO_2 at the same HR during land-based aerobic exercise, the lower HRs found in swimming may occur because the relative level of intensity during water-based aerobic exercise is higher for a given percent of the peak responses; VO_2 and HR peaks are lower during water-based aerobic exercise (21). In addition, HRs are subject to non-training influences that can lead to misinterpretation. Emotional factors, nervousness, and apprehension can affect the HR at rest and during exercise of light to moderate intensity (1, 14, 23). Given that the T-30 time trial and subsequent test runs were a novel method for the participants in this study, training intensity time trials and test runs were not (per subject self-report) part of their routine training practice, thus, they may not have been completely prepared for the test run experience associated with participation in this study. As a result, the participants may have been nervous or apprehensive about completing the T-30, and their MLSS value, as well as their other training intensity values, may not have been less accurate than if the subjects had prior experience with the T-30.

Finally, the literature indicates that fixed HR measures may not be the most appropriate method from which to assign and/or monitor training intensity. Fixed HR ranges do not account for the wide variation in maximum HRs among individuals. This means that a HR range of 160 to 180 bpm may represent the appropriate HR range for training at an intensity approximating the MLSS for an individual with a maximal HR of 190 bpm. This same HR range, however, will probably not represent the appropriate HR range for training at an intensity approximating the MLSS for an individual with a maximal HR of 210 bpm. As a result, other methods that incorporate maximal HR are commonly viewed as being more appropriate for assigning HR ranges. The methods that incorporate maximal HR are those that assign HR ranges as a percentage value of maximal HR or the maximal HR minus a specific amount of bpm (13). The literature has also indicated that percentage values of an athlete's HR at MLSS may provide an appropriate index from which to identify HR ranges that approximate each intensity zone (22). Table 4 provides the general rules for these HR determination methods.

By comparing the mean HR data for each

Table 4. Alternative methods for determining training intensity zone utilizing heart rate.

Intensity	Heart Rate Method for Assigning Intensity		
	% of Max Heart Rate	bpm – Max Heart Rate	% of MLSS
Recovery	65 to 79	50 to 70	80 to 90
Extensive Endurance	65 to 79	40 to 50	90 to 95
Intensive Endurance	80 to 90	30 to 40	95 to 100
MLSS	88 to 92	20 to 30	100 to 106
Aerobic Power	98 to Max	20 to Max	100 to Max

Table 5. Comparison of participants' mean heart rate per training intensity zone to percentage values of the mean heart rate at MLSS.

Intensity	Heart Rate Measures		
	Mean Heart Rate	% of MLSS for the Mean Heart Rate	% of MLSS Heart Rate Range
Recovery	152.25	81	80 to 90
Extensive Endurance	165.25	88	90 to 95
Intensive Endurance	178.00	95	95 to 100
MLSS	187.37	100	100 to 106
Aerobic Power	190.37	102	100 to Max

intensity zone in this study to the percentage values of the mean HR at MLSS, it becomes apparent that the mean HR at each intensity zone provided a more accurate measure of HR than did the fixed HR measures used in this study. See table 5.

Analysis of the data related to RPE revealed a positive and statistically significant correlation between RPE and training zone intensity ($r = 0.99$, $p < 0.001$), as well as blood lactate and HR. In terms of RPE and blood lactate concentrations the findings were consistent with the literature showing a positive and statistically significant correlation ($r = 0.82$, $p < 0.05$). Early research by Nobel, et al. (16) demonstrated that relationships between perceptual ratings from Borg's RPE scale and blood and muscle lactate accumulation displayed a strong positive correlation ($r = 0.78$, $p > 0.05$).

In this study, athletes rated their perceptions of intensity following each test run. The literature, however, indicates that

Table 6. Comparison of participants' mean RPE values to adjusted RPE ranges.

Intensity	RPE Values	
	Mean RPE Value	Adjusted RPE Value
Recovery	7.37	<9
Extensive Endurance	8.62	10 to 12
Intensive Endurance	12.25	12 to 14
MLSS	15.62	14 to 16
Aerobic Power	18.00	>16

the RPE numerical value and verbal descriptor on the 15-point Borg scale refer to the sensation of effort the individual should experience during the middle of the exercise, not near the beginning or end (13). Thus, ranges of RPE values can be identified and associated with each intensity zone rather than the specific numerical value and verbal descriptor that was used in this study (23). When the mean RPE data obtained from this study were compared to the adjusted RPE range, the majority of subjects' mean RPE values were within the specified numerical range associated with each intensity zone. See table 6.

The track and field/cross-country training intensity guidelines developed based on these study findings appear in table 7. Drawing upon the literature, and modeled with some adjustments after the intensity guide designed by U.S.A. Swimming, the training intensity guidelines shown in table 7 consist of nine intensity zones. The intensity guide designed by U.S.A. Swimming classifies training intensity as endurance and speed training, whereas the classification system used to categorize the training zones presented in table 7 has been expanded from two to four categories. These categories are recovery training, endurance training, speed training and economy training. Expanding the classification system from two to four categories should allow coaches to more easily associate a specific bio-motor ability and/or metabolic capability with a particular type of training and provide coaches with a more accurate representation of the adaptations expected with each type of training.

U.S.A. Swimming classifies training that will improve an athlete's aerobic muscular endurance and aerobic metabolic capabilities as endurance training. Determination of the proper intensity for each of the three endurance zones under U.S.A. Swimming's classification system is dependent upon the identification of the MLSS and/or the aerobic threshold along the blood lactate curve. Similarly, training classified as endurance training in table 7 can be used to improve an athlete's aerobic muscular endurance and aerobic metabolic capabilities. In addition, determination of the proper intensity for each of the endurance training zones presented in table 7 is also dependent upon the identification

Table 7. The amended training intensity categories.

