2018

# Periodization and the Annual Training Cycle: Effects on Anaerobic Power and Capacity in Division I Female Soccer Athletes

Lindsay Brown
*Longwood University*

## Recommended Citation

**Periodization and the Annual Training Cycle: Effects on Anaerobic Power and Capacity in Division I Female Soccer Athletes**

L. Brown, KS. Levers, TM. Purdom, P. Martin, J. Giles, C. McPherson, J. Howard

Health, Athletic Training, Recreation, Kinesiology Department, Longwood University, Farmville, VA 23909

**Brief Running Title:** Effects of self-directed training on maintenance of anaerobic power

**Corresponding Author:**

Kyle Levers, PhD, CSCS
College of Education & Human Services
Longwood University
Farmville, VA, 23909
Email: leversks@longwood.edu
Phone: (434) 395-2533

**ABSTRACT**

Seasonal variations in sprint speed, jumping power and repeated-sprint capacity have been shown to occur throughout an annual training cycle. However, how these changes in power and anaerobic capacity throughout the calendar year affect the maintenance of power and anaerobic capacity over the competitive season for Division I female soccer athletes, is not currently known. The aim of this study was to observe the changes in anaerobic power and capacity over the annual training cycle in collegiate female soccer athletes. Multiple anaerobic power tests were performed on fourteen Division I female soccer athletes (Mean ± SD: 19.4 ± 1.04yrs; 60.8 ± 5.4kg; 164.9 ± 6.2cm; 19.5 ± 3.2%BF; 48.9 ± 3.9kg FFM) at five specific time points throughout the 2016-2017 training calendar. Anaerobic power testing consisted of the countermovement vertical jump (CMJ) for vertical power (VPWR), the 40-yard sprint for horizontal power (HPWR). The 35-meter running anaerobic sprint test (RAST) was also used to measure peak horizontal power (RASTppwr), average horizontal power (RASTapwr), and anaerobic capacity (fINDX). Two 5x5 repeated measures ANOVAs (absolute and relative power) were used to observe changes in values across the five testing blocks. Post-hoc LSD pairwise comparisons were used when significant interactions occurred. The overall relative power statistical analyses revealed significant changes in anaerobic performance across the annual training calendar ($p$ <0.001) with an observed power of 0.991 (units). Pairwise comparisons showed a significant increase in anaerobic performance relative to FFM over the spring season (B2-B3), specifically in vertical power (Δ 14.75%, $p$ = 0.018), RAST max power (Δ 12.77%, $p$ = 0.005), RAST average power (Δ 13.38%, $p$ <0.001), and 40-yd sprint horizontal power (Δ 9.13%, $p$ = 0.049). During the self-directed summer training (SDST) period (B3-B4) significant decrements in relative vertical power (Δ -13.38%, $p$ = 0.017), RAST max power (Δ -5.69%, $p$ = 0.038), and RAST average power (Δ -4.96%, $p$ = 0.024) were demonstrated. Anaerobic performance over the entire off-season training period (B2-B4) showed a significant increase in relative RAST average power (Δ 7.47%, $p$ = 0.012). Anaerobic performance across SDST and the competitive season (B3-B6) showed a significant decrement in relative vertical power (Δ -13.08%, $p$ =

0.010) and RAST max power ($\Delta$ -6.64%, $p = 0.016$). While the spring training season had a significantly positive effect on anaerobic power, limited changes in anaerobic performance occurred throughout the annual training cycle, particularly over the entire off-season training period and the competitive season. Additionally, SDST significantly decreased competitive season readiness through decrements in anaerobic power likely attributed to an unstructured training environment and restricted athlete-coach communication. Due to high competitive season training volumes, Division I female soccer athletes are unable to recover from the lasting consequences of insufficient summer training during the competitive season. Additionally, the lack of change in anaerobic performance over the annual training calendar suggests the presence of barriers within the current training regimen that impede the sustainability of a proper anaerobic training foundation that can be built upon each year.

**Key Words:** Annual training calendar, training base, anaerobic capacity, anaerobic power, periodization

**INTRODUCTION**

Soccer is considered a high intensity sport that integrates powerful athletic actions such as jumping, kicking, sprinting, frequently changing directions, acceleration, and deceleration in great frequency throughout an entire match (Stølen, Chamari, Castagna, & Wisløff, 2005). Performance measures such as vertical power, horizontal power, and anaerobic capacity can be used to predict performance components in populations of soccer participants. The ability to properly periodize a training program to improve anaerobic power and anaerobic capacity over the course of an annual training cycle, while maintaining power over the competitive season, is vital to improving competitive performance, skill development, recovery, and to reduce the incidence of injury (Caldwell & Peters, 2009; Kraemer et al., 2004). Therefore, timing of the appropriate training stimuli as well as preplanning for recovery and rest periods throughout the annual training program, are vital components that allow athletes to avoid overtraining.

Overtraining can be described as any increase in exercise or training volume and/or intensity that results in long-term (several weeks or months, or longer) physical performance decrements and fatigue (A. Fry & Kraemer, 1997; Kuipers & Keizer, 1988). An indicator of overtraining is a decrease in physical performance despite continued training. Overtraining can result in reductions in muscular force production, decreased reaction time, and decrements in mental cognition and psychological performance (A. Fry & Kraemer, 1997; Kraemer et al., 2004). Research suggests that overtraining can be due to prolonged physiological and psychological stress combined with excessively high training loads in a short period of time (A. Fry & Kraemer, 1997; Kraemer et al., 2004). Symptoms of overtraining are commonly identified in collegiate soccer athletes, especially during the competitive season, due to the prolonged exposure to high levels of physical and mental stress from practices, conditioning, competition and travel, in addition to inadequate rest and recovery timelines (Kraemer et al., 2004).

Athletes involved in sports that require frequent and prolonged periods of high intensity speed, strength, power and coordination are more susceptible to overtraining (A. Fry & Kraemer, 1997).

Overtraining can also be due to highly aerobic activity as well as anaerobic exercise, though the two stimuli do not necessarily relate (A. C. Fry, Kraemer, Koziris, Lynch, & Triplettl, 1994; A. Fry & Kraemer, 1997). Furthermore, longitudinal studies regarding overtraining and highly aerobic activity have been performed, but limited long-term research is available regarding overtraining and anaerobic exercise (A. Fry & Kraemer, 1997;  A. C. Fry, Kraemer, & Ramsey, 1998; Hooper, MacKinnon, Gordon, & Bachmann, 1993; Lehmann et al., 1991). As a result, it is highly important to schedule performance tests and evaluate the athletes throughout the annual training cycle to observe the impact of seasonal training programming on vital soccer performance variables such as anaerobic power and capacity (Silva, Brito, Akenhead, & Nassis, 2016).

Previous research has recognized that variations in seasonal training intensity and volume causes alterations in anaerobic power and capacity over the course of the annual training cycle in soccer athletes (Caldwell & Peters, 2009; Hartmann et al., 2015; Kraemer et al., 2004; Ostojic, 2003). Other literature suggests that changes in anaerobic power and capacity are due to training goals associated with the change in the annual calendar relevant to the competitive season (Caldwell & Peters, 2009). In a periodized training program, training blocks should be designated to promote optimal performance during the competitive season. These blocks can be broken down into the pre-competitive season, competitive season, post-competitive season, the off-season, and spring training in which these blocks all have specific outcomes aimed at improving sport performance (Hartmann et al., 2015). Generally, it has been found that pre-season training has a positive effect on anaerobic power and detraining periods have a negative effect on anaerobic power. A study involving thirteen semiprofessional male soccer athletes tested the subjects five times over a 12-month period to investigate seasonal variations in physical fitness. Utilizing the countermovement standing vertical jump and a 15-meter sprint test, this study found that vertical and horizontal anaerobic power significantly increased during the pre-season but, decreased during the post-competitive season (off-season). The study also found that vertical power

significantly decreased from mid-competitive season to post-competitive season, while horizontal power remained unchanged over the same time period (Caldwell & Peters, 2009).

Another study investigated twenty-five male collegiate soccer athletes five times over an 11-week competitive season to observe changes in physical performance levels in starters versus non-starters (Kraemer et al., 2004). By measuring maximal vertical jump height in addition to the 20-yard and 40-yard sprint tests, Kraemer et al. found that starting players' 20-yard sprint times significantly decreased from the start of the competitive season to post-competitive season, while no significant changes occurred in the 40-yard sprint over the competitive season. Over the same period, vertical jump height in the starting players significantly decreased. Nonstarters, however, displayed no significant changes in the 20-yard sprint, 40-yard sprint, or vertical jump height over the competitive season. The study concludes that athletes should have a planned program of conditioning, that does not result in acute overtraining, prior to pre-competitive season to avoid performance reductions during the competitive season (Kraemer et al., 2004). An additional study involving fifteen Spanish Division I male soccer athletes observed seasonal variations in performance by testing in September (beginning of the league championship) and again in February (beginning of the second round of league championship). A countermovement jump was used to measure anaerobic power. This study reported no significant changes in vertical anaerobic power over the testing period, while athletes maintained their fitness level, with a high $VO2_{max}$, throughout league championship season (Casajús, 2001).

