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Original Research

Evaluation of Body Composition and Athletic Performance in Division III Women's Volleyball Players During a Competitive Season

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Abstract

International Journal of Exercise Science 19(6): 1-9, 2026. *https://doi.org/10.70252/IJES2026603* Monitoring an athlete's physiology during a competitive season is important to determine the effectiveness of sport and strength and conditioning practices. The purpose of this study was to measure body composition and athletic performance across a competitive season in collegiate volleyball players. Sixteen female NCAA Division III volleyball players (age- 19.9 ± 1.4 years, height- 1.7 ± 0.1 m, mass- 72.6 ± 10.5 kg) participated in the study. Data was collected during three weeks of the season: preseason (T1), midseason (T2), and postseason (T3). Body composition measurements via dual-energy X-ray absorptiometry (DXA), vertical jump height, hemoglobin, and subjective measurements of perceived athletic performance and energy levels (1-10 scale) were measured at each timepoint. Data was analyzed using one-way repeated measures analysis of variance. There were no significant differences between jump heights ($p = 0.378$), hemoglobin ($p = 0.144$), subjective performance ($p = 0.472$), or energy levels across the season ($p > 0.329$). DXA results revealed a significant increase in overall bone mineral density (BMD) ($p < 0.001$). Segmental analysis revealed that left leg BMD significantly increased ($p = 0.037$). Lean body mass significantly increased ($p = 0.012$) while fat mass significantly decreased ($p < 0.001$) from T1 to T3. The results suggest that repetitive jumping during practices and games can have favorable impacts on body composition. Coaches, sport scientists and nutritionists can use this information to optimize adaptations for VB players while improving performance and reducing the risk of injury during a competitive season.

Keywords: Bone Density, college sports, female athletes, DXA, fatigue

Introduction

Collegiate female athletes must balance many factors to be successful competitors while maintaining healthy lifestyles. Factors such as academics, strength and conditioning training, mental health, physical wellness, and many other variables are all important to consider.[1,2] The ability for athletes in a team sport, such as volleyball (VB), to succeed requires the demand to simultaneously handle stress off the court, and work as a team on the court. In the case of a student athlete, these factors, if not handled successfully, can lead to poor academic performance,[3] increased risk of developing the female athlete triad[4] and an increase rate of injury.[5] In any collegiate sport, the goal is to balance academic obligations with athletic performance to optimize overall performance.

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The sport of volleyball (VB) is characterized by explosive movements requiring upper and lower body power. Volleyball players with higher vertical jumps have been shown to be more successful on the court.[6] Furthermore, Division I VB players have been shown to have higher vertical jumps than Division III players.[7] Over the course of a competitive season, strength and power can significantly improve by completing a well-designed resistance training program.[8] Maintaining or increasing power output throughout a match and during an entire season can determine success on the court. However, with less research in lower-level collegiate VB players, such as National Collegiate Athlete Associations (NCAA) Division III, it is unclear the extent at which adaptations occur.

Body composition is an important physiological measurement for all sports. In VB, typically, front row players have significantly greater lean mass and bone mineral density (BMD) compared to back row players.[9] These differences may be attributed to repetitive jumping to block and attack in front row players. Body composition may also predict athletic performance in power and agility measurements.[10] Therefore, promoting improvements in body composition could directly enhance sport performance on the court. Monitoring body composition and other markers, such as energy availability and menstrual dysfunction, are important in female athletes. Female athletes are at a greater risk in developing the female athlete triad. At the Division III level at least 29%[11] of female athletes show at least one risk factor of female athlete triad. Measuring BMD and hemoglobin levels during the season can give athletes information regarding their potential risks.

Over the course of a competitive season for an athlete there is an increase in challenges to manage training and performance. These challenges are only enhanced at the Division III level, where athletes have limited resources, whether that be receiving direct scholarships, nutrition programs,[12] academic stress and limited training time. Being able to consistently monitor performance and physiological measurements during the season will allow for sport and strength and conditioning coaches to optimize practice and training sessions. Therefore, the purpose of the current investigation was to measure body composition, jump performance, hemoglobin and subjective measurements of perceived athletic performance and energy levels during a competitive Division III volleyball season. It was hypothesized that each of these variables would be maintained across the duration of the season.

