Body Composition Changes Among Female NCAA Division 1 Athletes Across the Competitive Season and Over a Multiyear Time Frame

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Abstract

Stanforth, PR, Crim, BN, Stanforth, D, and Stults-Kolehmainen, MA. Body composition changes among female NCAA division 1 athletes across the competitive season and over a multiyear time frame. *J Strength Cond Res* 28(2): 300–307, 2014—Body composition can affect athletic performance. Numerous studies have documented changes in body composition in female collegiate athletes from pre- to postseason; however, longitudinal studies examining changes across years are scarce. Therefore, the primary purpose of this study was to assess longitudinal body composition changes among female collegiate athletes across 3 years. Two hundred twelve female athletes from basketball (BB; $n = 38$), soccer (SOC; $n = 47$), swimming (SW; $n = 52$), track (sprinters and jumpers; TR; $n = 49$), and volleyball (VB; $n = 26$) with an initial mean age of 19.2 ± 1.2 years, height of 172.4 ± 8.9 cm, and total mass of 66.9 ± 9.0 kg had body composition assessments using dual-energy x-ray absorptiometry pre- and postseason over 3 years. A restricted maximum-likelihood linear mixed model regression analysis examined body composition differences by sport and year. Changes ($p < 0.05$) over 3 years included the following: Lean mass increased in VB from year 1 to 2 (0.7 kg), year 2 to 3 (1.1 kg), and year 1 to 3 (1.8 kg) and in SW from year 1 to 3 (0.6 kg); and percent body fat (%BF) increased in BB from year 1 to 3 (1.7%). There were no changes in SOC or TR. These results indicate that during their college careers, female collegiate athletes can be expected to maintain their %BF and athletes in sports like SW and VB can anticipate an increase in lean mass, but the increases may be less than many athletes, coaches, and trainers envision.

Key Words DXA, lean body mass, percent fat, basketball, soccer, swimming, track, volleyball

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Introduction

Many factors determine sports performance, including body size and composition (5). In addition, too high or too low of a percent body fat (%BF) can have negative health consequences. Because of these factors, many athletes and athletic teams have their body composition assessed (8,34). This information can be used with the individual athlete and the team in a variety of ways, including as part of a general overall health assessment and to track training adaptations and changes across a season, a year, and multiple years.

In general, excess body fat is detrimental and fat-free mass (FFM) is beneficial for athletic performance (5). Females achieve their adult level of FFM by 15–16 years of age and show an increase in fat mass and %BF in their 20s (19). With the rigorous strength and conditioning programs that most female collegiate athletes engage in, what body composition changes can they expect throughout their collegiate career? Numerous investigators have reported the body composition of intercollegiate female athletes within various sports (1,4,6,7,9,10,12–18,20–23,26,27,29,31,33,35,37,38). Several have examined off/preseason to peak season changes in female collegiate basketball (BB) (6,14,33,35), soccer (SOC) (7,23), swimming (SW) (6,14,15,18,22,27,29,31,38), track and field (TR) (6,14,21), and volleyball (VB) (6,14) athletes. However, multiyear body composition data on female collegiate athletes are sparse (30).

Most pre- to postseason investigations have shown %BF to decrease in SW (21,22,27,29,31,33)and TR (6,14,21) but not change in BB (6,14,35), SOC (7), and VB (6). Studies indicate that FFM increases in SW (6,18,22,27,29,31,33) and TR (6,14,21), does not change in SOC (7) and VB (6), but are equivocal for BB (6,14,33,35). Can these within season changes be expected to continue over the course of a collegiate career? One longitudinal study reported no significant changes in mass, %BF, or FFM over 4 years in female collegiate BB players (30), and another reported that total and lean mass increased over a 3-year period in elite female Australian SW (32). Are the results of these 2 investigations representative of the changes to expect in collegiate BB and

SW athletes and in athletes from different sports? Clearly, this is an important question to answer.

The primary purpose of this study was to document yearly changes in body mass, %BF, fat mass, and lean mass of National Collegiate Athletic Association (NCAA) Division 1 female athletes in BB, SOC, SW, TR (sprinters and jumpers), and VB using the dual-energy x-ray absorptiometry (DXA) measurement technique. It was hypothesized that there would be no changes in BB and that SW would increase total and lean mass. No hypotheses were made for the other sports. Secondary purposes were to expand the existing body composition literature examining changes from pre- to postseason and differences among the athletes in these same sports. It was hypothesized that from pre- to postseason, SW and TR would increase lean mass and would show a significant decrease in %BF. It was also hypothesized that TR would have lower %BF than all other sports and BB and VB would be taller, heavier, and have more lean mass than all other sports.

