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The Effect of the Annual Training Cycle on Aerobic Capacity in Division I Female Soccer Players

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ABSTRACT

Purpose: To assess the effect of variable training stress throughout the annual training cycle on aerobic capacity (AC) in female soccer players. **Methods**: Eleven Division l female soccer players (Mean ± SD: 19.3 ± 1.0 yrs; 164 ± 6.4 cm; 60.1 ± 5.4 kg; 19.44 ± 3.5 %BF, 48.3 ± 4.0 kg FFM, 43.3 ± 3.3 ml/kg/min VO_{2max}) were tested across the annual training cycle at six specific time points (B1-B6): post-season 2016 (B1), transition (detraining) (B2), spring-season (B3), pre-season (B4), mid-season (B5), and post-season 2017 (B6). Prior to exercise for each testing block, subjects arrived at the lab where height, weight, and body density (3-site skinfold method) were measured. Body fat was then estimated by using the Brozek equation. After a 5min self-selected warmup on the treadmill, subjects completed an incremental treadmill test to measure VO_{2max}. VO_2 values were collected each minute of the tests by using a 15sec average to assess AC. A 2x6 repeated measures ANOVA was used to analyze AC and fat free mass (FFM) changes across te annual training calendar (B1-B6). The LSD post hoc analysis was used if significant differences were found. **RESULTS**: Statistical analysis revealed a significant main effect of time on AC and FFM ($F_{1,5}$ 2513.1, $p = 0.001$), with an observed power of 1.0. Pairwise comparisons showed a significant increase (Δ +16.3%, $p < 0.01$) in AC along with increased FFM (Δ +2.4%, $p = 0.027$) between B1-B3 following the 2016 competitive season (B1). However, AC decreased (Δ -7.0%, $p = 0.021$) without a significant change in FFM from B3 prior to the competitive season (B4). Aerobic capacity and FFM remained unchanged across the 2017 competitive season (B4-B6) despite the reduced AC from B3. **CONCLUSION:** Following the 2016 competitive season (B1), AC increased ($p < 0.05$) indicating the reduced training load over the transition period (B2) increased AC without a change in FFM. Aerobic capacity and FFM increased significantly after the spring season training (B2-B3) where concurrent style training was largely incorporated. Aerobic capacity declined up to 7.04% over the summer training period (B3-B4) when NCAA rules limit athlete-coach communication. Aerobic capacity and FFM went unchanged ($p > 0.05$) across the 2017 competitive season (B4-B6) despite the 2.03% reduction. **PRACTICAL APPLICATIONS:** As AC was shown to fluctuate throughout the annual training, it is recommended to monitory frequently assess physiological status. In Division I female soccer players, implementing a transition period after heavy training stresses could potentially positively influence AC. Additionally, concurrent training can have positive benefits to AC and FFM if appropriate rest is provided. Testing can ensure adequate rest and programmed training stress, where players will be able to maintain peak physiological fitness and therefore maintain a competitive advantage across the annual training cycle.
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Key words: Annual Training Cycle, Stress, Aerobic Capacity, Training load, Recovery, Fat Free Mass

Introduction:

Soccer is a sport that prioritizes aerobic capacity (AC) in combination with repeated short anaerobic sprints (Alves, Oliveira, Costa, & Samulski, 2006). Frequent high intensity competitions along with practice and off-season training leads to accumulated stress which can lead to decrements in physiological performance (Alves et al., 2006; Lago-Peñas, Casais, Dellal, Rey, & Domínguez, 2011). With accumulated training stress and inadequate rest, athletes can become prone to overtraining syndrome (Lago-Peñas et al., 2011) which produces symptoms such as: fatigue, decreased performance, loss of appetite, respiratory fatigue, and mood swings (Alves et al., 2006). Furthermore, athletes have different training loads and goals throughout the annual training cycle which includes: pre-competitive, competitive season, and a transition period (detraining) (J. R. Silva, Brito, Akenhead, & Nassis, 2016). These periods are generally recognized as common practice, but may further differentiate within each period. The type of training varies depending on the time of year (training period) with the intention to maximize results and reduce the risk of overtraining (Sæther & Aspvik, 2014; J. R. Silva et al., 2016) during the competitive season. While aerobic power (capacity) has been regarded highly as a determinant of soccer performance at elite levels (Covic, N., Rado, I., Dzenan, 2016; C. D. Da Silva, Bloomfield, & Marins, 2008; Ingebrigtsen, Dillern, & Shalfawi, 2011), the seasonal variation of training goals in Division I female athletes may influence AC across the annual training cycle.

