International Journal of Sports Science 2019, 9(4): 92-99
DOI: 10.5923/j.sports.20190904.03

# NCAA In-Season Coaching Time Regulations Negate Strength and Conditioning Gains in Women's Division-II Basketball Team

**Zacharias Papadakis[1,*], Andreas Stamatis[2], Robert N. Padgett[3], Brandon K. Sanders[4]**

[1]Human Performance Laboratory, Sport and Exercise Sciences, Barry University, Miami Shores, FL, USA
[2]Sport and Wellness, State University of New York, Plattsburgh, NY, USA
[3]Educational Psychology, Baylor University, Waco, TX, USA
[4]Intercollegiate Athletics, Sport Performance, Barry University, Miami Shores, FL, USA

**Abstract** Strength and conditioning (SC) coaches are responsible for student-athletes' conditioning. National Collegiate Athletic Association (NCAA) time regulations may hinder SC coach's success. This study aimed to characterize the effects of NCAA in-season time restrictions of SC training on preseason lower-body power performance in a collegiate DII women's basketball team. During pre-season 14 players completed 3 hrs/wk of SC, while the in-season time was reduced to 2 hrs/wk. Average countermovement jump (CMJ) height and peak average power (PAP) were measured 1/wk for 10 weeks. CMJ and PAP examined relatively, allometrically scaled and analyzed using repeated measures ANOVAs primary for time and secondary for position. Statistical significance was set at $p < 0.05$. Statistical analyses were performed using R. Training season differences were found for PAP ($F(9, 117) = 4.63$, $p<.001$, $\eta^2=.263$) and scaled PAP scores ($F(4.8, 62.4) = 2.78$, $p=.0265$, $\eta^2=.176$). Pre-season PAP was higher than in-season controlling for player position (Est = 93.22 W, SE = 38.88, p = .033). Forwards had higher PAP than guards (Est = 400.6 W, SE=157.7, p =.022). Scaled PAP was higher pre-season than in-season controlling for player position (Est = 5.727($W \cdot kg^{-0.67}$), SE = .85, p =.002). SC program success is subjected to the NCAA regulations. Three hrs/wk seem to be the threshold that below that pre-season lower-body performance gains during the in-season are diminished. NCAA regulations may need to be revised so they do not influence the work of SC coaches.

**Keywords** Periodization, Countermovement jump, CSCS, Anaerobic power

## 1. Introduction

Strength and conditioning (SC) training for basketball requires a year-long commitment in periodization [1,2]. The ultimate goal is reaching peak performance at the appropriate time points [3]. Such accomplishment has been the difference between winning teams and average teams [4]. However, in the sport of collegiate basketball in the US, National Collegiate Athletic Association (NCAA) time-restricted SC practices may interfere with the capitalization of the adaptive responses of the student-athletes to SC stimuli [5].

For example, NCAA bylaw 2.14 governs the number of hours student-athletes can be trained both for pre-season and in-season. Division II student-athletes cannot be trained more than 8 hours per week during pre-season (of which no more than 2 hours per week will be spent on individual skill workouts) and 20 hours (including practice and competition) per week during in-season [6]. In addition, NCAA Bylaw's 17.1.5.1 and 17.1.5.2 restrict the in-season participation to maximum 4 hours per day [6].

Basketball coaches are not allowed to conduct practice sessions during off-season. When the academic year starts they can work with maximum 4 athletes at the time and not for more than 2 hours per week. Such off-season restrictions allow for greater training volume from strength and conditioning coaches (SCCs) compared to pre-season [1].

Female basketball players need to generate power, decelerate and accelerate quickly, change direction to a visual or auditory stimulus, and possess high levels of aerobic and musculoskeletal endurance [7,8]. Therefore, a typical SC program will focus on the development of the bioenergetic systems, agility, and muscular strength and power [9,10]. Furthermore, due to the importance of the power element for the actual on-court basketball success, SCCs are focusing throughout the year on increasing the lower-body performance on their athletes [8,11]. For

* Corresponding author:
zpapadakis@barry.edu (Zacharias Papadakis)
Published online at http://journal.sapub.org/sports

example, lower-body performance (i.e. vertical jump height and power performance) is integral to the game of basketball [7,8,11-13]. Nevertheless, during the in-season phase, fitness levels either remain unchanged or may decrease due to reduction in the frequency of the training sessions per week [14].

The necessity to maintain lower-body performance during in-season is paramount for providing a competitive edge. In-season SC training of 1-2 sessions per week in addition to the high-volume of skill training and competition has been shown to elicit beneficial effects on both countermovement jump (CMJ) and generated power production on female basketball players [15].

To date, however, it is unknown whether changes in frequency of a SC program may alter the well-documented physiological adaptations in female basketball players during pre-season and in-season [12,13]. With limited opportunity for in-season training due to NCAA regulations, are SC periodized programs ineffective to serve their purpose? So, in other words, will the expected and observed lower-body performance adaptations that occurred during the pre- season period be lost during the in-season due to the less time spend in the weight-room?