Methods

Participants

Sixteen female NCAA Division III volleyball players (age- 19.9 ± 1.4 years, height- 1.7 ± 0.1 m, mass- 72.6 ± 10.5 kg) at the University of Wisconsin-Platteville participated in the study. The positional breakdown is as follows outside hitter (n = 4), libero (n = 4), setter (n = 4), middle blocker (n = 1), opposite hitter (n = 3). The sample size used for this investigation was determined by the number of active athletes on the team's roster. Participants had to be on the active Division III roster across the entire season and free from injury to be included in the study. Prior to partaking in the study, participants were informed of the purposes and design of the study then completed an informed consent form. The Institutional Review Board at the University of Wisconsin- Platteville approved all procedures and the authors followed ethical guidelines as established in the Declaration of Helinski. This research was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science*.[13]

Protocol

This study employed observational methodology to analyze body composition and athletic performance over a competitive collegiate volleyball season. Subjects were asked to attend three separate sessions for testing. The first session (T1) was conducted in the last week of the team's preseason, a week before their official season started. The second session (T2) was conducted four weeks after T1. Finally, the third session (T3) was conducted a week after the team's season ended following the conference tournament, six weeks after T2. To start each session, the subjects had their height and mass measured then they underwent a dual-energy X-ray absorptiometry scan (DXA). To end the session, the researchers collected hemoglobin through a finger prick blood sample and measurement. Participants completed each DXA and hemoglobin testing session at the time of day and day of week to control potential changes. In the same week as these sessions, subjects filled out a subjective survey regarding their athletic performance and energy levels and completed a vertical jump test at a team's strength and conditioning training session, administered by the team's strength and conditioning coach. Over the course of the investigation, participants completed full body strength and conditioning training sessions 3-4 times per week. Depending upon the position the participant played they trained in one of three groups: 1. outside and opposite hitters, 2. middle blockers and setters and 3. defensive specialist and liberos.

Height was measured using a mechanical beam scale (402KL, Health O Meter®, McCook, IL, USA). Heights were measured in cm and only recorded during T1. Body mass was measured using a portable digital scale (PS-6600 ST, Befour, Saukville, WI, USA) at each timepoint prior to completing DXA testing.

A vertical jump mat (Just Jump, Power Systems, Knoxville, TN, USA) was used to collect vertical jump heights. Prior to completing jump height testing, subjects completed a full-body dynamic warm-up. Subjects were then instructed to step onto the testing mat and jump as high vertically as they could, then land back onto the mat. They were instructed to not kick their legs out or squat in a way to maximize their time in the air, potentially manipulating the results. Subjects made three attempts, and the best jump height was used for data collection. Prior to data collection, subjects were familiarized with the testing device through strength and conditioning sessions to ensure they properly jumped during experimental trials.

Hemoglobin levels were collected using a finger-prick method. Subjects' fingers were sterilized, air dried, then pricked using a lancet. The initial blood droplet was wiped and discarded. An 8 µL sample of blood was collected into a microcuvette (Hemo Control Microcuvette, EKF Diagnostics, Cardiff, UK) then analyzed using a portable blood hemoglobin analyzer (Hemo Control, EKF Diagnostics, Cardiff, UK). This analyzer uses a photometric azide methemoglobin method, which provides highly reliable and valid results with coefficient of variation of less than 2%.

Body composition was measured with a DXA scan (Horizon, Hologic, Marlborough, MA, USA). Subjects arrived at the exercise physiology lab in the morning and completed the test at the same time throughout the study. Subjects then laid supine on the device positioned in a way to maximize the reading. The researchers encouraged them to remain as still as possible throughout the test to get the best results. The following variables were collected: fat mass, lean body mass (LBM), body fat percentage, and bone mineral density (BMD). Segmental fat mass and LBM measurements included the left arm, right arm, trunk, left leg and right leg. Segmental BMD measurements included left arm, right arm, left ribs, right ribs, thoracic spine, pelvis, left leg and right leg. Prior to testing each day, the DXA was calibrated in accordance with the manufacture's guidelines.

Subjects filled out a survey regarding their subjective energy levels and viewed athletic performance. The survey questions consisted of, "What is your perceived energy level?" and "At what level do you perceive your athletic performance is at?" The subjects then responded numerically, 1 being poor and 10 being excellent. The surveys were administered prior to the strength and conditioning sessions where jump performance was measured.

