THE EFFECT OF SYSTEM BASED TRAINING™ ON THE INDIVIDUAL LACTATE PROFILE AND 5-KILOMETER TIME TRIAL PERFORMANCE IN COLLEGIATE DISTANCE RUNNERS

By

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ABSTRACT

THE EFFECT OF SYSTEM BASED TRAINING™ ON THE INDIVIDUAL LACTATE PROFILE AND 5-KILOMETER TIME TRIAL PERFORMANCE IN COLLEGIATE DISTANCE RUNNERS

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Purpose: To evaluate the efficacy and effectiveness of System Based Training™ (SBT™) in a sample of collegiate distance runners. SBT™ is a proprietary, individualized blood lactate testing and training method for endurance athletes, yet this program has not been formally evaluated. Methods: Collegiate distance runners (n = 21) performed a 5-kilometer time trial and SBT™ Physiological Profile Test (PPT™) before and again after a 12-week summer training period leading up to a fall cross-country season. The training program for each subject was determined from the results of the SBT™ PPT™. Subjects also were required to record all training session data into a training log which was used to quantify adherence to SBT™. Adherers to SBT™ (≥ 75% adherence to: (1) number of prescribed training sessions, (2) total training volume, and (3) total intensity) were compared with non-adherers (≤ 70% adherence) for pretest-posttest differences in 5-kilometer performance time (s) (independent samples t-test) and interpolated running pace (s/1600m) at the 5.0 and 8.0 mM/L blood lactate concentrations (one-way MANOVA) as indicated from the SBT™ PPT™. Results: Ten subjects were included in the experimental analysis. Adherers to SBT™ experienced a greater improvement in 5-kilometer time trial performance (Adherers: M = 92.0 s; Non-Adherers: M = 11.5 s; t [8]...
= 3.04, \( p = .016 \)) between pretest and posttest when compared to non-adherers. Additionally, adherers improved their running pace at the 5.0 (Adherers: \( M = 33.9 \) s; Non-Adherers: \( M = -8.8 \) s) and 8.0 mM/L (Adherers: \( M = 25.2 \) s; Non-Adherers: \( M = -6.5 \) s) blood lactate concentrations more so than non-adherers. This difference was also significant (\( V = 0.62, F[2, 7] = 5.60, p = .035 \)). Conclusion: Adhering to SBT\textsuperscript{TM} could result in distance runners experiencing greater improvements in 5-kilometer time trial performance and the running paces at 5.0 and 8.0 mM/L than typical distance running training programs.
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REVIEW OF LITERATURE

Identifying a training program that optimizes physiological response and endurance sports performance has been a heavily debated and researched topic (Belcher & Pemberton, 2012; Enoksen, Tjelta, & Tjelta 2011; Esteve-Lanao, Foster, Seiler, & Lucia, 2007; Loprinzi & Brodowicz, 2008; Seiler, 2010; Tjelta & Enoksen, 2010; Tjelta, 2013; Tjelta, Tonnessen, & Enoksen, 2014). Much of this debate centers around both the total training volume and the proportion of training volumes that should be performed at different intensities (Guellich, Seiler, & Emrich, 2009; Seiler & Kjerland, 2006; Seiler, Haugen, & Kuffel, 2007; Tjelta & Enoksen, 2010; Tjelta et al., 2014). While many training methods to enhance endurance performance have been proposed, the variability in athlete improvement suggests an optimal training program for endurance athletes has yet to be determined, and may be dependent upon individual differences (Enoksen et al., 2011; Guellich & Seiler, 2010; Seiler & Kjerland, 2006).

Training Zones

The popular coaching and research literature are replete with information on training zones as a means to guide the training process and ensure that the desired physiological adaptations will take place in the athlete (Seiler & Kjerland, 2006). There is substantial variation in the suggested rationales for different training zones, much of which are based on easy-to-identify measures such as heart rate and running pace (Esteve-Lanao et al., 2007). Some researchers have suggested that blood lactate is the best marker of exercise intensity and should be a guide to prescribing training in endurance sports. Additionally, it has been suggested that improvements in exercise
intensity (e.g., running pace) at predetermined blood lactate values better indicate training
adaptation than VO2 max (Belcher & Pemberton, 2012; Olbrecht, 2000). Thus, both
national and international governing bodies of sport have suggested training zones based
around the heart rate-blood lactate relationship (using typical lactate values at
standardized heart rate ranges) (Seiler & Kjerland, 2006; Seiler & Tonnessen, 2009;
Seiler, 2010). While these standardized training zones provide some specificity, they
don’t account for individual variation in the heart rate-blood lactate relationship (Jones,
2006; Nicholson & Sleivert, 2001; Seiler & Tonnessen, 2009).

To account for this individual variation, some researchers have suggested the
development of aerobic training zones anchored around the first and second ventilatory
turnpoints (VT\(_1\) and VT\(_2\)), which are highly correlated with the first and second lactate
turnpoints (e.g., 2.0 mM/L and 6.0 mM/L), respectively (Seiler, 2010; Seiler & Kjerland,
2006; Seiler & Tonnessen, 2009). These individually derived ventilatory-based training
zones create a three-zone model where zone 1 consists of low-intensity training taking
place below VT\(_1\) (typically less than 2.0 mM/L blood lactate), zone 2 consisting of
“threshold” training taking place between VT\(_1\) and VT\(_2\) (typically between 2.0 and 6.0
mM/L blood lactate), and zone 3 consisting of training above VT\(_2\) (typically above 6.0
mM/L blood lactate). The testing process for the determination of these individualized
training intensity breakpoints involves using a metabolic cart to measure ventilatory
volumes and heart rate in an incremental intensity protocol (Esteve-Lanao et al., 2007;
Guellich et al., 2009).
From the aforementioned training zones, three primary methods for quantifying training intensity distribution have emerged from the literature: the time-in-zone approach, the session-goal approach, and the training volume approach (Fiskerstrand & Seiler, 2004; Enoksen et al., 2011; Esteve-Lanao et al., 2005; Esteve-Lanao et al., 2007; Guellich & Seiler, 2010; Neal, Hunter, & Galloway, 2011; Seiler & Kjerland, 2006; Seiler, 2010; Tjelta, 2013; Tjelta & Enoksen, 2010; Tjelta et al., 2014). The time-in-zone approach strictly quantifies the minutes spent in each heart rate zone (e.g., zone 1, zone 2, and zone 3) (Esteve-Lanao et al., 2005; Esteve-Lanao et al., 2007; Guellich & Seiler, 2010; Neal et al., 2011; Seiler & Kjerland, 2006; Seiler, 2010). The session-goal approach determines the primary training zone utilized during the workout and classifies that entire training session accordingly (Esteve-Lanao et al., 2007; Seiler & Kjerland, 2006). Finally, the training volume approach simply quantifies the total volume of training (measured in kilometers or miles) performed in each training zone (Enoksen et al., 2011; Tjelta, 2013; Tjelta & Enoksen, 2010; Tjelta et al., 2014).

It has been suggested that the time-in-zone approach routinely underestimates the impact of high-intensity training, as an athlete typically cannot perform substantial volume above VT₁, and it does not account for the additional sympathetic nervous system stress accumulated from particularly high-intensity training (e.g., greater than 9.0 mM/L blood lactate) (Seiler & Kjerland, 2006). Additionally, the time-in-zone approach inflates the impact of zone 1 training--as warm-up runs, cool-down runs, and the lag in time it takes to reach an elevated heart rate during high-intensity workouts and races are all attributed to zone 1. The other hand, the session-goal approach is suggested to better
represent the overall physiological stress of a training session (Esteve-Lanao et al., 2007). However, there is a limitation to the session-goal approach as all training above VT2 is assumed to create an equivalent physiological response (e.g., 6.0 mM/L vs. 10mM/L). To the author’s knowledge, no critical evaluations have been provided for the training volume approach. However, this approach assumes all types of training (whether measured in time units (e.g., minutes) or distance units (e.g., miles) will create an equivalent physiological response. For instance, many athletes will state that they run a certain number of miles or hours per week, but it remains unclear how much of that training volume is performed at various intensities (e.g., zone 1, zone 2, and zone 3) (unpublished observations).

**Training Patterns of Elite, Sub-Elite, and Recreational Athletes**

Elite, sub-elite, and recreationally competitive endurance athletes tend to self-organize their training according to one of the aforementioned training quantification methods (Esteve-Lanao et al., 2005; Guellich et al., 2009; Guellich & Seiler, 2010; Loprinzi & Brodowicz, 2008; Neal et al., 2011; Seiler & Kjerland, 2006; Tjelta, 2013; Tjelta & Enoksen, 2010). The training methods employed by these athletes draw interest from the scientific and coaching community, as these methods frequently serve as a model for current training programs of various groups of endurance athletes. As a result, many descriptive and some experimental studies have been published in which the training patterns of these athletes and the physiological and performance effects of training in such a manner are reported (Esteve-Lanao et al., 2005; Guellich et al., 2009;
Guellich & Seiler, 2010; Loprinzi & Brodowicz, 2008; Neal et al., 2011; Seiler & Kjerland, 2006; Tjelta, 2013; Tjelta & Enoksen, 2010).

**Training Patterns of Elites Athletes.** The reports of the training programs of elite athletes (e.g., world-class) are typically descriptive rather than experimental, as elite athletes rarely are willing to have their training altered for the benefit of scientific research (Pyne, Lee, & Swanwick, 2001; Seiler & Kjerland, 2006). That said, these descriptives of those competing in races lasting between two minutes and several hours provide insight into the training process of elite endurance athletes. Elite distance runners perform high volumes of training (80-150 miles per week or equivalent) while primarily adopting a polarized training model, prioritizing zone 1 training (below VT₁/2.0mM/L blood lactate) (~70-80% of training sessions) with the remaining 20-30% at higher intensities (Esteve-Lanao et al., 2005; Esteve-Lanao et al., 2007; Guellich & Seiler, 2010; Seiler, 2010; Seiler & Kjerland, 2006; Seiler & Tonnessen, 2009; Tjelta, 2013; Tjelta & Enoksen, 2010). The proportion of training at higher intensities typically varies based on the phase of the training cycle, with higher volumes of zone 2/“threshold” training (VT₁-VT₂/2.0-6.0 mM/L) typically occurring during the non-competitive training segments and while training for longer races (i.e., cross-country, marathon, etc.). In contrast, zone 3, high-intensity training (>VT₂/>6.0mM/L) typically occurs more frequently during the competitive phases of training (Esteve-Lanao et al., 2005; Esteve-Lanao et al., 2007; Guellich & Seiler, 2010; Seiler, 2010; Seiler & Kjerland, 2006; Seiler & Tonnessen, 2009; Tjelta, 2013; Tjelta & Enoksen, 2010).
**Training Patterns of Sub-Elite and Recreational Athletes.** Unlike elite athletes, sub-elite and recreational athletes are more likely to allow their training to be altered for scientific study. For the purposes of this discussion, the author is defining sub-elite and recreational athletes as those who do not compete on the world-class level. Therefore sub-elite athletes include collegiate, regionally competitive, and nationally competitive endurance athletes (e.g., distance runners, cyclists, swimmers, rowers, triathletes, etc.). These athletes typically perform substantially less training volume (40-80 miles per week or equivalent) and tend to perform higher proportions of zone 2 training at the expense of zone 1 when compared with elite endurance athletes (Esteve-Lanao et al., 2005; Loprinzi & Brodowicz, 2008; Neal et al., 2011).

Seiler and Kjerland (2006) documented the training volume and intensity distribution of a group of national-class Norwegian junior cross-country skiers \(n=11\) during a 32-day period in their pre-competition training phase. The skiers performed an estimated training volume of 12-15 hours per week, with 91% of their total training time (time-in-zone approach) in zone 1, 6% in zone 2, and 3% in zone 3 (according to their laboratory-determined VT\(_1\) and VT\(_2\) training intensity breakpoints). However, when the session-goal approach was used, 75% of the training sessions were primarily performed in zone 1, 8% in zone 2, and 17% in zone 3. These athletes (which included Norway’s first and second-ranked junior cross-country skiers) followed a training intensity distribution which more closely mirrored that of the senior national-class Norwegian cross-country skiers and aforementioned elite athletes, despite the fact that the senior
cross-country skiers performed a substantially higher volume of training (25-30 hours per
week) (Seiler & Kjerland, 2006).

Esteve-Lanao et al. (2005) analyzed the training content of a group of nationally and regionally competitive Spanish male cross-country runners (n=8) in the six months leading up to the Spanish national cross-country championships. The athletes performed a peak training volume of 90-100 kilometers per week with an intensity distribution of 71% in zone 1, 21% in zone 2, and 8% in zone 3 using their laboratory-determined VT₁ and VT₂ training intensity breakpoints (time-in-zone approach). A strong negative correlation was reported for the relationship between total training time performed in zone 1 and 4.2 kilometer (r=-0.79) and 10.1 kilometer cross-country race performance time (r=-0.97), suggesting the need to spend adequate time training at low intensities in order to perform well in longer cross-country races (Esteve-Lanao et al., 2005).

Loprinzi and Brodowicz (2008) reported that a group of male high school cross country runners (n=7) performed 184 minutes of running per week during their nine-week cross-country season. These athletes performed 45% of their training time (time-in-zone approach) below VT₁, 24% between VT₁ and VT₂, and 31% above VT₂ (based on their laboratory-determined VT₁ and VT₂ training intensity breakpoints). The athletes also improved VO₂max by 5.1% and 5-kilometer race performance by 3.7% from the start of the season. It is likely that the 184 minutes per week of training approximated 25-30 miles per week of running volume. However, these athletes logged less than 10 miles of running per week in the summer prior to the cross-country season (Loprinzi & Brodowicz, 2008). Performing such a low training volume during the summer could
explain the significant improvement levels, as the runners were likely “out-of-shape” when the season started, leading to ease in performance improvement. Clearly, this training intensity distribution indicates an increased proportion of training performed in zone 2 and zone 3 at the expense of zone 1. It remains to be seen if training at such low volume levels (3 hours per week) is best optimized with more emphasis on zone 2 and zone 3 training.

In analyzing the training content of recreationally competitive, middle-aged Ironman triathletes in the six-months leading up to an Ironman triathlon, Neal et al. (2011) reported that these athletes trained 8-11 hours per week and performed 69% of their training time (time-in-zone approach) below the first lactate turnpoint (zone 1), 25% of their training time between the first lactate turnpoint and the second lactate turnpoint (zone 2), and 6% above the second lactate turnpoint (zone 3) (based on their laboratory-determined VT1 and VT2 training intensity breakpoints). Every two months the performance of the athletes was assessed via: (A) swim 150-meter time at the first lactate turnpoint and (B) second lactate turnpoint, (C) cycle ergometer power output at the first lactate turnpoint and (D) second lactate turnpoint, and (E) running speed at the first lactate turnpoint and (F) second lactate turnpoint. Over the course of the six-month training cycle, the following changes from baseline were determined: (A=0.7%), (B=2.3%), (C=3.3%), (D=0.0%), (E=7.8%), (F=3.9%) (Neal et al., 2011). Over the course of the study, the proportion of time spent training in zone 1 during run sessions (67-80%) was higher than bike (58-71%) and swim sessions (64-69%). Similar to the aforementioned studies, it can be inferred that performing a higher proportion of training
below the first lactate turnpoint/ventilatory threshold results in an improved running speed at the first and second lactate turnpoints/ventilatory thresholds.

**Effect of Training Intensity on Sympathetic Nervous System.** It can be inferred from several of the aforementioned studies that non-elite athletes tend to perform a considerably higher proportion of their training in zone 2 (threshold) and zone 3 (high-intensity interval training) than elites. Zone 2 and zone 3 training causes increased sympathetic nervous system stress when compared with zone 1 training, thus delaying recovery and potentially leading to overtraining (Seiler et al., 2007). Additionally, it has been suggested that overtrained endurance athletes have a suppressed ability to mobilize glycogen as a substrate, even with adequate intramuscular glycogen levels at rest (due to suppressed catecholamine sensitivity) (Bosquet et al., 2001).

**Effects of Training Intensity Manipulation.** In one of the few studies in which training intensities were manipulated, Esteve-Lanao et al. (2007) compared the relative impact of performing a high percentage of training in zone 1 (low-intensity) versus zone 2 (threshold) over a five-month training cycle (preseason and competitive season) in regionally and nationally competitive male cross-country runners (10-kilometer personal records of 30:30-35:00). These athletes performed training volumes of 80-90 kilometers per week and were randomized into two groups: zone 1 or zone 2 emphasis. The “Zone 1” group performed 80% of their total training time (time-in-zone approach) in zone 1, 12% in zone 2, and 8% in zone 3 while the “Zone 2” group performed 67% of their total training time (time-in-zone approach) in zone 1, 25% in zone 2, and 8% in zone 3. The “Zone 1” group improved 10.4-kilometer cross-country time trial performance by 157
seconds (7.0% improvement from pretest) and the “Zone 2” group improved by 122 seconds (5.8% improvement from pretest). However, the mean pretest time trial performances (37:29 for the Z1 group and 37:51 for the Z2 group [interpolated to 36:02 and 36:24 for the 10-kilometer distance]) were substantially slower than their 10-kilometer personal best performance times (30:30-35:00). While the pretest-posttest improvements in 10.4-kilometer cross-country time trial performance of both groups appear inflated as a result of very slow pretest performance times, the results of this study indicate that performing more threshold training at the expense of low-intensity training is not an optimal approach to training of regionally and nationally competitive cross-country runners. During pilot testing, the authors aimed to assess the impact of increasing the proportion of zone 3 training (up to 15% of total training time and included in 25-30% of all training sessions). They discovered that performing this training intensity distribution was not sustainable for most of the subjects, as they showed symptoms of overtraining (Esteve-Lanao et al., 2007).

Seiler and Tonnessen (2009) examined increasing higher-intensity training among a group of elite Spanish “Under-23” road cyclists. The cyclists increased their overall training volume from 211 hours from November-February to 260 hours from March-June to include more than four times the volume performed in zone 3 (5 hours to 21 hours) (above VT2). The cyclists showed no improvement in power output at VT1 and VT2 as well as no improvement in VO2 max. However, other researchers have found that when athletes have not been performing threshold and high-intensity interval training, replacing
less than 20% of those training sessions with threshold and/or high-intensity interval
sessions leads to fitness and race performance improvements (Seiler & Tonnessen, 2009).
These findings, along with those of Esteve-Lanao et al. (2007), indicate that training at an
intensity level that has been neglected can lead to improvements, as those associated
components of fitness may have detrained over time, provided that the volume is not high
enough to induce symptoms of overreaching and/or overtraining.