Methods

Experimental Approach to the Problem

With the lack of longitudinal body composition data on female collegiate athletes, efforts were made to document body composition changes of female athletes by measuring their body composition pre- and postseason throughout their collegiate career. Female athletes participating in BB, SOC, SW, VB, and TR (sprinters and jumpers only) at a NCAA Division 1 university completed DXA scans to measure total body mass, fat mass, lean mass, and %BF at the beginning of their organized conditioning season in August/September (preseason) and again near the end of their competitive season (postseason). Typically, the post measurement was in November for SOC, December for VB, February/March for BB and SW, and April/May for TR. These teams were tested over a number of years: BB and TR from 2003 to 2010, SW from 2006 to 2010, and SOC and VB from 2007 to 2010. All teams trained throughout the whole year. During the summer, SOC and TR athletes trained on their own with team prescribed programs, whereas most BB, SW, and VB athletes trained on campus under supervision. Most BB and SW athletes did not train under supervision for 2–3 weeks in mid-to-late August. Soccer did not contain as much strength and power training as the other sports.

Subjects

Two hundred twelve female athletes, 18–23 years of age, from BB ($n = 38$), SOC ($n = 47$), SW ($n = 52$), TR ($n = 49$), and VB ($n = 26$) participated in this study. Figure 1 provides the number of participants and the number of years followed. To contextualize the level of athlete studied, during their respective time periods: (a) BB was in the NCAA tournament 5 of 8 years advancing to at least the second round 3 of 8 years; (b) SOC was in the NCAA tournament 3 of 4 years advancing to at least the second round 2 of 4 years and was the Big 12 Conference Champion 1 year; (c) SW finished first or second in the Big 12 Conference

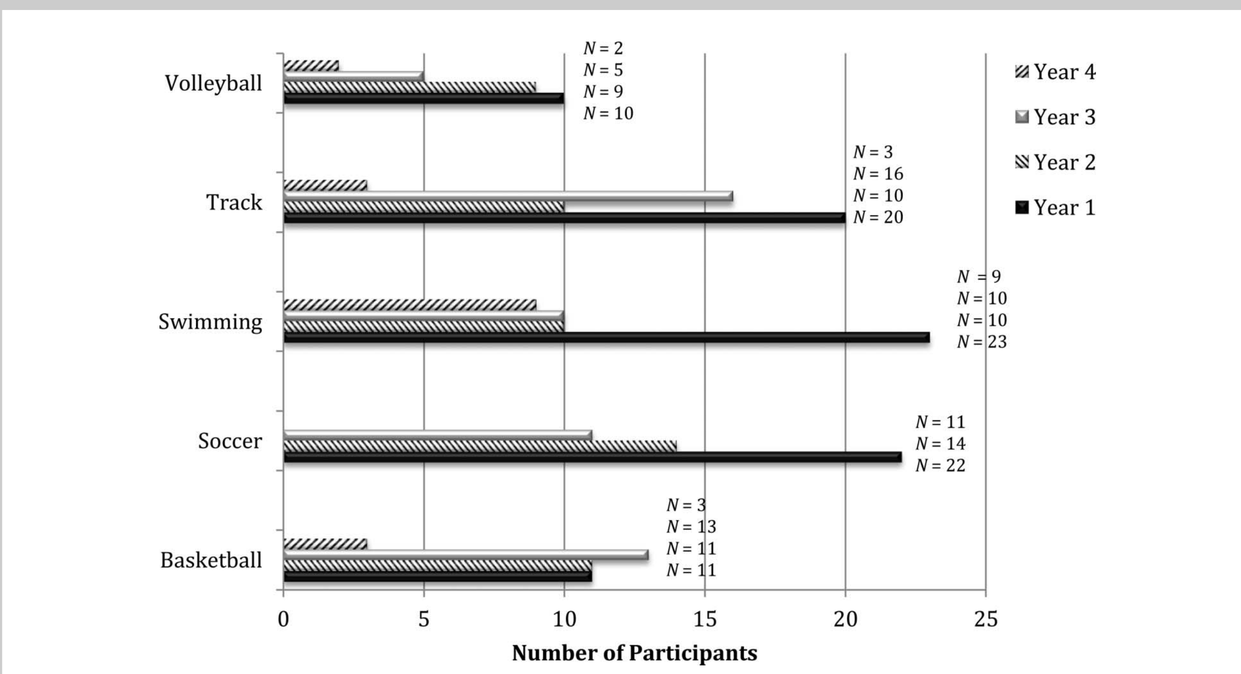

Figure 1. Number of athletes followed for 1, 2, 3, and 4 years.