Category (Abbreviation)	Physiological Ability	Purpose	Subjective Intensity	Interval Time	Recovery Interval	Intensity / Speed	Lactate (mmol/L)	Expected Heart Rate (HR)	RPE	Example of Set (Athlete's MLSS pace is 1:40 per 400 meters)
Recovery (REC)		Warm-up, cool-down, and drills	Very Light	N/A	N/A	<80% of MLSS	Resting levels to 2	80 to 90% of MLSS HR	<9	15 minute warm-up prior to workout
Extensive Endurance (E1)		Maintain & develop aerobic adaptations	Light	> 45 minutes	Continuous or 10-30 seconds	80 to 90 % of MLSS	1 – 2.5	90 to 95% of MLSS HR	10-12	45 minutes out and back continuous run @ E1 (8:00 mile pace)
Intensive Endurance (E2)	Aerobic Capacity / Sub-maximal Aerobic Endurance	Develop aerobic adaptations	Somewhat Hard	> 45 minutes	Continuous or 10-30 seconds	90 – 95% of MLSS	2 – 3.5	95 to 100% of MLSS HR	12-14	30 minutes out and back continuous run @ E2 (7:20 mile pace)
MLSS (E3)		Improve MLSS, aerobic endurance	Hard or Heavy	6 to 45 minutes	1/5 of run time or Continuous	95 – 103% of MLSS	3 – 5	100 to 106% of MLSS HR	14-16	4 x 1600 @ E3 (6:40 mile pace) with 60 second recovery
VO_2max (E4)	Aerobic Power / Maximal Aerobic Endurance	Improve aerobic power	Very Hard	3 to 5 minutes	< 60 seconds or 1:1 work to rest ratio	109 – 111% of MLSS	> 6	>100% of MLSS HR	>16	4 x 1200 @ E4 (1:30 per 400 meters) with 4:00 recovery
Lactate Tolerance & Buffering (S1)	Anaerobic Capacity / Strength Endurance	Improve lactate tolerance & buffering		1 to 3 minutes	30 seconds to 8 minutes or longer	90 – 100% of max run for 1 to 3 minutes	Max	N/A	>16	1 x 600 @ S1 (95% of max 800) with 10 minute recovery
Lactate Production (S2)	Anaerobic Power / Speed Endurance	Improve ability to produce lactate	Extremely Hard to Maximal Exertion	5 to 50 seconds	2 to 5 minutes	90 – 100% of max run for 5 to 50 seconds	N/A	N/A	N/A	4 x 200 @ S2 (95% of max 200) with 5 minute recovery
Sprint (S3)	Alactate Power / Muscular Power / Maximum Speed	Improve maximum sprint speed and power		0.1 to 5 seconds	1 to 5 minutes	Max speed for 0.1 to 5 seconds	N/A	N/A	N/A	4 x block starts with 5 minute recovery
Economy (Econ)	Metabolic Efficiency / Coordination	Improve metabolic cost at race specific speed and technique		! or less of race distance	Enough to maintain form and/or speed	Race pace or speed at which technique can be maintained	N/A	N/A	N/A	4 x 400 @ 1600 meter goal race pace with full recovery

of the MLSS and/or the aerobic threshold along the blood lactate curve. Unlike the intensity guide developed by U.S.A. Swimming, the training intensity guidelines developed for this study consist of four levels of endurance training, Extensive endurance training (E1), Intensive endurance training (E2), MLSS training (E3), and VO_2max training (E4).

Extensive endurance training is used to induce peripheral adaptations that enhance the rate of oxygen delivery and utilization of the Slow Twitch (ST) muscle fibers and some low threshold Fast Twitch Type a (FTa) muscle fibers, provided the duration of the run is sufficient to deplete the glycogen stores of the ST muscle fibers that were initially used. Specifically, extensive endurance training will increase the number and size of mitochondria and will improve capillarization, blood shunting abilities, lactate removal rates, and the rate of fat metabolism among the working muscle fibers.

Intensive endurance training will result in a slightly elevated blood lactate value when compared to extensive endurance training. This rise in blood lactate probably indicates that a greater number of FTa muscle fibers are being recruited. For that reason, intensive endurance training probably provides a greater stimulus for increasing the aerobic capabilities of both ST and FTa muscle fibers than extensive endurance training.

The development of valid and reliable training intensity guidelines, based on the blood lactate curve and associated psycho-physiologic metrics (i.e., HR and RPE) provide specific directions for the prescription of workload intensities, thereby facilitating the ability of coaches to more objectively plan and monitor collegiate track and field/cross-country training programs. As beneficiaries of the training intensity guidelines model, track and field/cross-country athletes will likely experience a decreased incidence of under- and/or over-training and increased performance potential.

The following areas of inquiry are suggested for further study: (a) replication of this study with a larger sample, perhaps large enough to include and compare findings across different track and field event areas (e.g., endurance athletes, multi-event athletes, field event specialists, sprinters, etc.); (b) comparisons across athletes based on event areas, sport demographics (e.g., interscholastic and intercollegiate training history), and personal demographics (e.g., age and gender); (c) randomization of the order of run sessions; and (d) given the learning curve associated with use of the T-30 to estimate and generate training intensity zone pace, replicating this study, repeatedly, with a group of athletes over time—perhaps over the course of a season would likely increase the reliability of the T-30 time trial and its associated training intensity zone pace prescriptions.

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