**Adherence to Coaches’ Training Prescription.** While so much attention is paid
by coaches to training program design, an often neglected, yet critical element of
coaching is how to ensure that the athletes execute the training prescribed by the coaches
(unpublished observations). It has been suggested that there is a fine line between proper
training and overtraining (Fiskerstrand & Seiler, 2004; Seiler et al., 2007). Therefore, if
an athlete does not train in the correct training zones for each training session, the risk of
overtraining or undertraining increases (Madsen & Lohberg, 1987; Olbrecht, 2000). The
previously discussed studies of the training intensity distributions of non-elite endurance
athletes align with the findings of studies which suggest that sub-elite athletes train at too
high of an intensity on “easy” days relative to the training prescription provided by the
coach, which will delay the ability to recover from those training sessions before their
next scheduled “hard” session, increasing the risk of overtraining (Bouchard et al., n.d.;
Loprinzi & Brodowicz, 2008; Neal et al., 2011; Seiler & Kjerland, 2006; Seiler &
Tonnessen, 2009; Seiler, 2010).
Individualizing Training to the Athlete

Athletes tend to adapt to training at different rates, with some athletes not adapting in the desired way (Grady, 2013; Guellich & Seiler, 2010; Hudson & Fitzgerald, 2008; Magness, 2014). In fact, longitudinal data from 2010-2013 indicates that NCAA Division II 5-kilometer track runners improve performance time annually by a mean rate of only 0.7%, with 65% of these athletes improving by 2% or less in any one-year time period (“2014 collegiate outdoor tf 5000m rankings”, 2014). In addition to suboptimal training program design by coaches and lack of adherence to coach-prescribed training programs by athletes, the variation in individual physiological differences among athletes can explain much of the differences in training adaptation and thus performance improvement in endurance athletes (Guellich & Seiler, 2010; Magness, 2014).

It is likely that there is not a single training volume level and/or intensity distribution that is optimal for every athlete, as high-levels of improvement depend on many factors, including the current development of the physiological system being trained and the relevance of that system to the event being trained for (Seiler & Kjerland, 2006; unpublished observations). Thus, the idea of individualizing training to the specific athlete has emerged as a method to increase the performance levels of all athletes (Hudson & Fitzgerald, 2008; Magness, 2014; McMillan, 2013). However, the concept of individualizing training does not have an agreed-upon definition and implementation practice by the coaching community (Hudson & Fitzgerald, 2008; Magness, 2014).

There is a wide range in the level of individualization that takes place in the American distance running coaching community. Some coaches do not individualize at
all in what Jack Daniels, Ph.D. refers to as the “eggs against the wall” approach to coaching and training. Daniels is referring to the practice of giving every athlete the same training stimulus (typically very high in volume) with the hope that a few of the athletes adapt well, similar to the idea of throwing a basket of eggs against a wall and hoping that a few of them do not break (Daniels, 2014). In doing so, some coaches develop very successful athletes but poorly develop countless others (e.g., athletes who suffer from overtraining, injury, burnout, etc.). Many other American distance running coaches individualize training by adjusting training volume to the athlete and/or prescribing training based on the event that the athlete is training for (Hudson & Fitzgerald, 2008; Magness, 2014; unpublished observations). However, this approach does not truly individualize training to the athlete, as they do not prescribe training based on the actual physiological makeup of the athlete as they relate to the event being trained for (Grady, 2013; Grady, 2015; Magness, 2014).

Janssen (2001) as well as Belcher and Pemberton (2012) suggested more individualized approaches centered around identifying the lactate threshold (LT) or maximal lactate steady state (MLSS) heart rate and running pace through a field or laboratory test (using blood lactate testing and/or non-invasive measures). Then individualized training zones are created which are derived from standard percentages of the athlete’s individual LT or MLSS (e.g., aerobic recovery runs should be performed at a heart rate of 75-90% of the heart rate at MLSS). These approaches aim to base training off of a specific physiological marker (i.e., LT or MLSS), which assumes that a group of athletes will benefit equally from all types and amounts of training from the proposed
training phases (Belcher & Pemberton, 2012; Janssen, 2001). Since, the driver of these methods is heart rate as a percentage of MLSS heart rate, intensities above the MLSS may not effectively be pinpointed to plan high-intensity training sessions (e.g., greater than 6.0 mM/L blood lactate). Additionally, it assumes no variation in the heart rate-blood lactate relationship across the intensity spectrum, and that these standardized percentages will create the desired training stimulus and response for each athlete (i.e., the set percentages will be valid for all athletes). Thus, it appears that these methods only partially account for the individual variation among athletes.

Magness (2014) has suggested individualizing training by muscle fiber type. His approach is to prescribe training which accounts for the inherent weaknesses caused by lacking a high proportion of either Type I or Type II muscle fibers. According to this approach, Magness expressed that athletes who possess higher proportions of Type I muscle fibers should frequently perform high-intensity training, which recruits more Type IIa and Type IIX muscle fibers and produces high lactate values in order to enhance the anaerobic characteristics of these fibers (inherent weakness). Rather than performing a muscle biopsy, one can project which type of muscle fibers predominates by comparing the personal best performances of an athlete across multiple events using performance equivalency tables to determine which events (and metabolic energy systems) are weaker (Magness, 2014). If the coach or sports scientist owns a blood lactate analyzer, they can also have the athlete perform an anaerobic blood lactate test (e.g., maximal effort 600-meter run prior to blood lactate sampling). Theoretically, an athlete with a high net maximum lactate accumulation value would possess a higher proportion of Type
Ilax/Type IIx muscle fibers than one with a lower value (Magness, 2014). While the approach used by Magness may provide a general tool to individualize training for endurance athletes, the validity of his methods to determine the predominant muscle fiber type in athletes is unclear. For instance, several training, environmental, and nutritional factors can positively and negatively affect net lactate accumulation as measured during a blood lactate test. Also, the question remains of when a coach should alter the training stimulus for an athlete as they prepare for their goal event. Additionally, it should be noted that Magness’ approach has not been evaluated in a controlled, scientific study.

Olbrecht (2000) suggested the idea of routine blood lactate testing in swimmers to monitor training intensity, prescribe training, and quantify the changes in the aerobic (e.g., swimming velocity at 2.0 mM/L) and anaerobic energy systems (e.g., maximal net lactate accumulation) as a result of a recently completed training cycle. Olbrecht’s methods have been used by many world-class swimmers, several of which have earned medals at the Olympic Games and World Championships since 1996. Unlike the standard intensity scales provided by national and international governing bodies of sport, the swimming velocities which corresponded to varying lactate concentrations from the lactate test results were individualized to the specific athlete (Olbrecht, 2000). Additionally, the world record holder in the women’s marathon, Paula Radcliffe, would use blood lactate testing to: (1) determine individualized heart rate and pace-based training zones, (2) evaluate changes in fitness, (3) determine training emphases for the future training segments, and (4) accurately estimate race performance abilities (Jones, 2006). Unsurprisingly, the methods and protocols of Radcliffe’s testing were not
discussed, as she was still competing at the world-class level at the time of the study (Jones, 2006). However, this adds to the speculation that blood lactate testing and training application could be a key tool to utilize when individualizing training of endurance athletes.

**Blood Lactate: A Physiological Marker to Monitor Training Intensity**

Carbohydrates stored as intramuscular and liver glycogen are considered a major fuel source to synthesize adenosine triphosphate (ATP) for the 5,000-10,000-meter track events (Powers & Howley, 2012). Through the glycolytic pathway, the glycogen molecule is converted into two pyruvate molecules which can either enter the mitochondria to metabolize aerobically via oxidative phosphorylation, or form two lactate and two hydrogen ions when there is more pyruvate than can be oxidized in the mitochondria (Brooks, Fahey, & Baldwin, 2005; Olbrecht, 2000). While the glycolytic and oxidative phosphorylation metabolic energy systems are both always contributing to total ATP production in a continuum, the primary determinant of whether pyruvate converts to lactate or enters the mitochondria for oxidative phosphorylation depends on the glycolytic and mitochondrial enzyme rates (Brooks et al., 2005; Faude, Kindermann, & Meyer, 2009; Olbrecht, 2000; Stallknecht, Vissing, & Galbo, 1998; Tiidus, 1985). If the rate of glycolytic enzymes exceeds the rate of mitochondrial enzymes, more pyruvate will be formed than can be oxidized in the mitochondria and the hydrogen ions will accumulate in the cytoplasm (Brooks et al., 2005; Olbrecht, 2000; Stallknecht et al., 1998).
There is controversy as to whether or not the glycolytic pathway is the source of hydrogen ion accumulation that results in exercise-induced metabolic acidosis, as hydrogen ion accumulation is thought to be a result of ATP hydrolysis, the formation of carbonic acid from carbon dioxide and water, and the production of lactate during glycolysis (Powers & Howley, 2012; Robergs, 2001). A majority of current literature suggests that most of the accumulated hydrogen ions can be buffered (e.g., the bicarbonate system) (Plowman & Smith, 2014). However, the lowering of intracellular pH created by excess hydrogen ion accumulation causes the glycolytic enzymes (specifically phosphofructokinase), and to a lesser extent, the mitochondrial enzymes to begin to denature and deactivate (Plowman & Smith, 2014). This change in the enzyme activity rates ultimately slows down the rate of ATP production and forces the athlete to slow down (Brooks et al., 2005; Pyne, 1989; Olbrecht, 2000). Robergs (2001) states that there is not evidence that lactate production increases in equal amounts to the hydrogen ions released within and from skeletal muscle. However, he does argue that lactate is a “good indirect marker of an alteration in cellular metabolism causing acidosis and a non-steady state metabolic milieu” (p. 17). Hence, measuring lactate is a useful index of exercise intensity.

**Lactate Testing: Techniques and Physiological Considerations**

Blood lactate is typically measured with a lancet-induced prick of the fingertip or earlobe for blood sampling with a lactate analyzer (Bourdon, 2000; Plowman & Smith, 2014). Once collected, lactate is measured in millimoles per liter (mM/L) of blood. Resting lactate values should be 1.0-1.5 mM/L and maximal lactate values following
maximal exercise efforts of 1-2 minutes in length are frequently greater than 20.0 mM/L (Billat, 1996; Madsen & Lohberg, 1987).

The blood lactate technician should be aware of several nutritional, environmental, and training-related factors that can impact the level of lactate production in the muscle. Researchers have suggested the following factors increase lactate accumulation: increased ambient temperatures, dehydration, caffeine ingestion, and anemia (Bourdon, 2000; Plowman & Smith, 2014). The following factors have been suggested to decrease lactate accumulation: glycogen depletion, decreased catecholamine sensitivity due to overreaching and overtraining, and decreased ambient temperatures (Billat, 1996; Bosquet et al., 2001; Bourdon, 2000; Faude et al., 2009; Nicholson & Sleivert, 2001; Pyne, 1989; Pyne et al., 2001). When possible, these factors should be controlled for to enhance the validity and reliability of each blood lactate sample.

When taking a blood lactate reading, the blood lactate technician should be aware of the lactate kinetics that may affect the reading. As discussed previously, lactate is produced in the muscle when pyruvate is not oxidized in the mitochondria (Stallknecht et al., 1998). Lactate can then be removed from muscle in any of the following ways: taken up by the heart as fuel, taken up by the liver to be resynthesized as glycogen (primarily following exercise), uptake by the same muscle fiber or adjacent muscle fibers to be oxidized in the mitochondria (after conversion to pyruvate), temporarily rest in the interstitial space between muscle fibers (prior to uptake), or diffuse into the blood (Billat, 1996; Brooks et al., 2005; Madsen & Lohberg, 1987; Magness, 2014; Olbrecht, 2000; Plowman & Smith, 2014). Once produced, lactate can be shuttled in and out of the cell
via monocarboxylate transport proteins, MCT1 and MCT4, which are located in slow-twitch and fast-twitch muscle fibers respectively. Through training, the number and activity of these transport proteins increases, thus increasing the turnover of lactate to pyruvate and total energy production (Brooks et al., 2005; Magness, 2014). Given the complexities in the lactate kinetics at the intercellular and intracellular level, it is not appropriate to assume the level of lactate in the blood is entirely reflective of lactate in the muscle (Bourdon, 2000; Pyne, 1989).

**Lactate Testing: Identifying the Lactate Threshold/Maximal Lactate Steady State**

Many sports scientists and coaches believe the value of lactate testing lies within the identification of the LT or MLSS, due to the high correlation with running velocity at the lactate threshold with distance running performance (Billat, 1996; Bourdon, 2000; Faude et al., 2009; Nicholson & Sleivert, 2001). Aside from the value of knowing the lactate threshold in order to predict distance running performance, some researchers and endurance sports coaches have suggested that the LT or MLSS represents a critical training intensity, since it represents the highest intensity where lactate production and clearance are in equilibrium; training at this intensity may improve lactate clearance mechanisms (Belcher & Pemberton, 2012; Faude et al., 2009; McMillan, 2013).

Currently there is no agreed-upon best-practice method to identify the LT (Bourdon, 2000; Faude et al., 2009). However, the MLSS is typically detected in runners as the greatest running velocity that yields less than a 1.0 mM/L increase in blood lactate from the 10-minute mark to the 30-minute mark in a 30-minute, continuous, steady state running test and can range from 1.5 to 7.0 mM/L (Beneke, 2003; Billat, 1996; Goodwin,
Hernandez, Harris, & Gladden, 2007). Since the MLSS test protocol requires a constant velocity to be maintained over the course of the test, determining the true MLSS can require several attempts over several days (Magness, 2014).

Another problem arises when it comes to interpreting MLSS test results. A performance test should be only performed if it can positively direct the training that should be performed in future training cycles by an athlete in order to improve race performance (Lambert, 2006; Olbrecht, 2000). Many exercise physiology laboratories can perform a MLSS test, but the question of how to best utilize the test result data in order to guide the training process remains to be conclusively answered at this time. While some researchers have suggested that the LT or MLSS represents a critical training intensity for endurance athletes, the research on endurance training indicates that physiological adaptations are specific to the intensity at which they are performed, and different adaptations will take place across the exercise intensity spectrum (Baechle & Earle, 2008; Billat et al., 2001; Esteve-Lanao et al., 2007; Seiler & Tonnessen, 2009). Therefore, by overly emphasizing LT or MLSS training, athletes may ignore components of fitness that can only be achieved from performing training sessions at higher intensities (Grady, 2013). As previously discussed, training at the LT or MLSS (zone 2) also has been shown to substantially stress the sympathetic nervous system, potentially leading to delays in recovery and a suppressed ability to mobilize glycogen as a substrate (Bosquet et al., 2001; Seiler et al., 2007).
**Lactate Testing: A New Paradigm**

How improvements in velocity/power at specific blood lactate concentrations (e.g. running velocity at 4.0 mM/L blood lactate) translate into actual competition performance is a frequently asked question within the endurance coaching community (Pyne et al., 2001). Some researchers did not find a convincing relationship between increased cycle ergometer power output at set blood lactate concentrations with competition performance at the time of the study (Guellich & Seiler, 2010; Pyne et al., 2001). As a result, some coaches and researchers have expressed doubt in the necessity of lactate testing to improve competition performance (Madsen & Lohberg, 1987; Pyne et al., 2001). However, it has been noted that many of those researchers failed to measure anaerobic capacity (i.e., maximal net lactate accumulation) which has been suggested to maintain balance of the energy systems and prevent overstressing the aerobic system (Olbrecht, 2000; *Secrets of Lactate*, 2005).

As previously discussed, Olbrecht (2000) suggested routine blood lactate testing to monitor training intensity, prescribe training, and quantify the changes in the aerobic (e.g., swimming velocity at 2.0 mM/L) and anaerobic energy systems (e.g., maximal net lactate accumulation) as a result of a recently completed training cycle. In addition to the routine testing to optimally adapt the training stimuli to the individual athlete, the primary goal of Olbrecht’s (2000) lactate testing and training application is to maintain an optimal balance between the aerobic and anaerobic energy systems by developing the aerobic system maximally and the anaerobic system to the minimum level needed for the desired competition distance.
A set blood lactate reading (e.g., 4.0 mM/L) can be achieved through lower lactate production and lower lactate clearance or higher lactate production and higher lactate clearance. Specifically, developing the aerobic system maximally will enable athletes to utilize their anaerobic system for a longer period of time as lactate clearing rates of the aerobic system improve. Olbrecht (2000) reported that elite swimmers produce up to 25% more lactate per minute at the same net blood lactate concentration when compared with non-elites (methods not stated); indicating the strength of both the aerobic and anaerobic energy systems of the elite swimmers compared to non-elites.

**Lactate Testing: Suggested Protocol Guidelines**

The validity of a lactate test lies within the design of the test protocol. If the goal of a lactate test is to reflect the ability of the aerobic system to synthesize ATP through oxidative phosphorylation and utilize the lactate produced to synthesize additional ATP, the test protocol needs to be designed in a manner that allows for a steady state to be reached during each stage (Madsen & Lohberg, 1987). Researchers have suggested stages ranging from 2-15 minutes to allow for the steady state to occur (Bourdon, 2000; Faude et al., 2009; Madsen & Lohberg, 1987; Pyne et al., 2001). The shorter the stage duration, the less likely a steady state will occur (Bourdon, 2000; Madsen & Lohberg 1987; Olbrecht, 2000). However, this can be negated by keeping the rest period between intervals short and the intensity increment small, as a steady state is more likely to occur (Secrets of Lactate, 2005). However, if the rest period is too long and/or there is a substantial increase in intensity in successive stages, the earlier test stages will likely overestimate the running velocity at different blood lactate concentrations as the muscle
lactate likely will not have yet been reflected in the blood measure (Billat, 1996; Bourdon, 2000; Faude et al., 2009). In this situation, lactate accumulation in the blood is likely to increase rapidly in the later stages of the test (Bourdon, 2000).

The test protocol design for an anaerobic capacity test is rather simple. The test should be long enough to ensure that the anaerobic glycolytic energy system has time to maximally engage to produce the ATP necessary to fuel the test, but short enough to prevent the aerobic system from clearing much of the produced lactate. Researchers have suggested a maximal effort test of 40-90 seconds as adequate to measure the anaerobic capacity (Madsen & Lohberg, 1987; Magness, 2014; Olbrecht, 2000). Following an anaerobic capacity test, blood lactate should be measured every other minute in order to determine the highest lactate reading, which is usually achieved during recovery (Magness, 2014; Olbrecht, 2000). Typically it will take 5-9 minutes for the produced lactate after a maximal effort test to appear in the blood sample (Billat, 1996; Magness, 2014).

Olbrecht’s testing involved an evaluation of both the aerobic and anaerobic energy systems. Specifically, he would assess one or multiple aerobic intervals (200-400m swim intervals [e.g., 2-5 minutes]) with 10-20 minutes rest between intervals. Then he would assess anaerobic capacity with a maximal effort 50-200m swim interval (e.g., 22-95 seconds). Sometimes this maximal lactate would be evaluated on a separate day as a post-competition lactate accumulation value. Under Olbrecht’s method, all recorded lactate values were determined to be the highest reading of blood samples taken
every other minute for 5-12 minutes after completion of the interval (up to five minutes for aerobic intervals and up to 12 minutes for maximal effort anaerobic intervals).

**Lactate Testing and Training Prescription: System Based Training™**

Taking the lactate testing process one step further, Shannon Grady, M.S., founder of Go! Athletics, LLC, created System Based Training™ (SBT™). SBT™ is an individualized testing and training program which is tailored to the athlete based on the strength and balance of their biochemical energy systems and the event they are training for. Thus the roadmap to creating the individualized training plan has many different routes, all based on these factors. Compared to Olbrecht’s test protocols, the PPT™ involves more stages (i.e., 6-8 stages of increasing intensity) with short rest intervals. Also the PPT™ does not assess a “true” maximal net lactate accumulation value whereas Olbrecht does aim to assess this. SBT™ also differs from Olbrecht’s method as well as other “individualized” programs in the training application from testing results.

