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The Effects of Off-Season and In-Season Training on Lactate Threshold in NCAA Division III Female Soccer Players

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Abstract:
Soccer requires a significant amount of aerobic and anaerobic training to improve one's performance. Because lactate threshold (LT) is an important component of endurance sport performance, testing the LT of soccer players in response to their off-season and in-season training regimens could help to gauge the success of those programs in improving or maintaining fitness levels. This study evaluated the effects of off-season training and in-season training types on LT in 11 NCAA Division III female soccer players (age 19.5± 1.3 years). Off-season training was comprised of aerobic and anaerobic workouts, while in-season training was more sport-specific, and involved playing soccer six days a week. Each athlete performed two LT tests on a cycle ergometer after off-season training and in-season training were completed. There were no significant differences in mean LT levels between off-season training and in-season training (125.5± 18.9 Watts vs. 119.5± 13.4 Watts, respectively, $p=0.33$). It was concluded that LT levels were maintained, but not improved, by in-season, sport-specific training when compared to off-season training. Other metrics, such as shuttle run performance or VO_2max testing, may be more useful in assessing the differences between the two training types.

Key Words: aerobic capacity, endurance, exercise intensity

Introduction:

Soccer is one of the most widely played sports in the world, with 265 million players. The average soccer player competing in the full 90 minutes of a game runs approximately 10 to 12 km (6.2 to 7.4 miles) (13,15,16). For that reason, cardiorespiratory fitness is essential for soccer players to be successful. Cardiorespiratory fitness indicates the strength of an individual's aerobic system. Endurance plays a significant role on the duration and intensity of one's overall play. Without an aerobic base, soccer players are unable to perform optimally for the full duration of play. Lactate Threshold tests are useful tests for soccer players since soccer matches last 90 minutes, therefore requiring a great deal of endurance at a high intensity. LT levels are commonly tested for athletes because the results signify the individual's overall endurance performance potential (10). The test indicates the individual's maximum intensity before accumulating a significant amount of lactate and hydrogen ions in the muscles and blood. Due to the long duration of play in a soccer match, muscle fatigue is bound to occur while and/or after playing in a soccer match. There is not one singular physiological cause for muscle fatigue, but muscle fatigue may occur when contractile proteins are impaired, and the accumulation of lactate and hydrogen ions can contribute to this (9).

In soccer, muscle fatigue may be caused by intense muscle activity due to the long duration of play, which leads to a decline in performance and/or their ability to exert force (9). As muscle fatigue manifests, a significant amount of lactate builds up in one's muscles (6). Lactate accumulates in the muscles when the glycolytic cycle is backed up and glucose is converted into lactate rather than pyruvate (12). The buildup of lactate is troublesome for soccer players as it causes muscle fatigue in active muscles, which may subsequently slow down the individual's speed of play. LT testing is an effective way to measure overall performance intensity, as well as training effectiveness (4). This enables the individual to pinpoint the training intensity needed to improve their maximum power output in the LT test, therefore, improving one's overall fitness. LT is determined by the break point at which an individual's blood concentration of lactate is accumulated faster than it is removed (6). The key mechanisms in LT are the decreased removal of lactate, the increased amount of fast-twitch motor unit recruitment, the imbalance of glycolysis and mitochondrial respiration, and a low amount of oxygen in the blood (4, 12).

The purpose of this study was to determine the effects of off-season and in-season training on LT in NCAA Division III female soccer players. The off-season training primarily focused on improving the individual's aerobic capacity/strength, followed by improving anaerobic speed (Table 1). Aerobic training improves the transport of oxygen to the cardiovascular system. Slow twitch muscles are essential in endurance runners, which are primary examples of aerobic training. Distance running improves the athlete's endurance as well as creating a threshold to improve one's overall efforts (3). Conversely, anaerobic training primarily focuses on the ability to act quickly with force, such as in weightlifting or running sprints. High intensity interval training (HIIT) is a subtype of anaerobic training. These exercise bouts are relatively short and equivalent to running anywhere between 100 meters to 800 meters on a track. Fast twitch muscles are used to create power and speed in these exercises, but these muscle types produce the most lactate.