Statistical Analysis

All statistical analyses were completed using SPSS (v29, IBM Corporation, Armonk, NY, USA). Body composition, jump height and subjective measurement data collected at T1, T2 and T3 are reported as mean ± standard deviation (SD). An alpha level of $p < 0.05$ was used to determine significance. All data were analyzed using one-way repeated measures analysis of variance (RMANOVA). If a significant main effect was observed, a least significant differences post hoc test was used to determine pairwise comparisons. Mauchly's test of sphericity was used to test the assumption of sphericity. If Mauchly's test was violated ($p < 0.05$) a Greenhouse-Geisser correction was applied. Partial eta squared (η^2) was calculated for each RMANOVA to determine effect sizes. Effect sizes interpretations are as follows: 0.01 = small effect; 0.06 = moderate effect; 0.14 = large effect. During the study, all 16 subjects were unable to attend each of the three strength and conditioning sessions due to schedule conflicts. Therefore, only 11 subjects' data was used for analysis with jump performance and subjective measurements.

Results

Fat and Lean Body Mass

Body mass did not significantly change throughout the season (F = 2.74, p = 0.081). However, there was a significant main effect for LBM (F = 3.7, p = 0.037). T3 LBM was significantly greater than T1 LBM (p = 0.012). However, there were no differences between T1 to T2 (p = 0.084) or T2 to T3 LBM (p = 0.371). Although there was a significant main effect for LBM, analysis of segmental regions of left arm, right arm, trunk, left leg and right leg revealed no significant changes.

Fat mass (F = 22.32, $p < 0.001$) and percentage body fat (F = 27.11, $p < 0.001$) were both significantly different over the course of the season. Fat mass and body fat percentage significantly decreased from each timepoint across the season. Segmental analysis for fat mass revealed a main effect for trunk fat mass (p = 0.01) with each timepoint significantly decreasing. Post hoc testing revealed trunk fat mass significantly decreased at each timepoint across the season. Fat mass and LBM data are presented in Table 1.

Bone Mineral Density

Over the course of the competitive season there was a significant difference in full body BMD (F = 12.02, $p < 0.001$). BMD increased from T1 to T2 ($p < 0.001$) and T3 (p = 0.007). There was no difference observed between T2 and T3 measurements (p = 0.273).

Since there was a significant overall increase in BMD across the season, the authors analyzed segmental BMD data provided by DXA. Left leg BMD was the only measurement that significantly changed during the season (F = 4.13, p = 0.026). Left leg BMD significantly increased from T1 to T2 (p = 0.002). There were no other significant differences between time points. BMD data is presented in Table 2.

Table 1. Body Mass Measurements.

Variable	Pre-Season	Mid-Season	Post-Season	Main Effect P-Value	Partial Eta Squared
Body Mass (kg)	72.8 ± 10.89	73.08 ± 10.62	72.31 ± 10.67	0.081	0.155
Body Fat (%)	31.43 ± 5.37	30.84 ± 5.23	29.49 ± 5.17	< 0.001*	0.644
Fat Mass (kg)	22.97 ± 6.85	22.44 ± 6.24	21.21 ± 6.25	< 0.001*	0.598
Lean Mass (kg)	49.02 ± 5.49	49.47 ± 5.96	49.75 ± 5.97	0.037*	0.198
Left Arm Fat Mass (kg)	1.36 ± 0.41	1.41 ± 0.49	1.32 ± 0.42	0.503	0.045
Right Arm Fat Mass (kg)	1.32 ± 0.45	1.23 ± 0.39	1.20 ± 0.39	0.197	0.106
Trunk Fat Mass (kg)	9.33 ± 3.14	8.97 ± 2.82	8.01 ± 3.10	0.010*	0.333
Left Leg Fat Mass (kg)	4.97 ± 1.57	4.88 ± 1.51	4.89 ± 1.85	0.715	0.011
Right Leg Fat Mass (kg)	4.96 ± 1.66	4.86 ± 1.58	4.74 ± 1.91	0.287	0.076
Left Arm Lean Mass (kg)	2.46 ± 0.45	2.42 ± 0.49	2.45 ± 0.47	0.707	0.023
Right Arm Lean Mass (kg)	2.75 ± 0.49	2.73 ± 0.55	2.63 ± 0.49	0.517	0.043
Trunk Lean Mass (kg)	22.95 ± 2.46	22.89 ± 2.61	22.65 ± 2.63	0.654	0.015
Left Leg Lean Mass (kg)	8.52 ± 1.15	8.67 ± 1.33	9.14 ± 2.21	0.157	0.128
Right Leg Lean Mass (kg)	8.63 ± 1.23	8.98 ± 1.15	9.16 ± 1.93	0.106	0.156

Data is reported as mean ± standard deviation. *Significant main effect ($p < 0.05$). Partial eta squared effect sizes are interpreted as follows: 0.01 = small effect; 0.06 = moderate effect; 0.14 = large effect.