A transition period can be defined as a complete cessation or significant reduction in training load (Mujika & Padilla, 2001; J. R. Silva et al., 2016) and typically lasts 2-8 weeks (Mujika & Padilla, 2000, 2001). During a transition period, AC can be reduced by as much as 20% (Mujika & Padilla, 2000). However, a 6.9% drop in VO_{2max} was observed in collegiate soccer players following a five-week transition period (Mujika & Padilla, 2001). Regardless of the time of training cessation, training reversibility (reversal of specific physiological adaptations) appears to be influenced by time and training experience (Mujika & Padilla, 2001). Despite the reduction in physical improvements, detraining provides athletes with an adequate amount of rest to reduce the accumulated training stress and help prevent overtraining and injury (Mujika & Padilla, 2001).

While there is decline in AC throughout the transition period (Alves et al., 2006) due to the reduction in training volume, the sudden increase in training volume typical of the pre-competitive season (preseason) can lead to increased risk of injury (J. R. Silva et al., 2016). High volume and frequency of exercise is common throughout the six months of training during the pre-competitive season (J. R. Silva et al., 2016) which typically lasts from February through July in collegiate soccer players. The pre-competitive season frequently includes concurrent training (CT) that incorporates the combined strength and endurance exercises (Wilson et al., 2012). Concurrent training increases total volume and frequency of exercise and therefore increases the training load (J. R. Silva et al., 2016; Wilson et al., 2012). If programmed correctly, benefits of CT include increases in AC and favorable changes in body composition (decrease in %BF and increase in FFM (Aagaard & Andersen, 2010; Chtara et al., 2005).

Current research of adult soccer players (age ≥18) suggests that fluctuates (J. R. Silva et al., 2016) throughout the calendar year. Considering body mass is included in relative AC measurement (ml/kg/min) (Covic, N., Rado, I., Dzenan, 2016; Goran, Fields, Hunter, Herd, & Weinsier, 2000; Lago-Peñas et al., 2011), changes in body composition can influence AC (Aagaard & Andersen, 2010; Chtara et al., 2005). The primary oxidative tissue relevant to AC is FFM (Covic, N., Rado, I., Dzenan, 2016), therefore increases in FFM from CT would likely increase AC (Alves et al., 2006; Chtara et al., 2005; Wilson et al., 2012). On the other hand, adipose tissue does not contribute to maximal oxygen consumption and therefore an inverse relationship exists between fat tissue and AC (Covic, N., Rado, I., Dzenan, 2016). Additionally, the inverse relationship may diminish AC due to the additional fat mass that is metabolically irrelevant (Covic, N., Rado, I., Dzenan, 2016). Acknowledging all the reported benefits of CT, there is a high incidence of overtraining (Wilson et al., 2012) that may be caused by the rapid increase in training load after the transition period prior to the spring season. (J. R. Silva et al., 2016; Wilson et al., 2012).

The rapid increase in training load during the spring season and preseason could potentially affect how the players perform during the competitive season, specifically resulting in decreased AC (Alves et al., 2006; J. R. Silva et al., 2016; Wilson et al., 2012). Considering the games within the competitive season are usually moderate to high intensity(~70-80% VO_{2max}) (Alexandre et al., 2012), AC is relied on heavily throughout the competitive season. The rapid increase in training load during the spring season and preseason following the transition period (recovery) (Alves et al., 2006) can perpetuate physiological and psychological stresses that accumulate leading to an increase in fatigue prior to the competitive season (J. R. Silva et al., 2016). Lack of appropriate progression after the transition period can lead to accumulated stress which can result in greater fatigue that can lead to injury throughout the competitive season (J. R. Silva et al., 2016). Silva et al. (2016) observed soccer players following a transition period to study the development of fatigue due to increased training loads. The rapid increase in training load can lead to an over trained state which may result in a decreased training response mitigating training adaptation (J. R. Silva et al., 2016).