Therefore, the purpose of the present study was to examine the effects of NCAA in-season time restrictions on SC training during pre-season lower-body power performance in a collegiate Division II (DII) women's basketball team. The authors hypothesized that the NCAA regulations in regards to time- and frequency-restriction of SC program during in-season will not affect the observed pre-season gains in lower-body performance.

## 2. Methods

### 2.1. Experimental Approach

Pre- and in-season 2018-2019 archival SC performance data from a NCAA DII women's basketball team were used (i.e., body weight, CMJ height, and related power) in a retrospective longitudinal observational case study manner. Data collected as part of the team's usual pre- and in-season performance testing routine. This routine consisted of a periodized program for 10 weeks, which involved 4 weeks of pre-season SC sessions followed by 6 weeks of in-season, playing 1-2 matches per week combined with basketball practices as well as SC regimen (Table 1). Athletes were familiar with all the testing and training sessions since they had completed these routines for at least one year. Pre-season SC program included upper and lower body exercises targeting strength and power. Lower-body performance was assessed at week-1 and every week until the week-10 using a countermovement jump.

All testing sessions were performed on a single day, during morning hours, in an air-conditioned facility during both the pre- and in-season, when no team basketball practice was scheduled and supervised by National Strength and Conditioning Association (NSCA) certified SCCs. Each athlete followed the same customized, periodized SC team program. The authors assigned lower-body power performance (i.e., average CMJ height and peak average power) as variable of interest in order to examine differences in lower-body power performance over the combined 4-week pre-season and 6-week in-season SC program. Countermovement vertical jump was selected due to sports-specific basketball relevance [13]. Peak anaerobic power (PAP) values were calculated based on Sayers formula and the obtained vertical jump height [16].

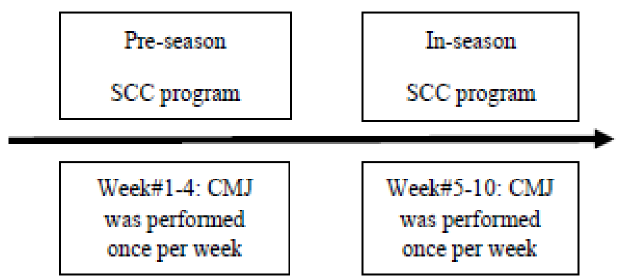
$$\text{PAP (Watts)} = 60.7 \times \text{jump height (cm)} + 45.3 \times \text{body mass (BM) (kg)} - 2055 \quad [16] \quad (1)$$

Countermovement jump height and related power were expressed in relative terms. In addition to that, CMJ and power data were normalized for body size using allometric scaling [17].

$$CMJ_n = CMJ/\ BM^{0.67} \quad [17] \quad (2)$$

$$PAP_n = PAP/BM^{0.67} \quad [17] \quad (3)$$

Players provided their consent for these assessments as part of their sport requirement. Based on the archival nature of these data, this study was qualified for educational exempt review and approved by the Ethics Committee of the University's Institutional Review Board for use of human participants in research.




Note. See Table 1 for detailed explanation of the strength and conditioning (SCC) program.

**Figure 1.** Study design for weeks 1-4 and 5-10

### 2.2. Participants

Fourteen DII female basketball players participating in the South East Region basketball conference were assessed for their lower-body performance. Participants were between 18 and 22 years old and their mean body mass was 71.4 kg ± 9.4. Participants had experience at national/international level. All international athletes have played at the club level in their respective countries. Playing positions were represented among the team as 6 forwards (F) and 8 guards (G) to avoid bias effect of playing position on the lower-body performance [18].

### 2.3. Countermovement Vertical Jump

Countermovement vertical jump was measured using a Just Jump System™ (Probotics, Huntsville, AL, USA) as previously described [19]. A specific warmup was followed involving: a) core exercise: (2x10) of deadbug, bird dog, and prone shoulder tap and b) bar (45lb.) warmup: (2x5) of Romanian Deadlift (RDL), squat, shoulder press, row. The CMJ was performed with the athlete standing still on the Just Jump Mat™, after the specific warm-up was performed with the same order: core/hip/barbell. Two box jumps onto an 18-inch box were done followed with two CMJ. The athlete would hold a PVC pipe across their upper back to eliminate arm swing. When instructed, the athlete would perform a squat jump, landing back in the same place from which they took off. The applied pre-season SC program that was followed from week-1 until week-4 and in-season from week-5 until week-10 is shown in Table 1.