Table 2. Bone Mineral Density Measurements.

Variable	Pre-Season	Mid-Season	Post-Season	Main Effect P-Value	Partial Eta Squared
Full Body BMD (g/cm^2)	1.267 ± 0.800	1.296 ± 0.889	1.290 ± 0.932	< 0.001*	0.611
Left Arm BMD (g/cm^2)	0.796 ± 0.055	0.818 ± 0.099	0.833 ± 0.134	0.425	0.055
Right Arm BMD (g/cm^2)	0.837 ± 0.050	0.855 ± 0.058	0.842 ± 0.047	0.424	0.056
Left Ribs BMD (g/cm^2)	0.778 ± 0.070	0.766 ± 0.060	0.759 ± 0.053	0.362	0.065
Right Ribs BMD (g/cm^2)	0.739 ± 0.052	0.754 ± 0.053	0.757 ± 0.059	0.245	0.089
Thoracic Spine BMD (g/cm^2)	0.925 ± 0.090	0.923 ± 0.084	0.934 ± 0.138	0.819	0.007
Lumbar Spine BMD (g/cm^2)	1.248 ± 0.103	1.168 ± 0.304	1.227 ± 0.135	0.377	0.058
Pelvis BMD (g/cm^2)	1.326 ± 0.096	1.340 ± 0.106	1.304 ± 0.163	0.315	0.070
Left Leg BMD (g/cm^2)	1.335 ± 0.085	1.365 ± 0.097	1.356 ± 0.092	0.026*	0.216
Right Leg BMD (g/cm^2)	1.332 ± 0.064	1.342 ± 0.083	1.341 ± 0.081	0.724	0.021

Data is reported as mean ± standard deviation. *Significant main effect ($p < 0.05$). Partial eta squared effect sizes are interpreted as follows: 0.01 = small effect; 0.06 = moderate effect; 0.14 = large effect.

Hemoglobin, Jump Performance and Subjective Measurements

Hemoglobin levels did not significantly change over the course of the season (T1: 13.2 ± 1.7 mg/dL, T2: 13.4 ± 0.7 mg/dL, T3: 14.0 ± 0.7 mg/dL, F = 2.3, $p = 0.144$, $\eta^2 = 0.133$).

Jump performance did not significantly change over the course of the season (T1: 50.0 ± 4.8 cm, T2: 50.2 ± 4.0 cm, T3: 51.0 ± 3.9 cm, F = 1.02, $p = 0.378$, $\eta^2 = 0.093$).

Subjective measurement of perceived performance did not significantly change over the course of the season (T1: 7.0 ± 1.7, T2: 7.6 ± 0.9, T3: 7.3 ± 1.0, F = 0.78, $p = 0.472$, $\eta^2 = 0.072$). There was also no difference for the subjective measurement of energy levels (T1: 6.8 ± 1.3, T2: 7.5 ± 1.0, T3: 7.1 ± 0.9, F = 1.18, $p = 0.329$, $\eta^2 = 0.105$).

Discussion

The findings of this study suggest that Division III VB athletes can have favorable physiological adaptations over the course of a competitive season. This also occurs while maintaining jump performance, healthy hemoglobin levels and perceived levels of performance and energy. Our findings are consistent with prior research showing favorable lean and fat mass adaptations during a competitive season.[14,15] However, it is important to note that these favorable changes were seen at the lower collegiate level compared to higher levels (Division III to Division 1 and professional). Maintaining and potentially improving performance through a competitive season are goals that all athletic teams at any level strive for.