Grady developed SBT™ through analyzing over 90,000 athlete testing samples and observing how the training performed by the athlete influenced subsequent PPT™ as well as competition performance. Through Grady’s research, she developed the “Grady Human Performance Theory” (GHPT), suggesting that “the optimal way to increase the overall human performance [in events lasting longer than 90 seconds] is to increase rates of speed [pace] at 2.0 mM/L and increase physiological range [difference between maximum and minimum net lactate accumulation]” (Grady, 2015).

Grady (2013) has implemented testing protocols for every endurance sport, but the running protocol will be the emphasis of this section. The SBT™ Physiological
Profile Test™ (PPT™) running protocol consists of a series of 800-meter interval runs of increasing velocity which are performed on an indoor or outdoor track while wearing a heart rate monitor, with recoveries lasting less than 90 seconds. The first interval is performed 40 seconds slower than current 5-kilometer race pace per 800 meters, with each successive interval prescribed to be run 10 seconds faster than the previous one. Depending on the performance level of the athlete, each 800-meter interval should last between 2 and 4 minutes. The test is designed to last between 6 and 8 stages. Blood samples are collected for blood lactate measures via lancet-induced finger-prick following each interval; the test is continued until the athlete cannot perform a faster interval. At the end of the test, the athlete has the option to perform a maximum-intensity 400-meter repeat if the maximum net lactate accumulation value is less than 10.0 mM/L by this point of the test. The purpose of this repeat is to attain a maximal lactate value at the end of the test. This lactate value is not the true maximal lactate value for the athlete, due to the following factors: (1) the duration of the continuous test protocol and (2) since true maximal lactate values usually occur 5-9 minutes after maximal efforts. Thus, the reliability of this measure is unclear as the time at the lactate kinetics could affect the reading at the time of blood collection. However, the maximal lactate value determined from the PPT™ is touted to provide an approximation of the endurance–specific anaerobic capacity of the athlete (Grady, 2013).

The SBT™ Physiological Profile Test™ (PPT™) is touted as providing an evaluation of the aerobic and anaerobic energy systems and includes an approximated maximum net lactate accumulation value. The combination of short stages (2-4 minutes
in duration), short rest periods (less than 90 seconds), and relatively small intensity increments (10 seconds faster per successive 800-meter segment) allow for several stages to be completed in the test, while maintaining the validity of the test with respect to the balance between net muscle and blood lactate accumulation during the early stages of the test. The multiple stages also allow the coach/sports scientist to determine the intensity levels when lactate increases rapidly.

Following completion of a SB™ PPT™, stage interval times are related to blood lactate concentrations and heart rates to determine individualized training intensity zones for the athlete (Table 1) (Grady, 2013). Training prescriptions are determined based on the physiological state of the athlete and the event in which the athlete is training for (Appendix A). Grady (2015) has suggested that the net lactate accumulation for a training session is the stimulus that triggers the biochemical change leading to the desired physiological adaptation. Training sessions are then organized in 4-6 week phases with each phase targeted to improve running pace at the 0.7-3.0 mM/L net lactate accumulation level (“Aerobic Foundation” and “Progressive Long Run”) as well as the running pace at the “Main System Workout” (MSW) intensity of that phase (e.g., LTCC). Phases are then sequenced to improve the running pace in up to the three most relevant intensities to the event being trained for.
<table>
<thead>
<tr>
<th>Session Type</th>
<th>Expected Net Lactate Accumulation</th>
<th>Individualized Intensity Determined By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerobic Foundation (AF)</td>
<td>&lt;2.0 mM/L</td>
<td>Heart Rate</td>
</tr>
<tr>
<td>Progressive Long Run (PLR)</td>
<td>2.0–3.0 mM/L</td>
<td>Heart Rate</td>
</tr>
<tr>
<td>Main System Workout (MSW): Lactate Tolerance, Clearing, and Capacity (LTCC)</td>
<td>4.0–6.0 mM/L</td>
<td>Running Pace</td>
</tr>
<tr>
<td>Main System Workout (MSW): Aerobic Rate Capacity 2 &amp; 3 (ARC-2, ARC-3)</td>
<td>6.0–9.0 mM/L</td>
<td>Running Pace</td>
</tr>
<tr>
<td>Main System Workout (MSW): Aerobic Rate Capacity 1 &amp; 2 (ARC-1, ARC-2)</td>
<td>9.0–12.0 mM/L</td>
<td>Running Pace</td>
</tr>
<tr>
<td>Economy Intervals (EI)</td>
<td>NA</td>
<td>Running Pace</td>
</tr>
</tbody>
</table>

When the athlete is in his or her non-competitive, offseason training cycle, they perform a slightly modified version of SBT™, SBT™ “System Priming”. SBT™ “System Priming” for collegiate distance runners is used to improve the athlete’s running pace at 2.0 mM/L while maintaining the strength of each remaining system in the 2-12 mM/L range. Sample PPT™ as well as corresponding profile analyses and systems targeted in SBT™ “System Priming” for collegiate distance runners are shown in Appendix A. Using the three-zone training model described in many studies (Zone 1: ≤2.0 mM/L blood lactate, Zone 2: 2.0-6.0 mM/L blood lactate, Zone 3: ≥6.0 mM/L blood lactate), SBT™ “System Priming” requires athletes to complete 73-77% of training sessions in Zone 1, 7-9% in Zone 2, 4-5% in Zone 3, and 9-10% as non-lactate accumulating Economy Interval sessions. This intensity distribution mirrors that of the training programs performed by elite athletes, even though the overall training volume is typically much less during SBT™ “System Priming” (e.g., 4-7 hours per week of AF and
PLR volume prescribed to subjects as part of this study). The descriptive studies of sub-
elite and recreational athletes who perform similar weekly training volumes to those of
athletes performing SBT™ “System Priming” document them performing significantly
more training in Zone 2 at the expense of Zone 1.

This individualized system of testing and training is currently being used by
individual endurance athletes and teams at the high school, college, recreational, sub-
elite, and elite level. Atypically high levels of race time improvement have been reported
for those who have adhered to SBT™ in the respective endurance sport/event they train
for (Grady, 2013).

**Purpose of this Study**

Sports scientists and endurance sport coaches have long searched for the training
program which best stimulates the desired physiological adaptation and improves race
performance (Belcher & Pemberton, 2012; Enoksen et al., 2011; Esteve-Lanao et al.,
2007; Loprinzi & Brodowicz, 2008; Seiler, 2010; Tjelta, 2013; Tjelta & Enoksen, 2010;
Tjelta et al., 2014). The descriptive studies of elite endurance athletes suggest training
guidelines that have been successful in improving fitness and race performance:
performing high volumes of training with a high proportion of that training at lower
intensities (e.g., less than VT₁) with the remainder at higher intensities (Esteve-Lanao et
al., 2005; Esteve-Lanao et al., 2007; Guellich & Seiler, 2010; Seiler, 2010; Seiler &
Kjerland, 2006; Seiler & Tønnessen, 2009; Tjelta, 2013; Tjelta & Enoksen, 2010). Less
experienced, sub-elite and recreational endurance athletes tend to perform higher
proportions of their overall training volume at intensities above VT₁ (Esteve-Lanao et al., 2005; Loprinzi & Brodowicz, 2008; Neal et al., 2011). While it can be speculated that the higher emphasis on training at intensities above VT₁ could lead to overtraining, these athletes typically perform substantially less overall volume and it could be the case that a high percentage of intense training can be tolerated when performing less overall volume. However, the annual 0.7% rate of improvement among NCAA Division II 5-kilometer track runners from 2010-2013 suggests sub-elite athletes are not training in the best way to improve performance. Therefore, the question remains of how to improve endurance race performance for all athletes.

An increasing number of sports scientists, endurance coaches, and athletes across the globe are using lactate testing to monitor and prescribe training intensities due to the advent of inexpensive, portable blood lactate analyzers. To the author’s knowledge, no published studies exist on the effects of lactate testing and the resulting training prescription on physiological and performance improvements. Specifically, System Based Training™ (SBT™) has not been evaluated. The purpose of this study is to evaluate the efficacy and effectiveness of SBT™ “System Priming” among NCAA Division II distance runners over a summer training period leading up to the fall cross country season with regard to improvement in 5-kilometer track running performance and improvement in running pace at set blood lactate concentrations (5.0 and 8.0 mM/L).
METHODS

Research Design

A pretest-posttest design was used to evaluate the efficacy and effectiveness of System Based Training™ (SBT™) “System Priming” over a cross-country preseason summer training period among collegiate distance runners with respect to improvements in 5-kilometer time trial performance and running pace at set blood lactate concentrations (5.0 and 8.0 mM/L). Adherers to SBT™ were compared with non-adherers for differences in these improvements in order to determine if the athletes who adhered to SBT™ experienced greater rates of improvement when compared to those that did not.

Subjects performed a pretest SBT™ Physiological Profile Test™ (PPT™) and 5-kilometer running time trial, both of which took place at the Humboldt State University 440-yard outdoor track. Following the pretest, each subject received an individualized, 12-week summer training plan that was designed to improve 5-10-kilometer running performance. All training programs were based on the results of their SBT™ PPT™. After recording the actual summer training performed in a training log, all subjects performed a posttest 5-kilometer time trial and SBT™ PPT™.

Exploratory analyses were conducted to informally evaluate the “Grady Human Performance Theory” (GHPT). Specifically, the author examined if subjects who improved their running pace (s/1600m) at 2.0 mM/L and also improved physiological range experienced the greatest improvements in 5-kilometer time trial performance as well as running pace (s/1600m) at the 5.0 and 8.0 mM/L blood lactate concentrations between the pretest and posttest.
A follow-up questionnaire was administered to all subjects who completed the study \( (n = 21) \) to elucidate perceptions of SBT™ and its implementation. The questionnaire addressed the following topics: wearing a heart rate monitor while training, keeping a training log, training variables which were perceived to affect training, and the differences between SBT™ and the summer training they would typically perform in preparation for a cross country season. Additionally, the questionnaire aimed to identify factors that may have influenced adherence to SBT™ and may influence future adherence to SBT™.

**Subjects**

Male and female collegiate distance runners who tried out for the Humboldt State University or College of the Redwoods cross-country or track and field teams during the 2013-2014 academic year were recruited (with written permission from their head cross-country coach) for participation in the study. This study was approved by the Humboldt State University Institutional Review Board. To be included in the study, the subjects must have met the following criteria: (1) be 18-25 years of age at the start of the study, (2) specialize in track and field events ranging from the 800-meters to the 10,000-meters, (3) have been cleared for athletic participation during the 2013-2014 academic year at their college or university, (4) be currently running at least 30 miles per week, (5) routinely perform high-intensity interval training sessions, (6) be free from illness or injury at the beginning of the study, (7) have competed in a maximal intensity track race in the 3 months preceding the study, (8) and not possess any of the following American College of Sports Medicine contraindications to exercise: acute systemic infection,
chronic infectious disease, or rheumatoid, musculoskeletal, or neuromotor disorders that are exacerbated by exercise. All subjects who met the inclusion criteria and chose to participate in the study provided informed written consent before participation.

**Procedures**

**Informed Consent Meeting.** The research team recruited potential subjects at a team meeting approved by the head cross-country coaches of Humboldt State University and College of the Redwoods. At the team meeting, the nature of the project, risks, responsibilities, and benefits of participating were discussed with potential subjects. In the event when a prospective subject could not attend the initial meeting, a second meeting was scheduled with those potential subjects.

The potential subjects who expressed interest in participating ($N = 28$) were asked to complete the following forms: informed consent (Appendix B), inclusion criteria (Appendix C), running history survey (Appendix D). The running history survey form required the potential subjects to answer questions relating to their running experience, current training volume (miles per week), and 5-kilometer race performance times. The “Instructions for Subjects” (Appendix E) was also distributed to every potential subject; this outlined the requirements of the subject for the duration of the study. This document also specified the pretest instructions for the SBT™ PPT™ and 5-kilometer time trials. These instructions were also verbally communicated to each subject and published on a “Youtube” video which was e-mailed to each subject. Seven subjects did not complete the study due to missing training logs, relocation, and/or failure to complete the posttests due to injury, thus reducing the number of subjects to 21.
Heart Rate Monitor Distribution. Heart rate monitors (Timex T5K217, Middlebury, CT) were assigned to every subject for the duration of the study. The heart rate monitors were assigned and distributed to each subject one week before the 5-kilometer time trial so that the subjects would become experienced with using the device before the start of the study. This model was validated for accuracy when compared with EKG readings at increasing treadmill running intensities in the Humboldt State University Human Performance Lab prior to the start of the study.

System Based Training™ PPT™ (Pretest & Posttest). All subjects who met the inclusion criteria, submitted a complete informed consent form, and chose to participate in the study reported to the Humboldt State University outdoor track at the scheduled time to complete their SBT™ lactate profile pretest (see Appendix F for pretest and posttest calendar). Subjects were asked to wear racing attire to include running shorts, singlet, assigned heart rate monitor watch/chest transmitter, and racing flats/spiked track shoes. Subjects were instructed to perform a self-selected warm-up that they would normally perform prior to track races. Prior to starting the test, the height and weight of each subject was recorded. Subjects performed the test individually.

The test protocol involved a set of 800-meter intervals of increasing velocity, each with a 60-second recovery before starting the next interval. The first repeat was assigned to be run 40 seconds slower than their 5-kilometer race pace (determined by the coaching staff of each subject) per 800 meters. Each successive repeat was assigned to be run 10 seconds faster than the previous interval goal time. Prior to each interval, the research team informed the subject of the goal time to run the next interval along with pacing
splits at 200 meters, 400 meters, and 800 meters. Additionally, a member of the research team called out interval times when the subject reached the 200-meter, 400-meter, and 800-meter marks during the interval. The test continued until the subject could not complete a faster interval.

Following each interval, the subject took a 20-second walking recovery to the lactate testing table where they reported their interval duration time, peak heart rate, rate of perceived exertion (Borg’s 1-10 scale), and had their blood lactate concentration sampled by the primary investigator via lancet-induced finger prick. The blood lactate sample was collected in a 32-microliter capillary tube and analyzed with a portable lactate analyzer (Nova Biomedical Lactate Plus, Waltham, MA). As part of the standard SBT™ protocol, if the highest lactate measurement during the test was less than 10.0 mM/L, the subject was asked to run a maximal-effort 400-meter interval in order to attain the highest blood lactate concentration possible. All heart rate, interval duration time, rate of perceived exertion, and blood lactate data was recorded following each stage, including the maximal effort 400-meter interval if applicable. Upon conclusion of the test, each subject was instructed to perform the same cool-down routine they usually performed following track races.

A repeat test of the SBT™ lactate profile pretest was performed for one subject during the pretest, as this subject was very inconsistent in pacing throughout the intervals, which potentially could have created an inaccurate profile. A repeat SBT™ lactate profile posttest was performed for two subjects: one occurred as a result of the Lactate Plus analyzer giving extremely unexpected readings during the original posttest (i.e.,
lactate values did not increase as intensity increased). Due to the regular season (not SBT™) training plan, this subject performed an interval training session less than 48 hours before the retest of the posttest (i.e., creating large deviation from standardized pretest instructions). The second subject informed the research team after the initial posttest that he performed the most recent prescribed SBT™ interval training session less than 48 hours before the SBT™ lactate profile posttest. In both of these scenarios, glycogen levels and sympathetic nervous system activity likely were suppressed, potentially leading to an inaccurate SBT™ lactate profile posttest. Thus, the second profile test was used for each of these subjects in the pretest-posttest analysis.

In most testing scenarios when the lactate readings appeared to be inaccurate (e.g., minimum lactate values of 10.0 mM/L, lactate values following a non-increasing pattern after the first few stages, etc.), the blood sample was reanalyzed for lactate concentration. If the samples were within 1.0 mM/L of each other, an average of the two samples was recorded. If the difference of the two samples was greater than 1.0 mM/L, the value was recorded that aligned properly with the pattern of blood lactate concentration as exercise intensity increased. For instance, suppose the lactate readings showed as follows with equal increases in intensity over the SBT™ PPT™: 2.0, 3.0, 4.0, 16.1 & 5.2, 8.1, 10.2. In this case, the 16.1 value would be eliminated and replaced with the 5.2 reading. In the case where a value appeared to be inaccurate upon conclusion of the test and thus was not reanalyzed during the test, the corresponding value was marked as an “error”. For instance, suppose the lactate readings showed as follows with equal
increases in intensity over the SBT™ PPT™: 2.0, 3.0, 5.2, 9.1, 3.6, 12.1. In this case, the 3.6 reading would be marked as an error.

Other challenges occurred as a result of the subjects not adhering to the pretest instructions:

- Seven subjects, who performed their SBT™ lactate profile posttest in the morning, stated that they did not eat breakfast prior to their SBT™ lactate profile posttest. This data was not collected for the pretest.
- One subject admitted to not having enough money to buy food, and thus may have been glycogen depleted before the pretest.

5-Kilometer Time Trial (Pretest & Posttest). The 5-kilometer time trials were performed at the Humboldt State University outdoor track within 46-195 (84 ± 32) hours of their SBT™ PPT™. Scheduling conflicts of each subject and the availability for testing at the Humboldt State University outdoor track accounted for:

- 4 of the initial 28 subjects performed their 5-kilometer pretest time trial prior to their SBT™ PPT™.
- 15 of the 21 subjects who completed the study performed their 5-kilometer posttest time trial prior to their SBT™ PPT™.
- A wide range of recovery in between the tests (46-195 hours).

Most subjects (N = 18) who completed the study performed the pretest and posttest time trials with other subjects to simulate an actual competition; one subject performed both time trials independently, one performed the pretest time trial
independently and the posttest time trial with multiple subjects, and the final subject performed the pretest time trial independently and the posttest time trial with another subject. This variance was a direct result of scheduling conflicts with the testing schedule. With respect to the posttest, the 17 subjects who performed the 5-kilometer time trial on August 27 and August 28 performed the time trial with members of the Humboldt State cross country team (in an effort to keep all of the athletes on the same training cycle) who did not participate in the study.

Subjects performing the time trial were asked to wear similar attire to what they wore during the SBT™ PPT™. Before the time trial, all subjects performed the same warm-up routine that was performed prior to the SBT™ PPT™. Subjects were instructed to run as hard as they could for the duration of the 5-kilometer distance. Pacing splits were called out each lap (440 yards) to assist the subjects with pacing throughout the time trial. Subjects were verbally encouraged during the time trial in order to perform their best. Following the time trial, subjects were instructed to perform the cool-down routine they performed following their SBT™ PPT™.

Only 8 of the 21 subjects who completed the study performed their SBT™ lactate profile posttest within two hours of the same time of day as the pretest. However, 20 of the 21 subjects performed their 5-kilometer time trial within two hours of the same time of day as the pretest. Subjects were encouraged to replicate conditions as much as possible between the pretest and posttest.