Though data has been reported regarding the effect of seasonal changes on elite soccer athletes (Caldwell & Peters, 2009), there is a lack of research investigating anaerobic performance changes by season or throughout the annual training calendar in Division I soccer female athletes. Other studies have observed the physiological profile of male soccer athletes. A study by Ostojic (2003) tested thirty professional male soccer athletes to observe alterations in body composition and sprint performance over the annual training cycle (Ostojic, 2003). Data revealed body fat percentage was significantly lower and 50-meter sprint times were faster at post-competitive season compared to pre-competitive season, as

well as body fat percentage significantly dropped during conditioning periods and increased during the off-season (Ostojic, 2003). Another study by Loturco and colleagues (2016) investigated training methods to improve speed and power performances during a short-term preseason in twenty-seven high-level male soccer athletes, finding jump squat exercises were superior to the Olympic push-press in improving speed and power abilities in their population (Loturco et al., 2016).  Spierer et al. (2011) examined the effect of visual and auditory stimuli on sprint speed, sprint time and reaction time on fifteen collegiate male soccer athletes and found that visual stimuli rather than auditory stimuli improved sprint response times (Spierer, Petersen, & Duffy, 2011). A more recent study by Jezdimirovic et al. (2013) on anaerobic performance parameters used thirty-two male soccer athletes to investigate explosive leg power based on field position (Jezdimirovic, Joksimovic, Stankovic, & Bubanj, 2013). Analysis of vertical jump height variables expressed that goalkeeper, defense and forward field positions had a significantly higher vertical jump compared to midfield field positions.

Previous research suggests that males and females have similar levels of anaerobic and aerobic capacities, however, it is difficult to compare the two due to a lack of data regarding female athletes in the existing literature (Andersson et al., 2008; Davis & Brewer, 1993; Stølen et al., 2005). Additionally, the current literature tends to favor acute studies, examining only seasonal blocks of time compared to a complete 12-month training cycle. This results in a paucity of literature investigating anaerobic performance changes over the entire calendar year and the effects of annual periodization on anaerobic sustainability throughout the competitive season, particularly in female soccer athletes.

The purpose of our study was to observe the changes in anaerobic power and capacity over the annual training cycle in collegiate female soccer athletes. In addition, another aim of this study was to determine how changes in power and capacity throughout the calendar year, affect the maintenance of anaerobic power and capacity over the competitive season. We hypothesized that anaerobic power and capacity would increase after spring season training, decrease after the competitive season, and decrease following the post-competitive season detraining period. Additionally, we also hypothesized that self-

directed summer training in this population would have a negative impact on power and anaerobic capacity and the maintenance of power and capacity during the competitive season.

## METHODS

### Experimental Approach to the Problem

Division I female soccer athletes were utilized to examine changes in anaerobic power and anaerobic capacity over the course of an annual training cycle. Data collection for this study took place at five time points (blocks) throughout the 2016-2017 training calendar. Block 1 (B1) took place in November immediately after the 2016 competitive season, block 2 (B2) at the beginning of the spring season in January 2017 (after a 9-wk detraining period), block 3 (B3) at the end of the spring season in April, block 4 (B4) at the beginning of the competitive season in August (prior to pre-season training) and block 6 (B6) in November immediately after the 2017 competitive season. The overall study timeline is shown in Figure 1.

All subjects completed an informed consent and a health history questionnaire which were completed before the familiarization session. Subjects then completed a group familiarization session where they were provided detailed information regarding the study design and testing procedures. Within the five pre-designated research blocks, subjects completed all measures in a single testing session. Inclusion criteria were female Division I collegiate soccer players between the ages of 18 and 25 years old, that also participated in consistent running activities for at least six months prior to the study. Subjects who self-reported diagnosed medical conditions within their health history, including, but not limited to cardiovascular, pulmonary, endocrine, and/or orthopedic (precluding or limiting testing performance) pre-existing conditions were excluded from the study. Prior to each testing block, the subjects were instructed to arrive at the testing laboratory having fasted for four hours, refrain from caffeine for 12 hours, and avoid alcohol and exercise for 24 hours prior to testing. This study was approved by the Longwood University Institutional Review Board.

Assessed for eligibility and
consented (n=22)

Block I
(n=22)
Post-2016 Competitive Season [Nov 2016]

Dropped from study (n=1):
• Quit collegiate soccer team after
  contracting mononucleosis before end
  of competitive season (n=1)

Block II
(n=21)
Pre-Spring Season [Jan 2017]

Dropped from study (n=2):
• Quit collegiate soccer team during
  Spring season for reasons unrelated to
  the study (n=2)

Block III
(n=19)
Post-Spring Season [Apr 2017]

Dropped from study (n=2):
• Quit collegiate soccer team during
  Spring season for reasons unrelated to
  the study (n=2)

Block IV
(n=17)
Pre-2017 Competitive Season [Aug 2017]

Block VI
(n=17)
Post-2017 Competitive Season [Nov 2017]

Removed from study analysis (n=3):
• Considerable training, competition,
  and testing (> 1 testing block) missed
  due to injury. Broken toe (n=1); ACL
  tear and reconstruction (n=1)
• Back-up goal keeper with limited
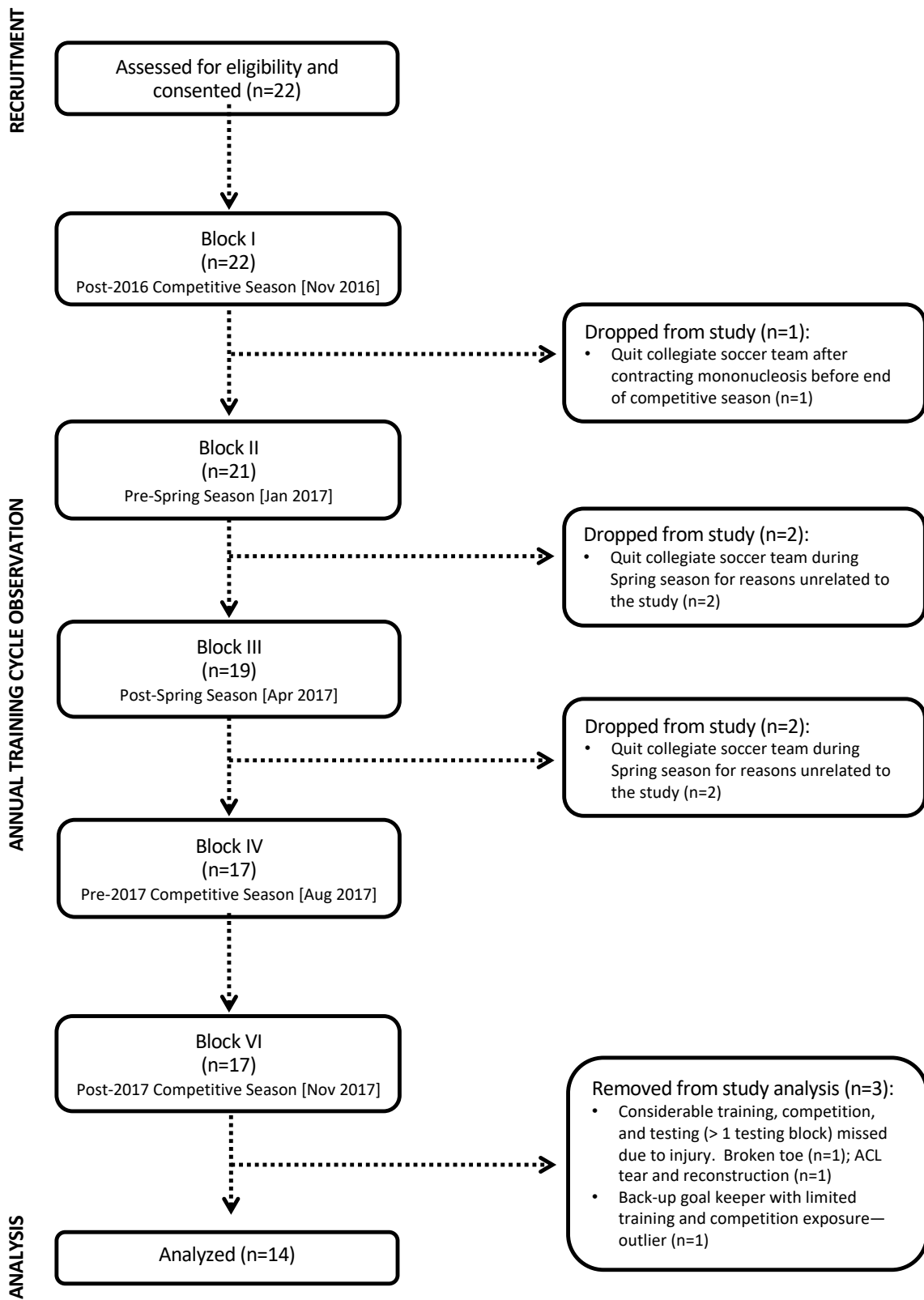  training and competition exposure—
  outlier (n=1)

Analyzed (n=14)

Figure 1. Consort diagram breakdown of the subject population from recruitment to data analysis.