Accumulated stress can push athletes from an over reached state (Wilson et al., 2012), to an over trained state (Alves et al., 2006; J. R. Silva et al., 2016) during the competitive season that is defined by excessive training stress paired with little rest between games and training (Kraemer et al., 2004; Silvestre et al., 2006). Overreaching can be defined as the accumulation of stressors over days to weeks, while overtraining can last from weeks to months (Winsley & Matos, 2010). The continual stress placed on a player's body while training and competing can create an imbalance in the homeostatic anabolic and catabolic processes within muscle which can negatively influence performance (Kraemer et al., 2004). Furthermore, female athletes are 36% more likely to become over trained compared to male athletes (26%) (Matos, Winsley, & Williams, 2011). Therefore, the aim of this study was to monitor AC with consideration of body composition across the annual training cycle in Division I female soccer players. Additionally, it is predicted that the annual training cycle will create fluctuations in AC as well as body composition.

Methods:

Experimental approach to the problem:

Using a repeated measures design, this study investigated the effect of the annual training cycle on AC and body composition. Eleven Division I female soccer players completed a series of graded exercise tests (GXTs) to assess AC over six designated time points: 2016 post season (B1), transition (B2), spring season (B3), preseason (B4), midseason (B5), and 2017 post season (B6). Subjects were excluded if they had any cardiovascular, metabolic, pulmonary disorders, pregnancy, or had experienced any orthopedic injuries preventing safe testing. Pre-test guidelines included no exercise for 24 hours, refrain from caffeine for 12 hours, and not to consume any food four hours before testing. Prior to exercise testing, a 3-site skin fold method (triceps, suprailiac, thigh) was used to estimate body composition. All trials were completed within one year of the 2016 competitive season. Participants completed all GXTs with one-minute stages that progressively increased in velocity (mph) until volitional fatigue. Expired gases and heart rate (HR) were averaged over 15 seconds at the end of each stage where rating of perceived exertion (RPE) was given. Each GXT repeated the above procedure at the predesignated time points for the entirety of the study.

Subjects:

Twenty-two subjects initially consented to participate in this study. Five subjects dropped, three subjects were excluded due to positional characteristics (goalies), and three for injury and attrition. Therefore, 11 Division l female soccer players (Mean ± SD: 19.3 ± 1.0 yrs; 164 ± 6.4 cm; 60.1 ± 5.4 kg; 19.4 ± 3.5 %BF, 48.3 ± 4.0 kg FFM, 43.3 ± 3.3 ml/kg/min VO_{2max}) who had been participating in consistent running activities for a minimum of six months prior to testing were included in the study. Subjects were presented the inclusion criteria for the study as well as any risks that could occur during the study prior to giving informed written consent. The study was approved by the Longwood University Institutional Review Board and subjects completed a health history questionnaire prior to participation. Subjects were excluded if they had any cardiovascular, metabolic, pulmonary disorders, pregnancy, or had experienced any orthopedic injuries preventing safe testing. Subjects were asked not to exercise for 24 hours, refrain from caffeine for 12 hours, and not to consume any food four hours before testing.

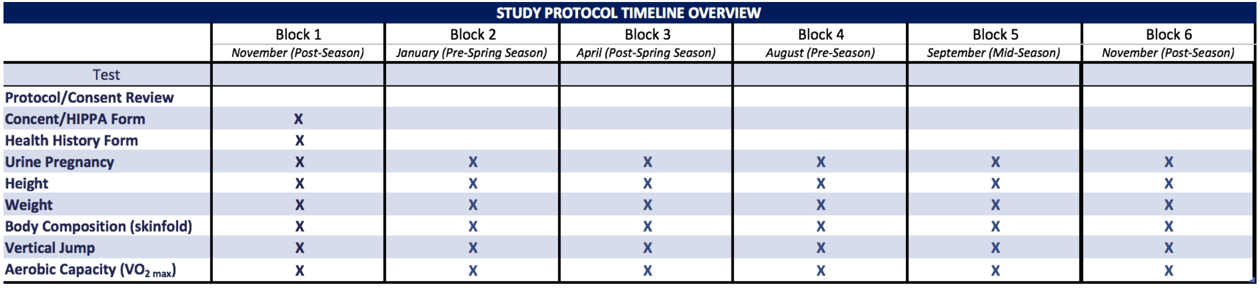
Body composition:

Prior to exercise for each testing block, subjects arrived at the lab where height and weight were measured via an electric standiometer and a scale (Seca Corp., Chino, CA, USA). Body density was estimated by a trained researcher using hand held calipers (Beta Technology, Santa Cruz, CA, USA) and the three site skin fold method: triceps, suprailiac, and thigh as described within the ACSM Guidelines for Exercise Testing and Prescription (American College of Sports Medicine, 2014). Using the body density measurement, percent body fat (%BF) was estimated using the Brozek conversion equation (Brožek, Grande, Anderson, & Keys, 1963).