Bishop, Jenkins and Mackinnon's (7) as well as Bangsbo (3) and Wells, et al. (16) aerobic and anaerobic training studies concluded that aerobic training improves exercise intensity as well as the individual's LT. Bangsbo (1) reported that if soccer players perform more than two HIIT sessions each week, along with a normal training regimen, the athlete's aerobic and anaerobic capacity significantly improve. In addition, Wells, et al., (16) studied the effects of high intensity running workouts on soccer players. This study discovered that if soccer players performed six consecutive weeks of high intensity intermittent training, overall running capacity improved. Soccer requires a mixture of both aerobic and anaerobic workouts depending on the position and the player's individual duration of play. Therefore, for this study, the in-season training included sport-specific training comprised of playing soccer six days a week for 90 to 120 minutes each day (Table 2).

There are many unknowns as to what training holds the greatest yield for soccer players in the off-season. Most published literature available has specifically examined the change of male LT and/or VO_2max rather than females. Males typically have a larger build and a larger cardiovascular system than females, and therefore are likely to have a higher VO_2max and LT. Due to the duration and intensity of soccer, both off-season and in-season training is pivotal for the athlete's success. It is vital that athletes train vigorously during the off-season to maintain or to increase one's overall VO_2max and LT levels during the soccer season.

Therefore, the aim of this investigation was to examine the effect of off-season and in-season training on LT in NCAA Division III female soccer players. Comparing the results of these two different training regimens will provide evidence about the type of training that is more effective for this population. It was hypothesized that off-season training would increase the LT of female soccer players more than in-season training.

Methods:

Experimental Approach to the Problem:

This study examined two different types of training, off-season and in-season in NCAA Division III female soccer players. The participants conducted a combination of anaerobic and aerobic training in the off-season (Table 1) and then completed a LT test. Next, the participants completed sport-specific, in-season training (soccer, Table 2), followed by a LT test at the end of season.

Participants:

11 NCAA Division III female soccer players aged 19.5±1.3 years old participated in this study. A total of 22 individuals were admitted to this study. However, due to injury, illness and participant dropout, only 11 participants completed both LT tests and are included in the

analysis. Written voluntary informed consent was obtained from each participant, and the study was approved by the Institutional Review Board at Hamline University.

Procedures:

Each participant performed two LT tests on the VeloTron DynaFit Pro cycle ergometer (Racermate, Seattle, Wash, USA), using VeloTron Coaching Software. The first test occurred after the participants completed their off-season training (August). The participants then completed the fall soccer season, and completed the second LT test one week after the season ended (November). Prior to testing, each participant had an electrocardiogram (EKG) test completed to screen for cardiac abnormalities. Before the LT test, the participants completed a general questionnaire (name, date of birth, email, emergency contact), the bike was adjusted accordingly, height and weight was recorded, and the participants were fitted with a heart rate monitor.

Participants warmed up for five minutes at 80 W. Following the warm up, the test started at 100 W for the first stage, and Wattage was increased by 20 W in five minute increments. During the 4th minute of each stage, blood lactate (mmol/L), rate of perceived exertion (RPE), and heart rate (HR) was determined. After these readings were recorded, the Wattage increased by 20 W increments. A drop of blood from the participant's finger was collected using lactate test strips and the Lactate-Plus device, which analyzed the blood lactate levels. After a break point in lactate levels was apparent, the participant cooled down for approximately 5 minutes to end the test, while the researcher recorded the individual's HR variability 5-minutes prior to ending the actual test. In addition, the individual's HR recovery to a resting rate was also recorded (in minutes).

Off-Season Training: Aerobic and Anaerobic Training

Specific training workouts are indicated in Table 1 and 2. Table 1 represents one week of the off-season training workouts. Each week there were different workouts created by a Hamline Track and Field coach. Weightlifting exercises were created by Hamline’s Strength and Conditioning coach and made specifically for female soccer players. An example of a sprint workout included: a 10-minute warm up, 8 sets of 15/30/30 (15 second walk, 30 second jog, 30 second sprint), followed by a 5-minute cool down. An example of cross training was playing soccer or biking for 20-30 minutes. Lastly, an example of a weightlifting workout (month 1, workout 1) included a set amount of repetitions and set of power cleans, front squats, hang cleans, back squats, bench press, band pull apart, piston squats, Russian dead lifts, E-Z bar reverse curls, straight bar triceps extension, Russian twists, and partner ball throw (abdominals).