Demographic and anthropometric measures that included height, weight, and body composition (three-site skin fold method described in *Procedures*) were measured at each block before exercise testing. Then, the countermovement vertical jump (CMJ), 40-yard sprint time, and 35-meter running anaerobic sprint test (RAST) were measured to determine values of anaerobic power and capacity. All subjects participated in a standardized warm-up protocol prior to performance data collection.

**Subjects**

Fourteen healthy, Division I female soccer athletes participated in this study. Subjects were recruited through electronically distributed study advertisements and open study informational sessions at Longwood University. Figure 1 demonstrates the breakdown of the subject population as it pertains to the study progression. Discontinuation of any subject participation was not related to any aspect of the testing protocol or study overall. Subjects who did not complete one or more of the five testing blocks and were not included in the final data analysis.

**Procedures**

All testing took place in a temperate controlled indoor environment to ensure consistent conditions throughout the annual training calendar. Additionally, prior to all performance testing, subjects completed a standardized 5-minute warm-up protocol consisting of cardiovascular exercise and task-relevant movement preparation activities.

*Body Composition*

The three-site skinfold technique for females defined by the American College of Sports Medicine (ACSM) was utilized to analyze body composition for this study (ACSM, 2014). This skinfold technique utilized a Lange skinfold caliper (*Beta Technology, Santa Cruz, CA, USA*) to measure the width of a pre-designated skin pinch, containing a double layer of skin and underlying fat. The three predesignated measurement sites consisted of (1) back of the upper arm (triceps), (2) above the hipbone (suprailiac) and (3) middle of the thigh (thigh). Subjects were instructed to stand in anatomical position for this procedure. Each measurement was taken on the right side of the body and was taken a minimum

of two times (if measurements were not within 1 to 2 mm of each other, additional measurements were taken) to assure accuracy. The Jackson and Pollock three-site skinfold formula was then used to determine body density due to its proven accuracy in women of differing age and body composition (Jackson, Pollock, & Ward, 1980). The accumulated width of all three-site measurements utilizing this formula was used to estimate subjects' body density. Once body density was calculated, the Brozek formula was used to convert body density values to body fat percentage as previous research has demonstrated this formula to have high accuracy amongst female athletes (Broiek, Grande, Anderson, & Keys, 1953; Sinning & Wilson, 1984).

*Countermovement Vertical Jump*

The countermovement vertical jump (CMJ) test measures vertical anaerobic power and was the first performance measure implemented in the testing battery. A Vertec Jump Trainer (*Jump USA, Sunnyvale, CA, USA*) was used to measure vertical jump height. The Harmon formula was then used to estimate vertical power from changes in vertical jump height due to its proven validity in utilization of jump height and body mass to estimate vertical peak and average power (Canavan & Vescovi, 2004; Harman, Rosenstein, Frykman, Rosenstein, & Kraemer, 1991). Additionally, the Harmon formula has proven relevance in athletic populations, providing accuracy in quick screening of athletes and monitoring progress of physical training (Canavan & Vescovi, 2004; Harman et al., 1991). The dominant arm of the subject was recorded prior to measuring standing reach height. Subjects were not allowed to take any steps leading into the jump and performed three jump attempts with a 30-second rest between attempts. Vertical jump height was calculated by subtracting standing reach height from the maximal jump height achieved for each attempt. The greatest jump height attained within the three attempts was recorded.
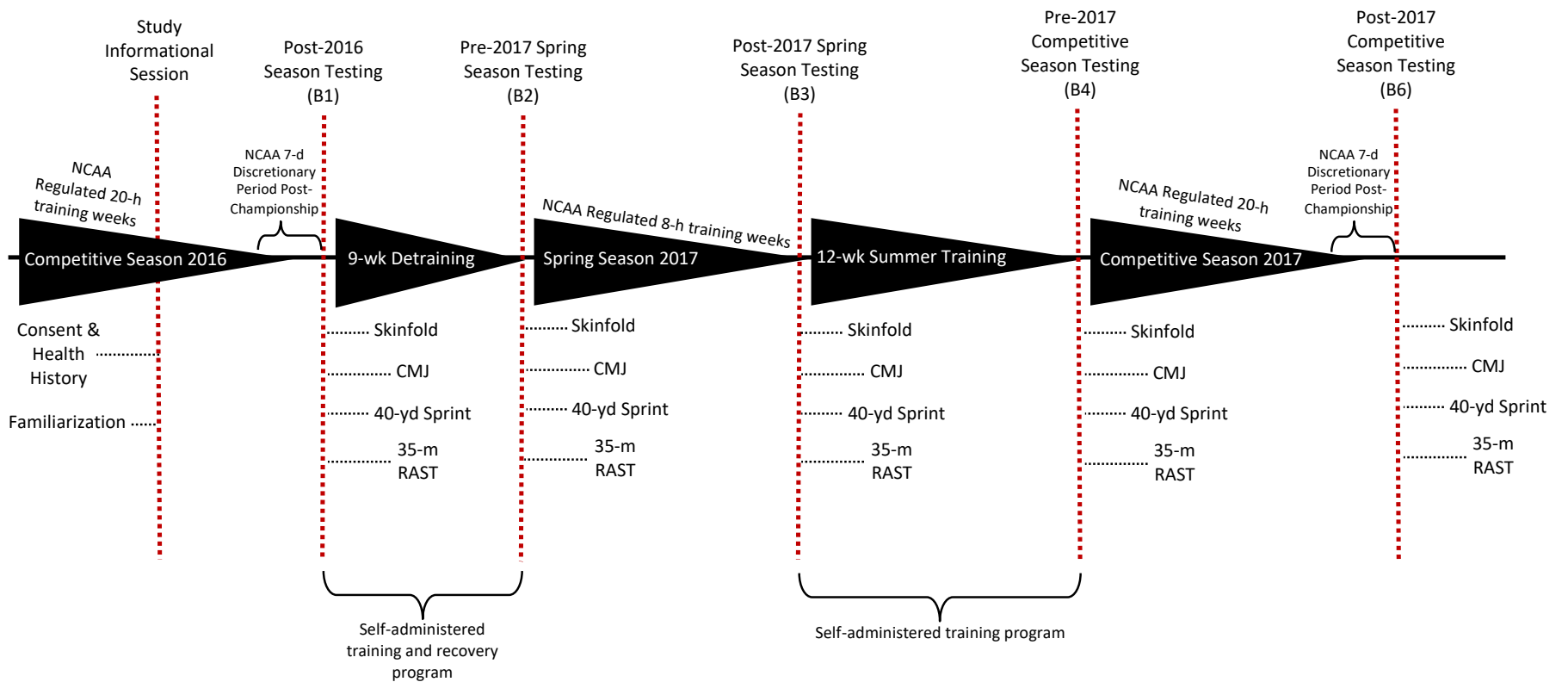
Figure 2. Experimental study design. CMJ = countermovement jump, 35-m RAST = 35-meter running anaerobic sprint test, 7-d = 7-day, 8-h = 8-hour, 20-h = 20-hour.

*40-yard Sprint*

The 40-yard sprint test was used to measure linear anaerobic power and was the second performance measure implemented in the testing battery. Footwear and the two-point staggered sprint starting position were standardized across all subjects and blocks. Subjects started the sprint when prompted by the researcher, and sprint performance was recorded to the one-hundredth of a second using a handheld stopwatch (*Robic Timers, Hilton Head Island, SC, USA*). Subjects completed two maximal sprint trials with a standardized three-minute recovery between trials. The average sprint time attained between the two trials was recorded. Horizontal power from the 40-yard sprint test was calculated by utilizing body mass and running times to asses anaerobic power (power (watts) = (body mass (kg) x distance$^2$ (m)) / time$^3$ (s)) (Draper & Whyte, 1997; Fernández-de-las-Peñas, Downey, & Miangolarra-Page, 2005).