**Table 1.** Strength and conditioning program for weeks 1-4 and 5-10

Pre-Season: Week 1-4

| Skill Work Sessions | Conditioning Workouts | Strength and Conditioning Workouts | Open Gyms |
|---|---|---|---|
| An informal practice, consisting of position specific drills | Workouts conducted by the basketball coach, focus on cardiovascular/ muscular endurance. No basketball specific skill work | Strength | Basketball scrimmage against each other. No coaching instruction |
| 2 day per week; 45-minute sessions | 2 days per week; 1-hour session | Hypertrophy | 1 day a week; 1- hour |
| | Lifts would be after practice | Bodyweight Plyometrics | |
| | | 3 days per week; 1-hour sessions | |

In-Season: Week 5-10

| Practice | Strength and Conditioning Workouts | Official Games |
|---|---|---|
| 5 days a week; 2-hour sessions | Focus for week 5-8 was general strength | Team participated in 5 competitive games during the time of data collection |
| | Focus for week 9 and 10 was strength and power | Note that on game days, they had a light practice for 1 hour, going over offensive plays and strategy on defending the opposing team. They also shot around more |
| | 2 days a week; 1-hour session | |
| | Lifts would be after practice | |

### 2.4. Statistical Analyses

All statistical analyses were performed using *R* [20]. Data were screened for missing and miscoded values. Missing values were imputed using the mice package [21] and naniar package [22]. Imputation was conducted by creating a prediction equation for each variable based on the inter correlations with all other variables. Variables with at least $r = .1$ (Pearson's correlation) were included in the prediction equation. The remaining steps followed the default settings in mice to perform imputation by chained equations. One complete dataset was created based on the imputation.

The repeated measures ANOVA assumptions (normality of residuals and sphericity) were checked for each outcome. Normality of the residuals was checked using Shapiro-Wilks test of normality and qq-plots. The assumption of sphericity was checked using Mauchly's test. When sphericity was violated, we used the Huynh-Feldt correction to the degrees of freedom and conducted the omnibus test of the effect of time on the outcome.

Outcomes were analyzed by a one-way repeated measures ANOVA and in case of significance a complex contrast was conducted to test the effect of the first four weeks (pre-season) vs. the effect of the last six weeks (in-season). Outcomes were analyzed by a series of two-way repeated measures ANOVA, having time and position as the two factors. If one of the omnibus tests for the effect of each factor (time, position, or interaction) was significant then we tested the contrast appropriate for effect that was significant. Statistical significance was set at $p < 0.05$, corrections for multiple testing were made with the false-discovery-rate (FDR) adjustment [23].

## 3. Results

The summary statistics of all variables in this analysis are reported in Table 2. Means and standard deviations of all outcomes are reported across all 10 weeks.

### 3.1. Results of One-Way Repeated Measures ANOVA

The results of all the one-way repeated measures ANOVA are reported in Table 3. We did not find evidence of any effect for the effect of time on body weight ($F$(3.1, 40.3) = 2.15, $p$=.108, $\eta^2$=.142), average CMJ ($F$(5.4, 69.6) = 1.50, $p$=.198, $\eta^2$=.103), on relative average CMJ ($F$(4.4, 56.5) = 1.20, $p$=.329, $\eta^2$=.085), on relative PAP ($F$(4.9, 63.9) = 1.40, $p$=.238, $\eta^2$=.097), nor on scaled CMJ ($F$(3.5, 44.9) = 1.80, $p$=.154, $\eta^2$=.122). For each of these analyses, we found evidence for the tenability of the assumption of normally distributed residuals. Some issues may have occurred with extreme values, but these cases were not excluded due to these data being collected from a small purposeful sample of athletes. For these four analyses, all of Mauchly's test of sphericity were significant. The Huynh-Feldt corrections are reported in Table 3.

The omnibus test of the effect of time was significant for PAP ($F(9, 117) = 4.63$, $p<.001$, $\eta^2=.263$) and scaled PAP ($F(4.8, 62.4) = 2.78$, $p=.0265$, $\eta^2=.176$). For both tests, we found evidence for the tenability of the normality of residuals. For PAP, Mauchly's test of sphericity gave evidence of the tenability of the assumption of sphericity ($W = 0.995$, $p = .469$); but, not for scaled PAP ($W = 0.0002$, $p < .001$) and the Huynh-Feldt correction was used for scaled PAP. Post-hoc analyses were conducted for PAP and scaled PAP. The contrast tested whether the effect of pre-season training (average effect of weeks 1-4) was equal to the effect of in-season training (average effect of weeks 5-10). For PAP, we found evidence of a statistically significant difference ($Est = 100.23$ W, $SE = 38.41$, $p = .009$). Pre-season scores were higher on average than in-season. The major differences observed were between weeks 3 and weeks 6-10. A similar trend was found for scaled PAP where pre-season scores were higher on average than in-season scores ($Est = 6.43$ W $\cdot$ kg$^{-0.67}$, $SE = 1.90$, $p < .001$). However, after controlling for multiple hypothesis testing, the scaled PAP scores did not statistically significantly differ across time (see Table 3, FDR $p$-value = .287).