Table 1: Off-season training regimen

	Mon.	**Tue.**	**Wed.**	**Thurs.**	**Fri.**	**Sat.**	**Sun.**
Aerobic	3-mile run			XT		4-mile run	OFF

Anaerobic		Weight-lifting	Sprint workout		Weight-lifting		OFF

The workouts changed each week depending on the type of workout: aerobic or anaerobic.

In-Season Training: Sport-Specific Training

Table 2 gives an example of one week of in-season training. Each week was different, depending on when the soccer games were scheduled. Practice time included warming up, the soccer practice, and cooling down. The duration of play in each game was different for each participant; however, the time listed below, is for the maximum duration of play on game day (90-minute games and 40-minute warm up).

Table 2: In-season training regimen

	Mon.	**Tue.**	**Wed.**	**Thurs.**	**Fri.**	**Sat.**	**Sun.**
Sport-specific training	Practice	Practice	Game	Practice	Practice	Game	OFF
Duration (minutes)	90-120	90-120	130	90-120	90-120	130	OFF

Statistical Analysis:

The data was analyzed with paired t-tests using SPSS software. The significance level was set at $p < 0.05$. The SPSS stepwise regression program was used to compare LT Wattage (dependent variable) to the significant variables, which were weight and age (independent variables). Two models were used in this regression: weight as only a predictor and both weight and age as a predictor.

Results:

Participant characteristic and LT results

The participants' characteristics after training and completing the LT tests are shown in Table 3. There was a slight difference in LT between off-season (mean±SD: 125.5±18.9 W) and in-season training (119.5±13.4 W), but the difference was not statistically significant (p=0.33).

Table 3: Participant characteristics and LT results

	Off-Season Training (n=11)	In-Season Training (n=11)	P-Values
Age (y)	19.2±1.1	19.5±1.6	0.14

Height (cm)	167±6.6	167±6.6	-
Weight (kg)	63.5±5.8	63.4±6.4	0.94
Lactate Threshold (W)	125.5±18.9	119.5±13.4	0.33
Heart Rate Variability (bpm) After 5 minutes	62.9±10.3	64.6±11.9	0.512
Heart Rate Recovery to Resting (minutes)	13.2±2.4	13.7±1.5	0.44

No significant differences. The values are expressed as mean ± standard deviation.

Position and training

Table 4 displays the difference between LT in respect to the player's field position and training type. There was no statistically significant increase or decrease among each position and training type.

Table 4: LT results in respect to position and training

Position (n=11)	LT Wattage Off-Season	LT Wattage In-Season	P-Value
Forwards (n=3)	132.3±33.6	114.3±14.0	0.26
Midfielders (n=4)	126.3±13.1	114.8±9.32	0.31
Defenders/Goalie (n=4)	119.8±13.2	128±15.1	0.35

No significant differences. The values are expressed as mean ± standard deviation.

Age and training

Table 5 displays the difference in LT between each different ages and training. There were no statistically significant differences between off-season and in-season training among each age group in the soccer team.

Table 5: LT results in respect to age and training

Age (n=11)	LT Off-Season	LT In-Season	P-Value
18 (n=4)	126.8±16.6	113.5±8.7	0.32

19 (n=2)	115.5±7.8	121.0±17.0	0.81
20 (n=2)	105.0±14.1	112.5±17.7	0.20
21(n=3)	144.3±13.6	131.0±12.8	0.36

No significant differences. No trend amongst the participants, which could be due to many factors such as one's duration of play in-season, muscular strength, and endurance.
The values are expressed as mean ± standard deviation.