**SBT™ Summer Training Prescription.** The results of the SBT™ PPT™ were charted in a table, relating stage number, interval duration time, final heart rate attained
during the interval, blood lactate concentration, rate of perceived exertion, and blood lactate increase from the previous stage. These results were used to estimate the net lactate accumulation at different running velocities and provide an estimation of the maximum lactate production of the athlete. This maximum net lactate accumulation value is likely not a true maximum net lactate accumulation value of the athlete, but is the highest value attained during the SBT™ PPT™. In turn, these values were the basis for the design of each individual, 12-week summer training program. The rationale for and guidelines of the training program are shown in Appendix A.

Each subject was instructed to do the following for each training session over the 12-week training period: wear the heart rate monitor and chest transmitter for every training session and log the results of their training in the provided training log (all subjects during summer training were expected to keep a detailed training log [per head coach instructions] regardless whether or not they chose to participate in the SBT™ portion of the research).

Subjects were expected to record the following data in the training logs:

- Pretest and posttest 5-kilometer performance time (s)
- Pretest and posttest SBT™ Physiological Profile Test (PPT™) data (800-meter interval time [s] and blood lactate [mM/L])
- Training log data submitted by each subject (training session type [run, bike, elliptical, etc.], duration [min], average heart rate [bpm], rate of perceived exertion [Borg’s 1-10 scale], and interval times [if applicable]).
Subjects were contacted by the primary investigator via telephone, text message, e-mail, and/or face-to-face contact during weeks 1, 4, 7, 9, and 11 to answer any questions about the training plans. Athletes also contacted either the primary investigator or faculty investigator over the course of the 12-week training period if they had questions relating to the training plan, heart rate monitor, etc. After the sixth week of the study, the subjects were requested to e-mail the first 6 weeks of their training log to the faculty advisor for this project, Tina Manos, Ed.D. (tina.manos@humboldt.edu). However, only 9 subjects returned their logs at the 6-week mark. 20 of the 21 subjects who completed both the pretest and posttest time trials and SBT™ PPT™ e-mailed their final, completed training logs to Tina Manos, Ed.D. (tina.manos@humboldt.edu) after the completion of both posttests. The results of the training logs were used to determine which subjects adhered to SBT™ and which ones did not.

**Instruments**

During the SBT™ lactate profile pretests and posttests, the Lactate Plus blood lactate analyzer (Nova Biomedical, Waltham, MA) was used to determine blood lactate values. Immediately prior to each day of SBT™ PPT™ testing, the analyzer was checked for validity by applying a drop of the Lactate Plus Control Solutions. Each time, the analyzer assessed the control solution lactate concentration to be within the expected control solution range. The Lactate Plus has been tested for validity and reliability ($r = .97$) against the “gold-standard” Yellow Springs bench-top lactate analyzer (Hart, Drevets, Alford, Salacinski, & Hunt, 2012). Also, when the same blood sample was analyzed between two different Lactate Plus analyzers, a strong positive correlation was
produced ($r = .99$). Thus, the Lactate Plus portable analyzer is a valid and reliable alternative to bench top analyzers.

**Statistical Analyses**

The 800-meter interval times were converted to 1600-meter times as pace/1600m is a commonly used metric by American distance running coaches. Estimates of running pace (s/1600m) at the 2-12 mM/L blood lactate concentrations were then interpolated using the raw data from the SBT™ PPT™ of each subject. A linear, weighted average approach was used (see Appendix G) to determine these values. This technique was applied, as there is no agreed-upon curvilinear approach to interpolate intensities at predetermined blood lactate concentrations (e.g., 2.0 mM/L) (Bourdon, 2000). Additionally, the linear approach is a simple, easy to understand method that coaches and sports scientists can easily calculate from any location, without the need of a curve-fitting software program.

Descriptive statistics (mean ± $SD$) were calculated for all subject characteristics. Mean ± $SE$ were calculated for 5-kilometer time trial performance and running pace (s/1600m) for each blood lactate concentration (2-12 mM/L). The 5.0 and 8.0 mM/L blood lactate concentrations were the only values used in the analysis, as they represented the minimum and maximum levels shared by all subjects included in the experimental analysis (i.e., at least one subject did not have measures at 2-4 and/or 9-12 mM/L). Mean differences in 5-kilometer time-trial performance from pretest to posttest for each adherence group were analyzed using an independent samples t-test. The mean differences in running pace at the 5.0 and 8.0 mM/L between pretest and posttest for
adherers and non-adherers were analyzed using a one-way MANOVA. All statistics were analyzed using SPSS (IMB Corp., Chicago, IL, USA) version 22 with the criterion for significance set at alpha level of $p < .05$.

Exploratory analyses were conducted to informally evaluate the GHPT. Specifically, the author examined if subjects who improved their running pace (s/1600m) at 2.0 mM/L and also improved physiological range experienced the greatest improvements in 5-kilometer time trial performance as well as running pace (s/1600m) at the 5.0 and 8.0 mM/L blood lactate concentrations between the pretest and posttest.

Adherence Group Determination

Adherence was determined by the percentage of prescribed training sessions and volume completed by the subject over the 12-week summer preseason training period. Each completed training session was categorized as follows (based on actual training log data of the subject): “Aerobic Foundation” (AF), “Progressive Long Run” (PLR), “Main System Workouts” (MSW), or “Economy Intervals” (EI). Adherence was then determined by a modified version of the session goal approach. Over the course of the 12-week summer training period, AF sessions were the session goal four days per week, while PLR, MSW, and EI each were the session goal one day per week. Thus, adherence rates were determined by measuring adherence of each category, and weighting them as follows to determine the overall adherence rate: $\frac{(AF \times 4) + PLR + MSW + EI}{7}$. Adherers to SBT™ were defined as those with an overall adherence rate of $\geq 75\%$, while non-adherers were
defined as subjects with an overall adherence rate of \( \leq 70\% \). A detailed explanation of adherence calculation is shown in Appendix H.

**Limitations**

- The SBT™ PPT™ at posttest did not feature an exact replication of the pretest protocol due to variation in initial stage running paces (s/1600m) either by the choice of the subject or primary investigator in the instances where the posttest 5-kilometer time trial indicated substantially worse fitness than the pretest.

- The potential inaccuracy of running pace (s/1600m) using the linear interpolation method (Appendix G).

- The following threats to internal validity could not be controlled for:
  - An assistant coach for the Humboldt State University cross-country and track and field teams was the primary investigator for this study. All data was, with athlete’s permission, shared with the head cross-country coaches. This potentially could have influenced all results.
  - Variation in:
    - Environmental conditions during the time trials, SBT™ PPT™, and summer training sessions. Environmental conditions were recorded for the time trials and SBT™ PPT™.
    - Training volumes prescribed to each subject as part of the SBT™ summer training plan.
Relative strength of the aerobic and anaerobic system as documented on each athlete’s profile test. Possessing a weak aerobic system may lead to sizeable improvements following aerobic training.

Training performed and recovery time between the 5-kilometer time trials and SBT™ PPT™.

SBT™ PPT™: actual time duration of each interval, recovery time between intervals, quantity of intervals, and pacing during the intervals.

Time of day of the SBT™ PPT™ as well as consistency of the time of day between pretest and posttest for each subject.

Individual diet, stress, and sleep patterns before the pretests compared to the posttests.

Several of the subjects admitted to consuming varying quantities of alcoholic beverages the night before the PPT™ (both pretest and posttest).

Accuracy of the submitted training logs over the 12-week summer training period.

**Delimitations**

- Results are only generalizable to 18-25 year-old, collegiate distance runners competing in the 5k-10k events.
• SBT™ PPT™ were performed on an outdoor track (field-based) rather than on a treadmill.
RESULTS

A pretest-posttest design was used to evaluate the efficacy and effectiveness of System Based Training™ (SBT™) “System Priming” over a cross-country preseason summer training period among collegiate distance runners. Adherers to SBT™ were compared with non-adherers with respect to differences in 5-kilometer time trial performance and running pace at blood lactate concentrations (5.0 and 8.0 mM/L).

A two-tail independent samples t-test was conducted to compare the differences between adherers to SBT™ and non-adherers for differences in 5-kilometer time trial performance time (s) between the pretest and posttest. Additionally, a one-way MANOVA was conducted to compare the differences between adherers and non-adherers (i.e., pretest to posttest) in interpolated running pace (s/1600m) at the 5.0 and 8.0 mM/L blood lactate concentrations during the SBT™ PPT™.

Subject Descriptive Characteristics

A total of 28 subjects chose to participate on this study. Of those 28, 18 subjects were not included in the experimental analysis. The reasons for the removal of those subjects are shown in Figure 1. The descriptive statistics for the 10 subjects included in the experimental analysis (6 female and 4 male) are shown in Table 2.

It should be noted that 14 of the 18 subjects who were eliminated from the final analysis were eliminated for reasons unrelated to SBT™ when compared to their usual training regimen (e.g., all subjects during summer training were expected to keep a detailed training log [per head coach instructions] regardless whether or not they chose to participate in the SBT™ portion of the research). The remaining four subjects were
eliminated because they either lost their assigned heart rate monitor \((n = 1)\) or did not wear their heart rate monitor for at least 75% of their completed AF/PLR training sessions \((n = 3)\). These four attritions were counted as related to SBT™.

Figure 1. “Subject Attrition Map”. *Of the 18 subjects excluded from the final analysis, four were excluded for reasons related to SBT™. Notes: * Subjects excluded for reasons related to SBT™. Remaining excluded subjects eliminated for other reasons as noted.
Table 2

Subject Descriptive Statistics (n = 10)

<table>
<thead>
<tr>
<th></th>
<th>Female (Mean ± SD)</th>
<th>Male (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 6</td>
<td>n = 4</td>
</tr>
<tr>
<td>Age (years)</td>
<td>20.7 ± 1.3</td>
<td>22.1 ± 0.5</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>161.5 ± 1.9</td>
<td>172.4 ± 5.1</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>57.5 ± 5.5</td>
<td>65.9 ± 5.3</td>
</tr>
<tr>
<td>Personal Best 5-Kilometer Performance Time During Last 6 Months (s)</td>
<td>1265.7 ± 157.6</td>
<td>935.3 ± 33.2</td>
</tr>
<tr>
<td>Pretest Training Volume (miles/week)</td>
<td>43.8 ± 9.5</td>
<td>52.5 ± 12.6</td>
</tr>
<tr>
<td>Running Experience (months)</td>
<td>86.3 ± 19.8</td>
<td>102.0 ± 20.0</td>
</tr>
</tbody>
</table>

Adherence Rates of all Included Subjects

Adherers to SBT™ were defined as those with an overall adherence rate of 75% or higher while non-adherers were defined as subjects with an overall adherence rate of 70% or less. Adherence rates for all subjects are shown in Table 3. The lowest adherence rate of the four adherers was determined to be 78% while the highest adherence rate of the six non-adherers was 69%, indicating a clear distinction between the two groups. A detailed explanation of how adherence is calculated can be found in Chapter Two and Appendix H.
Table 3

Adherence Rates by Subject

<table>
<thead>
<tr>
<th>Subject</th>
<th>Gender</th>
<th>Adherence %</th>
<th>Prescribed AF &amp; PLR Training Volume (Minutes)</th>
<th>Actual AF &amp; PLR Training Volume (Minutes)</th>
<th>Prescribed AF &amp; PLR Training Sessions (#)</th>
<th>Actual AF &amp; PLR Training Volume (Meters)</th>
<th>Prescribed MSW &amp; EI Training Volume (Meters)</th>
<th>Actual MSW &amp; EI Training Volume (Meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>F</td>
<td>96%</td>
<td>2655-3535</td>
<td>3158</td>
<td>89</td>
<td>81</td>
<td>48000-57200</td>
<td>56600</td>
</tr>
<tr>
<td>B</td>
<td>M</td>
<td>85%</td>
<td>3510-4635</td>
<td>4063</td>
<td>100</td>
<td>94</td>
<td>68600</td>
<td>49000</td>
</tr>
<tr>
<td>C</td>
<td>F</td>
<td>80%</td>
<td>3430-4335</td>
<td>3067</td>
<td>92</td>
<td>68</td>
<td>55800-66200</td>
<td>56200</td>
</tr>
<tr>
<td>D</td>
<td>F</td>
<td>78%</td>
<td>2655-3535</td>
<td>3227</td>
<td>88</td>
<td>76</td>
<td>48000-57200</td>
<td>22400</td>
</tr>
<tr>
<td>E</td>
<td>M</td>
<td>69%</td>
<td>3510-4635</td>
<td>4788</td>
<td>100</td>
<td>89</td>
<td>66200</td>
<td>43000</td>
</tr>
<tr>
<td>F</td>
<td>F</td>
<td>62%</td>
<td>3140-4020</td>
<td>2050</td>
<td>89</td>
<td>54</td>
<td>48000-57200</td>
<td>27100</td>
</tr>
<tr>
<td>G</td>
<td>F</td>
<td>59%</td>
<td>3430-4335</td>
<td>2860</td>
<td>92</td>
<td>66</td>
<td>55800-66200</td>
<td>23800</td>
</tr>
<tr>
<td>H</td>
<td>M</td>
<td>45%</td>
<td>3540-4675</td>
<td>5392</td>
<td>101</td>
<td>76</td>
<td>68600</td>
<td>7200</td>
</tr>
<tr>
<td>I</td>
<td>M</td>
<td>40%</td>
<td>3510-4635</td>
<td>2985</td>
<td>100</td>
<td>61</td>
<td>68600</td>
<td>800</td>
</tr>
<tr>
<td>J</td>
<td>F</td>
<td>37%</td>
<td>3460-4375</td>
<td>2623</td>
<td>99</td>
<td>49</td>
<td>58200-68600</td>
<td>4800</td>
</tr>
</tbody>
</table>

1 AF = Aerobic Foundation
2 PLR = Progressive Long Runs
3 MSW = Main System Workouts
4 EI = Economy Intervals

Adherers vs. Non-Adherers: Differences in 5-Kilometer Time Trial Performance

Adherence group differences for 5-kilometer time trial performance time as well as running paces at the 5.0 and 8.0 mM/L blood lactate concentrations from pretest-posttest are shown in Table 4. The individual values for pretest and posttest 5-kilometer time trial performances (s) along with comparisons of 5-kilometer performance data for each subject during the six months before the study are shown in Table 5. A two-tail independent samples t-test was conducted to compare the differences of 5-kilometer time trial performance (s) between adherers to SBT™ and non-adherers. Tests to confirm assumptions for normality (Shapiro Wilk Test: $p > .05$) and homogeneity of variance (Levene’s Test: $p > .05$) were conducted and met. Additionally, the changes in time trial performance all were within 1.96 standard deviations of the mean, hence no outliers were present. Subjects who adhered to SBT™ experienced a significantly greater improvement ($t[8] = 3.04, p = .016$) in 5-kilometer time trial performance between the
pretest and posttest ($M = 92.0$ s, $SE = 42.0$ s) than non-adherers ($M = 11.5$ s, $SE = 40.6$ s). Additionally, an exceptionally large effect size existed, $d = 1.98$ when comparing adherers and non-adherers. Additionally, the adherers experienced a 7.1% improvement in 5-kilometer time trial performance over the 12-week study (non-adherers: 1.0% improvement), whereas the annual mean rate of improvement from 2010-2013 among NCAA Division II 5-kilometer track runners was 0.7%. The 5-kilometer performance time comparisons of adherers, non-adherers, and NCAA Division II 5-kilometer track runners (2010-2013) are shown in Figure 2 and Figure 3.
Table 4
5-Kilometer Time Trial Performance and Running Pace (s/1600 Meters) at 5.0 and 8.0 mM/L Blood Lactate Concentrations by Gender and Adherence Group

<table>
<thead>
<tr>
<th>N</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (s)</td>
<td>SE (s)</td>
<td>Mean (s)</td>
</tr>
<tr>
<td>Pretest 5-Kilometer Time Trial Performance (s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adherers</td>
<td>4</td>
<td>1287.3</td>
<td>222.5</td>
</tr>
<tr>
<td>Male</td>
<td>1</td>
<td>1007.0</td>
<td>0</td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>1380.7</td>
<td>147.9</td>
</tr>
<tr>
<td>Non-Adherers</td>
<td>6</td>
<td>1104.3</td>
<td>120.4</td>
</tr>
<tr>
<td>Male</td>
<td>3</td>
<td>1002.0</td>
<td>44.0</td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>1206.7</td>
<td>25.9</td>
</tr>
<tr>
<td>5.0 mM/L Blood Lactate (s/1600m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adherers</td>
<td>4</td>
<td>420.5</td>
<td>77.5</td>
</tr>
<tr>
<td>Male</td>
<td>1</td>
<td>331.4</td>
<td>0</td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>450.2</td>
<td>61.1</td>
</tr>
<tr>
<td>Non-Adherers</td>
<td>6</td>
<td>361.5</td>
<td>51.8</td>
</tr>
<tr>
<td>Male</td>
<td>3</td>
<td>318.0</td>
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<td>405.0</td>
<td>25.9</td>
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<tr>
<td>8.0 mM/L Blood Lactate (s/1600m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adherers</td>
<td>4</td>
<td>391.1</td>
<td>65.0</td>
</tr>
<tr>
<td>Male</td>
<td>1</td>
<td>309.7</td>
<td>0</td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>418.2</td>
<td>43.8</td>
</tr>
<tr>
<td>Non-Adherers</td>
<td>6</td>
<td>336.3</td>
<td>40.1</td>
</tr>
<tr>
<td>Male</td>
<td>3</td>
<td>302.7</td>
<td>18.2</td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>370.0</td>
<td>17.2</td>
</tr>
</tbody>
</table>

1Positive values for difference indicate subjects had faster 5-kilometer performance times (s) or faster pace (s/1600m) at posttest than pretest.