Championship 4 of 4 years; (d) TR was the NCAA National Champion 1 year and finished in the top 3 in the Big 12 Conference Championships 5 of 7 years; and (e) VB played in the NCAA Final four 3 of 4 years and was 1 win away from the Final 4 the other year. Each athlete was scanned pre- and postseason resulting in 798 total scans. Efforts were made to ensure that all athletes were tested at each time point; however, some scans were missed because of illness, injury, or noncompliance. In addition, there were more frequent absences for postseason testing during the athlete's final year of eligibility. The mean age at first scan was 19.2 ± 1.2 years. All participants were informed of the procedures, benefits, and risks before providing written informed consent before each DXA scan for this study, which was approved by the Institutional Review Board at The University of Texas at Austin.

Procedures

Athletes reported to the Fitness Institute of Texas for body composition assessment with DXA technology using a Lunar Prodigy (GE Medical Systems, Madison, WI, USA). All technicians were trained by GE Lunar DXA personnel, all procedures conformed to GE Lunar specifications, and all scans were analyzed using enCORE software (version 11.0; GE Medical Systems). The DXA was calibrated every other day using a spine phantom made of calcium hydroxyapatite embedded in a lucite block. The DXA passed calibration each time with a coefficient of variation of 0.3% for bone-mineral density and %BF. Subjects confirmed they were not pregnant before testing, were dressed in light athletic clothing, and removed all jewelry, plastic, and metal materials that could affect the x-ray beam. Because of scheduling complexities, there were no specific controls for such things as time of day, of the last meal, or of the last workout or hydration status. Height was measured to the nearest 0.3 cm using an adult/infant stadiometer (Perspective Enterprises, Portage, MI, USA) with the participant standing without shoes with their back to the stadiometer in a neutral position with their feet flat and with good posture. Because women stop growing at about 16 years of age (2) and because of time and logistic constraints, height was only measured at the initial visit. Body mass was measured to the nearest 0.1 kg at each visit using a standard physician scale.

Statistical Analyses

A restricted maximum-likelihood linear mixed model (LMM) regression analysis with a compound symmetric heterogeneous variance-covariance matrix structure was performed to determine if body composition differed by sport over the course of a season and between years of collegiate competition. This analysis was selected because most participants had repeated measures over a 1- to 4-year time period; these measurements were highly correlated and there were missing data (e.g., some athletes did not have all 3 years of measurements). Linear mixed models are less challenged by missing data and multicollinearity. Analysis was conducted with the PROC MIXED procedure (SAS 9.2; SAS Institute, Cary, NC, USA). The outcome variables of interest were %BF, lean mass, fat mass, and total mass. Percent body fat was calculated in the following manner: %BF = (fat mass/[fat mass + lean soft mass + bone mineral content]) × 100. The predictor variables were sport (BB, SOC, SW, TR, and VB), time of season (preseason vs. postseason), and year relative to first DXA scan. After examining Q-Q plots and residual plots for each outcome variable, it was determined that data were both normal and of equal variance, thus, meeting basic analysis assumptions. A linear mixed model was used to determine the main effect of each independent variable and interactions

TABLE 1. Means for all observed (unadjusted) data and adjusted (fitted) means for body composition of various sports across multiple time points and years.*

	Basketball	Soccer	Swimming	Track	Volleyball
Height (cm)	178.6 ± 1.5†‡§	166.3 ± 0.9‡‖	172.4 ± 0.8‖	168.7 ± 0.9‖	181.1 ± 2.0
Total mass (kg)	76.2 ± 0.8	62.5 ± 0.5	68.3 ± 0.4	62.2 ± 0.4	73.1 ± 0.7
Total mass adjusted	77.5 ± 1.4†‡§‖	63.3 ± 1.3‡‖	69.0 ± 1.3§‖	63.3 ± 1.2‖	72.0 ± 1.5
Fat mass (kg)	19.7 ± 0.6	15.2 ± 0.3	16.0 ± 0.3	10.0 ± 0.3	16.4 ± 0.4
Fat mass adjusted	21.0 ± 0.8†‡§‖	15.6 ± 0.8§	15.9 ± 0.8§	11.1 ± 0.7‖	16.6 ± 0.9
Lean mass (kg)	52.9 ± 0.3	44.4 ± 0.3	49.5 ± 0.3	49.3 ± 0.4	53.3 ± 0.6
Lean mass adjusted	52.5 ± 0.7†‡§	44.8 ± 0.7‡§‖	49.9 ± 0.7‖	49.6 ± 0.6‖	52.4 ± 0.8
%BF**	25.2 ± 0.5	24.1 ± 0.4	23.3 ± 0.3	16.0 ± 0.4	22.5 ± 0.5
%BF adjusted	26.8 ± 0.8†‡§‖	24.2 ± 0.1§	22.8 ± 0.1§	17.3 ± 0.1‖	22.5 ± 0.9