Body composition is an important component of VB players' success, specifically when considering that LBM and power output correlate with greater levels of success on the court.[10] Our investigation found favorable LBM and fat mass changes across the season with LBM improving from pre-to-post season and fat mass decreasing at each timepoint. Specifically, fat mass was significantly decreased across the season in the trunk region. The favorable changes in body composition may be attributed to following a strict strength and conditioning program[16] and a proper diet.[17] Participants in our investigation did follow a strict 3-4 day a week full body training program under the supervision of the team's strength and conditioning coach. Therefore, proper periodized training led to favorable body composition changes. Furthermore, a reduction of fat mass could be a product of the increase in kcal expenditure during the season which has been estimated to be ~215 kcals during practices, ~50 kcals during pre-game warm-ups and ~155 kcals during matches.[17] This result is especially surprising considering previous research with collegiate VB players suggests there is a lack of knowledge on nutrition[18] and when education is implemented, body composition[19] and dietary habits[20] can improve independently from sport specific and strength and conditioning practices. Previous VB research measuring body composition during a competitive season has also shown favorable improvements, however, these studies have been in elite players[15] or Division I athletes.[14]

One of the more novel findings of this investigation was the significant changes to BMD over the course of the season. There was a significant increase in total BMD (1.8%) and left leg BMD (1.6%). These increases are consistent with previous research,[21] but this study observed that it took two years to see an increase of 1.8%. BMD is an important health marker for female athlete health as females are at a higher risk for developing osteoporosis from the age of 50 and on.[22] A high impact sport with repetitive jumping such as VB may promote positive BMD changes that will help females maintain health and performance after college athletics. In female sports, BMD is often discussed in relationship to the female athlete triad, which is a syndrome characterized by having menstrual dysfunction, low energy availability, and osteoporosis. Although research suggests VB is not considered a lean sport, which is characterized by an emphasis on endurance training and having a lean physique, there is still an increased risk for development for female athlete triad.[23] We aimed to monitor potential signs that could lead to menstrual dysfunction by measuring hemoglobin levels during the season. Our findings suggested there were no changes in hemoglobin levels across the season with each timepoint eliciting levels that were considered within the normal range. These results may be explained by the participant utilizing proper nutrition,[24] proper hydration[25] and the prevalence of contraceptive usage.[26,27] Improving BMD during a competitive VB season while maintaining healthy hemoglobin levels are positive markers to promote athlete performance and overall health.

Athletes participating in the NCAA Division III level face an increased number of challenges compared to athletes at the Division I and II levels. A recent qualitative study highlighted themes related to nutrition such as awareness and knowledge, influence of team culture and environment and barriers as challenges[28] for Division III athletes. Other research suggests Division III athletes face significantly greater mental health challenges due to limited resources for athletes.[29] In comparison to higher level athletic programs where scholarships are offered, teams have dedicated sports dieticians, and there is more support for academics; thus, significant challenges are faced. We set to subjectively measure how subjects perceived performance and energy levels during the season. Our results did not significantly change during the study while averaging around 7 out 10 for both measures throughout the season. Although there are challenges for an athlete during the season, these results suggest subjective feelings are positive. This investigation highlights the importance that Division III athletes can display positive adaptations during a competitive season.

The strength of this study was the measurement of several dependent variables directly and indirectly relating to sports performance. However, the study was not without limitations. Dietary habits and patterns were not measured over the course of the study. Fluctuations in diet could have had impacts on body composition, performance, and hemoglobin levels. We also did not track menstrual cycles which would have also affected the outcomes of our investigation and may have provided some clarity on our findings. Future investigations should monitor menstrual changes and correlate them with nutrition intake and body composition changes. It would also be important to compare Division III athletes with higher level athletes. This would help identify further differences and potential interventions to optimize performance and adaptations for Division III athletes who have limited resources compared to higher levels.

This study demonstrated that women's VB players at Division III collegiate level can improve important performance indicators such as body composition while maintaining sport-specific jump performance. Although a competitive season provides many challenges for an athlete, such as academic stressors, personal life, and other health concerns, monitoring an athlete's physiology is important to ensure at minimum maintenance in performance. The subjective surveys measured perceived performance and energy levels which were found to be maintained throughout the entire competitive season lasting over the course of an academic term. In terms of health tracking, this may suggest these athletes have an ability to compartmentalize to maintain performance and energy levels despite outside fluctuations the academic term brings. Besides performance concerns, monitoring females' health is important to ensure they are at a lower risk for developing factors leading to the female athlete triad.

Tracking sport performance and physiology has become common in several sports at all collegiate and professional levels. The findings from this investigation can guide coaches, sport scientists and nutritionists to optimize adaptations for VB players and provide a foundation for intervention with the goals of improving performance, maintaining health and reducing the risk for injury.

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