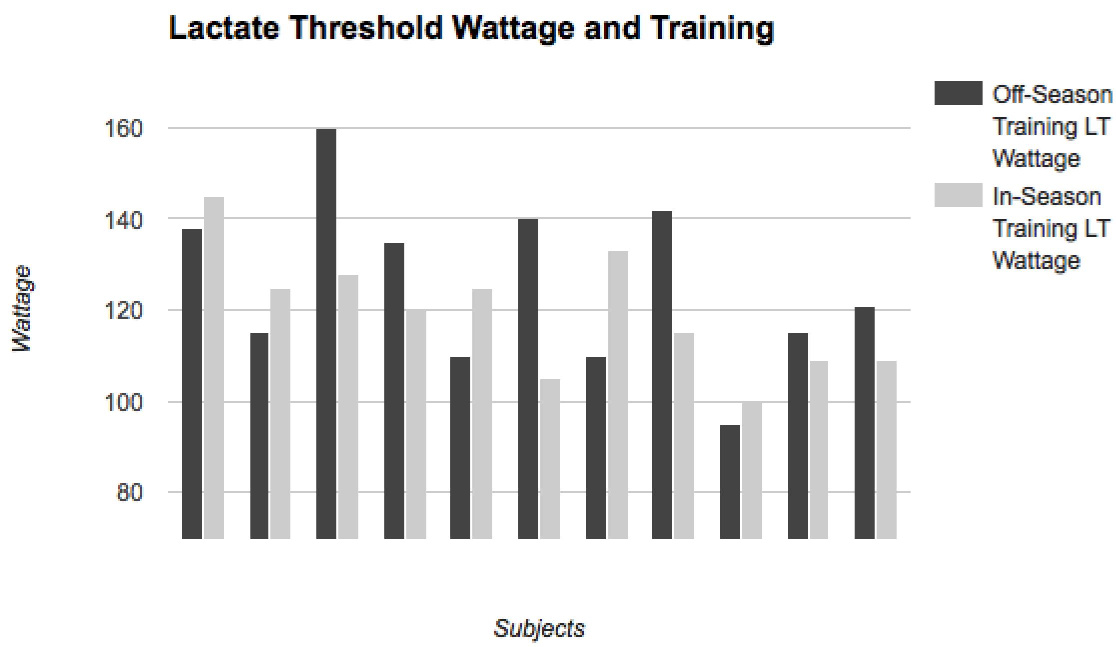

Figure 1: LT Wattage and training: individual's responses

This figure represents the difference in LT Wattage between each individual participant's off-season and in-season training. Some individuals increased in LT after the soccer season but others decreased, which could be due to difference in positions or training program adherences.

Stepwise regression of LT Wattage

Stepwise regression was performed using SPSS. The program removed all variables that were not significant (HR variability, resting HR, HR recovery, height) while leaving the significant factors, weight and age. LT Wattage was the dependent variable and weight and age were the independent variables (predictors). There were two very strong models created from this regression. The first model included only weight, while the second model included both weight and age. The results of the first model showed a moderate correlation between LT and weight (0.716), and that when weight is used as a predictor in the model, it accounts for 51.3% of the variation in LT. The results of the second model showed a strong correlation between LT, age, and weight (0.896), and that then when weight and age is used as a predictor in the model, it accounts for 80.3% of the variation in LT (Table 6).

Table 6: Stepwise regression results in relation to LT Wattage

Predictors	Model	R	R^2	F	P-value
Weight	1	0.716	0.513	9.48	0.13
Weight, Age	2	0.896	0.803	16.3	0.002

Weight and age were significant predictors of LT. The values are expressed as mean ± standard deviation.

Discussion:

The purpose of this study was to examine the effects of off-season and in-season training on LT in NCAA Division III female soccer players. The hypothesis of this study was that off-season training would increase female soccer players' LT more than in-season training. The findings do not support this hypothesis. LT levels were greater after off-season training, but not significantly greater than in-season training (Table 3, p=0.33). Some of the factors that may have affected these results are the individuals' overall endurance, strength, and duration of play over the in-season.

An interesting finding of this study was that weight and age were very strong predictors of individual's LT Wattage (Table 6). When weight was the only predictor, the correlation between LT and weight was 71.6%. When both weight and age were predictors, the correlation between LT and those predicators was 89.6%. There is limited published research available that focuses on LT, weight, and age in female soccer players. Most research on soccer players is primarily pertaining to VO_2max in males and fails to account for females. This study is unique since it investigates LT in female soccer players.