**Table 2.** Summary statistics of all variables at each week

| | Week 1 | | Week 2 | | Week 3 | | Week 4 | | Week 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Body Weight (kg) | 71.35 | 9.41 | 71.83 | 9.59 | 72.60 | 9.60 | 72.57 | 9.95 | 72.37 | 10.23 |
| Average CMJ (cm) | 40.80 | 5.57 | 41.28 | 6.52 | 43.17 | 5.57 | 42.77 | 4.47 | 43.31 | 5.02 |
| PAP (W) | 3729.5 | 384.3 | 3829.0 | 463.4 | 4085.4 | 287.4 | 3927.8 | 366.3 | 3946.1 | 406.1 |
| Average CMJ (cm· kg$^{-1}$) | 0.59 | 0.12 | 0.59 | 0.12 | 0.58 | 0.18 | 0.56 | 0.12 | 0.57 | 0.12 |
| PAP (W· kg$^{-1}$) | 52.69 | 5.16 | 51.46 | 5.60 | 53.34 | 5.90 | 52.88 | 5.73 | 52.53 | 3.85 |
| Scaled CMJ (cm · kg$^{-0.67}$) | 2.38 | 0.40 | 2.36 | 0.42 | 2.56 | 0.71 | 2.38 | 0.36 | 2.43 | 0.35 |
| Scaled PAP (W · kg$^{-0.67}$) | 213.96 | 18.30 | 218.32 | 23.99 | 227.02 | 22.37 | 218.34 | 14.02 | 216.26 | 13.57 |
| | Week 6 | | Week 7 | | Week 8 | | Week 9 | | Week 10 | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Body Weight (kg) | 72.49 | 9.94 | 72.62 | 10.38 | 72.41 | 10.11 | 72.77 | 10.20 | 72.43 | 10.41 |
| Average CMJ (cm) | 41.19 | 4.34 | 40.97 | 4.99 | 41.93 | 4.97 | 41.71 | 4.76 | 41.43 | 3.53 |
| PAP (W) | 3817.7 | 410.6 | 3681.8 | 405.2 | 3666.2 | 443.0 | 3816.1 | 465.6 | 3828.1 | 408.5 |
| Average CMJ (cm· kg$^{-1}$) | 0.58 | 0.12 | 0.55 | 0.10 | 0.59 | 0.12 | 0.63 | 0.14 | 0.56 | 0.08 |
| PAP (W· kg$^{-1}$) | 51.24 | 4.07 | 50.92 | 3.83 | 51.36 | 4.35 | 52.43 | 4.80 | 51.50 | 2.78 |
| Scaled CMJ (cm · kg$^{-0.67}$) | 2.27 | 0.38 | 2.27 | 0.35 | 2.38 | 0.39 | 2.39 | 0.41 | 2.33 | 0.29 |
| Scaled PAP (W · kg$^{-0.67}$) | 213.31 | 15.34 | 211.04 | 16.12 | 209.89 | 13.25 | 214.91 | 15.27 | 212.50 | 11.17 |

Note. Sample size is 14 across all weeks. CMJ = Countermovement jump; PAP = Peak average power; Wk = Week; M = Mean; S = Standard deviation.

**Table 3.** Summary of One-Way Repeated Measures ANOVAs

| Outcome | DF Time | DF Error | $F$ | $\hat{\varepsilon}$ | $p$-value[a] | $\eta^2$ | FDR $p$-value[b] |
|---|---|---|---|---|---|---|---|
| Body Weight (kg) | 3.1 | 40.3 | 2.15 | 0.33 | .108 | .142 | .287 |
| Average CMJ (cm) | 5.4 | 69.6 | 1.50 | 0.59 | .198 | .103 | .381 |
| **PAP (W)** | **9** | **117** | **4.63** | [c] | **< .001*** | **.263** | **.003*** |
| Average CMJ (cm·kg$^{-1}$) | 4.4 | 56.5 | 1.20 | 0.48 | .320 | .085 | .427 |
| PAP (W·kg$^{-1}$) | 4.9 | 63.9 | 1.40 | 0.55 | .238 | .097 | .381 |
| Scaled CMJ (cm·kg$^{-0.67}$) | 3.5 | 44.9 | 1.80 | 0.38 | .154 | .122 | .381 |
| **Scaled PAP (W·kg$^{-0.67}$)** | **4.8** | **62.4** | **2.78** | **0.53** | **.026*** | **.176** | **.287** |

Note. [a]The $p$-value reported is the Huynh-Felt adjusted $p$-value from the omnibus $F$-test for the effect of time. ). [b] FDR P-Value is the false-discovery-rate adjusted $p$-value which indicates whether the effect of time was significant after controlling for multiple hypothesis testing. [c]Mauchly's test was not significant so no correction used. $\hat{\varepsilon}$ = Huynh-Feldt correction factor for violation of sphericity, $\eta^2$ = eta-squared measure of effect size (proportion of variance explained). CMJ = Countermovement jump; PAP = Peak average power. *$p < .05$.

### 3.2. Results of Two-Way Repeated Measures ANOVA

The full results of all the two-way repeated measures ANOVAs and FDR *p*-value are reported in Table 4. For each analysis, we found evidence for the tenability of the assumption of normally distributed of the residuals and same corrections as the one-way repeated measures ANOVA were applied. All of Mauchly's test of sphericity were significant. The results of all analyses and the Huynh-Feldt corrections are reported in Table 4.

We found evidence for an average difference between the weight of players by position ($F(1,12) = 7.25$, $p = .020$, $\eta_p^2 = .377$), but not evidence for an effect of time ($F(3.0, 36.1) = 2.10$, $p = .117$, $\eta_p^2 = .149$) nor a time by position interaction ($F(3.0, 36.1) = 0.73$, $p = .539$, $\eta_p^2 = .058$). Forwards weighted 11.6 kg more on average then guards (*SE* = 4.4, $p = .007$). However, after controlling for multiple hypothesis testing, we did not have enough power to detect the differences in body weight across time (see Table 4).