Table 5
Individual Pretest and Posttest 5-Kilometer Time Trial Performance for Subjects (n = 10)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Gender</th>
<th>Adherer?</th>
<th>Average 5K Performance of Previous Six Months (s)</th>
<th>Pretest 5K Time Trial (s)</th>
<th>Average 5K-Pretest Difference (s)</th>
<th>Posttest 5K Time Trial (s)</th>
<th>Pretest-Posttest 5K Time Trial Difference (s)</th>
<th>Pretest-Posttest 5K Time Trial Difference %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>F</td>
<td>Y</td>
<td>1222</td>
<td>1221</td>
<td>1</td>
<td>1128</td>
<td>93</td>
<td>8%</td>
</tr>
<tr>
<td>B</td>
<td>M</td>
<td>Y</td>
<td>936</td>
<td>1007</td>
<td>-41</td>
<td>935</td>
<td>72</td>
<td>7%</td>
</tr>
<tr>
<td>C</td>
<td>F</td>
<td>N</td>
<td>NA</td>
<td>1408</td>
<td>NA</td>
<td>1258</td>
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<td>D</td>
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<td>Y</td>
<td>1513</td>
<td>NA</td>
<td>14601</td>
<td>NA</td>
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<td>4%</td>
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<tr>
<td>E</td>
<td>M</td>
<td>N</td>
<td>1002</td>
<td>1035</td>
<td>-33</td>
<td>971</td>
<td>64</td>
<td>1%</td>
</tr>
<tr>
<td>F</td>
<td>M</td>
<td>N</td>
<td>1192</td>
<td>1201</td>
<td>-9</td>
<td>1199</td>
<td>2</td>
<td>6%</td>
</tr>
<tr>
<td>G</td>
<td>F</td>
<td>N</td>
<td>1173</td>
<td>1263</td>
<td>-90</td>
<td>1237</td>
<td>26</td>
<td>2%</td>
</tr>
<tr>
<td>H</td>
<td>M</td>
<td>N</td>
<td>927</td>
<td>952</td>
<td>-25</td>
<td>946</td>
<td>6</td>
<td>3%</td>
</tr>
<tr>
<td>I</td>
<td>F</td>
<td>N</td>
<td>952</td>
<td>1019</td>
<td>-67</td>
<td>990</td>
<td>29</td>
<td>0%</td>
</tr>
<tr>
<td>J</td>
<td>F</td>
<td>N</td>
<td>1116</td>
<td>1156</td>
<td>-40</td>
<td>1214</td>
<td>-58</td>
<td>-5%</td>
</tr>
</tbody>
</table>

*Subject D stopped after 4600 meters (laps were miscounted). Thus, her slowest lap (determined from video analysis) was added to her finish time to estimate her 5-kilometer posttest time (s).
Figure 2. “Mean 5-Kilometer Performance Time at Pretest and Posttest for Males (12 weeks)”. Mean annual NCAA Division II 5-kilometer performance data also plotted for comparison (2010-2013).

Figure 3. “Mean 5-Kilometer Performance Time at Pretest and Posttest for Females (12 weeks)”. Mean annual NCAA Division II 5-kilometer performance data also plotted for comparison (2010-2013).
Adherers vs. Non-Adherers: Differences in Running Pace at 5.0 and 8.0 mM/L

Adherence group differences in interpolated running pace at the 5.0 and 8.0 mM/L blood lactate concentrations from pretest-posttest are shown in Table 4. The individual values for running paces at 5.0 and 8.0 mM/L during the SBT™ PPT™ (pretest and posttest) are shown in Table 6. A one-way MANOVA was used to compare the differences between adherers to SBT™ with non-adherers in running pace (interpolated s/1600m) at the 5.0 and 8.0 mM/L blood lactate concentrations. The 5.0 and 8.0 mM/L blood lactate concentrations represented the minimum and maximum interpolated blood lactate concentrations that each of the 10 subjects had measures for during both the pretest and posttest. Tests to confirm assumptions for normality (Shapiro Wilk Test: $p > .05$), linearity, and homogeneity of variance were conducted and met. The 5.0 and 8.0 mM/L running paces (s/1600m) for one subject was beyond 1.96 standard deviations from the mean. Therefore, these scores were conservatively winsorized to represent the scores 1.96 standard deviations above the mean for the running pace at 5.0 and 8.0 mM/L blood lactate concentrations. Subjects who adhered to SBT™ experienced a statistically significant improvement in running pace at 5.0 mM/L ($M = 33.9$ s, $SE = 37.4$ s) and 8.0 mM/L ($M = 25.2$ s, $SE = 19.4$ s) when compared with non-adherers at 5.0 mM/L ($M = -8.8$ s, $SE = 11.2$ s) and 8.0 mM/L ($M = -6.5$ s, $SE = 9.4$ s) ($V = 0.62$, $F [2, 7] = 5.60$, $p = .035$). Additionally, exceptionally large effect sizes were determined for the running pace (s/1600m) at the 5.0 ($d = 3.46$) and 8.0 mM/L ($d = 3.29$) blood lactate concentrations when comparing adherers and non-adherers.
### Exploratory Analysis: Evaluation of the “Grady Human Performance Theory”

In addition to the primary analyses conducted to compare the differences between adherers to SBT™ and non-adherers, comparisons were made to informally evaluate the “Grady Human Performance Theory” (GHPT). The GHPT suggests that “the optimal way to increase the overall human performance [in events lasting longer than 90 seconds] is to increase rates of speed [pace] at 2.0 mM/L and increase physiological range [difference between maximum and minimum net lactate accumulation]” (Grady, 2015).

Thus, a determination was made as to whether or not subjects who improved their running pace (s/1600m) at 2.0 mM/L and also improved physiological range experienced the greatest improvements in 5-kilometer time trial performance as well as running pace (s/1600m) at the 5.0 and 8.0 mM/L blood lactate concentrations between the pretest and posttest. Given that several subjects’ initial stages during their pretest and/or posttest SBT™ PPT™ were above 4.0 mM/L, the running pace (s/1600m) at 2.0 mM/L was not able to be determined. The minimum blood lactate concentrations and physiological

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**Table 6**

**Running Pace Differences at 5.0 and 8.0 mM/L Blood Lactate Concentrations for All Subjects**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Gender</th>
<th>Adherer?</th>
<th>Pretest Pace at 5.0 mM/L (s/1600 m)</th>
<th>Posttest Pace at 5.0 mM/L (s/1600 m)</th>
<th>5.0 mM/L Difference (s)</th>
<th>5.0 mM/L Difference %</th>
<th>Pretest Pace at 8.0 mM/L (s/1600 m)</th>
<th>Posttest Pace at 8.0 mM/L (s/1600 m)</th>
<th>8.0 mM/L Difference (s)</th>
<th>8.0 mM/L Difference %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>F</td>
<td>Y</td>
<td>379.7</td>
<td>348.7</td>
<td>31.0</td>
<td>8%</td>
<td>370.0</td>
<td>338.0</td>
<td>32.0</td>
<td>9%</td>
</tr>
<tr>
<td>B</td>
<td>M</td>
<td>Y</td>
<td>331.4</td>
<td>316.9</td>
<td>14.5</td>
<td>4%</td>
<td>309.7</td>
<td>301.1</td>
<td>8.6</td>
<td>3%</td>
</tr>
<tr>
<td>C</td>
<td>F</td>
<td>Y</td>
<td>486.0</td>
<td>398.7</td>
<td>87.3</td>
<td>18%</td>
<td>428.9</td>
<td>379.4</td>
<td>49.5</td>
<td>12%</td>
</tr>
<tr>
<td>D</td>
<td>F</td>
<td>Y</td>
<td>484.9</td>
<td>482.1</td>
<td>2.8</td>
<td>1%</td>
<td>455.7</td>
<td>445.4</td>
<td>10.3</td>
<td>2%</td>
</tr>
<tr>
<td>E</td>
<td>M</td>
<td>N</td>
<td>336.8</td>
<td>347.3</td>
<td>-10.5</td>
<td>-3%</td>
<td>320.3</td>
<td>319.3</td>
<td>1.0</td>
<td>0%</td>
</tr>
<tr>
<td>F</td>
<td>M</td>
<td>N</td>
<td>385.6</td>
<td>388.4</td>
<td>-2.8</td>
<td>-1%</td>
<td>358.6</td>
<td>368.8</td>
<td>-10.2</td>
<td>-3%</td>
</tr>
<tr>
<td>G</td>
<td>F</td>
<td>N</td>
<td>395.0</td>
<td>395.3</td>
<td>0.3</td>
<td>0%</td>
<td>361.6</td>
<td>366.2</td>
<td>-4.6</td>
<td>-1%</td>
</tr>
<tr>
<td>H</td>
<td>M</td>
<td>N</td>
<td>298.7</td>
<td>294.9</td>
<td>-3.8</td>
<td>1%</td>
<td>283.9</td>
<td>278.5</td>
<td>5.4</td>
<td>2%</td>
</tr>
<tr>
<td>I</td>
<td>F</td>
<td>N</td>
<td>318.6</td>
<td>335.9</td>
<td>-17.3</td>
<td>-5%</td>
<td>304.0</td>
<td>313.0</td>
<td>-9.0</td>
<td>-3%</td>
</tr>
<tr>
<td>J</td>
<td>F</td>
<td>N</td>
<td>434.4</td>
<td>460.0</td>
<td>-25.6</td>
<td>-6%</td>
<td>389.8</td>
<td>411.1</td>
<td>-21.4</td>
<td>-5%</td>
</tr>
</tbody>
</table>
ranges for each subject are shown in Table 7. It was discovered that only four subjects (A, B, C, and D) experienced both a decrease in their minimum lactate value and an increase in physiological range from the pretest to posttest. These four subjects were the four subjects that improved the most between running pace at 5.0 and 8.0 mM/L as well as 5-kilometer time trial performance. However, a significant limitation of this analysis is the variation in initial stage running paces during the pretest and posttest SBT™ PPT™ for each subject. Naturally, this could have influenced the pretest and posttest minimum lactate values for each subject.

Table 7

<table>
<thead>
<tr>
<th>Subject</th>
<th>Adherer?</th>
<th>5K Time Trial Performance Difference (s)</th>
<th>5.0 mM/L Running Pace Pretest-Posttest Difference (s/1600 Meters)</th>
<th>5.0 mM/L Running Pace Pretest-Posttest Difference (s/1600 Meters)</th>
<th>Minimum Lactate-Posttest (mM/L)</th>
<th>Minimum Lactate-Posttest (mM/L)</th>
<th>Physiological Range (Pretest) (mM/L)</th>
<th>Physiological Range (Posttest) (mM/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Y</td>
<td>93</td>
<td>31.0</td>
<td>32.0</td>
<td>2.8</td>
<td>1.4</td>
<td>5.3</td>
<td>8.0</td>
</tr>
<tr>
<td>B</td>
<td>Y</td>
<td>72</td>
<td>14.5</td>
<td>8.6</td>
<td>4.0</td>
<td>2.3</td>
<td>9.4</td>
<td>10.0</td>
</tr>
<tr>
<td>C</td>
<td>Y</td>
<td>150</td>
<td>87.3</td>
<td>49.5</td>
<td>5.0</td>
<td>1.8</td>
<td>7.9</td>
<td>10.8</td>
</tr>
<tr>
<td>D</td>
<td>Y</td>
<td>53</td>
<td>2.8</td>
<td>10.3</td>
<td>4.3</td>
<td>2.5</td>
<td>6.5</td>
<td>8.9</td>
</tr>
<tr>
<td>E</td>
<td>N</td>
<td>64</td>
<td>-10.5</td>
<td>-1.0</td>
<td>1.9</td>
<td>1.4</td>
<td>9.8</td>
<td>9.6</td>
</tr>
<tr>
<td>F</td>
<td>N</td>
<td>2</td>
<td>-2.8</td>
<td>-10.2</td>
<td>2.2</td>
<td>2.1</td>
<td>10.9</td>
<td>7.6</td>
</tr>
<tr>
<td>G</td>
<td>N</td>
<td>26</td>
<td>-0.3</td>
<td>-4.6</td>
<td>1.7</td>
<td>2.1</td>
<td>10.5</td>
<td>11.0</td>
</tr>
<tr>
<td>H</td>
<td>N</td>
<td>6</td>
<td>3.8</td>
<td>5.4</td>
<td>1.4</td>
<td>1.1</td>
<td>13.7</td>
<td>11.0</td>
</tr>
<tr>
<td>I</td>
<td>N</td>
<td>29</td>
<td>-17.3</td>
<td>-9.0</td>
<td>3.0</td>
<td>3.0</td>
<td>10.4</td>
<td>13.4</td>
</tr>
<tr>
<td>J</td>
<td>N</td>
<td>-58</td>
<td>-25.6</td>
<td>-21.4</td>
<td>4.5</td>
<td>5.0</td>
<td>7.9</td>
<td>9.1</td>
</tr>
</tbody>
</table>

1 All physiological range data calculated without maximal effort 400-meter final interval, as this interval was not performed by all subjects

Post-Study Questionnaire: Perceptions of and Experiences with SBT™

The full questionnaire results of all subjects (n = 21) who completed both the SBT™ PPT™ pretest and posttest were compiled and are shown in Appendix I and Appendix J. All 21 subjects were included in the questionnaire analyses. These
Questionnaires were completed anonymously to blind the author to the identity of the subject; thus it was impossible to determine which questionnaires belonged to the four adherers and six non-adherers who were included in the experimental analysis. The questionnaire addressed the following topics: wearing a heart rate monitor while training, keeping a training log, training variables which were perceived to affect training, and the differences between SBT™ and the summer training they would typically perform in preparation for a cross country season. Additionally, the questionnaire aimed to identify factors that may have influenced adherence to SBT™ for this study and which may influence future adherence to SBT™.
DISCUSSION

The purpose of this study was to evaluate the efficacy and effectiveness of System Based Training™ (SBT™) “System Priming” among collegiate distance runners over a summer training period leading up to the fall cross country season with regard to differences in 5-kilometer track running performance and running pace at set blood lactate concentrations (5.0 and 8.0 mM/L). Most training programs designed to improve endurance competition performance are based on specific overall volume levels (e.g., miles per week) and standardized percentages of those volumes at higher intensities (e.g., Zone 2 and Zone 3 in the VT model) (Esteve-Lanao et al., 2005; Esteve-Lanao et al., 2007; Guellich et al., 2009; Guellich & Seiler, 2010; Loprinzi & Brodowicz, 2008; Neal et al., 2011; Seiler, 2010; Seiler & Kjerland, 2006; Seiler & Tonnessen, 2009; Tjelta, 2013; Tjelta & Enoksen, 2010). Typically these training programs are based on the recommendations of previous researchers, the programs of elite athletes, or those that are expressed in the popular training literature (Esteve-Lanao et al., 2005; Guellich et al., 2009; Guellich & Seiler, 2010; Loprinzi & Brodowicz, 2008; Neal et al., 2011; Seiler & Kjerland, 2006; Tjelta, 2013; Tjelta & Enoksen, 2010). The level of training program individualization is typically limited to adjusting the overall volume level for specific athletes and adjusting the proportion of training at different intensities based on the event the athlete is training for (Daniels, 2014; Hudson & Fitzgerald, 2008; Magness, 2014; unpublished observations). However, these approaches do not account for differences in the physiological makeup of the athlete (Grady, 2013; Grady, 2015; Magness, 2014).
SBT™ is a proprietary, individualized testing and training program which is tailored to the athlete, based on the strength and balance of their biochemical energy systems and the event they are training for. Thus the roadmap to creating the SBT™ individualized training plan has many different routes, all based on these factors. SBT™ shares the focus of individualization of training with Olbrecht’s approach in which blood lactate tests are periodically performed to assess changes in these energy systems (e.g., running or swimming pace at 2.0 mM/L) and pinpoint training intensities. Despite these similarities in the rationale for testing, SBT™ differs with regard to the testing protocol (i.e., number and length of stages and rest duration between stages) and training application (i.e., determination of training intensities and sequencing of training periods). The only other blood lactate–driven individualized training approach identified in the literature was the method used by the women’s world record holder in the marathon, Paula Radcliffe (Jones, 2006). However, Jones (2006) did not explain the details of this approach, thus this method cannot be compared with SBT™.

The purpose of this study was to evaluate the efficacy and effectiveness of System Based Training™ (SBT™) “System Priming” among collegiate distance runners over a summer training period leading up to the fall cross country season with regard to differences in 5-kilometer track running performance and running pace at set blood lactate concentrations (5.0 and 8.0 mM/L). The four subjects who adhered to SBT™ (adherence rate of at least 75%) over the 12 weeks of the study experienced statistically significant improvements when compared to non-adherers (adherence rate of less than 70%) in 5-kilometer time trial performance and running pace (s/1600m) at the 5.0 and 8.0
mM/L blood lactate concentrations between the pretest and posttest. Additionally the
effect sizes of all three measurements suggest a sizeable difference between adhering to
SBT™ and not adhering with respect to 5-kilometer time trial performance time
difference as well as differences in running pace (s/1600m) at the 5.0 and 8.0 mM/L
blood lactate concentrations.

Comparison of Adherers and Non-Adherers: 5-Kilometer Time Trial Performance

The athletes that adhered to SBT™ improved their 5-kilometer race performance
level more so than the athletes who did not adhere. Specifically, the adherers improved
5-kilometer time trial performance time by a mean rate of 7.1%, whereas the non-
adherers improved by 1.0%. Improvements of this magnitude are not expected from
typical training programs. As a comparison, the 2010-2013 mean annual rate of
improvement in 5-kilometer race performance (s) among NCAA Division II 5-kilometer
track runners is 0.7% (“2014 collegiate outdoor tf 5000m rankings”, 2014). Loprinzi and
Brodowicz (2008) reported a 3.7% 5-kilometer performance improvement among seven
male high school cross-country runners over the course of a season. However, these
athletes likely were undertrained when the season began as they performed relatively low
preseason training volume (less than 10 miles per week compared to 25-30 miles per
week during the season), potentially leading to ease in 5-kilometer race performance
improvement.

Primary Limitations Related to 5-Kilometer Time Trial Performance.

As previously discussed, all subjects in this study performed the pretest 5-
kilometer time trial during their final exam week at Humboldt State University which
was also less than two weeks after the last competition of their spring track season. For most subjects, the pretest 5-kilometer time trial was performed slower than their mean 5-kilometer race performance of the last six months (excluding pretest result) (Table 4). The non-adherers who had competed in at least one 5-kilometer race in the last six months \((n = 6)\) performed worse on average during their pretest time trial (4.0% slower) (than their average 5-kilometer race performance of the last six months) when compared to their adhering counterparts \((n = 2)\) (1.9% slower). Interestingly, this could have inflated the 5-kilometer performance improvements of the non-adherers more so than the adherers, potentially indicating a greater significance level than reported in the results of this study.

The issue of slow pretest performance times potentially inflating rates of improvement has been present in other studies as well, notably that of Esteve-Lanao et al. (2007). Esteve-Lanao et al. (2007) reported a 157-second improvement (7.0% improvement) in 10.4-kilometer cross-country time trial performance time for six regional-national level Spanish male cross-country runners who completed a training program emphasizing Z1 (low-intensity) compared to a 121.5 second improvement (5.8% improvement) for the six runners who completed the Z2 (threshold emphasis) training program over a five-month period from their preseason through their competitive season. However, the two groups of athletes studied by Esteve-Lanao et al. (2007) performed the pretest time-trial substantially slower (3:36-3:38/km) than their personal best 10-kilometer race performance (3:03-3:30/km).
The subjects who adhered to SBT™ experienced eight times the 5-kilometer time trial performance improvement compared to non-adherers (92.0 s vs. 11.5 s improvement) while the subjects in the Z1 group in the study by Esteve-Lanao et al. (2007) only experienced an improvement 1.3 times greater than the Z2 group (157.0 s vs 121.5 s). Thus, SBT™ appears to be a very efficacious training program for collegiate distance runners in terms of improving actual 5-kilometer track performance time.