Training is essential in the overall success of the players and team, because soccer is such a physically demanding sport. When an individual understands their LT levels, they can pinpoint the training intensity needed to improve one's overall LT. This may improve the athlete's overall performance, which is crucial for soccer players' physical fitness. The aim of this study was to evaluate which type of training was more effective for improving female soccer players LT. Many athletes perform VO_2max to determine one's overall aerobic endurance; however, Helgerud et al. argued that LT tests better determine overall fitness (11). A study conducted by Bishop, Jenkin and Mackinnon found that aerobic training improves exercise intensity as well as LT (6); likewise, Bangsbo's results indicated that anaerobic training, along with a normal training regimen significantly improve the individual's aerobic and anaerobic capacity (2).

Recent LT studies focus mainly on professional male soccer players. Baumgart, Hoppe and Freiwald's study demonstrated that there is a gender difference in soccer player's endurance (5), resulting in different types of training and LT breakpoints. Another study conducted by Edwards, Clark, and Macfadyen (8) primarily focused on the effects of high intensity training during elite players' off-season. This study's results indicated that oxygen consumption and LT were significantly higher for individuals who participated in 14 hours of additional training each week compared to individuals who only completed two aerobic runs each week. The elite soccer players, performed a normal training regimen (soccer training, drills, weightlifting), as well as HIIT. This differs from the aim of this study, which was to examine a combination of aerobic and anaerobic training as well as sport-specific training. However, this present study did not demonstrate an increase on LT in our female soccer players.

Bangsbo et al. (1,2) found that soccer players competing in a match have a LT values around 75 percent, which is comparable in trained endurance athletes. In comparison, healthy individuals who do not train have LT values around 50 to 60 percent, while healthy individuals who do train have LT values around 70 to 80 percent. Many athletes perform VO_2max tests to determine an overall aerobic endurance; however, some recent research argues that LT better determines overall fitness (12). Proper training is essential for soccer players due to the high intensity of the game. To increase the oxidative capacity of the muscles, increase the number of capillaries serving the muscles, and increase the pumping action of the heart, months of training are required (14). Nonetheless, training can increase LT, essentially improving one's overall performance.

Since there was no increase in LT levels between off-season and in-season training in this study, future studies should consider using more sport-specific fitness tests. Fitness tests are designed to indicate the athlete's overall performance capabilities. There are many fitness tests conducted by soccer programs such as the Yo-Yo test, Suicides (cones or shuttle run), 2-mile test, and many more to assess the differences among adaptations. These fitness tests could potentially be performed in combination with blood lactate measures to be more indicative of an athlete's true fitness level. An example of this would be measuring lactate levels pre- and post-shuttle run at different time points during the off- and in-season training.

This study focuses primarily on training and how it differs between off-season to in-season. Many factors come into play when it comes to examining these two training regimens. One major factor is the off-season training is no monitored by anyone but the participant. This made it difficult to ensure the participants conducted the weekly workout (lifts, runs, sprints) at high-intensities. If the individuals did not train as hard during the off-season training as they do in-season, then this could account for a significant improvement during in-season. The participant may have trained at high intensities during off-season, but during in-season they may have experienced overtraining, causing their LT to decrease. Likewise, if the participants trained at high intensities during the off-season and never played during the season, their LT may have decreased. There are other factors that come into play why there is a wide variation in the results in Figure 1, but it all depends upon the individuals and their overall work rate.

There are several limitations to this study. One major limitation of this study is the small sample size. Due to the vigorous in-season demand, there were several participants who were unable to participate due to injury, illness and other reasons. It was imperative that the participants worked out according to the off-season training workout (Table 1), but since the workouts were not supervised, we cannot confirm that all participants adhered to the training. In addition, the testing was conducted on a cycle ergometer (VeloTron) and not a treadmill, which would have been more sport-specific. Lastly, the researcher did not increase the Wattage until the blood lactate was recorded from the previous stage. If the analyzer malfunctioned or another sample had to be taken, and the stage length was prolonged, which occurred a handful of times. This caused some of the participant's pace to slow down, which could have altered their overall performance.

Conclusion:

There are many factors that play a role in improving one's endurance for soccer. Aerobic and anaerobic training has been previously found to increase endurance, as well as sport-specific training. In this study, it was concluded that LT is maintained, but not improved, by in-season, sport-specific training when compared to off-season training. Further research needs to be completed on LT in female soccer players, since it is such a powerful predictor of endurance performance potential.

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