Aerobic capacity testing:

Prior to all exercise testing for each testing block, subjects were screened for pregnancy using a urine pregnancy test as pregnancy was an exclusion criterion for this study. Before each exercise test, subjects completed a 5-min self-selected warm-up in order to get acclimated to treadmill running (Life Fitness Inc., Rosemont, IL, USA) and design a customized exercise protocol. Each exercise test protocol was customized to the subject and developed to progress the subject continuously while ensuring that volitional fatigue would occur within 8-12min as described by Yoon et al. (2007). Prior to the initiation of the exercise test, resting VO_2, HR (Polar Inc., Warminister, PA, USA), and RPE were measured for 1-min using a metabolic cart (ADInstruments Inc., Sydney, Australia) in the standing position prior to exercise using a wireless signal integrated into the metabolic cart from a chest strap. The exercise protocol consisted of subjects performing a treadmill GXT until volitional fatigue, while VO_2, HR, and RPE were collected at 1-min intervals. Each participant began the GXT at a walking pace with increasing velocity every minute until volitional fatigue. Standardized criteria for the determination of VO_{2max} along with a 15-sec running average as described by Robergs et al. (2010) were used to determine VO_{2max}. Each testing block repeated the above procedure across the annual training cycle at six pre-designated time points: post season 2016 (B1), transition (B2), spring season (B3), preseason (B4), mid-season (B5), and post season 2017 (B6) shown in Table 1.

Table 1- Protocol at designated time points throughout the annual



STUDY PROTOCOL TIMELINE OVERVIEW						
	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
	November (Post-Season)	*January (Pre-Spring Season)*	*April (Post-Spring Season)*	*August (Pre-Season)*	*September (Mid-Season)*	*November (Post-Season)*
Test						
Protocol/Consent Review						
Concent/HIPPA Form	X					
Health History Form	X					
Urine Pregnancy	X	X	X	X	X	X
Height	X	X	X	X	X	X
Weight	X	X	X	X	X	X
Body Composition (skinfold)	X	X	X	X	X	X
Vertical Jump	X	X	X	X	X	X
Aerobic Capacity ($VO_{2\ max}$)	X	X	X	X	X	X

Statistical Analysis:

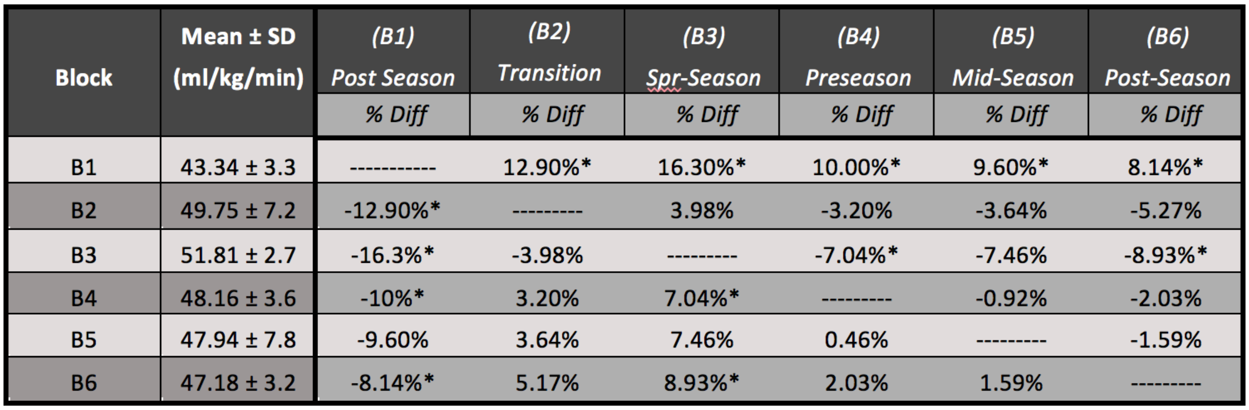
A 3x6 repeated measures ANOVA was used to analyze AC (VO_{2max}), %BF, and FFM across six time points (B1-B6) using Statistical Package for the Social Science (SPSS), Version 23 (IBM Corp., Armonk, NY, USA). The level of significance was set to ($p < 0.05$). When significant differences were observed, the LSD post hoc test was used to investigate any significant interaction between blocks.