*Mean ± SE.
†Significantly different than soccer.
‡Significantly different than swimming.
§Significantly different than track.
‖Significantly different than volleyball, $p < 0.05$.
**%BF = percent body fat.

Table 2. Means for all observed (unadjusted) data and adjusted (fitted) means for body composition of various sports pre- and postseason.*

	Seasonal period	Basketball	Soccer	Swimming	Track	Volleyball
Total mass	Preseason	76.8 ± 1.1	62.3 ± 0.7	68.5 ± 0.6	61.9 ± 0.6	72.7 ± 1.0
Observed (kg)	Postseason	75.5 ± 1.2	62.7 ± 0.7	68.1 ± 0.6	62.7 ± 0.6	73.6 ± 1.1
Total mass	Preseason	77.5 ± 1.2	63.3 ± 1.1	69.0 ± 1.1	63.3 ± 1.0	72.0 ± 1.3
Adjusted (kg)	Postseason	76.7 ± 1.2†	63.7 ± 1.1	68.6 ± 1.1	63.9 ± 1.0	72.5 ± 1.3
Fat mass	Preseason	20.4 ± 0.8	15.1 ± 0.4	16.6 ± 0.4	10.8 ± 0.4	16.5 ± 0.5
Observed (kg)	Postseason	18.9 ± 0.8	15.3 ± 0.4	15.4 ± 0.4	8.8 ± 0.4	16.3 ± 0.5
Fat mass	Preseason	21.6 ± 0.8	15.5 ± 0.8	16.5 ± 0.8	11.8 ± 0.7	16.7 ± 0.9
Adjusted (kg)	Postseason	20.5 ± 0.8†	15.7 ± 0.8	15.4 ± 0.8†	10.4 ± 0.7†	16.6 ± 0.9
Lean mass	Preseason	52.8 ± 0.5	44.4 ± 0.5	49.3 ± 0.4	48.2 ± 0.5	52.9 ± 0.9
Observed (kg)	Postseason	53.1 ± 0.5	44.5 ± 0.5	50.0 ± 0.4	50.9 ± 0.5	53.9 ± 1.0
Lean mass	Preseason	52.4 ± 0.7	44.7 ± 0.7	49.5 ± 0.7	48.7 ± 0.6	52.0 ± 0.8
Adjusted (kg)	Postseason	52.6 ± 0.8	44.9 ± 0.7	50.3 ± 0.7†	50.6 ± 0.7†	52.8 ± 0.8†
% Fat	Preseason	26.0 ± 0.7	24.0 ± 0.5	24.0 ± 0.4	17.4 ± 0.6	22.7 ± 0.7
Observed	Postseason	24.3 ± 0.7	24.2 ± 0.5	22.5 ± 0.5	14.0 ± 0.6	22.2 ± 0.7
% Fat	Preseason	27.4 ± 0.8	24.1 ± 0.8	23.5 ± 0.8	18.5 ± 0.8	22.8 ± 1.0
Adjusted	Postseason	26.2 ± 0.9†	24.2 ± 0.8	22.1 ± 0.8†	16.2 ± 0.8†	22.2 ± 1.0

*Mean ± *SE*.
†Significant change from preseason, $p < 0.05$.