*35-meter Running Anaerobic Sprint Test*

The 35-meter Running Anaerobic Spring Test (RAST) was utilized to measure linear anaerobic power and capacity (i.e. fatigue index) and was the last performance measure implemented in the testing battery. Subjects ran a series of six 35-meter sprints, each separated by a standardized 10 second rest period. Two researchers were used to time sprint and rest intervals for each RAST test, one at either end of the 35-meter runway. Footwear and the two-point staggered sprint starting position were standardized across all sprint intervals, subjects and blocks. Subjects started each sprint interval at the prompting of the researcher and sprint performance was recorded to the one-hundredth of a second using a handheld stopwatch (*Robic Timers, Hilton Head Island, SC, USA*). Subjects completed this test once within each testing block, allowing for proper measurement of horizontal power and fatigue index. The RAST uses body mass and running times to asses anaerobic power (Power = (Body Mass x Distance$^2$) / Time$^3$), (Peak Power = (Body Mass x Distance$^2$) / Fastest Time$^3$), (Minimum Power = (Body Mass x Distance$^2$) / Slowest Time$^3$) and fatigue index (FI = (Peak Power – Minimum Power / Peak Power) x 100) in each sprint (Draper & Whyte, 1997; Fernández-de-las-Peñas et al., 2005). Additionally, the RAST is relevant

in soccer populations due to the repeated sprint nature of soccer for 30 to 45-minute periods in addition to its high test reliability and validity (Fernández-de-las-Peñas et al., 2005).

**Statistical Analysis**

Data is presented throughout the text and in all tables as means and standard deviations (mean ± SD) or the percent change between training sessions. Absolute power data is reported as watts (W), relative power is reported as watts/FFM (kg). All related variables were grouped and analyzed using two 5x5 repeated measures ANOVAs for absolute power and relative power (FFM)). The IBM SPSS Statistical Software version 25.0 for Mac (*IBM Corporation, Armonk, NY, USA*) was used for statistical analysis. In addition, a 3x5 repeated measures ANOVA was performed to determine changes in body composition across the annual training calendar. When Mauchly's test indicated assumptions of sphericity violations within the statistical analysis, the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity. Post-hoc LSD pairwise comparisons were used to analyze any overall dependent variable significant differences ($p<0.05$) across time points. Data was considered statistically significant when the probability of error was less than 0.05 ($p<0.05$).

**RESULTS**

*Subject Characteristics*

Fourteen healthy, Division I female soccer athletes (19.4±1.0 yrs., 60.8±5.4 kg, 164.9±6.2 cm, 19.5±3.2% body fat, 48.9±3.9 kg FFM) participated in this study. There were no significant effects of the training periods within the annual training cycle on measures of body composition, $F_{(5, 9)} = 1.45$, $p < 0.152$, with an observed power of 0.690. We also found no significant changes across the annual training cycle in body weight, $F_{(2.32, 30.18)} = 1.89$, $p = 0.163$, body fat percentage, $F_{(4, 52)} = 1.57$, $p = 0.196$, and FFM , $F_{(2.32, 30.11)} = 1.84$, $p = 0.171$.

3x5 repeated measures ANOVA showed no significant changes in body composition statistically analyzed over the annual training calendar.  Furthermore, univariate analysis of all body composition variables showed no significant changes over the annual training calendar.

*Annual Training Cycle*

The overall absolute power statistical analysis revealed a significant effect of different training periods on absolute power, $F_{(5, 9)} = 3.11$, $p < 0.001$, with an observed power of 0.996. Examination of each outcome variable within the absolute power model revealed a significant effect of different training periods on RAST max power, $F_{(4, 52)} = 3.93$, $p = 0.007$, and RAST average power, $F_{(1.47, 19.13)} = 4.72$, $p = 0.030$, with an observed power of 0.876 and 0.638, respectively. Vertical power ($p = 0.141$), fatigue index ($p = 0.372$), and 40-yard sprint horizontal power ($p = 0.061$) did not show significant changes across time.

The overall relative power statistical analysis demonstrated a significant effect of different training periods on relative (FFM) power, $F_{(5, 9)} = 2.78$, $p < 0.001$, with an observed power of 0.991. Examination of each outcome variable within the relative (FFM) power analysis did not reveal significant changes for vertical power ($p = 0.097$), RAST max power ($p = 0.057$), RAST average power ($p = 0.080$), or 40-yard sprint horizontal power ($p = 0.232$) (Refer to Table 1. for analyses).

*Pre-Spring Season to Post-Spring Season 2017*

Table 1 reports absolute and relative anaerobic data collected before and after the spring season training period (B2-B3). Post-hoc analysis of the absolute power data over this training period revealed significant increases in vertical power ($\Delta$ 18.19%, $p = 0.012$), RAST max power ($\Delta$ 16.16%, $p = 0.003$), RAST average power ($\Delta$ 16.90%, $p < 0.001$), and 40-yd sprint horizontal power ($\Delta$ 12.38%, $p = 0.017$) as seen in Figure 3. Examination of power relative to FFM also displayed significant increases in vertical power ($\Delta$ 14.75%, $p = 0.018$), RAST max power ($\Delta$ 12.77%, $p = 0.005$), RAST average power ($\Delta$ 13.38%, $p < 0.001$), and 40-yd sprint horizontal power ($\Delta$ 9.13%, $p = 0.049$) as seen in Figure 4. No significant absolute or relative changes in fatigue index were observed during this training period ($p > 0.05$) as represented in Figure 5.

## Table 1: Annual Training Calendar (B1-B6)

| Variable | B1 (Nov 2016) | B2 (Jan 2017) | B3 (Apr 2017) | B4 (Aug 2017) | B6 (Nov 2017) | p-value |
|---|---|---|---|---|---|---|
| abs VPWR (W) | 395.12 ± 193.07 | 392.09 ± 189.90 | 448.02 ± 198.98 | 398.77 ± 218.66 | 406.08 ± 219.99 | $p = 0.141$ |
| rel VPWR (W/kg FFM) | 7.87 ± 3.45 | 7.94 ± 3.39 | 8.84 ± 3.41 | 7.93 ± 3.87 | 7.97 ± 3.83 | $p = 0.097$^ |
| abs RAST Max PWR (W) | 435.45 ± 87.95 | 397.76 ± 69.54 | 454.68 ± 53.57 | 421.04 ± 59.13 | 418.94 ± 41.95 | $p = 0.007$* |
| rel RAST Max PWR (W/kg FFM) | 8.94 ± 1.78 | 8.27 ± 1.29 | 9.23 ± 1.17 | 8.64 ± 0.99 | 8.55 ± 0.88 | $p = 0.057$^ |
| abs RAST Avg PWR (W) | 312.93 ± 78.08 | 313.96 ± 34.85 | 364.24 ± 37.49 | 340.09 ± 33.58 | 345.81 ± 34.63 | $p = 0.266$ |
| rel RAST Avg PWR (W/kg FFM) | 6.47 ± 1.71 | 6.54 ± 0.67 | 7.39 ± 0.82 | 6.99 ± 0.65 | 7.05 ± 0.65 | $p = 0.080$^ |
| Fatigue Index | 0.33 ± 0.10 | 0.34 ± 0.13 | 0.37 ± 0.10 | 0.34 ± 0.06 | 0.31 ± 0.06 | $p = 0.372$ |
| abs 40-yd Sprint HPWR (W) | 427.08 ± 68.21 | 410.47 ± 64.65 | 455.65 ± 60.59 | 431.32 ± 74.12 | 438.14 ± 67.89 | $p = 0.061$^ |
| rel 40-yd Sprint HPWR (W/kg FFM) | 8.75 ± 1.26 | 8.53 ± 1.13 | 9.25 ± 1.30 | 8.82 ± 1.16 | 8.88 ± 0.90 | $p = 0.232$ |

Data expressed as means ± SD. Data represents anaerobic power and capacity performance changes across the annual training calendar. Univariate ANOVA p-levels from the overall repeated-measures ANOVA analysis are presented for each variable under each condition (absolute and relative power). The Greenhouse-Geisser corrected value was reported for univariate measures that violated the assumption of sphericity. Significance at the $p<0.05$ p-level is indicated by the * superscript and significance at the $p<0.10$ p-level is indicated by the ^ superscript. abs = absolute; rel = relative; VPWR = vertical power; PWR = power; HPWR = horizontal power; W = Watts; FFM = free-fat mass; B1 = post-Competitive Season 2016; B2 = pre-Spring Season; B3 = post-Spring Season; B4 = pre-Competitive Season; B6 = post-Competitive Season 2017

## Table 2: Pre-Spring Season to Post-Spring Season (B2-B3)

| Variable | B2 (Jan 2017) | B3 (Apr 2017) | Raw Change | p-value |
|---|---|---|---|---|
| abs VPWR (W) | 392.09 ± 189.90 | 448.02 ± 198.98 | (+)55.92 | $p = 0.012$* |
| rel VPWR (W/kg FFM) | 7.94 ± 3.39 | 8.84 ± 3.41 | (+)0.90 | $p = 0.018$* |
| abs RAST Max PWR (W) | 397.76 ± 69.54 | 454.68 ± 53.57 | (+)56.92 | $p = 0.003$* |
| rel RAST Max PWR (W/kg FFM) | 8.27 ± 1.29 | 9.23 ± 1.17 | (+)0.96 | $p = 0.005$* |
| abs RAST Avg PWR (W) | 313.96 ± 34.85 | 364.24 ± 37.49 | (+)50.28 | $p < 0.001$* |
| rel RAST Avg PWR (W/kg FFM) | 6.54 ± 0.67 | 7.39 ± 0.82 | (+)0.85 | $p < 0.001$* |
| Fatigue Index | 0.34 ± 0.13 | 0.37 ± 0.10 | (+)0.03 | $p = 0.444$ |
| abs 40-yd Sprint HPWR (W) | 410.47 ± 64.65 | 455.65 ± 60.59 | (+)45.19 | $p = 0.017$* |
| rel 40-yd Sprint HPWR (W/kg FFM) | 8.53 ± 1.13 | 9.25 ± 1.30 | (+)0.71 | $p = 0.049$* |