Another limitation of this study was the pretest performance level of the female subjects adhering to SBT™. These three female subjects had mean pretest 5-kilometer time trial performances 174 seconds slower than the non-adhering females. Also both adherence groups (both males and females) had pretest 5-kilometer time trial performance times slower than the mean NCAA Division II 5-kilometer track runners from 2010-2013. This potentially could have indicated a high level of potential for improvement, according to the law of initial values (Benjamin, 1963). There was one female subject who was the only junior college athlete included in the final analysis (Subject D) and was by far the slowest athlete in the 5-kilometer pretest time trial (25 minutes and 13 seconds). However, she only improved by 53 seconds, whereas adhering female subjects A and C improved by 93 and 150 seconds, respectively despite having faster pretest 5-kilometer time trial performances. Thus, having a slower pretest performance level did not necessarily indicate greater potential for improvement.
Comparison of Adherers and Non-Adherers: Running Pace at 5.0 and 8.0 mM/L Blood Lactate

Aside from the sizeable improvements in 5-kilometer time trial performance, the adherers also improved the most in terms of running pace at the 5.0 and 8.0 mM/L blood lactate concentrations as determined from the pretest and posttest SBT™ Physiological Profile Test (PPT™). The subjects who adhered to SBT™ improved their running pace at the 5.0 mM/L and 8.0 mM/L blood lactate concentrations by 33.9 s/1600m (8.1% improvement) and 25.2 s/1600m (6.4% improvement), respectively. The running pace of the non-adherers slowed by 8.8 s/1600m (-2.4% improvement) and 6.5 s/1600m (-1.9% improvement) from the SBT™ PPT™ pretest to posttest for the 5.0 and 8.0 mM/L blood lactate concentrations, respectively. The combination of these differences between adherers and non-adherers in running paces at the 5.0 and 8.0 mM/L blood lactate concentrations and the apparent inflation of the non-adherers’ pretest-posttest improvements in 5-kilometer time trial performance indicate the plausibility that following SBT™ may lead to even greater 5-kilometer time trial performance gains than reported in this study.

Net lactate accumulation has been suggested to be a more sensitive indicator of endurance training adaptation than more commonly used measures such as VO₂ max (Belcher & Pemberton, 2012; Olbrecht, 2000). However, a few researchers have suggested that improvements in the lactate profile do not translate into improved endurance competition performance (Guellich & Seiler, 2010; Pyne et al., 2001). Thus, many coaches and sports scientists have suggested that lactate testing is unnecessary in
the development of endurance athletes (Madsen & Lohberg, 1987; Pyne et al., 2001). However, other researchers have criticized such logic, expressing that those who claimed improving power output at various blood lactate concentrations does not translate into endurance competition performance failed to measure anaerobic capacity (i.e., maximal net lactate accumulation) (Secrets of Lactate, 2005). Likewise, the findings in this study suggest that improving running paces (s/1600m) at the same blood lactate concentrations while maintaining an appropriately strong anaerobic system via sufficient maximum lactate production capability corresponds with improved 5-kilometer time trial performance capability in collegiate distance runners.

**Primary Limitations Related to Running Pace at 5.0 and 8.0 mM/L.**

There are several limitations with respect to the validity and reliability of the interpolated running paces at 5.0 and 8.0 mM/L blood lactate concentration. However, it should be noted that all of these measures equally could have affected the measures of each subject (regardless of adherence group).

As previously discussed, the SBT™ PPT™ did not feature an exact replication of the pretest protocol due to variation in initial stage running paces (s/1600m), either by the choice of the subject or primary investigator in the instances where the posttest 5-kilometer time trial indicated substantially worse fitness than the pretest. This likely influenced the minimum lactate values for all subjects, but was unlikely to influence the interpolated running paces at the 5.0 and 8.0 mM/L blood lactate concentrations.

The linear interpolation method to estimate running speeds at the 5.0 and 8.0 mM/L blood lactate concentrations was unlikely to accurately determine all measures.
However, no agreed-upon approach to interpolating exercise intensities across the blood lactate profile currently exists (Bourdon, 2000). Thus, this method was chosen as an easy-to-identify measure for coaches and sports scientists to use alike while quickly assessing test results.

The following factors could also have influenced the SBT™ PPT™ test results:  
(1) pretest diet of subjects, (2) pretest training of subjects, (3) time duration of each interval, (4) quantity of intervals, (5) pacing during the intervals, and (6) time at blood collection. Therefore, the repeatability of SBT™ PPT™ results could have been affected by these measures. Control of pretest diet and training as well as time at blood collection can be improved in future studies by employing strict guidelines to the athletes and testing procedures. Repeatability should also be assessed. Additionally, the pacing during each interval can be improved by having each athlete either run with a second athlete who is experienced in “pacing” or by running on a treadmill. However, performing the SBT™ PPT™ on a treadmill would remove the specificity of the field test on an outdoor track since most collegiate distance runners train on an outdoor track much more frequently than on a treadmill. The time (s) and quantity of intervals cannot be controlled for using the SBT™ PPT™ protocol.

**Evaluation of the “Grady Human Performance Theory”**

Through the development of SBT™, Shannon Grady, M.S. developed the “Grady Human Performance Theory” (GHPT) suggesting that “the optimal way to increase the overall human performance [in events lasting longer than 90 seconds] is to increase rates of speed [pace] at 2.0 mM/L and increase physiological range [difference between
maximum and minimum net lactate accumulation)” (Grady, 2015). As a secondary analysis, the author examined if subjects who both increased their pace (s/1600m) at 2.0 mM/L and physiological range also experienced the greatest improvements in 5-kilometer time trial performance from the pretest to posttest. It proved to be impossible to determine the running pace at 2.0 mM/L for each subject, as the lowest net lactate accumulation of most subjects during their SBT™ PPT™ was greater than 2.0 mM/L. However, a subject who experienced a minimum net lactate accumulation decrease from pretest to posttest (at approximately the same running pace) most likely would have also experienced an improvement in running pace at 2.0 mM/L. Therefore, the author instead examined the change in minimum net lactate accumulation and physiological range (Table 7). It was discovered that only the four adhering subjects (A, B, C, and D) experienced both a decrease in their minimum lactate concentration and an increase in physiological range from the pretest to posttest. These four subjects were four of the five subjects who improved the most from pretest to posttest in 5-kilometer time trial performance (A, B, C, D, E). They also were the only subjects that improved running pace at 5.0 and 8.0 mM/L as well as 5-kilometer time trial performance. However, the slight variation in initial stage running pace (due to error in pacing by the subject or prescription in some cases by the primary investigator) in the PPT™ pretest and posttest likely influenced the blood lactate concentration of the initial stage of the PPT™. Thus, conclusions on minimal lactate values are preliminary at best. A future, large-scale study should aim to more formally evaluate the GHPT including standardization of initial stage interval time for each athlete.
Post-Study Subject Questionnaire

The post-study questionnaire was administered to the 21 subjects who completed both PPT™ in order to illucidate perceptions of SBT™ and its implementation. The questionnaire assessed the following: (1) adjusting to wearing a heart rate monitor during training, (2) factors which caused deviation from SBT™ during the study, and (3) potential adherence to SBT™ during future training.

Adjusting to Wearing a Heart Rate Monitor. Before the study, only one of the initial 28 subjects had used a heart rate monitor in their previous training. As determined from the post-study questionnaire results, only two of the 21 subjects reported wearing their heart rate monitors less than 50% of the time during the 12-week training period. Out of the 21 subjects who completed the questionnaire, 19 said they either would wear a heart rate monitor in future training or would not wear one due to the discomfort of the chest strap. However, more models now exist which can estimate heart rate without the use of a chest strap, alleviating this concern. Thus, most of the athletes in this study found the heart rate monitor to be more of a benefit to training than a hindrance.

According to one subject, “I didn't realize how I drastically I was overtraining. The [heart rate] monitor gave me a concrete way to see how hard I was working on a given day”.

Factors which Caused Deviation from SBT™. Aside from the additional requirement of wearing the heart rate monitor, the author investigated other factors which caused deviation from SBT™. As indicated in the questionnaire results, the primary reasons for deviating from SBT™ over the 12-week study period were: (1) having a full
schedule without enough time to train, and (2) the desire to train with other people. A majority of the subjects in this study relocated to their hometowns during the summer where they held summer jobs and performed training sessions with athletes in other training groups who did not perform SBT™. Some of these subjects would perform training sessions that were longer, faster, or end up skipping the Main System Workout, Economy Interval, or Progressive Long Run sessions altogether in order to train with other athletes. Perhaps, adherence rates would have increased if the subjects trained together rather than with other athletes.

**Potential Adherence to SBT™ for Future Training.** The author also aimed to identify if athletes would follow SBT™ in the future and which barriers (if any) would prevent them from doing so. Of the 21 subjects who completed the questionnaire, 13 expressed that they would like to follow SBT™ in the future, three stated that they might (depending on the circumstances), and five expressed they would not. The reasons for those choosing to not follow SBT™ in the future were: (1) fear of burnout, (2) likelihood of forgetting to wear the heart rate monitor, (3) adoption of a training program they already enjoy, and (4) wanting to perform identical training to teammates of equal performance level. If a majority of athletes who perform SBT™ experience rates of improvement similar to those in this study, it is likely that these concerns can be alleviated.

**Future Directions of Research**

Perhaps the greatest limitations of this study involved the inconsistency in adherence to pretest instructions, logging the actual training performed, and adhering
closely to SBT™. A future study should eliminate these confounders through a longitudinal case study with stricter controls of training and non-training related variables. Additionally, future directions of research involving SBT™ should include:

- Reliability determination for SBT™ PPT™ protocol lactate concentrations at equivalent running paces.
- Study replication with a larger sample size and at different periods of the year, perhaps when an entire collegiate cross-country team trains together.
- Determination of the effects of SBT™ across different endurance event specialties (e.g., track events from 800m-10,000m, marathon, 2-kilometer rowing, Ironman triathlon).
- Formal evaluation of the “Grady Human Performance Theory” with a larger sample size.

**Conclusion**

Increasing amounts of research suggest that an optimal, standardized training program for endurance athletes does not currently exist, as training adaptation depends on a myriad of factors, particularly the individual differences among athletes (Enoksen et al., 2011; Guellich & Seiler, 2010; Seiler & Kjerland, 2006). The high rates of improvement in the 5-kilometer time trial and running pace (s/1600m) at the 5.0 and 8.0 mM/L blood lactate concentrations of adherers to SBT™ compared to non-adherers indicate the strength of the efficacy of SBT™ in this sample of collegiate distance runners. Additionally, the rates of improvement in 5-kilometer time trial by adherers to
SBT™ were much greater than the annual rate of improvement among NCAA Division II 5-kilometer track runners from 2010-2013, suggesting the large improvement potential for athletes adhering to SBT™ compared with typical training programs for collegiate athletes competing in the 5-kilometer track event.

The fact that only four subjects adhered to SBT™ suggests that many factors are critical in order to successfully implement SBT™. Given the differences in training program design of SBT™ and typical training programs for distance runners, many barriers may exist to limit adherence to SBT™ (e.g., belief in typical training programs, desire to run with other athletes, desire to run by “feel” rather than be governed by a heart rate monitor or time range, etc.). However, previous researchers suggest that the actual training performed by college athletes differs from that prescribed by the coach (Bouchard et al., 2013; Loprinzi & Brodowicz, 2008). Perhaps the lack of adherence to SBT™ or any prescribed training program could have been negatively influenced by subject preference in terms of types, intensities, and durations of training. However, if performing SBT™ is associated with greater endurance competition performance improvements when compared with typical training programs, it may only be a matter of time before more and more athletes and coaches adhere to and endorse SBT™.

Through SBT™ PPT™, coaches and sports scientists can potentially pinpoint the training zones (e.g., heart rate, running pace, etc.) that elicit the goal net lactate accumulation for each training session, creating the desired physiological training stress to allow for optimal training response. Since net lactate accumulation has been suggested to be a more sensitive training adaptation than VO₂ max, reevaluating the
lactate profile of an athlete via SBT™ PPT™ could allow the athlete, coach, and sports scientist to monitor the physiological responses to the applied training stimuli as well as reset the training zones and training prescription if necessary (Belcher & Pemberton, 2012; Olbrecht, 2000; Grady, 2013; Grady, 2015; Olbrecht, 2000). Athletes, coaches, and sports scientists could then ensure that all training is valuable training, which may optimize the physiological development of the athlete as they prepare for their goal endurance competition.
REFERENCES


Fukuda, D., Kendall, K., Smith, A., Dwyer, T., & Stout, J. (2011). The development of


from. Sportscience, 5(2), 1-20. Retrieved from

Secrets of Lactate (Version 1) [Computer Software]. Sport Resources Group.


APPENDIX A

The Effect of System Based Training™ on the Individual Lactate Profile and 5-Kilometer Time Trial Performance in Collegiate Distance Runners

Procedure for Determining SBT™ “System Priming” Training Program for Collegiate Distance Runners

1. Primary Goals (“Grady Human Performance Theory”)
   a. Improve running pace (s/1600m) at 2.0 mM/L
   b. Improve Physiological Range (difference between maximum and minimum net lactate accumulation)

2. Systems
   a. Aerobic Foundation (AF)
   b. Aerobic Rate Capacity-1 (ARC-1)
   c. Aerobic Rate Capacity-2 (ARC-2)
   d. Aerobic Rate Capacity-3 (ARC-3)
   e. Lactate Tolerance, Clearing, and Capacity (LTCC)

3. Types of Training Sessions
   a. Aerobic Foundation (AF)
      i. Frequency: 2-4 days per week during all phases
      ii. Intensity: Heart rate-based
      iii. Length: 20-60 minutes
      iv. Anticipated net lactate accumulation: <2.0 mM/L
   b. Progressive Long Run (PLR)
      i. Frequency: 1 day per week during all phases
      ii. Intensity: Heart rate-based
      iii. Length: 40-90 minutes
      iv. Anticipated net lactate accumulation: 2-3 mM/L
   c. Main System Workouts (MSW)
      i. ARC-1/ARC-2
         1. Frequency: 1 day per week during ARC-1/ARC-2 phase
         2. Intensity: ARC-1/ARC-2 pace
         3. Length: 2-3 miles of 300 to 600-meter intervals at ARC-1 to ARC-2 pace
         4. Anticipated net lactate accumulation: 9-12 mM/L
      ii. ARC-2/ARC-3
         1. Frequency: 1 day per week during ARC-2/ARC-3 phase
         2. Intensity: ARC-2/ARC-3 pace
         3. Length: 2-5 miles of 800 to 1600-meter intervals at ARC-2 to ARC-3 pace
         4. Anticipated net lactate accumulation: 6-9 mM/L
      iii. LTCC
         1. Frequency: 1 day per week during LTCC phase
         2. Intensity: LTCC pace
         3. Length: 2-5 miles of 800 to 1600-meter intervals at LTCC pace
         4. Anticipated net lactate accumulation: 4-6 mM/L
   d. Economy Intervals (EI)
      i. Frequency: 1 day per week during all phases
      ii. Intensity: ARC-1/ARC-2/ARC-3 pace
      iii. Length: 2-3 miles of 100 to 200-meter intervals at ARC-1 to ARC-3 pace
      iv. Anticipated net lactate accumulation: NA (combination of intensity and interval length is not high enough to generate net lactate accumulation)

4. Order of Training Phases (Length of Each Phase Depends on Athlete Profile)
   a. High Maximum Lactate Athlete (Maximum Lactate >12.0 mM/L)
Sample Profiles and Training Phase Order

<table>
<thead>
<tr>
<th>Stage</th>
<th>TIME (800-Meter Interval)</th>
<th>HR</th>
<th>LACTATE (mM/L)</th>
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</thead>
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<td>208</td>
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<table>
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<th>HR</th>
<th>LACTATE (mM/L)</th>
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</thead>
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</tr>
<tr>
<td>6</td>
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<td>196</td>
<td>12.1</td>
</tr>
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</table>

Subject A Profile Analysis
- Good aerobic metabolic efficiency (able to perform stages at ≤ 2.0 mM/L)
- Weak maximum lactate accumulation (maximum < 12.0 mM/L)
- Phase order: AF, ARC-1/ARC-2, LTCC, ARC-2/ARC-3

Subject B Profile Analysis
- Weak aerobic metabolic efficiency (not able to perform any stages at ≤ 2 mM/L)
- Strong maximum lactate accumulation (maximum > 12.0 mM/L)
- Phase order: AF, ARC-2/ARC-3, LTCC, ARC-1/ARC-2
APPENDIX B

The Effect of System Based Training™ on the Individual Lactate Profile and 5-Kilometer Time Trial Performance in Collegiate Distance Runners

Informed Consent for Participation

Project Description:

Athletes respond to training differently and improve at different rates. The purpose of this study is to evaluate whether a training method (System Based Training™ [SBT™]), based on the level of lactate in your blood, will improve 5-kilometer time trial running performance.

In order to Participate in this Study, You Must:

- Be 18-25 years of age.
- Be approved to participate in athletics by your college or university for the 2013-14 year.
- Be an athlete who tried out for the Humboldt State University or College of the Redwoods cross country or track and field team during the 2013-2014 academic year.
- Not have any leg injuries.
- Have run an average of at least 30 miles per week during the spring track season.
- Perform high-intensity interval workouts.
- Have competed in a race in the last 3 months.

How much time must subjects volunteer?

You will perform a SBT™ lactate profile test and 5-kilometer time trial (~1 hour each) before the training period. Then you will follow an individualized training program over the 12-week summer training period (~6-10 hours of training sessions per week). The time spent training will be very similar what you have encountered in the past. Following the training period, you will repeat the 5-kilometer time trial and SBT™ lactate profile test (~1 hour each). You will attend five sessions and are asked to complete the individualized training plan over the 12-week summer period which are detailed below.

Procedure:

Session 1: (1 hour)

- Complete running history survey and inclusion criteria form to determine if you can be in the study.
- If you are eligible for the study and wish to participate, you will need to sign a liability release form. Then we will schedule your lactate profile test and 5-kilometer time trial. These tests will take place at the HSU track.
- You will be given a heart rate monitor for the duration of the study. You will be asked to wear the heart rate monitor for each training session during the study.

Session 2: (1 hour)

- You will report to the HSU track at the scheduled time for your lactate profile test.
- You will be instructed to perform a series of 800-meter repeats on the track. You will receive a 60-second recovery between each repeat. The first repeat should be run 40 seconds slower than your 5-kilometer time trial pace per 800 meters. Each successive repeat should be run 10 seconds faster than the previous one. You will be asked to perform the repeats until you are unable to perform a faster repeat. At the end of the test if your highest lactate reading is less
than 10.0 mM/L, you will be asked to run a maximal effort 400-meter interval. This maximum 400-meter interval will determine a maximum lactate value for the test.
  o You will then hold out your index finger for blood lactate sampling at the end of each repeat during a 60-second recovery.
  o You will then be instructed of the goal time to perform the next interval along with the split times at 200 meters and 400 meters to help with pacing.
  o After the test, you will perform a self-selected cool down following the time trial.
  o You may stop the lactate profile test at any time.
  o All data will be recorded by research assistants. They will immediately submit the results to the faculty investigator. These results will be coded for confidentiality before the creation of the training programs.

Session 3: (1 hour)
  o You will report to the HSU track at the scheduled time for your 5-kilometer running time trial.
  o You will be encouraged to run the time trial as fast as you can.
  o You may stop the time trial at any time.