Table 3. Adjusted (fitted) means for body composition across seasons in various sports.*

	Body mass (kg)	Fat mass (kg)	Lean mass (kg)	%BF†
Basketball				
Year 1	75.7 ± 1.1‡	20.0 ± 0.7‡	52.2 ± 0.7	25.8 ± 0.8‡
Year 2	76.0 ± 1.2‡	20.1 ± 0.8‡	52.3 ± 0.7	25.9 ± 0.8
Year 3	77.9 ± 1.2	21.8 ± 0.8	52.5 ± 0.8	27.5 ± 0.9
Soccer				
Year 1	62.4 ± 1.1	14.7 ± 0.7	44.6 ± 0.7	23.2 ± 0.8
Year 2	62.2 ± 1.1	14.6 ± 0.8	44.5 ± 0.7	23.2 ± 0.8
Year 3	61.7 ± 1.2	13.9 ± 0.8	44.9 ± 0.7	22.3 ± 0.9
Swimming				
Year 1	67.5 ± 1.1	15.0 ± 0.7	49.7 ± 0.7‡	21.9 ± 0.8
Year 2	67.9 ± 1.1	15.1 ± 0.7	49.9 ± 0.7	22.0 ± 0.8
Year 3	67.6 ± 1.1	14.6 ± 0.8	50.3 ± 0.7	21.3 ± 0.8
Track				
Year 1	62.3 ± 1.0	10.2 ± 0.7	49.2 ± 0.6	16.4 ± 0.7
Year 2	62.6 ± 1.0	10.6 ± 0.7	48.9 ± 0.6	17.0 ± 0.7
Year 3	63.0 ± 1.1	10.9 ± 0.8	49.0 ± 0.7	17.4 ± 0.8
Volleyball				
Year 1	70.5 ± 1.2‡§	15.5 ± 0.8	51.9 ± 0.8‡§	21.5 ± 0.9
Year 2	71.7 ± 1.3	15.9 ± 0.9	52.6 ± 0.8‡	21.7 ± 1.0
Year 3	71.9 ± 1.4	15.2 ± 1.0	53.7 ± 0.9	20.7 ± 1.1

*Adjusted mean ± *SE*.
†%BF = percent body fat.
‡Significantly different than year 3. $p < 0.05$.
§Significantly different than year 2.

between sport and time of season and sport and year. Nonsignificant interactions were then eliminated to produce a final LMM model. Year 4 measurements were eliminated from the analysis because a dearth of data at this time point resulted in model inconvergence. Regression coefficients were tested using a t value generated for each comparison. Because height was measured only 1 time on each athlete, a 1-way analysis of variance (SPSS 19; SPSS, Inc., Chicago, IL, USA) was used to determine if there were significant differences between sports. The empirical cut-off value designating significance for all tests was set to $p \leq 0.05$ for all analyses.

Reliability measures were obtained for all DXA measures. Dual-energy x-ray absorptiometry scans, performed 3 times in a single day on 3 female, athletic college-aged individuals, exhibited coefficient of variation values of 0.15, 2.12, 0.82, and 2.12% for total mass, total fat mass, total lean mass, and %BF, respectively. These values match previous reliability testing from the same laboratory with the same DXA machine (36).

Results

Initial LMMs were additionally adjusted for age (years) and race (African American or other ethnicity), factors highly related to body composition that could confound results (36). However, age was not related to any outcome ($p > 0.5$) and thus was trimmed from all models. Ethnicity significantly predicted fat mass ($p = 0.006$) and %fat ($p = 0.0001$), but no other outcomes. Ethnicity was retained in models as trimming this factor did not influence other associations. In the tables, the means are adjusted for all other variables retained in the models: Ethnicity, Pre-Post, Sport, Test-Year, Sport × Pre-Post, Sport × Test Year interaction. Data were analyzed in a LMM; therefore, statistically significant differences are designated as adjusted means. Sport was significantly related to all outcomes ($p < 0.001$). The sport × year interaction was significant for total mass (df = 8/537, $F = 3.13$, $p = 0.0018$), total fat (df = 8/546, $F = 3.26$, $p = 0.0012$), total lean (df = 8/538, $F = 2.01$, $p = 0.0429$), and %BF (df = 8/551, $F = 2.80$, $p = 0.0048$). The sport × pre-post season interaction was significant for fat mass (df = 1/566, $F = 27.85$, $p < 0.001$), lean mass (df = 1/551, $F = 72.73$, $p < 0.001$), and %BF (df = 1/571, $F = 43.24$, $p < 0.001$), but not for total mass.