Results:

Aerobic capacity:

The ANOVA test revealed a significant main effect of time on AC throughout the annual training cycle ($F_{2,5} = 2513.1$, $p < 0.001$) with an observed power of 1.0. Pairwise comparisons along with percent differences are shown in Table 2. Following the 2016 competitive season (B1), AC increased ($p < 0.05$) albeit a 9-week transition period with a reduced training load (B2). Aerobic capacity also increased after the spring season training (B3), where AC peaked but was not shown to be significant ($p > 0.05$). There was a significant decrease ($p < 0.02$) of 7.04% in AC over the preseason training period following the spring season (B3-B4). Statistically, AC remained unchanged across the 2017 competitive season (B4-B6) despite an 8.9% ($p = 0.007$) reduction in AC from the spring season (B3-B6).

Table 2- Pairwise comparisons of aerobic capacity at predesignated time points. Data are represented as mean + SD and percent differences. Comparisons across training cycle are relevant to block mean shown on the left.



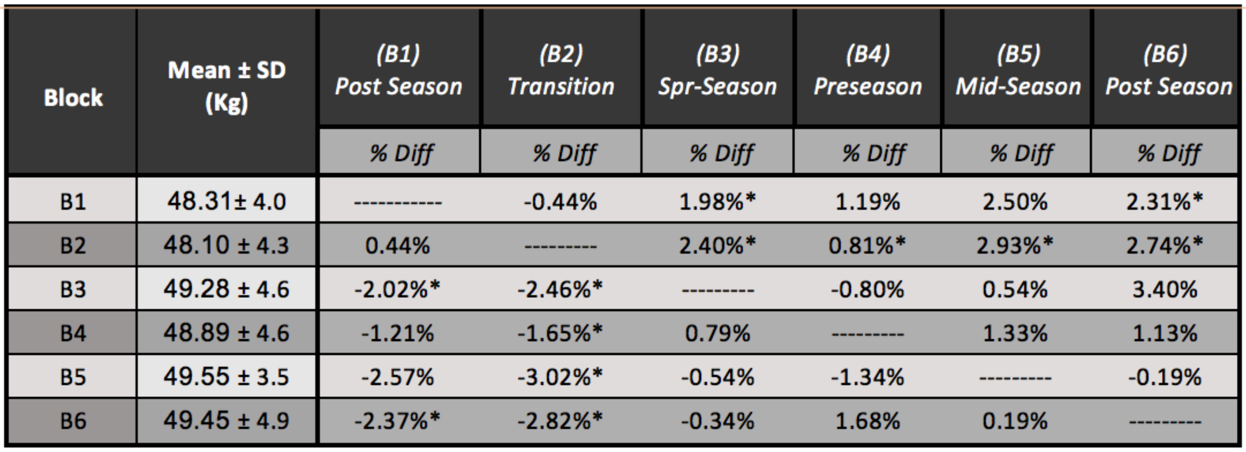
Block	Mean ± SD (ml/kg/min)	*(B1) Post Season*	*(B2) Transition*	*(B3) Spr-Season*	*(B4) Preseason*	*(B5) Mid-Season*	*(B6) Post-Season*
		% Diff	*% Diff*	*% Diff*	*% Diff*	*% Diff*	*% Diff*
B1	43.34 ± 3.3	-----------	12.90%*	16.30%*	10.00%*	9.60%*	8.14%*
B2	49.75 ± 7.2	-12.90%*	---------	3.98%	-3.20%	-3.64%	-5.27%
B3	51.81 ± 2.7	-16.3%*	-3.98%	---------	-7.04%*	-7.46%	-8.93%*
B4	48.16 ± 3.6	-10%*	3.20%	7.04%*	---------	-0.92%	-2.03%
B5	47.94 ± 7.8	-9.60%	3.64%	7.46%	0.46%	---------	-1.59%
B6	47.18 ± 3.2	-8.14%*	5.17%	8.93%*	2.03%	1.59%	---------

* Indicates significant difference compared to block mean (p < 0.05).