Data expressed as means ± SD. Data represents anaerobic power and capacity performance changes across the Spring-Season training period. Univariate ANOVA p-levels from the overall repeated-measures ANOVA analyses are presented for each variable under each condition (absolute and relative power) and are listed from the LSD post-hoc analysis. Significance at the $p<0.05$ p-level between timepoints is indicated by the * superscript.  abs = absolute; rel = relative; VPWR = vertical power; PWR = power; HPWR = horizontal power; W = Watts; FFM = free-fat mass; B2 = pre-Spring Season timepoint; B3 = post-Spring Season timepoint
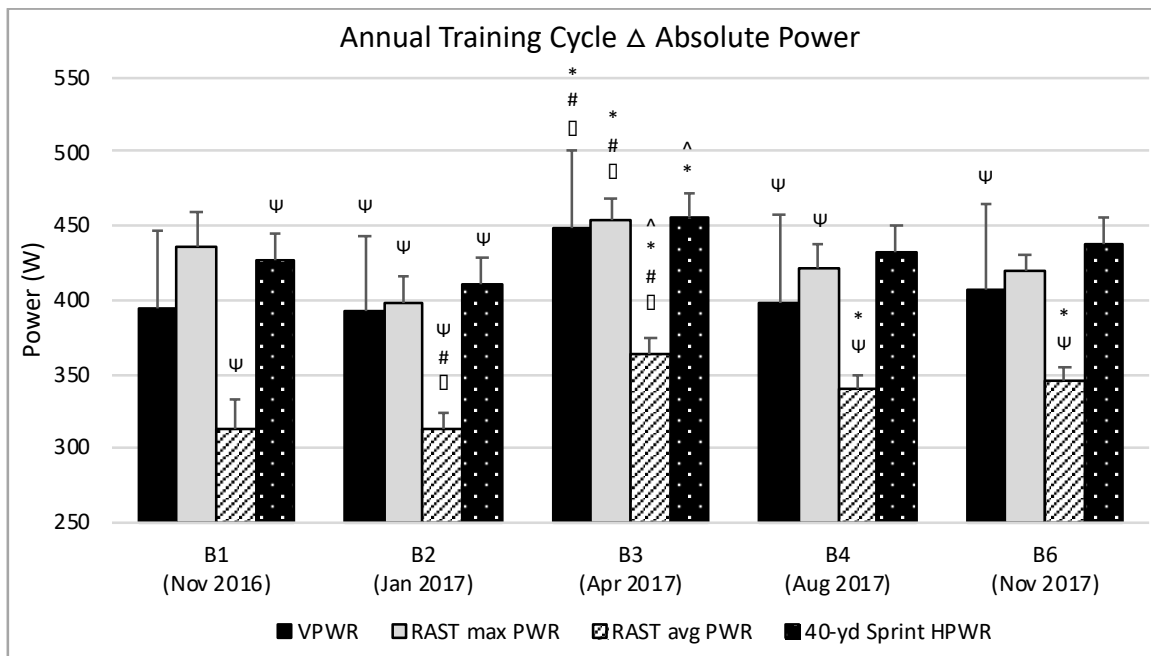
**Figure 3.** Changes in absolute anaerobic power measures over the annual training cycle. Data expressed as means ± SE. Significant differences derived from the LSD post hoc analysis is indicated by the following superscripts: ^ represents $p < 0.05$ difference from B1, * represents $p < 0.05$ difference from B2, Ψ represents $p < 0.05$ difference from B3, # represents $p < 0.05$ difference from B4, ♮ represents $p < 0.05$ difference from B6. VPWR = vertical power, RAST = running anaerobic sprint test, PWR = power, HPWR = horizontal power.

*Post-Spring Season to Pre-Competitive Season 2017*

Table 3 reports absolute and relative anaerobic data collected before and after the summer training period (B3-B4). Post-hoc evaluation of the absolute power data over this training period displayed significant decrements in vertical power (Δ -14.69%, $p = 0.006$), RAST max power (Δ -7.10%, $p = 0.012$), and RAST average power (Δ -6.35%, $p = 0.005$) as seen in Figure 3. Examination of power relative to FFM retained similarly significant decrements in vertical power (Δ -13.38%, $p = 0.017$), RAST max power (Δ -5.69%, $p = 0.038$), and RAST average power (Δ -4.96%, $p = 0.024$) as depicted in Figure 4. No significant absolute or relative changes in fatigue index were observed during this training period ($p > 0.05$) as represented in Figure 5.

**Table 3: Post-Spring Season to Pre-Competitive Season (B3-B4)**

| Variable | B3 (Apr 2017) | B4 (Aug 2017) | Raw Change | p-value |
|---|---|---|---|---|
| abs VPWR (W) | 448.02 ± 198.98 | 398.77 ± 218.66 | (-)49.25 | $p = 0.006^*$ |
| rel VPWR (W/kg FFM) | 8.84 ± 3.41 | 7.93 ± 3.87 | (-)0.91 | $p = 0.017^*$ |
| abs RAST Max PWR (W) | 454.68 ± 53.57 | 421.04 ± 59.13 | (-)33.64 | $p = 0.012^*$ |
| rel RAST Max PWR (W/kg FFM) | 9.23 ± 1.17 | 8.64 ± 0.99 | (-)0.59 | $p = 0.038^*$ |
| abs RAST Avg PWR (W) | 364.24 ± 37.49 | 340.09 ± 33.58 | (-)24.15 | $p = 0.005^*$ |
| rel RAST Avg PWR (W/kg FFM) | 7.39 ± 0.82 | 6.99 ± 0.65 | (-)0.40 | $p = 0.024^*$ |
| Fatigue Index | 0.37 ± 0.10 | 0.34 ± 0.06 | (-)0.03 | $p = 0.106$ |
| abs 40-yd Sprint HPWR (W) | 455.65 ± 60.59 | 431.32 ± 74.12 | (-)24.33 | $p = 0.223$ |
| rel 40-yd Sprint HPWR (W/kg FFM) | 9.25 ± 1.30 | 8.82 ± 1.16 | (-)0.42 | $p = 0.301$ |

Data expressed as means ± SD. Data represents anaerobic power and capacity performance changes across the summer training period. Univariate ANOVA p-levels from the overall repeated-measures ANOVA analyses are presented for each variable under each condition (absolute and relative power) and are listed from the LSD post-hoc analysis. Significance at the $p<0.05$ p-level between timepoints is indicated by the * superscript.  abs = absolute; rel = relative; VPWR = vertical power; PWR = power; HPWR = horizontal power; W = Watts; FFM = free-fat mass; B3 = post-Spring Season timepoint; B4 = pre-Competitive Season timepoint