Between Sports

Observed and adjusted means for height, total mass, lean mass, fat mass, and %BF across sports are shown in Table 1. Basketball had significantly greater height and lean mass than SOC, SW, and TR ($p < 0.05$) and significantly more total mass and %BF than all other sports ($p < 0.05$). Soccer weighed significantly less than BB, SW, and VB ($p < 0.05$), had significantly less lean mass than all other sports ($p < 0.05$), and had lower %BF than BB ($p < 0.05$) and higher %BF than TR ($p < 0.05$). Swimmers were shorter, lighter, and had less lean mass than BB and VB ($p < 0.05$) but were taller, heavier, and had more lean mass than SOC ($p < 0.05$). In addition, SW had more mass and %BF than TR ($p < 0.05$) and less %BF than BB ($p < 0.05$). Track had significantly less %BF than all other teams ($p < 0.05$), was shorter, weighed less, and had less lean mass than BB and volleyball ($p < 0.05$). In addition, TR had significantly more lean mass than SOC ($p < 0.05$) and less total mass than SW ($p < 0.05$). Volleyball was taller, heavier, and had more lean mass than SOC, SW, and TR ($p < 0.05$), was lighter and had less %BF than BB ($p < 0.05$) and more %BF than TR ($p < 0.05$).

Pre- to Postseason

Changes from pre- to postseason are shown in Table 2. Basketball significantly decreased total mass, fat mass, and %BF ($p < 0.05$). Soccer had no significant changes for any variable. Swimming and TR both significantly decreased fat mass and %BF and increased lean mass ($p < 0.05$). Volleyball significantly increased lean mass ($p < 0.05$).

Across Years Within Sport

Table 3 shows the means for all variables for all sports across 3 years. Basketball had a significant increase in total body mass and fat mass from years 1 and 2 to year 3 ($p < 0.05$) and a significant increase in %BF from year 1 to year 3 ($p < 0.05$). Swimming showed a significant increase in lean mass from year 1 to year 3 ($p < 0.05$). Volleyball showed a significant increase in lean mass from year 1 to year 2 ($p < 0.05$) and year 2 to year 3 ($p < 0.05$) and in total body mass from year 1 to year 2 and 3 ($p < 0.05$). There were no significant changes for any variables for SOC or TR ($p > 0.05$).

Discussion

The uniqueness of this study was examining body composition longitudinally across 3 years in collegiate female athletes. The primary significant changes were an increase in lean mass in SW and VB and an increase in total mass, fat mass, and %BF in BB. The pre- to postseason data confirmed our prediction that SW and TR would increase lean mass and TR would decrease %BF from pre- to postseason. However, contrary to expectations, BB and SW also decreased %BF, and VB increased lean mass. Findings were as anticipated when comparing sports. Basketball and VB were taller, heavier, and had more lean mass than the other sports, whereas TR had less %BF. In addition, SOC had less lean mass than all other sports and there was no difference in %BF among SOC, SW, and VB.

In general, females show an increase in fat mass and %BF in their 20s (19). Contrary to this, the SOC, SW, TR, and VB athletes in this study, who were already physically active before beginning college and who entered with a lower %BF than the average college female, showed no significant change in %BF. Surprisingly, BB showed an increase in total mass and %BF. This is contrary to previously published data showing no change in total mass or %BF over 3 years in collegiate female BB players (30). Based on this previous data and the data from the other teams in this study, the increase in %BF in BB is probably not typical.

Most females achieve their adult level of FFM by 15–16 years of age (19). The strength and conditioning programs for BB, SW, TR, and VB, more so than SOC, were designed to increase strength and power (personal communication with the team's strength and conditioning coaches) and therefore, presumably lean mass. Although SW, TR, and VB all increased lean mass from pre- to postseason, only SW and VB showed a significant longitudinal increase in lean mass. These findings for SW are consistent with data from a study where 31 elite female swimmers showed a significant increase in lean mass index over 3 years (32). Direct comparison is not possible because lean mass index, which is derived from "the relationship between changes in log-transformed mass and sum of skinfolds using repeated-measures multiple linear regression," (32) and not actual lean mass, was not reported. However, these results confirm that an increase in lean mass can be expected in SW over a period of years. The finding that TR reported significant increases in lean mass from pre- to postseason, but not across 3 years, is a bit of a conundrum, particularly when contrasted to the longitudinal increase in total and lean mass in VB, another sport where the power to weight ratio impacts performance. Track had a lower %BF than the other sports. Perhaps the need or desire to maintain this low %BF makes increasing lean mass more difficult. The lack of change in BB is somewhat surprising compared with SW and VB, but it is in agreement with previously published data (30). It is interesting that BB and VB have similar lean mass values; yet, VB increased lean mass from pre- to postseason and across 3 years, whereas BB did not. This potentially reflects a difference in the physiological demands or training for these 2 sports.