Body composition:

The ANOVA test revealed a significant main effect of time on body composition throughout the annual training cycle ($F_{2,5} = 2513.1$, $p < 0.001$), with an observed power of 1.0. No differences were observed in %BF ($p > 0.05$) throughout the annual training cycle (B1-B6) at any time point. Additionally, body mass was accounted for within the relative VO_2 (ml/kg/min) measures indicating that observed changes in AC where due to either training adaptation and/or FFM. Pairwise comparisons for FFM are presented in Table 3. After the conclusion of the 2016 competitive season (B1), FFM remained unchanged through the transition period (B2) while increasing by (Δ +2.6%, $p = 0.027$) over the spring season (B3). There was a non-significant (p >0.05) decrease in FFM (-0.39 kg) following the spring season prior to the competitive season (B3-B4). No differences ($p > 0.05$) were observed through the remainder of the 2017 competitive season (B5-B6).

Table 3- Pairwise comparisons of fat free mass at predesignated time points. Comparisons across training cycle are relevant to block mean shown on the left. Data are represented as mean± SD and percent differences.



Block	Mean ± SD (Kg)	*(B1) Post Season*	*(B2) Transition*	*(B3) Spr-Season*	*(B4) Preseason*	*(B5) Mid-Season*	*(B6) Post Season*
		% Diff	*% Diff*	*% Diff*	*% Diff*	*% Diff*	*% Diff*
B1	48.31± 4.0	-----------	-0.44%	1.98%*	1.19%	2.50%	2.31%*
B2	48.10 ± 4.3	0.44%	---------	2.40%*	0.81%*	2.93%*	2.74%*
B3	49.28 ± 4.6	-2.02%*	-2.46%*	---------	-0.80%	0.54%	3.40%
B4	48.89 ± 4.6	-1.21%	-1.65%*	0.79%	---------	1.33%	1.13%
B5	49.55 ± 3.5	-2.57%	-3.02%*	-0.54%	-1.34%	---------	-0.19%
B6	49.45 ± 4.9	-2.37%*	-2.82%*	-0.34%	1.68%	0.19%	---------

* Indicates significant difference compared to block mean ($p < 0.05$).

Discussion:

The purpose of this study was to observe the effect of the annual training cycle on AC in Division 1 female soccer players. The results indicate that the annual training cycle influenced both FFM and AC over the annual training calendar. Fat free mass is the principle tissue responsible for oxygen utilization during exercise and therefore players with a higher FFM typically possess a higher VO_{2max} (Covic, N., Rado, I., Dzenan, 2016; Gil, Gil, Ruiz, Irazusta, & Irazusta, 2007; Lago-Peñas et al., 2011). Our results suggest that FFM played a part in AC but was not the sole factor as to why AC fluctuated over the annual training cycle. Following the 2016 competitive season (B1-B2), a positive increase in AC ($p < 0.01$) occurred despite having no change in FFM ($p > 0.05$) (Figure 1). Our findings disagree with Gil et al. (2007) who assessed body composition and AC variances in young soccer athletes where players performed better in the aerobic test with increased percentages of muscle mass (Gil et al., 2007). However, Gil et al. (2007) used the Astrand bike test to predict VO_{2max} where we measured maximal aerobic capacity. While current literature on elite soccer athletes suggests that FFM has a positive effect on VO_{2max} resulting in an increased AC (Covic, N., Rado, I., Dzenan, 2016; Goran et al., 2000; Lago-Peñas et al., 2011), our results suggest that there is no relationship between FFM and VO_{2max} throughout the transition period (Figure 1) where rest was prioritized. Alternatively, prolonged rest time (greater than four weeks) has shown to decrease AC (Mujika & Padilla, 2000, 2001). However, Figure 1 demonstrates that prolonged rest positively influenced AC ($p < 0.01$) in the current population. A possible explanation for this is that a prolonged rest mitigated the amount of accumulated stress from the sustained increased training load throughout the competitive season.

FIGURE 1 HERE

Following the transition period, the spring season (B2-B3) included a rapid increase in training load that included CT. Incorporating CT can be problematic because it can lead to unnecessary increases in accumulated stress(J. R. Silva et al., 2016; Winsley & Matos, 2010) pushing the athlete into an over trained state (Alves et al., 2006; J. R. Silva et al., 2016), which has been previously shown to decrease AC (2,14). However, AC peaked in our population with CT throughout the spring season (B3) along with a significant increase in FFM ($p < 0.03$) shown in Figure 1. Concurrent training was the primary method utilized across B2-B3 and increases in FFM and AC were observed which agrees with previous literature (J. R. Silva et al., 2016; Wilson et al., 2012). The significant increase in FFM and AC were the result of CT which has been shown to decrease %BF while increasing FFM and AC if appropriate rest is included (Aagaard & Andersen, 2010; Chtara et al., 2005; Winsley & Matos, 2010).