Session 4: (12 weeks, 6-10 hours of training per week)
  o You will be provided with a summer training program to follow. This training plan will be individualized based on your strengths and weaknesses according to your lactate profile test.
  o The head HSU and CR cross country coaches will provide all athletes the “usual” summer training plan. If subjects decide to drop out the study, they can simply follow the “usual” training plan prescribed by their head coach.
  o You should wear your heart rate monitor for all training sessions. You should record all training session data in a training log. The training log will be provided with the training plan.
  o You will e-mail your completed training logs through the 6-week period (by July 17) and 12-week period (by August 25) to the faculty advisor, Tina Manos, Ed.D. (tina.manos@humboldt.edu).

Session 5: (1 hour)
  o This session is identical to session 2.

Session 6: (1 hour)
  o This session is identical to session 3.

Benefits:
  • We will provide you with the information from the testing procedures. These tests normally cost about $75 each.
  • The individualized training program provided to you is designed to improve distance running performance.

Possible Risks and Discomforts:
  • You may experience discomfort from the finger prick during blood sampling. Risk of infection and transmission of blood-borne pathogens exist when blood is sampled.
  • You may experience discomfort from maximal and near maximal bouts of exercise. You may injure yourself while performing any of these activities. As is true for any exercise, you might experience abnormal heart rate, blood pressure, and in rare instances, death.
  • While highly unlikely, subjects have the potential to faint from performing the lactate profile tests or the 5-kilometer time trials.
  • The student investigator is also an assistant coach for the HSU cross country and track and field teams. The results of the 5-kilometer time trials, SBT™ lactate profiles, the individualized training plan prescriptions, and the results of the training logs will be shared with the head coaches of the HSU and CR cross country teams (after the study).
Risk Management:

- Proper supervision and instruction during exercise tests will be provided. This will minimize the risk of injury.
- SBT™ is routinely used by high school, college, and adult competitive runners.
- The training prescribed to the athletes will consist of training sessions routinely performed by college distance runners. The training programs will be approved by the HSU and CR head cross-country coaches.
- The HSU and CR cross country coaches will review the lactate profiles and time trial test results (after the study). Time trials and training logs are routinely used by cross country teams (including HSU) to determine roster decisions.
- The risk of fainting will be minimized. Subjects will perform a 20-second walking recovery to the lactate testing table prior to blood sampling.
- Following the 5-kilometer time trial, subjects will perform their usual post-race cool down.
- The student investigator is CPR/AED certified. The student investigator will have a cell phone available should an emergency call be needed.
- A number of procedures are in place to prevent the transmission of blood borne pathogens. The student investigator will be the only one serving as the blood lactate technician. The student investigator has completed the HSU Blood Borne Pathogen Training.
- Lactate testing procedures due to field-based vs. lab based data collection have updated. These changes have been cleared through HSU's Environmental Health and Safety Coordinator, Sabrina Zink on 4/30/14.
- All blood samples will be treated as potentially infectious. Proper handling will occur.
- The lancets used to pierce the fingertip are of the “single-use type”. Manufacturer instructions on use of lancets and handling of samples will be followed.
- Gloves will be worn by the lactate technicians. Gloves will be changed between subjects.
- Very small quantities (drops) of blood will be taken (< 32 uL) after preparing the site using alcohol swab and piercing skin with a lancet.
- Biohazard waste disposal containers will be used.

Responsibilities as a Participant:

- Answer the exercise survey truthfully.
- Report any allergies (i.e., latex).
- Report if you have any infectious disease (i.e., HIV, Hepatitis).
- Report if you do not feel well, are injured, or have a fever prior to testing on any day.
- Report any unusual feeling you may have during the tests. For example: excessive fatigue, shortness of breath, chest discomfort or similar occurrences.
- Follow the subject instructions sheet.

Maintaining Confidentiality of Your Information:

- We will maintain your confidentiality to the fullest extent of the law.
- We will store hardcopy information in a locked cabinet in the Human Performance Lab.
- We will store all electronic information in password-protected computers. Only the faculty investigator will have the passwords for these computers.
- We will maintain all information for 5 years. After 5 years, all information will either be shredded or deleted from the computers.

Compensation:
Subjects will be given the opportunity to purchase their assigned heart rate monitors at the end of the study. The cost will be the same as the cost of the student investigator ($50). This cost is less than manufacturer’s suggested retail price ($150).

Questions:

If you have any questions about the study, please ask the following investigators.

Principal Investigator:
Chris Benassi, B.S.
Department of Kinesiology and Recreation Administration
707-845-0903
cbb165@humboldt.edu

Faculty Advisor:
Tina M. Manos, Ed.D.
Department of Kinesiology and Recreation Administration
1 Harpst Street
Humboldt State University
707-826-5962
tmm52@humboldt.edu

The investigator will answer any questions you have about this study. Your participation is voluntary and you may stop at any time.

If you have concerns with this study, contact the Chair of the Institutional Review Board for the Protection of Human Subjects, Dr. Ethan Gahtan, at eg51@humboldt.edu or (707) 826-4545.

If you have questions regarding your rights as a participant, report them to the Humboldt State University Dean of Research, Dr. Rhea Williamson at Rhea.Williamson@humboldt.edu or (707) 826-5169.

Signature:

Your signature indicates that you have read the above information and are willing to take part in this study.

I, __________________________________________ have read and agree to participate in this study described above.

Signed: ____________________________________ Date _______________
## APPENDIX C

The Effect of System Based Training™ on the Individual Lactate Profile and 5-Kilometer Time Trial Performance in Collegiate Distance Runners

### Inclusion Criteria Form

<table>
<thead>
<tr>
<th>Name</th>
<th>Name: _____________________________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
</tr>
<tr>
<td></td>
<td>Female</td>
</tr>
<tr>
<td>Date of Birth</td>
<td>D.O.B.: ___________ (mm/dd/yyyy)</td>
</tr>
<tr>
<td>Do you currently possess any of the following American College of Sports Medicine contraindications to exercise? (Please circle accordingly)</td>
<td>Acute Systemic Infection</td>
</tr>
<tr>
<td></td>
<td>Chronic Infectious Disease</td>
</tr>
<tr>
<td></td>
<td>Neuromotor, Musculoskeletal, or Rheumatoid disorders that are exacerbated by exercise</td>
</tr>
<tr>
<td></td>
<td>None of the Above</td>
</tr>
<tr>
<td>Are you cleared for athletic participation for the 2013-2014 academic year at your college or university?</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td>How many miles per week are you currently running?</td>
<td>_____ MPW</td>
</tr>
<tr>
<td>Do you currently have any running-related injuries?</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Do you routinely perform high-intensity interval sessions?</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Have you completed a maximal intensity race in the last three months?</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>No</td>
</tr>
</tbody>
</table>

**Signature:**

Your signature indicates that you have answered the survey questions as accurately as possible.

I, ____________________________ have answered the survey as accurately as possible.

(Print Full Name Above)

Sign: ____________________________ Date _______________
## APPENDIX D

The Effect of System Based Training™ on the Individual Lactate Profile and 5-Kilometer Time Trial Performance in Collegiate Distance Runners

### Running History Survey

<table>
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<td>Male     Female</td>
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<td>E-mail Address</td>
<td>E-mail: ________________________________________</td>
</tr>
<tr>
<td>Date of Birth (mm/dd/yyyy)</td>
<td>D.O.B.: ____________ (mm/dd/yyyy)</td>
</tr>
<tr>
<td>Height (in)</td>
<td>Inches_____</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>Pounds____</td>
</tr>
<tr>
<td>Running Experience (Years &amp; Months)</td>
<td>Years____  Months____</td>
</tr>
<tr>
<td>Collegiate Running Experience (Years &amp; Months)</td>
<td>Years____  Months____</td>
</tr>
<tr>
<td>2014 5K or 10K Race Results (list all times recorded and the date of each race)</td>
<td>Date:__ Event:__ Result:__ Date:__ Event:__ Result:__</td>
</tr>
<tr>
<td>Personal Best 5K Time (mm:ss) for Each of the Last 4 years: (leave blank if unsure)</td>
<td>2011:____ (mm:ss) 2012:____ (mm:ss)</td>
</tr>
<tr>
<td>Current Training Volume (Miles Per Week)</td>
<td>MPW:________</td>
</tr>
<tr>
<td>Do you Currently Wear a Heart Rate Monitor for Training Sessions?</td>
<td>Yes  No</td>
</tr>
</tbody>
</table>

**Signature:**
Your signature indicates that you have answered the survey questions as accurately as possible.

I, ______________________________________ have answered the survey as accurately as possible.

(Print your full name here)

Sign: ___________________________  Date _____________
APPENDIX E

The Effect of System Based Training™ on the Individual Lactate Profile and 5-Kilometer Time Trial Performance in Collegiate Distance Runners

Instructions for Subjects

One Week Prior to 1st 5-K Time Trial
   1. Subjects will be assigned heart rate monitor for duration of study.
   2. Subjects will have turned in the following forms to the student investigator:
      a. Informed Consent
      b. Inclusion Criteria
      c. Running History Survey

Performance Tests
   1. Subjects should maintain a healthy sleep schedule, remain hydrated, and consume a balanced, high-carbohydrate diet for the 72 hours prior to all performance tests.
   2. Subjects will report to the Humboldt State University outdoor track at the scheduled time for all performance tests (5-K time trial and SBT™ lactate profile test).
   3. Subjects should wear the same attire they would wear during a track race (watch, singlet, shorts, spiked shoes/lightweight running shoes).
   4. Subjects should perform a self-selected warm-up as they would usually perform prior to track races.
   5. Following performance tests, subjects should perform a self-selected cool-down as they would usually perform following track races.
   6. Subjects should replicate as much as possible between the pretest and posttest of the 5-kilometer time trials and SBT™ lactate profile tests.

System Based Training™ Lactate Profile Test (SBT™)
   1. Subjects will wear their heart rate monitor for the SBT™.
   2. Subjects will perform lactate profile test on a staggered schedule with one other athlete (your “partner” will start their interval when you complete the first lap of your first interval).
   3. Subjects will receive 60 seconds rest between each interval.
   4. Each subsequent interval should be run 10 seconds faster than the previous interval.
   5. Even pacing is critical to the reliability of the test. Subjects should use their heart rate monitor to maintain even pacing. A student research assistant will also call out interval times at the 200-meter and 400-meter checkpoints during each interval for each athlete.

Training Plan
   1. Individualized training plan will be provided before June 1 (June 1 will the start of the 11-week summer training program).
   2. Subjects will be provided with a training log (excel spreadsheet) where they are to record the volume, duration, average heart rate, and comments for each day’s training session for the entire 11-week period.
   3. Subjects will e-mail to Tina Manos, Ed.D. (tina.manos@humboldt.edu) their completed training log through the first 5 weeks of the training period (by July 10) and through the total 11 weeks (by August 18).
APPENDIX F

The Effect of System Based Training™ on the Individual Lactate Profile and 5-Kilometer Time Trial Performance in Collegiate Distance Runners

Testing Calendar

(All tests dates/times reflect final test used for analysis if repeat tests were performed)

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<thead>
<tr>
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<th>Time</th>
<th>Number of Subjects</th>
</tr>
</thead>
<tbody>
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<td></td>
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</tr>
<tr>
<td>5/10/2014</td>
<td>8:45 AM - 6:45 PM</td>
<td>11</td>
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<td>5/11/2014</td>
<td>9:20 AM - 6:00 PM</td>
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</tr>
<tr>
<td>5/18/2014</td>
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5-Kilometer Time Trial Pretest

<table>
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<th>Time</th>
<th>Number of Subjects</th>
</tr>
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<tr>
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<td>4:15 PM</td>
<td>14</td>
</tr>
<tr>
<td>5/14/2014</td>
<td>4:20 PM</td>
<td>12</td>
</tr>
<tr>
<td>5/17/2014</td>
<td>4:20 PM</td>
<td>1</td>
</tr>
<tr>
<td>5/19/2014</td>
<td>1:00 PM</td>
<td>1</td>
</tr>
</tbody>
</table>

SBT™ Lactate Profile Posttest

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Number of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/23/2014</td>
<td>1:40 PM - 7:50 PM</td>
<td>3</td>
</tr>
<tr>
<td>8/30/2014</td>
<td>8:02 AM - 11:03 AM</td>
<td>4</td>
</tr>
<tr>
<td>8/31/2014</td>
<td>9:00 AM - 5:00 PM</td>
<td>12</td>
</tr>
<tr>
<td>9/4/2014</td>
<td>12:00 PM</td>
<td>1</td>
</tr>
<tr>
<td>9/7/2014</td>
<td>4:00 PM</td>
<td>1</td>
</tr>
</tbody>
</table>

5-Kilometer Time Trial Posttest

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Number of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/27/2014</td>
<td>3:30 PM</td>
<td>13</td>
</tr>
<tr>
<td>8/28/2014</td>
<td>3:30 PM</td>
<td>4</td>
</tr>
<tr>
<td>9/3/2014</td>
<td>3:30 PM</td>
<td>1</td>
</tr>
<tr>
<td>9/3/2014</td>
<td>6:00 PM</td>
<td>1</td>
</tr>
<tr>
<td>9/4/2014</td>
<td>2:30 PM</td>
<td>2</td>
</tr>
</tbody>
</table>

21 of the 28 subjects completed the study (7 subjects completed the pretests but not the posttests).
APPENDIX G

The Effect of System Based Training™ on the Individual Lactate Profile and 5-Kilometer Time Trial Performance in Collegiate Distance Runners

Calculation of Linear Interpolated Velocities Example (2-12 mM/L)

Steps for Interpolation Calculation:

1. If the actual blood lactate concentration (mM/L) is equivalent to the desired concentration (e.g., 2.0 mM/L) multiply the time of the corresponding stage (in seconds) by 2 to convert from time per 800 meters to time per 1600 meters.
2. If the desired lactate concentration (e.g., 2.0 mM/L) falls between two stages, follow steps 3-8.
3. Determine test stages which serve as an upper and lower bound for the desired lactate concentration (e.g., for Subject A, 3 mM/L lactate would lie between stages 4 and 5).
4. Multiply the time (in seconds) of the slower stage by the distance of the lactate concentration of the faster stage from the desired lactate concentration.
5. Multiply the time (in seconds) of the faster stage by the distance of the lactate concentration of the slower stage from the desired lactate concentration.
6. Add the results of step 3 & 4.
7. Divide by the total lactate distance between the two stages.
8. Multiply by 2 to convert the interpolated pace per 800 meters to represent the pace per 1600 meters.

Exceptions:

- If the first stage(s) show a decrease in lactate concentration, use the lowest lactate concentration during the test as the starting point, eliminating the initial higher stages from calculations.
- If the lactate concentration is displayed as an error, the corresponding stage will be eliminated from calculations.
- The velocities at each lactate concentration will not be calculated using 400-meter interval times if the subject performed a 400-meter interval for their final stage.
- The fastest calculated pace will be determined at each lactate concentration.
- If the pace at a set lactate concentration cannot be determined, it will be recorded as “NA”
- If the calculated pace decreases, the calculated pace will be recorded as “NA”
### SUBJECT: 1

<table>
<thead>
<tr>
<th>Stage</th>
<th>TIME (800-Meter Interval)</th>
<th>HR</th>
<th>LACTATE (mM/L)</th>
<th>Change in Lactate from Previous Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3:40</td>
<td>175</td>
<td>1.5</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>3:30</td>
<td>189</td>
<td>1.9</td>
<td>0.4</td>
</tr>
<tr>
<td>3</td>
<td>3:20</td>
<td>193</td>
<td>2.0</td>
<td>0.1</td>
</tr>
<tr>
<td>4</td>
<td>3:10</td>
<td>198</td>
<td>2.4</td>
<td>0.4</td>
</tr>
<tr>
<td>5</td>
<td>3:00</td>
<td>203</td>
<td>4.3</td>
<td>1.9</td>
</tr>
<tr>
<td>6</td>
<td>2:50</td>
<td>204</td>
<td>6.0</td>
<td>1.7</td>
</tr>
<tr>
<td>7</td>
<td>2:40</td>
<td>208</td>
<td>9.4</td>
<td>3.4</td>
</tr>
</tbody>
</table>

### Example Using Subject 1

<table>
<thead>
<tr>
<th>Blood Lactate Concentration (mM/L)</th>
<th>Calculation</th>
<th>Pace (s/1600m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>[200 \times 2]</td>
<td>400.00</td>
</tr>
<tr>
<td>3</td>
<td>[190 \times 1.3 + 180 \times 0.6] \times 2</td>
<td>373.68</td>
</tr>
<tr>
<td>4</td>
<td>[190 \times 0.3 + 180 \times 1.6] \times 2</td>
<td>364.6</td>
</tr>
<tr>
<td>5</td>
<td>[180 \times 1.0 + 170 \times 0.7] \times 2</td>
<td>351.76</td>
</tr>
<tr>
<td>6</td>
<td>170 \times 2  \times 2</td>
<td>340.00</td>
</tr>
<tr>
<td>7</td>
<td>[170 \times 2.4 + 160 \times 1.0] \times 2</td>
<td>334.12</td>
</tr>
<tr>
<td>8</td>
<td>[170 \times 1.4 + 160 \times 2.0] \times 2</td>
<td>324.29</td>
</tr>
<tr>
<td>9</td>
<td>[170 \times 0.4 + 160 \times 3.0] \times 2</td>
<td>322.35</td>
</tr>
<tr>
<td>10</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>11</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>12</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
APPENDIX H

The Effect of System Based Training™ on the Individual Lactate Profile and 5-Kilometer Time Trial Performance in Collegiate Distance Runners

Adherence Criteria

To be included in the experimental results, subjects must:

- Wear their assigned heart rate monitor for at least 75% of all prescribed “Z1/Z2 Low” run sessions.
- Perform at least 50% of prescribed training volume over the 12-week training period, as indicated from the training logs.

Adherers vs. Non-Adherers

- Adherers were determined to be subjects who displayed total adherence rates of at least 75%.
- Non-Adherers were determined to be subjects who displayed total adherence rates of less than 70%, while performing at least 50% of prescribed training volume over the 12-week training period, as indicated from the training logs.

How Adherence is Determined

- Each prescribed training session was categorized according to the type of session performed:
  - Aerobic Foundation (Z1/Z2 Low Run/Cross Training) (A)
  - Progressive Z2 Long Run (B)
  - Main System Workout (VIS/VIL/LT) (C)
  - Economy Interval Workout (D)

- Calculation of adherence for each category
  - Aerobic Foundation (Z1/Z2 Low Run/Cross Training) (A)
    - % Prescribed Total Training Volume Performed x % Expected Training Sessions Performed
    - Rationale: Ensure that training volume was not condensed into fewer training sessions than prescribed
  - Progressive Z2 Long Run (B)
    - % Prescribed Total Training Volume Performed x % Expected Training Sessions Performed
    - Rationale: Ensure that training volume was not condensed into fewer training sessions than prescribed
  - Main System Workout (VIS/VIL/LT) (C)
    - % Prescribed Total Training Volume Performed
    - Rationale: Athletes performed all VIS/VIL/LT training very close to the prescribed paces, so % of volume performed effectively measured adherence.
  - Economy Interval Workout (D)
    - % Prescribed Total Training Volume Performed
    - Rationale: Athletes performed all EI training very close to the prescribed paces, so % of volume performed effectively measured adherence.