For PAP scores, the omnibus tests revealed evidence of the main effects of time ($F(6.03, 72.35) = 4.61$, $p < .001$, $\eta_p^2 = .277$) and differences between position ($F(1,12) = 6.45$, $p = .026$, $\eta_p^2 = .349$). We did not find evidence of an interaction ($F(6.03, 72.35) = 0.95$, $p = .468$, $\eta_p^2 = .07$). We tested two post-hoc contrasts. The first was the same as the one-way ANOVA and controls for position. The second just compared the two positions controlling for time. First, we found evidence for pre-season PAP scores are higher on average than in-season scores controlling for player position (*Est* = 93.22 W, *SE* = 38.88, $p = .033$). We also found evidence for between position differences, where forwards (F) had higher peak power than guards (G) on average controlling for the effect of time (*Est* = 400.6 W, *SE*=157.7, $p = .022$). However, after controlling for multiple hypothesis testing, the PAP scores only statistically differed across time (FDR *p*-value = .011) and not position (FDR *p*-value = .136).

**Table 4.** Summary of two-way repeated measures ANOVA

| Outcome | DF | DF Error | $F$ | $\hat{\varepsilon}$ | *p*-value[a] | $\eta_p^2$ | FDR *p*-value[b] |
|---|---|---|---|---|---|---|---|
| Body Weight (kg) | | | | | | | |
| **Position** | **1.00** | **12.00** | **7.25** | | **.020*** | **.38** | **.136** |
| Time | 3.00 | 36.10 | 2.10 | 0.33 | .117 | .15 | .410 |
| Time × Position | 3.00 | 36.10 | 0.74 | 0.33 | .539 | .06 | .628 |
| Average CMJ (cm) | | | | | | | |
| Position | 1.00 | 12.00 | 0.06 | | .817 | .01 | .817 |
| Time | 5.34 | 64.02 | 1.51 | 0.59 | .196 | .11 | .413 |
| Time × Position | 5.34 | 64.02 | 1.10 | 0.59 | .370 | .08 | .519 |
| PAP (W) | | | | | | | |
| **Position** | **1.00** | **12.00** | **6.44** | | **.026*** | **.35** | **.136** |
| **Time** | **6.03** | **72.35** | **4.61** | **0.67** | **.001*** | **.28** | **.011*** |
| Time × Position | 6.03 | 72.35 | 0.95 | 0.67 | .468 | .07 | .578 |
| Average CMJ ($cm \cdot kg^{-1}$) | | | | | | | |
| Position | 1.00 | 12.00 | 1.41 | | .258 | .11 | .417 |
| Time | 4.11 | 49.35 | 1.17 | 0.45 | .334 | .09 | .500 |
| Time × Position | 4.11 | 49.35 | 0.70 | 0.45 | .594 | .06 | .657 |
| PAP ($W \cdot kg^{-1}$) | | | | | | | |
| Position | 1.00 | 12.00 | 0.56 | | .467 | .05 | .578 |
| Time | 4.65 | 55.79 | 1.45 | 0.51 | .223 | .11 | .417 |
| Time × Position | 4.65 | 55.79 | 1.53 | 0.51 | .196 | .11 | .413 |
| Scaled CMJ ($cm \cdot kg^{-0.67}$) | | | | | | | |
| Position | 1.00 | 12.00 | 2.02 | | .181 | .14 | .413 |
| Time | 3.77 | 45.23 | 1.85 | 0.41 | .139 | .13 | .413 |
| Time × Position | 3.77 | 45.23 | 1.37 | 0.41 | .258 | .10 | .417 |
| Scaled PAP ($W \cdot kg^{-0.67}$) | | | | | | | |
| Position | 1.00 | 12.00 | 0.06 | | .809 | .01 | .817 |
| **Time** | **4.99** | **59.90** | **2.98** | **0.55** | **.018*** | **.20** | **.136** |
| Time × Position | 4.99 | 59.90 | 1.97 | 0.55 | .096 | .14 | .404 |

*Note.* [a]The *p*-value reported is the Huynh-Felt adjusted *p*-value from the omnibus *F*-test for the effect of time). [b] FDR P-Value is the false-discovery-rate adjusted *p*-value which indicates whether the effect of was significant after controlling for multiple hypothesis testing. The same Hunyh-Feldt correction is applied to the degrees of freedom for both within subjects factors (i.e., time and the interaction) and a correction is not needed for the between subjects only factor (Position). DF = degrees of freedom, $\hat{\varepsilon}$ = Huynh-Feldt correction factor for violation of sphericity, $\eta_p^2$ = partial eta-squared measure of effect size (proportion of variance explained controlling for other factors). CMJ = Countermovement jump; PAP = Peak average power. *$p < .05$.