*Pre-Spring Season to Pre-Competitive Season 2017*

Table 4 reports absolute and relative anaerobic data collected over the entire off-season training period (B2-B4). Post-hoc investigation of the absolute power data over this training period exposed a significant increase in RAST average power ($\Delta$ 9.01%, $p = 0.009$) as demonstrated in Figure 3. Assessment of power relative to FFM demonstrated a significant increase in RAST average power ($\Delta$ 7.47%, $p = 0.012$) over this same period as shown in Figure 4. No significant absolute or relative changes in fatigue index were observed during this training period ($p > 0.05$).
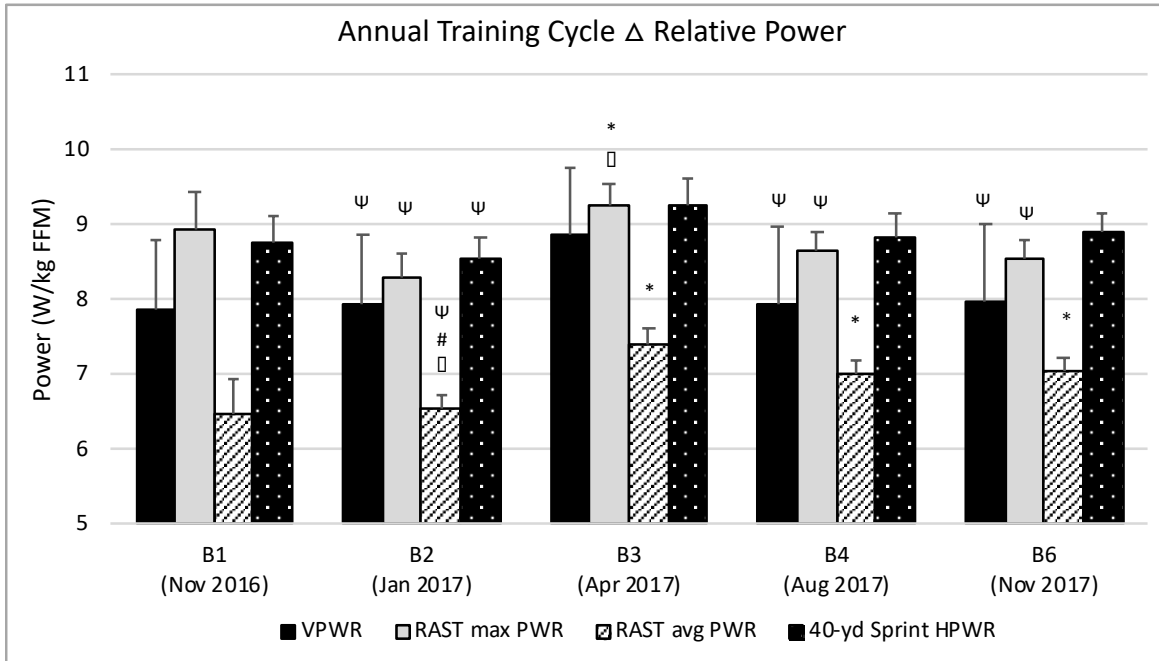
**Figure 4.** Changes in anaerobic power measures relative to FFM over the annual training cycle. Data expressed as means ± SE. Significant differences derived from the LSD post hoc analysis is indicated by the following superscripts: ^ represents $p < 0.05$ difference from B1, * represents $p < 0.05$ difference from B2, Ψ represents $p < 0.05$ difference from B3, # represents $p < 0.05$ difference from B4, ♮ represents $p < 0.05$ difference from B6. VPWR = vertical power, RAST = running anaerobic sprint test, PWR = power, HPWR = horizontal power.

*Post-Competitive Season 2016 to Pre-Competitive Season 2017*

Post-hoc analysis of absolute and relative (FFM) anaerobic data collected immediately after the 2016 competitive season compared to the pre-competitive season 2017 (B1-B4) showed no significant changes in any of the performance parameters ($p > 0.05$) as seen in Table 1.

*Pre-Competitive Season to Post-Competitive Season 2017*

Post-hoc analysis of absolute and relative (FFM) anaerobic data collected before and after the entire 2017 competitive season (B4-B6) revealed no significant changes in any of the performance parameters ($p > 0.05$) as demonstrated in Table 1.

*Post-Spring Season to Post-Competitive Season 2017*

Table 5 reports absolute and relative anaerobic data collected after the spring season compared to the end of the 2017 competitive season (B3-B6). Post-hoc analysis of absolute power across these two

training periods disclosed significant decrements in vertical power ($\Delta$ -13.48%, $p$ = 0.012), RAST max power ($\Delta$ -7.29%, $p$ = 0.006), RAST average power ($\Delta$ -4.7%, $p$ = 0.047), and fatigue index ($\Delta$ -10.80%, $p$ = 0.042) as depicted in Figure 3. Evaluation of power relative to FFM also showed a significant decrement in vertical power ($\Delta$ -13.08%, $p$ = 0.010) and RAST max power ($\Delta$ -6.64%, $p$ = 0.016) as demonstrated in Figure 4.

### Table 4: Pre-Spring Season to Pre-Competitive Season (B2-B4)

| Variable | B2 (Jan 2017) | B4 (Aug 2017) | Raw Change | p-value |
|---|---|---|---|---|
| abs VPWR (W) | 392.09 ± 189.90 | 398.77 ± 218.66 | (+)6.67 | $p$ = 0.790 |
| rel VPWR (W/kg FFM) | 7.94 ± 3.39 | 7.93 ± 3.87 | (-)0.01 | $p$ = 0.982 |
| abs RAST Max PWR (W) | 397.76 ± 69.54 | 421.04 ± 59.13 | (+)23.28 | $p$ = 0.133 |
| rel RAST Max PWR (W/kg FFM) | 8.27 ± 1.29 | 8.64 ± 0.99 | (+)0.37 | $p$ = 0.234 |
| abs RAST Avg PWR (W) | 313.96 ± 34.85 | 340.09 ± 33.58 | (+)26.13 | $p$ = 0.009* |
| rel RAST Avg PWR (W/kg FFM) | 6.54 ± 0.67 | 6.99 ± 0.65 | (+)0.45 | $p$ = 0.012* |
| Fatigue Index | 0.34 ± 0.13 | 0.34 ± 0.06 | (-)0.002 | $p$ = 0.946 |
| abs 40-yd Sprint HPWR (W) | 410.47 ± 64.65 | 431.32 ± 74.12 | (+)20.85 | $p$ = 0.139 |
| rel 40-yd Sprint HPWR (W/kg FFM) | 8.53 ± 1.13 | 8.82 ± 1.16 | (+)0.29 | $p$ = 0.274 |

Data expressed as means ± SD. Data represents anaerobic power and capacity performance changes across the off-season training period. Univariate ANOVA p-levels from the overall repeated-measures ANOVA analyses are presented for each variable under each condition (absolute and relative power) and are listed from the LSD post-hoc analysis. Significance at the p<0.05 p-level between timepoints is indicated by the * superscript. abs = absolute; rel = relative; VPWR = vertical power; PWR = power; HPWR = horizontal power; W = Watts; FFM = free-fat mass; B2 = pre-Spring Season timepoint; B4 = pre-Competitive Season timepoint

*Post-Competitive Season 2016 to Post-Competitive Season 2017*

Post-hoc analysis of absolute and relative (FFM) anaerobic data collected at the beginning and end of the complete annual training cycle (B1-B6) showed no significant changes in any physiological parameters ($p$ > 0.05) as demonstrated in Table 1.

## Table 5: Post-Spring Season to Post-Competitive Season (B3-B6)

| Variable | B3 (Apr 2017) | B6 (Nov 2017) | Raw Change | p-value |
|---|---|---|---|---|
| abs VPWR (W) | 448.02 ± 198.98 | 406.08 ± 219.99 | (-)41.94 | $p =$ 0.012* |
| rel VPWR (W/kg FFM) | 8.84 ± 3.41 | 7.97 ± 3.83 | (-)0.87 | $p =$ 0.010* |
| abs RAST Max PWR (W) | 454.68 ± 53.57 | 418.94 ± 41.95 | (-)35.74 | $p =$ 0.006* |
| rel RAST Max PWR (W/kg FFM) | 9.23 ± 1.17 | 8.55 ± 0.88 | (-)0.68 | $p =$ 0.016* |
| abs RAST Avg PWR (W) | 364.24 ± 37.49 | 345.81 ± 34.63 | (-)18.43 | $p =$ 0.047* |
| rel RAST Avg PWR (W/kg FFM) | 7.39 ± 0.82 | 7.05 ± 0.65 | (-)0.34 | $p =$ 0.085 |
| Fatigue Index | 0.37 ± 0.10 | 0.31 ± 0.06 | (-)0.06 | $p =$ 0.042* |
| abs 40-yd Sprint HPWR (W) | 455.65 ± 60.59 | 438.14 ± 67.89 | (-)17.51 | $p =$ 0.342 |
| rel 40-yd Sprint HPWR (W/kg FFM) | 9.25 ± 1.30 | 8.88 ± 0.90 | (-)0.36 | $p =$ 0.334 |