Sudden increases in training load can be beneficial when appropriate rest is provided (J. R. Silva et al., 2016). While AC decreased following the spring season (B3), an abrupt increase in training load via the competitive season maintained the suppressed AC (Δ -8.9%, $p = 0.007$) despite large doses of competition and training (Table 2). Interestingly, a nonsignificant ($p >$

0.05) increase (3.4%) in FFM was observed across the competitive season (B4-B6) without an increase in AC (Figure 1). The increase in FFM suggests the increase in training load prompted favorable body composition changes. However, the increase in training load paired with little recovery may have suppressed AC because of accumulated stress in our population. Contrariwise, following a nine-week transition period (detraining) AC increased by 12.9% throughout the spring season (B3). During this time despite large doses of CT, there was a reduced volume of competitive games and training sessions. Across the preseason (pre-competitive season) (B3-B4), there was a 7% decrease (p <0.02) in aerobic capacity (Table 2) without a change in FFM (Table 3).

The spring season (B3) elicited the greatest adaptations from an increased training load from CT and direct oversight from coaching and strength and conditioning staff. During the spring season (B2-B3) our population had regular accessibility to coaches, strength staff, and athletic trainers. This coaching support leads to a greater training adherence (Anderson & Lavallee, 2008) and therefore more consistent and increased training adaptations. This same coaching support was not present during the preseason (B3-B4) which likely led to variations in training adherence (Anderson & Lavallee, 2008; Way, Jones, & Slater, 2012) and therefore impacted training volume and intensity. The limited coaching support led to a 7.0% (p = 0.021) decrease in AC from B3-B4 despite summer league competitions and self-directed training. The drop in AC prior to the competitive season was detrimental to the subject's physiological status because they were not able to recover from the decrease in AC experienced throughout the preseason (B3-B4). Furthermore, the increase in training load can put athletes at risk for unnecessary fatigue (Alves et al., 2006) (inability to recover from training stress), increased risk of injury (J. R. Silva et al., 2016), and suppression of training adaptations that include AC (Alves et al., 2006; Caldwell & Peters, 2009; Sæther & Aspvik, 2014).

The preseason typically focuses on performance development to prepare the athletes for the stresses of the competitive season (J. R. Silva et al., 2016). Our findings indicate that the coaching strategy deployed in the preseason (B3-B4) had negative outcomes despite the attempt to increase and/or maintain peak physiological performance capacity observed throughout the spring season (B3). A possible explanation for the deleterious effects on AC may stem from a perceived lack of coaching support during the preseason (Anderson & Lavallee, 2008). Division I conference guidelines limit player/coach communication throughout the preseason (B3-B4) leading to training programming and management limitations. The lack of coaching support during the preseason may have a psychological effect on players resulting in a lack of training adherence. Additionally, variations in training motivation can lead to poor training adherence (Way et al., 2012) negatively effecting training volume and frequency.

Performance throughout the competitive season may rely on the training volume and frequency that occurs during the preseason. Our population maintained a suppressed AC during the competitive season B4-B6 (48.16 ± 3.6; 47.94 ± 7.8; 47.18 ± 3.2 ml/kg/min; $p = 0.41$ respectively) despite the significant training load incurred by seasonal game play and practice sessions. Theoretically, players should be able to sustain peak performance capacity throughout the competitive season despite the accumulated training stress. While there was no change in AC during the competitive season (B4-B6), our sample competed with an 8.9% ($p = 0.007$) disadvantage from their peak measured potential prior to the competitive season (B3).

From B2 to B4 there were no relevant differences in AC (49.75 ± 7.2; 48.16 ± 3.6; $p = .450$). This is concerning because during this time there was six months of preparatory training prior to the competitive season. Prior to B2, there was a nine-week transition period where training load was significantly reduced. From B2-B4 there was increased training loads in an effort to prepare for the competitive season. However, our data show that AC was no different at the start of the competitive season than after nine weeks of rest despite the sustained increase in training load from B2-B4. Interestingly, despite lack of differences in AC at B2 and B4 time points, AC peaked at B3 and then reduced by 7.04% ($p = 0.021$) (Figure 1).