For scaled PAP scores, the omnibus repeated measures ANOVAs did not reveal evidence of an effect of a time by position interaction ($F(4.99, 59.91) = 1.97$, $p = .196$, $\eta_p^2 = .141$) nor between positions ($F(1,12) = 0.06$, $p = .809$, $\eta_p^2 = .005$), but we did find evidence of an effect of time ($F(4.99, 59.91) = 2.98$, $p = .018$, $\eta_p^2 = .199$). Therefore, the post-hoc comparison of interest was the aggregate of weeks 1-4 vs. weeks 5-10. We found evidence for pre-season scaled PAP scores are higher on average than in-season scores controlling for player position ($Est = 5.727(W \cdot kg^{-0.67})$, $SE = .85$, $p = .002$). However, after controlling for multiple hypothesis testing, we did not have enough power to detect the differences in scaled PAP scores across time (see Table 4).

## 4. Discussion

Results of this study indicate that a SC program on lower-limb power performance in women's collegiate DII basketball student-athletes during pre-season and in-season is subjected to time devoted to this kind of training. In fact, the effect of NCAA in-season time restrictions of SC training on pre-season lower-body power performance in a collegiate DII women's basketball team was found to be buffering.

Pre-season SC training elicited on average higher power scores than in-season. Three hrs/wk for 3 weeks seemed to be adequate stimulus to produce an increase in power performance. Continuing a SC program for more than 3 weeks with less than 3 hrs/wk was not enough to maintain the already achieved adaptations. More than 7 weeks and up to 10 weeks of SC with 2 hrs/wk had no influence on improving lower-limps power performance above baseline week-1 values (Figure 1).

Periodized undulating SC programs for strength-endurance, strength, and power increases and power maintenance are commonly applied during pre-season and in-season lasting for 8-10 weeks [24]. Results from our study are in agreement with the literature, even though the 3 weeks duration of the SC program. Even so, participants were able to increase their average peak power above their baseline values. This may highlight the fact that, in order to see power improvements in female basketball players in DII, the duration of the periodized SC program can be as little as 3 weeks only. Of course, such a short program may not be able to set the necessary foundations for maintaining the desirable outcomes during in-season. In fact, in this particular sample players' power dropped significantly after the week-3 and did not recover even at week-10. This is in contrast with documented increases in average power output on jumping test on female basketball players during in-season with only 1-2 SC sessions per week [15]. This might have been the side-effect of NCAA regulations that limited the time spent in the gym and weight-room. At the same time, there is a chance that, if the pre-season SC was longer in duration (e.g., 8-10 weeks), the participants might have been able to resist the negative effect of the time constrains employed due to NCAA regulations. But, NCAA strictly defines the duration of the pre-season to a maximum of eight hours per week with not more than two hours per week spent on skill-related workouts [6].

Strength and conditioning coaches are devoting a considerable amount of time on enhancing their athletes' jumping ability [25]. Hoffman et al. [14] reported that in a 15 weeks of SC program vertical jump height was decreased by 9%, while Hunter et al. [26] noted that over 4 years of following 42 NCAA players their vertical jump height was increased by 8%. Eight weeks of pre-season training have been shown to be enough to increase vertical jump [10]. Athletes participating in this specific study were able to improve their jumping ability in only 5 weeks and later, they exhibited a drop in their vertical jump height. By the end of the week -10, their respective jump heights were close to heights observed during week-2. For once more, authors believe that this might have been the side-effect of NCAA regulations and their imposed time restrictions on periodized SCCs work.

Time spent on SC training seems to be a critical factor when lower-body performance is the goal. In a year-round SC program with no plyometrics included and consisted of four in-season sessions per week and a SC training session every other day during in-season (one day recovery before game) did not increase the vertical jump performance [27]. A study of 8 weeks during the pre-season on female basketball players DII increased lower-body performance [10]. SC employed a pre-season 4-week program with three sessions per week, which was focused on strength. That program was able to increase lower-body performance, as well. The in-season program was longer than the pre-season (i.e., 6 weeks) and had less hours spent in the weight-room (i.e., two in-season, periodized SC sessions lasting 1 hour each). It was not enough to maintain achieved pre-season gains on lower-body performance. Weeks 5-8 were focused on general strength, while weeks 9-10 targeted the strength/power relationship. A study that had a longer pre-season SC duration (5 weeks) with three sessions per week also failed to show any improvements during in-season. In fact, during $10^{th}$ week of the in-season vertical jump was significantly reduced [14]. This in-season reduction in vertical jump was also observed in our study, which averaged a decrease of 0.6% in CMJ from pre-season to in-season. Such observation highlights the fact that there might be an in-season frequency threshold in vertical jump were below that whatever gains were achieved during pre-season are hindered.

According to the FITT principle [28], parameter that may have influenced the results of this study may have been the type of employed SC program to enhance jumping and power performance. Compared to regular strength training, plyometric training involves movements that replicate more closely the actual basketball movements [29]. This cohort did bodyweight plyometrics during the pre-season for 4 weeks and 3 hours per week, while during in-season they did not perform any plyometrics other than what they did during in-court sessions and focused for two weeks on strength and power. Such SC design with the concomitant decrease in time spend in the weight-room may explain the decrease in both jump and power performance.