- Weighted average approach used to weight each category as they related to the number of days per week each training category was emphasized.
  - A:B:C:D=4:1:1:1
  - Represents that (A) sessions represent 4 days of each training week, (B) sessions represent 1 day of each training week, (C) sessions represent 1 day of each training week, and (D) sessions represent 1 day of each training week.

Exceptions

- If a subject performed more Aerobic Foundation or Progressive Long Run volume than prescribed, the amount of excess training performed would be decreased from the upper bound of the training prescription, decreasing adherence.
- If a subject performed more Economy Interval volume than prescribed, the subject received a % Prescribed Total Training Volume Performed equal to 100%. The purpose here was to not penalize a subject for accidentally performing one more 100 or 200-meter interval than prescribed. This happened once.
- The purpose of “% Expected Training Sessions Performed” is to quantify the number of training sessions a subject should have completed, depending on how much volume was completed, in order to not overly penalize a subject for performing low volume.
- If a subject did not wear a heart rate monitor for a prescribed heart rate-based training session, the RPE recorded in the training log for that session was used to determine if the effort was at the right intensity.
  - RPE will be compared with other training sessions logged at the same prescribed intensity.
  - If the RPE falls within the range of RPE’s found for equivalent training sessions, the session was classified as “adhered to” in terms of the intensity.
### Example Adherence Calculations for Sample Subject:

<table>
<thead>
<tr>
<th></th>
<th>A: Aerobic Foundation (Z1/Z2 Low)</th>
<th>B: Progressive Long Run Workouts</th>
<th>C: Main System Workouts</th>
<th>D: Economy Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prescribed Volume</strong></td>
<td>3000-3800 Minutes</td>
<td>700-810 Minutes</td>
<td>40,000-45,000 Meters</td>
<td>20,000 Meters</td>
</tr>
<tr>
<td><strong>Completed Volume</strong></td>
<td>2562 Minutes</td>
<td>815 Minutes</td>
<td>42,000 Meters</td>
<td>18,000 Meters</td>
</tr>
<tr>
<td><strong>% Prescribed Total Training Volume Performed</strong></td>
<td>=2562/3000 =0.854</td>
<td>=805/810 =0.994</td>
<td>=42,000/42,000 =1.000</td>
<td>=18,000/20,000 =0.900</td>
</tr>
<tr>
<td><strong>Prescribed Sessions</strong></td>
<td>80</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Completed Sessions</strong></td>
<td>55</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>% Expected Training Sessions Performed</strong></td>
<td>=55/80=0.854</td>
<td>=10/11=0.915</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Adherence By Category</strong></td>
<td>=0.854 x 0.805 =0.687</td>
<td>=0.994 x 0.915 =0.910</td>
<td>1.000</td>
<td>0.900</td>
</tr>
<tr>
<td><strong>Total Adherence</strong></td>
<td>=(4*0.687+0.910+1.000+0.900)/7=0.794</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

79.4% Adherence
APPENDIX I
The Effect of System Based Training™ on the Individual Lactate Profile and 5-Kilometer Time Trial Performance in Collegiate Distance Runners

Post-Study Questionnaire & Response Frequency Table

<table>
<thead>
<tr>
<th>Question/Response</th>
<th>Frequency/Mean Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall, you adhered to SBT™ this summer:</td>
<td></td>
</tr>
<tr>
<td>1 – Always</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>3 – Sometimes</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5 – Never</td>
<td>2</td>
</tr>
<tr>
<td>How often would you wear your heart rate monitor?</td>
<td></td>
</tr>
<tr>
<td>75-100% of HR-Based Training Sessions</td>
<td>14</td>
</tr>
<tr>
<td>50-75% of HR-Based Training Sessions</td>
<td>5</td>
</tr>
<tr>
<td>25-50% of HR-Based Training Sessions</td>
<td>1</td>
</tr>
<tr>
<td>0-25% of HR-Based Training Sessions</td>
<td>1</td>
</tr>
<tr>
<td>Which of the following factors prevented you from wearing your heart rate monitor?</td>
<td></td>
</tr>
<tr>
<td>(Select ALL that Apply)</td>
<td></td>
</tr>
<tr>
<td>Losing the Watch or Chest Strap</td>
<td>5</td>
</tr>
<tr>
<td>Chafing/Skin Irritation Caused by the Heart Rate Monitor</td>
<td>10</td>
</tr>
<tr>
<td>Forgetting to Wear It</td>
<td>7</td>
</tr>
<tr>
<td>None of the Above</td>
<td>1</td>
</tr>
<tr>
<td>Other (please specify)</td>
<td>2</td>
</tr>
<tr>
<td>Would you continue to wear a heart rate monitor and chest strap in your future training?</td>
<td>Variation in open-ended responses (Appendix J)</td>
</tr>
<tr>
<td>Before participating in this study, would you keep a training log?</td>
<td></td>
</tr>
<tr>
<td>1 – Always</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>3 – Sometimes</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>5 – Never</td>
<td>3</td>
</tr>
<tr>
<td>The amount of information you were required to input into the SBT™ training logs was:</td>
<td></td>
</tr>
<tr>
<td>Too Much (Overwhelming)</td>
<td>2</td>
</tr>
<tr>
<td>Appropriate</td>
<td>18</td>
</tr>
<tr>
<td>Not Enough</td>
<td>1</td>
</tr>
</tbody>
</table>
Rank the following training variables based on your belief of how important they are in improving 5k-10k performance: (1=most important, 6=least important)

<table>
<thead>
<tr>
<th>Training Variable</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tempo Runs (10k pace-1/2 Marathon Pace)</td>
<td>2.8</td>
</tr>
<tr>
<td>Recovery (Sleep, Nutrition, Etc.)</td>
<td>2.9</td>
</tr>
<tr>
<td>Long Runs</td>
<td>3.0</td>
</tr>
<tr>
<td>Interval Workouts (3k-5k pace)</td>
<td>3.2</td>
</tr>
<tr>
<td>High Mileage</td>
<td>3.9</td>
</tr>
<tr>
<td>Speed/Repetition Training (100m-1500m pace)</td>
<td>5.3</td>
</tr>
</tbody>
</table>

How was your prescribed System Based Training™ plan different than how you would normally train? Please explain.

Variation in open-ended responses (Appendix J)

When the study began, how did you think your fitness would change as a result of following SBT™?

<table>
<thead>
<tr>
<th>Change</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve a Lot</td>
<td>7</td>
</tr>
<tr>
<td>Improve a Little</td>
<td>7</td>
</tr>
<tr>
<td>Stay the Same</td>
<td>1</td>
</tr>
<tr>
<td>Deteriorate a Little</td>
<td>3</td>
</tr>
<tr>
<td>Deteriorate a Lot</td>
<td>1</td>
</tr>
<tr>
<td>I Didn't Think About It</td>
<td>2</td>
</tr>
</tbody>
</table>

When the study concluded, how did you think your fitness had changed as a result of following SBT™?

<table>
<thead>
<tr>
<th>Change</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved a Lot</td>
<td>7</td>
</tr>
<tr>
<td>Improved a Little</td>
<td>6</td>
</tr>
<tr>
<td>Stayed the Same</td>
<td>2</td>
</tr>
<tr>
<td>Deteriorated a Little</td>
<td>1</td>
</tr>
<tr>
<td>Deteriorated a Lot</td>
<td>2</td>
</tr>
<tr>
<td>I Didn't Follow SBT</td>
<td>3</td>
</tr>
</tbody>
</table>

Rank the following factors (in order) in terms of how much they caused you to deviate from following SBT™. (1=caused most deviation, 7=caused least deviation)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work Schedule/Full Daily Schedule</td>
<td>1.6</td>
</tr>
<tr>
<td>Training with other People</td>
<td>2.8</td>
</tr>
<tr>
<td>Desire to Perform Non-SBT™ Training</td>
<td>3.0</td>
</tr>
<tr>
<td>Access to a Track for Intervals</td>
<td>3.2</td>
</tr>
<tr>
<td>Motivation to Run</td>
<td>3.2</td>
</tr>
<tr>
<td>Travel</td>
<td>3.6</td>
</tr>
<tr>
<td>Other</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Do you have any other comments about the SBT™ training plan? If so, please explain.

Variation in open-ended responses (Appendix J)

Please rank the following barriers to following SBT™ in terms of their likelihood to prevent you from following SBT again: (1=largest barrier, 6=smallest barrier)

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Total Training Volume Was Too Low</td>
<td>2.6</td>
</tr>
<tr>
<td>Following a Training Plan That Was Different Than the Rest of the Team</td>
<td>2.7</td>
</tr>
<tr>
<td>The Z1/Z2 Low Runs Were Too Short</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Other</td>
<td>3.9</td>
</tr>
<tr>
<td>Keeping a Training Log</td>
<td>4.1</td>
</tr>
<tr>
<td>Blood Lactate Testing</td>
<td>4.7</td>
</tr>
</tbody>
</table>

What did you like most about SBT™?
Variation in open-ended responses (Appendix J)

What did you like least about SBT™?
Variation in open-ended responses (Appendix J)

Would you follow SBT™ again? Why or why not?
Variation in open-ended responses (Appendix J)
APPENDIX J

The Effect of System Based Training™ on the Individual Lactate Profile and 5-Kilometer Time Trial Performance in Collegiate Distance Runners

Open-Ended Responses to Post-Study Questionnaire

Would you continue to wear a heart rate monitor and chest strap in your future training? Why or why not?

“Yes, I found it to provide good information during training.”
“Yes, because I believe it can help guard one from overtraining.”
“Yes, the HRM is a great way to monitor effort and correlate to pace on flat runs (ex a 145 HR equals 7 min pace on flat roads).”
“Yes, because it is interesting and good to know what my heart rate is at during runs. However, I found myself being too concerned with where my heart rate was which took away from the enjoyment of running.”
“Yes! I didn't realize how drastically I was over training. The HR monitor gave me a concrete way to see how hard I was working on a given day.”
“No it really irritated my skin.”
“No. It was really uncomfortable.”
“Yes for certain parts of my training for sure.”
“Yes because I like knowing my HR and it is a good indicator for how fast or slow I should be going on recovery days.”
“Yes, to gauge whether I am recovering during recovery runs.”
“No, it’s easy to forget.”
“Yes, it helps with pacing and controlling my own pace during my workouts.”
“No, it makes running to organized. Has me slow down even if I feel good or I have to go faster even if I feel bad. Makes me think too much.”
“I would on my easy days to prevent myself from training too hard and not letting myself recover.”
“Not so much because the chafing was really irritating and sometimes when I felt like I could go at a faster pace, I couldn’t because my heart rate would be too high according to my heart rate zone.”
“No I will buy another one.”
“No simply because I like just wearing a watch.”
“Maybe I more prefer to just run then keep track the whole time I might use it to see what my heart rate is at periodically”
“I would on the Progression Runs for sure. I enjoyed increasing my effort and seeing how my body reacted at different HR levels. Easy runs I like to run easy and it is not really a problem staying under my HR limit.”
“In workouts possibly. For easy runs not so much because it seems like more of a hassle and I do not have the problem of going too fast on easy runs.”
“Yes, because even though my results weren't what I would have liked to see, the program itself I believe is a highly productive system for training individuals for long distance running.”
How was your prescribed System Based Training™ plan different than how you would normally train? Please explain.

“A lot slower than I would normally run.”
“I would normally train with 1 anaerobic tempo, 1 aerobic tempo, and a set of mile repeats each week.”
“The runs were shorter than I would normally run, also the workouts were faster than usual”
“It was less tempo runs and more short intervals than I would typically do”
“My easy runs were at a much easier pace than I normally would have run them. I had more double days than I’ve done in the past, but many of them were done via cross training, which greatly benefited me. Furthermore, I have never done such short reps for speed workouts and I was very surprised how well this training worked for me.”
“It was a lot less mileage than I am use to running and the paces for my recovery days were slower than what I was used to.”
“It started off a lot slower and the long runs were a lot easier than the workouts when usually I feel like the workouts don't feel as intense compared to the recovery runs”
“There was way more short distance interval workouts.”
“I ran a lot less mileage and hard workouts with SBT.”
“Less mileage. Used to 70-80+mpw”
“Normally I wouldn't do any workouts during the summer.”
“The mileage was less than what I was used to but later I was able to adapt to the training plan as I was given more mileage.”
“I had less mileage, and more speed workouts early in the summer.”
“It was different because I did more cross training and the 100m repeats were something I have never done before”
“It was a lot more consistent. I had just started to get back in shape so it was a lot more helpful.”
“I had alot of intervals like mile repeats 1000s 100s 200s and 800s it was hard especially because at times I didn’t have access to a track.”
“Lower mileage than what I was expecting.”
“Normally I would do mostly long runs over the summer not as many intervals.”
“It had a different method of getting into shape than I am used to. The first three weeks were not as hard as I would have made if I would have made the training plan myself, but I think I learned how a nice and easy buildup could be more productive in the long haul. Also the workouts near the end of the training were really fast. Faster than I have ever gone before. (Mile reps in 4:35 for example.) I would like to think that if I had not have messed up and taken those 4 consecutive days off half way through perhaps I would have ran that workout at a more successful level.”
“Normally, I would not do as many double days during the summer. The workouts seem like normal workouts, but generally typical in my summer training.”
“With my coach, for cross country season we usually run six to seven days a week. Monday and Wednesday are our speed days. We usually have speed training at different distances and typically run 30-45 minutes afterwards. Tuesday and Thursday are "recovery" days where we run at a slower pace for about 6 miles. Tuesday is just under talking pace, and Thursday is a comfortable conversation pace. Friday we often do tempo runs with some speed training. Mon. and Wed. we do pain-thresh (strength-training), and Tue. and Thu. we have weights. Weekends typically consist of long runs, and tempo runs. Every Wed. in the evening our team has ab workouts.”
Do you have any other comments about the SBT training plan? If so, please explain.

“Did not allow for any hill training for cross country. The slower runs were frustrating and the speed intervals were too much. I couldn't walk for three days after one.”

“It's a good program that I would recommend to others.”

“Seems like a great training plan to train for peak performance, but not for summer base training.”

“I would like to continue it through the season!!!!!!!”

“It was hard to follow with a full work schedule and without access to cross training equipment.”

“I thought it was helpful but really difficult to follow because of work.”

“Need more clarity/space on how to record interval results.”

“I would like to do it again and do it better. Also doing nearly everything alone was a bit of a challenge. Sometimes life can bring you down and it is nice having a support system.”

“I liked that the workouts built off of each other. I liked the long runs. It was very time consuming doing so many double days throughout the week.”

“I would say that My leg pains and asthma caused the most deviation. My physical therapist concluded that I have overuse injuries in both of my IT Bands in my legs making running very painful and recovery difficult.”

What did you like most about SBT™?

“Kept me accountable to run.”

“The specificity of the training program.”

“Progressive long runs.”

“Finding out my lactate levels and where I needed to improve.”

“I liked that it wasn't high volume and it was specifically tailored to me and my needs. There was really no way I could over train while using SBT, which is a problem I have had in the past.”

“I liked being able to see the different zones I was in with the HRM and watch.”

“I liked having a schedule and being motivated to keep a log or journal.”

“There was plenty of rest.”

“It helped me stay focused and motivated to run.”

“Results/remedial intervals.”

“Blood Lactate test.”

“The workouts were perfectly balanced with the SBT z1 and z2 tempo runs/pick ups.”

“The intervals, when I did them”

“I liked that it didn't make my legs hurt all the time, and that it gave me the option to cross train some days to make it interesting to help me not lose motivation.”

“My workouts were specifically made for me.”

“The long runs and mile repeats. I wish it also included weights in the SBT”

“Workouts weren't hard at all.”

“That I had a set plan for the summer.”

“Having a plan and the consistency of the program with long run days and workouts.”

“I liked the long runs the most. They were very challenging.”

“I liked how it was so personalized and now I know more about the pace I need to run to truly recover.”
What did you like least about SBT™?

“Inconsistency in intensity. The recovery runs mileage was not enough and the interval training was too fast and too much.”

“Wearing a HR monitor.”

“The fast workouts that early in the summer.”

“It was hard to follow (mostly because of my job, not the program itself).”

“Knowing it was only going to last for 12 weeks.”

“Wearing the HR”

“The heart rate monitor”

“Too much short speed interval workouts too soon.”

“Too little mileage and chafing from the HR monitor.”

“Economy intervals were difficult to get in because I want to run with people, not alone.”

“Heart rate monitor.”

“The Heart Monitor was a little annoying at times specially after running more than 12 miles during a long run.”

“The less miles and separating them.”

“I didn't like having to write everything down because at times I didn't have time to write it down or I forgot to write it down.”

“Wearing the heart rate monitor.”

“The intervals.”

“The overall mileage.”

“That I had a set plan for the summer.”

“HR monitor on easy days. Also the un-flexibility of having off days.”

“Training on my own. It was hard to find people to run with twice a day for a very short run.”

“I know that my z1 and z2 zones are designed for me to recover properly, but I didn't like how slow they were; I have chronic asthma and my lungs need a workout daily to help keep it under control. If I'm not running fast for a few days, then when I have a speed workout, it's much harder to breath.”
Would you follow SBT™ again? Why or why not?

“Probably not. I have learned enough about the study to understand what I need to work on as an athlete and to not subject myself to the frustration and pain that the study caused me. I also worked 45-50+ hours a week during the study and tried to maintain ministry work with my church during the study as well. Overall it was a lot. However, I am thankful for the opportunity to learn more about myself as a runner and training to be an overall better athlete.”

“No, because I am already following a training program that I believe in. However, I would have no problem trusting SBT as a training program.”

“Yes, I would try SBT training when training during a track season.”

“Yes, if I knew I would be able to follow it religiously and see if I could actually improve.”

“YES...”

“Yes I would prefer doing it at a different time than summer, maybe during the break we have off for winter.”

“I would just to try it but I don't think I would ever be able to if I didn't have a gym membership for the cross training.”

“No because I think that that would completely burn me out for the rest of the season.”

“Yes, if I didn't have work because then I would be able to follow it better.”

“Yes, but more likely if I had training partners doing the same.”

“Probably not. Just because I would forget to wear my heart rate monitor too many times.”

“I would definitely do it again!”

“Maybe, if it goes with what I would prefer and know what’s best for me.”

“I would follow it again because i saw a significant improvement and I didn't get injured and stayed fairly motivated.”

“It depends on how different the workout is from the team.”

“Yes I would.”

“Under different circumstances perhaps. I feel like following it over the winter would have been a better option.”

“Yes I would like to have people that were in similar plans to me though.”

“Yes Please!”

“This exact plan I would say probably not. The variation in training paces of participants made me unsure. For example, I would see someone who I felt I was as fast as and they would be doing the same workout as me except way faster paces. So the inconsistency troubled me a bit. I enjoy running longer runs in the summer time as opposed to shorter runs. It feels like I am just getting started then I am done with my run already. This also made it difficult to run with people. A big thing was keeping track of time as opposed to mileage. I understand why time is used, but I am just so accustomed to running by miles.”

“Yes, I think it's an amazing program well suited for all individuals because it's so customized. I'm very thankful that I got to participate in such a cool study.”