It appears that, in general, athletes, coaches, and trainers should not expect longitudinal changes in %BF during the collegiate career of female BB, SOC, SW, TR, and VB players; however, they should expect a small but significant increase in lean mass of 0.6–1.8 kg in SW and VB. To understand body composition changes over time in female collegiate athletes, more studies are needed. Additional variables including training practices, power and strength performance measures, and competitive rankings are needed to increase the value of interpreting these data. Expanding this research stream to include a wider variety of sports would also be beneficial.

Pre- to postseason changes were similar to those shown previously. %BF: The significant pre- to postseason decreases of −0.8 %BF, −1.4 %BF, and −2.3 %BF in BB, SW, and TR, respectively, are similar to the previously reported average values of −1.4 %BF in BB (6,14,33,35), −1.6 %BF in SW (6,14,15,18,22,27,29,31,33,38), and −1.5 %BF in TR (6,14,21). The nonsignificant changes seen in this study of 0.1 %BF in SOC and −0.6 %BF in VB are also similar to the previously reported nonsignificant average change of 0.1 %BF seen in both SOC (7,23) and VB (6,14). Lean mass: Significant increases in lean mass of 0.8 kg for SW, 1.9 kg for TR, and 0.8 kg for VB were also observed. These changes are similar to the previously reported mean change of 0.9 kg for SW (6,14,15,18,22,27,29,31,33,38) and 1.7 kg for TR (6,14,21); however, both previous studies showed nonsignificant decreases of −0.3 kg (6) and −1.1 kg (14) in VB. Nonsignificant changes in lean mass of 0.2 kg were found in both BB and SOC. The nonsignificant changes in SOC are in agreement with previous studies (7,23); however, 2 (33,35) of 4 (6,14) previous studies have reported significant increases in FFM in BB with the mean pre- to postseason change for all 4 studies equal to 0.8 kg. The emerging consensus from within season research leads to the expectation that: (a) BB, SW, and TR will significantly decrease %BF by 1–2 %BF, but %BF will not change in SOC and VB; and (b) SW and TR will significantly increase lean mass by 1–2 kg, but lean mass will not change in SOC. The lean mass results are equivocal for BB and VB.

Although monitoring body composition pre- to postseason can be used to assess changes of the team as whole, it can also be used to track individual athletes. A potential problem and one that should be monitored during the season is an increase in %BF (5), particularly in reserves. Although this did not occur at the team level in this study, it did with individual athletes. For example, 1 VB player increased her total mass by 4.0 kg, her fat mass by 4.2 kg, and her %BF by 4.4% from pre- to postseason. The training staff was completely unaware of this and while it was too late to change it for that season, they worked with the athlete in the off-season. By the end of the next season, she had lost 0.6 kg of total mass, 2.4 kg of fat mass, and 3.0% BF and gained 1.9 kg of lean mass.

Two other studies have compared the body composition of collegiate female BB, SW, TR, and VB (6,14), 1 has compared BB and VB (26), and another has compared SW and VB (10). No studies have compared SOC to BB, SW, TR, or VB in collegiate female athletes. Basketball values for 1 study (26) varied greatly from all other studies and were not included in this discussion. Similar to previous studies (6,14): (a) BB and VB were taller than SW, and SW was taller than TR; (b) BB and VB were heavier than SW, and SW was heavier than TR; (c) BB and VB had more lean mass than SW and TR; and (d) SW and VB had similar %BF, which were higher than TR. Contrary to previous data (6,14), this study found BB to have higher %BF than VB. These differences highlight the body composition profiles that are probably most advantageous for these sports.

Although this analysis was unique in that it examined changes in body composition over a period of years, the current data may have limited generalizability because all athletes were from the same university. This necessitates a comparison of values with previous work, but this must be interpreted with caution for 2 primary reasons. First, different measurement techniques can yield different results (3,24). Most studies with collegiate female athletes have used hydrostatic weighing (4,7,14–18,21–23,27,31,33,35,38), but some, primarily more recent studies, have used DXA (6,10,12,26,29,37). Second, women athletes in some sports may have changed over the last several decades. The current height and FFM values for BB are similar to the previously reported (6,14,17,33,35) values. Although the current body mass and %BF are similar to the recently reported values (6), they are higher than the values reported before 1992 (14,17,33,35). Conversely, for SW (1,6,10,14,15,18,29,31,33,38) and VB (6,10,13,14,16,26), the current %BF is similar to the previously reported values. However, the current height, mass, and FFM are similar to the recently reported values for SW (6,37) and VB (6,10) but higher than the values reported in all studies before 1996 in VB (13,14,16,26) and all (1,10,14,15,18,22,29,31,33,38), but 1 (37) in SW. The same findings were not observed for SOC and TR. For SOC, the height and mass are similar, but the %BF is higher and the FFM is lower than the previously reported values in NCAA Division 1 players (7,12,23). The TR values for height, FFM, and %BF are similar while the mass is higher than those reported previously (14,20,21). Although the use of DXA in the recent studies instead of hydrostatic weighing used in earlier studies may partially explain these differences, current female collegiate BB players may be heavier and fatter, but not taller or more muscular, than players before 1992. Similarly, current VB and SW athletes may be taller, heavier, and more muscular but not leaner than athletes before 1995. These are interesting observations; however, because this study was not designed to investigate these differences, studies designed to do so are warranted.