Data expressed as means ± SD. Data represents anaerobic power and capacity performance changes across the summer training period. Univariate ANOVA p-levels from the overall repeated-measures ANOVA analyses are presented for each variable under each condition (absolute and relative power) and are listed from the LSD post-hoc analysis. Significance at the $p<0.05$ p-level between timepoints is indicated by the * superscript. abs = absolute; rel = relative; VPWR = vertical power; PWR = power; HPWR = horizontal power; W = Watts; FFM = free-fat mass; B3 = post-Spring Season timepoint; B6 = post-Competitive Season timepoint
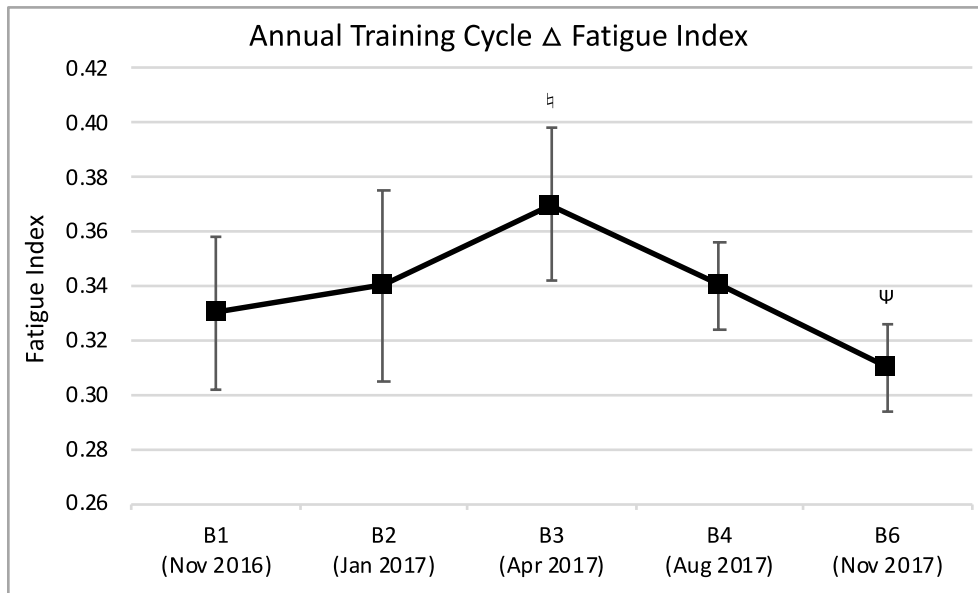
**Figure 5.** Change in anaerobic capacity over the annual training cycle. Data expressed as means ± SE. Significant differences derived from the LSD post hoc analysis is indicated by the following superscripts: ^ represents $p < 0.05$ difference from B1, * represents $p < 0.05$ difference from B2, Ψ represents $p < 0.05$ difference from B3, # represents $p < 0.05$ difference from B4, ♮ represents $p < 0.05$ difference from B6.

## DISCUSSION

The purpose of the current study was to observe changes in anaerobic power and capacity over an annual training cycle in collegiate female soccer athletes. An additional objective was to determine how changes in anaerobic power and anaerobic capacity throughout the calendar year affected the maintenance of anaerobic performance over the 94-day competitive season. This study was one of the first studies to examine anaerobic power and capacity changes in Division I female soccer athletes over the course of the collegiate annual training cycle. We hypothesized that anaerobic power and capacity would increase because of spring season training, decrease over the competitive season, and decrease during the post-competitive season detraining period. Additionally, we also hypothesized that self-directed summer training in this population would have a negative impact on power and anaerobic capacity as well as maintenance during the competitive season. This study found the spring season training to have an overall positive effect on performance. There were no significant changes that occurred during the competitive season or post-competitive season, and self-directed summer training had an overall negative effect on performance.

The values obtained from spring season training (B2-B3) displayed a positive effect on anaerobic power variables. Caldwell et al. (2009) reported similar findings regarding the standing vertical jump test and 15-meter sprint test, revealing a significant increase in vertical power and sprint speed from pre-season training to post-preseason training in semiprofessional male soccer athletes (Caldwell & Peters, 2009). Caldwell et al. (2009) suggested results may have been due to prioritizing basic and functional muscle strength training during pre-season training (Caldwell & Peters, 2009). Results of the current study raise speculation that increases in anaerobic power could have been attributed to structured and supervised training with more emphases on resistance training and less on sport specific skill training.

Fatigue index was highest post-spring season, suggesting that spring training had a negative impact on anaerobic capacity. This could be supported by the fact that NCAA training restrictions permit only eight hours of structured training contact time per week, suggesting that training to stimulate proper anaerobic capacity development is derived primarily from competitive season training and game play in this population. Gebbett et al. (2008) investigated international elite female soccer athletes and found they performed almost five repeated-sprint bouts (defined as a minimum of three consecutive sprints with less than 21 seconds of recovery in between each) per game with active recovery between bouts (Gabbett & Mulvey, 2008). The study by Gabbett et al. (2008) supports the current study's speculation that anaerobic capacity development is primarily derived from competitive season training. Moreover, due to the increase in power and decrease in capacity, it can be speculated that spring season training was not highly focused on sport specific energy system development and game play. A study on twenty League I French male soccer athletes investigated repeated-sprint ability (Carling, Le Gall, & Dupont, 2012). It reported that athletes with the lowest performance decrements in repeated-sprint ability performed more high-intensity actions with sort recovery times (Carling et al., 2012). Actions such as those are representative of a competitive game, suggesting again that anaerobic capacity is primarily developed during the competitive season. The reduction in capacity during spring season

training further supports the current study's claim that spring season training primarily focused on developing power. The spring season training period is considered a time for physical performance development in this population with less focus on sport application, hence the overall rationale for the results displayed during this training period.

*Post-Spring Season to Pre-Competitive Season 2017*

Data analyzed from self-directed summer training (B3-B4) revealed decrements in power output, alluding to the fact that decrements were likely attributed to an unstructured training environment. Though not significant, this training period also had a positive impact on anaerobic capacity. The decrease in anaerobic power over this period displays an inability for athletes to maintain training benefit developed from the preceding spring season training period, suggesting that self-directed summer training is not effective in this population. It is likely that game play performance would suffer coupled with an elevated risk of injury during this training period. Kraemer et al. (2004) supports these findings by stating the nature in which athletes enter the competitive season can have a significant impact on physical performance throughout the competitive season (Kraemer et al., 2004). This study suggests that large emphasis should be placed on the structure of cardiovascular endurance training in relation to strength training during the summer training period to avoid decrements in physical parameters throughout (Kraemer et al., 2004).

Additionally, it can be noted that both peak and average power derived from the 35-m RAST decreased during this training period, while 40-yard dash horizontal power remained unchanged. The RAST consists of six 35-meter sprints, equivalent to 38.3-yards, indicating that the RAST running course is similar to the 40-yard dash. The inconsistency in performance results during this training period might suggest that this population has the ability to produce power but is unable to maintain that power over a series of repeated sprints. Testing order might have also contributed to these inconsistent findings, as the RAST was the last test to be performed during data collection, proposing physical and psychological fatigue as barriers to performance. Several of the athletes stated that the RAST was the

most dreaded test to perform, potentially causing lack of motivation and/or effort due to negative psychological associations with the test.

*Post-Competitive Season 2016 to Pre-Competitive Season 2017*

Results gathered over the complete off-season training period (B1-B4) exposed no significant changes in any of the physiological parameters. Unchanging performance over this training period implies that the off-season training regimen employed combined with the struggles associated with self-monitored training periods were not effective in this population for the purposes of anaerobic and competitive season performance development. Though performance levels varied from block to block, the overall duration of the off-season displayed an inability for the athletes to maintain anaerobic performance above baseline values recorded at the beginning of the off-season. It is likely that performance game play quality decreased during this time frame due to apparent performance nullification across all testing variables.

*Pre-Competitive Season to Post-Competitive Season 2017*

Data collected over the competitive season (B4-B6) revealed no significant changes in any anaerobic parameters during this training period. Caldwell et al., found that from post-preseason to mid-competitive season vertical power and sprint speed significantly increased, whereas the current study did not see any changes in these variables over the competitive season (Caldwell & Peters, 2009). Differences could be attributed to the distance sprinted, where the present study utilized a substantially longer distance of 40-yards (36.6 meters) compared to Caldwell et al. (2009), utilizing a 15-meter sprint (Caldwell & Peters, 2009). Additionally, differences could have related to slightly different testing time points or a discrepancy in gender between the tested populations. However, in congruence with the current study, Caldwell et al. (2009) found no significant changes in anaerobic power from mid-competitive season to end-competitive season, where the current study found no significant power changes over the competitive season (Caldwell & Peters, 2009). It can be speculated that anaerobic

power stability was due to a primary functional muscle strength training focus with little basic muscle strength during this period (Caldwell & Peters, 2009).

*Post-Spring Season to Post-Competitive Season 2017*

Analysis from physiological peak to post-competitive Season (B3-B6) demonstrated an overall decrement in anaerobic power. While anaerobic parameters were maintained throughout the competitive season (B4-B6), results from this training period revealed that anaerobic power at the end of the competitive season was lower than the peak of the annual calendar. The inability of athletes to maintain high levels of power throughout the competitive season could be representative of their training where on-field training was emphasize and less training time was spent in the weight room. This proposal is supported by the increase in anaerobic capacity during this period as fatigue index was the lowest at the end of the competitive season. Additionally, NCAA guidelines allow for twenty hours of training on the field during the competitive season, compared to the eight hours of field training during spring season training. The decrease in power and increase in capacity implies that Division I female athletes are unable to recover from the lasting consequences of insufficient summer training during the competitive season. Results of the current study imply that a self-directed summer training program was not effective in this population. Similarly, a study involving collegiate male soccer athletes over the competitive season reported significant decrements in the 20-yard sprint test and maximal vertical jump test (utilizing Vertec vertical ump measurement device) over the competitive season in starting players (Kraemer et al., 2004). The study suggested that intense training prior to the start of the competitive season, combined with high intensity training during competitive season practices and games could have contributed to chronically elevated cortisol and suppressed testosterone concentrations, causing decrements in force productions (Kraemer et al., 2004). Kraemer et al. (2004) suggested that monitoring summer training, as well as structuring appropriate endurance and strength-related conditioning during summer training might be necessary in order to understand changes that occur throughout the

competitive season (Kraemer et al., 2004). Moreover, it is likely that athletes' performance quality decreased as a result of inadequate summer training prior to the competitive season in the current study.