Conclusion:

Our results indicate that the annual training cycle affects both FFM and AC. Dramatic increases in training volume along with insufficient recovery may result in accumulated stress and therefore regular testing is warranted to evaluate the physiological status of athletes throughout the annual training cycle. While there was a dramatic increase in training volume following both the transition period (B2) and preseason (B4), the athletes responded differently to increased training load shown during the spring (B2-B3) and competitive (B4-B6) seasons. Concurrent training coupled with adequate recovery time in the spring season (B2-B3) provided the greatest improvement in AC and FFM with a decrease in %BF after spring season (B3). The perceived lack of coaching support during the preseason (B3-B4) may have influenced training motivation and therefore training adherence, thus reducing AC. The reduced AC throughout the preseason had residual effects negatively impacting performance capacity during the competitive season (B4-B6). The accumulated stress along with poor recovery during the competitive season likely resulted in chronic fatigue maintaining the suppressed AC. Therefore, pre-planning training outcomes across the annual training cycle is necessary to maintain high levels of AC and manage the fluctuation of training stress. Additionally, regular testing is warranted to monitor AC and body composition as they can be a performance indicator of fatigue in Division 1 female soccer players.

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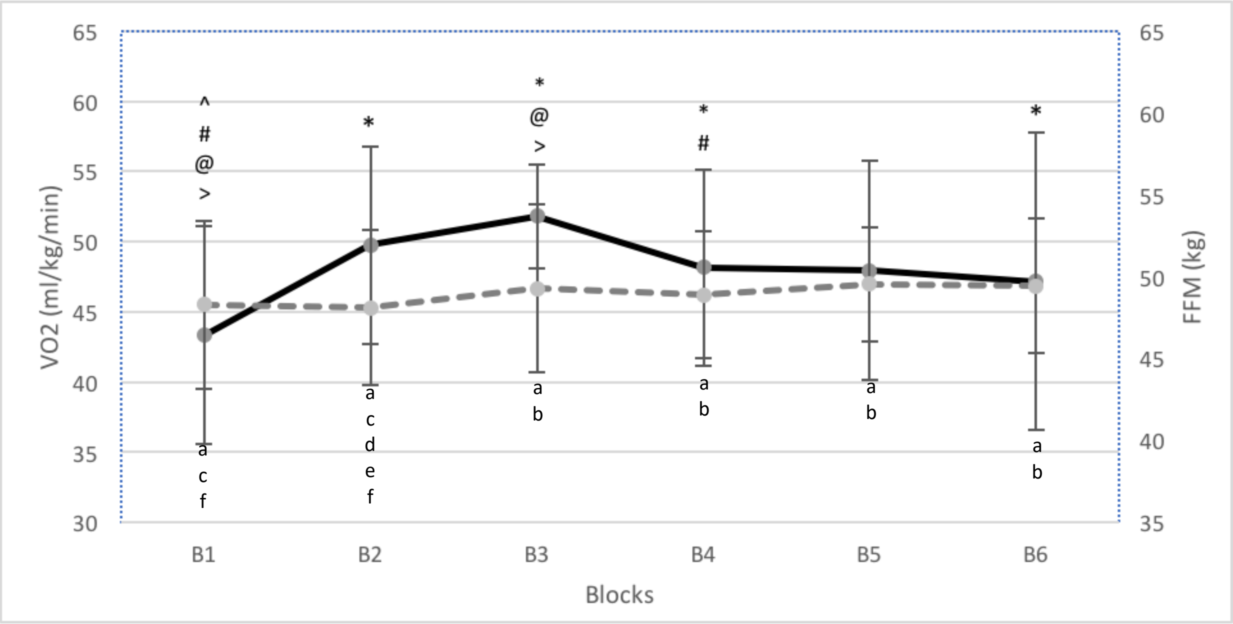

Figure 1- The solid line represents relative VO2max change across the annual training cycle while the dotted line represents fat free mass (FFM).

* Significantly different from B1 VO$_2$,	(a) significantly different from B1 FFM
^ Significantly different from B2 VO$_2$,	(b) significantly different from B2 FFM
# significantly different from B3 VO	(c) significantly different from B3 FFM
@ significantly different from B4 VO$_2$,	(d) significantly different from B5 FFM
+ Significantly different from B5 VO$_2$,	(e) significantly different from B6 FFM
> significantly different from B6 VO$_2$	