Another limiting issue might be the applied stimulus-load program to maximize the power output for lower-body performance [30]. Are low-intensity loads (<50% of 1RM) [31], moderate loads of 50-70% [32], or a mixed model which variety of loads and exercises are utilized [33] optimal for power generating capacity? This study sample used complex training methods and such stimuli have been shown to improve lower-body performance in athletes from various sport disciplines [33].

Moreover, due to ethical considerations and possible practical implications (e.g., post-intervention beneficial effects), a control group was not included. So, all athletes followed the same pre- and in-season SC team program. Experimental studies in competitive NCAA sports are very difficult to be executed due to withholding potential beneficial effects. Therefore, neither coaches nor players would agree on having some members of the team receiving the intervention and the rest to be the control group. It is almost unrealistic to try and locate another team (going through the exact same training and competing at the same level) to agree to act as either the experimental or the control group [34].

This study sample was female athletes and, due to sex-specific characteristics (e.g., hormonal influences from menstrual cycle), there may be an underlying complexity to methodological design. Hormonal influence of estrogen and progesterone across the menstrual cycle has been shown to influence physiological responses during exercise, ultimately affecting sports performance. However, these effects have been shown to be highly individual [35], with controversial findings in regards to anaerobic performance [36,37].

### 4.1. Practical Applications

Authors recognize the level of difficulty to get granted access to NCAA programs. The results of this study relate to a specific DII women's basketball team. Therefore, it may be possible other DI, DII, or DII teams to be unaffected by the in-season time restriction compared to pre-season in SC practices. There are definitely many confounding factors such as SC programs and head coach basketball practices that this longitudinal descriptive study could not have been possible to address and may have biased these results. Regardless, if the SC field needs to establish its role in the US collegiate level even more, similar research studies could be beneficial to move the field from anecdotally- to evidence-based practices [38, 39]. This study showed that in-season NCAA time constraint is at expense of SC programs' success pointing the fact that involved stakeholders need to re-evaluate the NCAA regulations.

For SCCs and basketball coaches, this study may be useful when developing a periodized SC program focusing on strength and power adaptations and how much impact the NCAA regulations may have on their team success. Sport coaches may assume that the high intensity of basketball practices and games alone is sufficient to maintain lower-body power performance and compensate for the reduction in SC practices, but results of this study do not support such assumptions.

## 5. Conclusions

This study indicated that most of the improvements shown in pre-season period cannot be maintained in-season, when the time of SC regimen is limited to 2 hours per week due to the imposed NCAA regulations. Therefore, all stakeholders (e.g., NCAA, coaches) may need to reconsider the amount of in-season time and frequency allocated for strength and conditioning practices.

## ACKNOWLEDGEMENTS

We would like to thank the Division of Academic Affairs and the Department of the Intercollegiate athletics for giving us access to the student-athletes.

## REFERENCES

[1] Taylor, J., *A Tactical Metabolic Training Model for Collegiate Basketball.* Strength & Conditioning Journal, 2004. 26(5): p. 22-29.

[2] Naclerio Ayllón, F., J. Moody, and M. Chapman, *Applied periodization: a methodological approach.* Journal of Human Sport and Exercise, 2013. 8(2): p. 350-366.

[3] Haff, G.G. and N.T. Triplett, *Essentials of Strength Training and Conditioning.* 4th ed. 2015, Champaign, IL: Human Kinetics.

[4] Groves, B., R. Gayle, and S. Brunet, *BASKETBALL: Strength training and team success in NCAA Men's Division I basketball.* Strength & Conditioning Journal, 1989. 11(6): p. 26-29.

[5] Narazaki, K., et al., *Physiological demands of competitive basketball.* Scand J Med Sci Sports, 2009. 19(3): p. 425-32.

[6] Ayers, K., M. Pazmino-Cevallos, and C. Dobose, *The 20-hour rule: Student-athletes time commitment to athletics and academics.* Vahperd Journal, 2012. 33(1): p. 22-27.

[7] Alemdaroğlu, U., *The relationship between muscle strength, anaerobic performance, agility, sprint ability and vertical jump performance in professional basketball players.* Journal of Human Kinetics, 2012. 31: p. 149-158.

[8] Spiteri, T., et al., *Physical Determinants of Division 1 Collegiate Basketball, Women's National Basketball League, and Women's National Basketball Association Athletes: With Reference to Lower-Body Sidedness.* J Strength Cond Res, 2019. 33(1): p. 159-166.

[9] Schweigert, D., *Normative Values for Common Preseason Testing Protocols: NCAA Division II Women's Basketball.* Strength & Conditioning Journal, 1996. 18(6): p. 7-10.

[10] Marzilli, T.S., *The effects of a preseason strength training program on a division II collegiate women's basketball team.* International Journal of Fitness, 2008. 4(1).

[11] Chaouachi, A., et al., *Lower limb maximal dynamic strength and agility determinants in elite basketball players.* J Strength Cond Res, 2009. 23(5): p. 1570-7.

[12] Dawes, J.J. and T. Spiteri, *Relationship between pre-season testing performance and playing time among NCAA DII basketball players.* Sports and Exercise Medicine, 2016. 2(2).