*Post-Competitive Season 2016 to Post-Competitive Season 2017*

Results representative of the annual training calendar (B1-B6) disclosed that no significant changes occurred in any of the anaerobic parameters over the course of the entire year. While spring season training was considered a physiological peak in anaerobic power, those power variables were unable to be maintained throughout the full training year. Furthermore, analyses showed that training methods throughout the completed year were ineffective and did not have a positive effect on anaerobic performance variables.

*Strengths and Limitations*

Strengths of the current study included being one of the first studies to investigate a Division I female soccer athlete population over the duration of an annual training season. Working with a colligate population was another strength, as there tend to be fewer studies examining this population. Additionally, the population for the current study was very representative of a soccer team as all positions were proportionately represented and all returning athletes were healthy and avoided any major injuries.

The current study being an observational study was a major limitation. Several factors were unable to be controlled some being: training regimens, self-directed summer training, minutes played per athlete during the competitive season, injuries, and illnesses. The level of athlete motivation was another limitation, because there was not a way to know athletes' level of motivation therefore, we assumed that they performed at their maximal effort during testing periods.

*Future Research*

If this study was continued in the future, it would be recommended that an experimental design be implemented, allowing for factors to be controlled and application of specific training regimens. It

would also be recommended that more data collection time points be added, specifically mid-summer training and mid-competitive season, to allow for better analysis of changes in anaerobic parameters.

**Acknowledgements**

# REFERENCES

ACSM. (2014). *ACSM Guidelines for Exercise Testing and Prescription*. *Medicine & Science in Sports & Exercise* (Vol. 37). https://doi.org/9781609136055

Andersson, H., Raastad, T., Nilsson, J., Paulsen, G., Garthe, I., & Kadi, F. (2008). Neuromuscular fatigue and recovery in elite female soccer: Effects of active recovery. *Medicine and Science in Sports and Exercise*, *40*(2), 372–380. https://doi.org/10.1249/mss.0b013e31815b8497

Broiek, J., Grande, F., Anderson, J. T., & Keys, A. (1953). d l , d 2 ) ,.

Caldwell, B. P., & Peters, D. M. (2009). Seasonal variation in physiological fitness of a semiprofessional soccer team. *Journal of Strength and Conditioning Research*, *23*(5), 1370–1377. https://doi.org/10.1519/JSC.0b013e3181a4e82f

Canavan, P. K., & Vescovi, J. D. (2004). Evaluation of power prediction equations: Peak vertical jumping power in women. *Medicine and Science in Sports and Exercise*, *36*(9), 1589–1593. https://doi.org/10.1249/01.MSS.0000139802.96395.AC

Carling, C., Le Gall, F., & Dupont, G. (2012). Analysis of repeated high-intensity running performance in professional soccer. *Journal of Sports Sciences*, *30*(4), 325–336. https://doi.org/10.1080/02640414.2011.652655

Casajús, J. A. (2001). Seasonal Variation in Fitness Variables in. *Journal of Sports Medicine and Physical Fitness*, *41*(4), 1–17.

Davis, J. A., & Brewer, J. (1993). Applied physiology of female soccer players. *Sports Medicine (Auckland, N.Z.)*, *16*(3), 180–189. https://doi.org/10.2165/00007256-199316030-00003

Draper, N., & Whyte, G. (1997). Anaerobic performance testing - Here's a new running-based test of anaerobic performance for which you need only a stopwatch and a calculator. *Peak Performance*.

Fernández-de-las-Peñas, C., Downey, C., & Miangolarra-Page, J. C. (2005). Validity of the lateral gliding test as tool for the diagnosis of intervertebral joint dysfunction in the lower cervical spine. *Journal of Manipulative and Physiological Therapeutics*, *28*(8), 610–616. https://doi.org/10.1016/j.jmpt.2005.08.014

Fry, A. C., Kraemer, W. J., Koziris, L. P., Lynch, J. M., & Triplettl, N. T. (1994). Does Short-Term Near-Maximal Intensity Machine Resistance Training Induce Overtraining ? *Medicine and Science in Sport and Exercise*, *8*(3), 188–191. https://doi.org/10.1519/1533-4287(1994)008<0188

Fry, A., & Kraemer, W. J. (1997). Resistance exercise overtraining and overreaching. Neuroendocrine responses. *Sports Medicine*, *23*(2), 106–129. https://doi.org/10.2165/00007256-199723020-00004

Fry, a C., Kraemer, W. J., & Ramsey, L. T. (1998). Pituitary-adrenal-gonadal responses to high-intensity resistance exercise overtraining. *Journal of Applied Physiology (Bethesda, Md. : 1985)*, *85*(6), 2352–2359. https://doi.org/10.1152/jappl.1998.85.6.2352

Gabbett, T. J., & Mulvey, M. J. (2008). Time-motion analysis of small-sided training games and competition in elite women soccer players. *Journal of Strength and Conditioning Research*, *22*(2), 543–552. https://doi.org/10.1519/JSC.0b013e3181635597

Harman, E. A., Rosenstein, M. T., Frykman, P. N., Rosenstein, R. M., & Kraemer, W. J. (1991). Estimation of Human Power Output from Vertical Jump. *The Journal of Strength & Conditioning Research*, *5*(3), 116–120. https://doi.org/10.1080/14763140208522785

Hartmann, H., Wirth, K., Keiner, M., Mickel, C., Sander, A., & Szilvas, E. (2015). Short-term Periodization Models: Effects on Strength and Speed-strength Performance. *Sports Medicine*. https://doi.org/10.1007/s40279-015-0355-2

Hooper, S. L., MacKinnon, L. T., Gordon, R. D., & Bachmann, a W. (1993). Hormonal responses of elite swimmers to overtraining. *Medicine and Science in Sports and Exercise*.

Jackson, A. S., Pollock, M. L., & Ward, A. (1980). Generalized equations for predicting body density of women. *Medicine and Science in Sports and Exercise*, *12*(3), 175–181. https://doi.org/10.1079/BJN19780152

Jezdimirovic, M., Joksimovic, A., Stankovic, R., & Bubanj, S. (2013). DIFFERENCES IN THE VERTICAL JUMP IN SOCCER PLAYERS ACCORDING TO THEIR POSITION ON THE TEAM Ratko Stankovi ć , Saša Bubanj. *Physical Education and Sport*, *11*(3), 221–226.

Kraemer, W. J., French, D. N., Paxton, N. J., Häkkinen, K., Volek, J. S., Sebastianelli, W. J., … Knuttgen, H. G. (2004). Changes in exercise performance and hormonal concentrations over a big ten soccer season in starters and nonstarters. *Journal of Strength and Conditioning Research*, *18*(1), 121–128. https://doi.org/10.1519/00124278-200402000-00018

Kuipers, H., & Keizer, H. A. (1988). Overtraining in Elite Athletes: Review and Directions for the Future. *Sports Medicine*. https://doi.org/10.2165/00007256-198806020-00003

Lehmann, M., Dickhuth, H. H., Gendrisch, G., Lazar, W., Thum Kaminski, M. R., Aramendi, J. F., … Keul, J. (1991). Training - overtraining. A prospective, experimental study with experienced middle- and long-distance runners. *International Journal of Sports Medicine*, *12*(5), 444–452. https://doi.org/10.1055/s-2007-1024711

Loturco, I., Pereira, L. A., Kobal, R., Maldonado, T., Piazzi, A. F., Bottino, A., … Nakamura, F. Y. (2016). Improving sprint performance in soccer: Effectiveness of jump squat and olympic push press exercises. *PLoS ONE*, *11*(4), 1–12. https://doi.org/10.1371/journal.pone.0153958

Ostojic, S. M. (2003). Seasonal alterations in body composition and sprint performance of elite soccer players. *Journal of Exercise Physiology*, *6*(3), 24–27.

Silva, J. R., Brito, J., Akenhead, R., & Nassis, G. P. (2016). The Transition Period in Soccer: A Window of Opportunity. *Sports Medicine*, *46*(3), 305–313. https://doi.org/10.1007/s40279-015-0419-3.

Sinning, W. E., & Wilson, J. R. (1984). Validity of generalized equations for body composition analysis in woman athletes. *Research Quarterly for Exercise & Sport*, *55*(2), 153–160. https://doi.org/10.1080/02701367.1984.10608392

Spierer, D. K., Petersen, R. A., & Duffy, K. (2011). Response time to stimuli in division i soccer players. *Journal of Strength and Conditioning Research*, *25*(4), 1134–1141. https://doi.org/10.1519/JSC.0b013e3181d09e4c

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: An update. *Sports Medicine*. https://doi.org/10.2165/00007256-200535060-00004