[13] Wen, N., et al., *Power Testing in Basketball: Current Practice and Future Recommendations.* J Strength Cond Res, 2018. 32(9): p. 2677-2691.

[14] Hoffman, J.R., et al., Strength, *Speed and Endurance Changes During the Course of a Division I Basketball Season.* The Journal of Strength & Conditioning Research, 1991. 5(3): p. 144-149.

[15] Hakkinen, K., *Changes in physical fitness profile in female basketball players during the competitive season including explosive type strength training.* J Sports Med Phys Fitness, 1993. 33(1): p. 19-26.

[16] Sayers, S.P., et al., *Cross-validation of three jump power equations.* Med Sci Sports Exerc, 1999. 31(4): p. 572-7.

[17] Markovic, G. and S. Jaric, *Is vertical jump height a body size-independent measure of muscle power?* J Sports Sci, 2007. 25(12): p. 1355-63.

[18] Hoare, D.G., *Predicting success in junior elite basketball players--the contribution of anthropometic and physiological attributes.* J Sci Med Sport, 2000. 3(4): p. 391-405.

[19] Whitmer, T.D., et al., *Accuracy of a vertical jump contact mat for determining jump height and flight time.* J Strength Cond Res, 2015. 29(4): p. 877-81.

[20] Team, R.C., R: *A language and environment for statistical computing.* 2013.

[21] Buuren, S.v. and K. Groothuis-Oudshoorn, *mice: Multivariate imputation by chained equations in R.* Journal of Statistical Software, 2010: p. 1-68.

[22] Tierney, N.J. and D.H. Cook, *Expanding tidy data principles to facilitate missing data exploration, visualization and assessment of imputations.* arXiv preprint arXiv:1809.02264, 2018.

[23] Benjamini, Y. and Y. Hochberg, *Controlling the false discovery rate: a practical and powerful approach to multiple testing.* Journal of the Royal Statistical Society: Series B (Methodological), 1995. 57(1): p. 289-300.

[24] Turner, A., *The Science and Practice of Periodization: A Brief Review.* Strength and Conditioning Journal, 2011. 33(1): p. 34-46.

[25] Ziv, G. and R. Lidor, *Vertical jump in female and male basketball players--a review of observational and experimental studies.* J Sci Med Sport, 2010. 13(3): p. 332-9.

[26] Hunter, G.R., J. Hilyer, and M.A. Forster, *Changes in fitness during 4 years of intercollegiate basketball.* The Journal of Strength & Conditioning Research, 1993. 7(1): p. 26-29.

[27] Groves, B.R. and R.C. Gayle, *Physiological changes in male basketball players in year-round strength training.* The Journal of Strength & Conditioning Research, 1993. 7(1): p. 30-33.

[28] American College of Sports Medicine, *ACSM's guidelines for exercise testing and prescription.* 2018.

[29] Markovic, G., *Does plyometric training improve vertical jump height? A meta-analytical review.* British journal of sports medicine, 2007. 41(6): p. 349-355.

[30] Soriano, M.A., et al., *The Optimal Load for Maximal Power Production During Lower-Body Resistance Exercises: A Meta-Analysis.* Sports Med, 2015. 45(8): p. 1191-205.

[31] Kirby, T.J., T. Erickson, and J.M. McBride, *Model for Progression of Strength, Power, and Speed Training.* Strength and Conditioning Journal, 2010. 32(5): p. 86-90.

[32] McMaster, D.T., et al., *A brief review of strength and ballistic assessment methodologies in sport.* Sports Med, 2014. 44(5): p. 603-23.

[33] Bauer, P., et al., *Combining higher-load and lower-load resistance training exercises: A systematic review and meta-analysis of findings from complex training studies.* J Sci Med Sport, 2019. 22(7): p. 838-851.

[34] Shalfawi, S.A.I., *Statistical Use in Applied Sport Research*. Strength and Conditioning Journal, 2016. 38(5): p. 88-91.

[35] Sims, S.T. and A.K. Heather, *Myths and Methodologies: Reducing scientific design ambiguity in studies comparing sexes and/or menstrual cycle phases.* Exp Physiol, 2018. 103(10): p. 1309-1317.

[36] Julian, R., et al., *The effects of menstrual cycle phase on physical performance in female soccer players.* PLoS One, 2017. 12(3): p. e0173951.

[37] Arazi, H., S. Nasiri, and E. Eghbali, *Is there a difference toward strength, muscular endurance, anaerobic power and hormonal changes between the three phase of the menstrual cycle of active girls?* Apunts. Medicina de l'Esport, 2019. 54(202): p. 65-72.

[38] Stamatis, A., E.L. Robinson, and G.B. Morgan, *Mental Toughness in Collegiate Strength and Conditioning: Widely Used, Widely Misunderstood.* International Research in Higher Education, 2018. 3(35-50): p. 10.

[39] Stamatis, A. and Z. Papadakis, *What a Difference a Mentally-Toughening Off-Season Makes: A Case of NCAA DI Rowers.* International Journal of Sports Science, 2018. 8(5): p. 152-157.