One shortcoming and potential criticism of most studies examining BB and VB, including the current study, is that they do not split out post and guard players in BB and hitter/blockers and setters/defensive specialist in VB. Only one study (17) split BB into positions, and none have done so with VB. To address this shortcoming, in an exploratory analysis was conducted using these splits within the current data set. Similar to previous research (17), BB guards compared to post players had less height (172.8 vs 185.6 cm), total mass (69.4 vs 82.6 kg), fat mass (16.2 vs 23.6 kg), lean mass (50.0 vs 55.1 kg), and %BF (23.0 vs 28.0%). Similarly, VB defensive specialists and setters had less height (170.3 vs 187.3 cm), total mass (66.7 vs 76.9 kg), and lean mass (47.0 vs 56.3 kg), but higher %BF (25.0 vs 21.9%) than hitters and blockers. The overall body composition values were similar between BB guards and VB defensive specialists and between BB post players and VB hitters. The exception was that VB hitters had a much lower %BF than BB post players. It is unknown if the lower %BF in VB hitters compared to BB post players is typical. To our knowledge, there is no comparable published data. Further research is needed to confirm and extend these findings.

The athletes in this study had very healthy body mass index (BMI) values. At their first measurement, the mean BMI was $22.5 \pm 4.4\ \mathrm{kg \cdot m^{-2}}$ with 84.0% having a BMI between 18.5 and $24.9\ \mathrm{kg \cdot m^{-2}}$. Only 1.9% had a BMI $< 18.5\ \mathrm{kg \cdot m^{-2}}$ and 0% had a BMI $\geq 30.0\ \mathrm{kg \cdot m^{-2}}$. This contrasts with the 55.8 and 31.9% (11) of the 20- to 39-year-old women in the U.S. with BMI values of ≥ 25.0 and $\geq 30.0\ \mathrm{kg \cdot m^{-2}}$, respectively. In addition, the athletes in this study had a similar mean BMI (22.5 vs. $22.0\ \mathrm{kg \cdot m^{-2}}$) but lower %BF (22.3 vs. 31.0%) than a large cohort of exercising female students from the same university who were measured in our laboratory during the same time period under the same conditions and with the same DXA machine (36). This contrast between BMI and %BF between collegiate female athletes and nonathletes has been shown previously (28) and is consistent with previous studies indicating that a high BMI does not necessarily represent over fatness across athletic populations (25,39). Finally, compared to their exercising college student counterparts (36), the athletes in this study were taller (172.3 vs. 163.2 cm) and had more total mass (66.9 vs. 61.2 kg,) and lean soft tissue mass (48.7 vs. 38.9 kg). This is also consistent with previously published data (28).

To our knowledge, this is only the second longitudinal body composition study with collegiate female athletes and highlights the need for further research. The primary strength of this study is that data were collected over a number of years. This increases the number of subjects and decreases the chances of having data skewed by a single team with their unique characteristics. Limitations include: (a) analyses did not discern between high and low performers based on minutes played or performance times; (b) lack of control for injury or sickness; (c) exact testing times, dates, and conditions were not tightly controlled; (d) age at the initial test varied; (e) some missing values; (f) all subjects were from the same university; and (g) the lack of a nonathletic control group.

Practical Applications

Monitoring individual and team body composition can be important for athletes, coaches, and trainers. The body composition for most college female athletes should be in the normal healthy range with a lower %BF than the student population. Expect TR runners and jumpers to have the lowest %BF. Anticipate small, but significant positive changes from pre- to postseason. Those who regress significantly should be identified. During their college careers, female collegiate athletes can be expected to maintain their %BF and athletes in sports like SW and VB can anticipate an increase in lean mass, but the increases may be less than most athletes, coaches, and trainers envision.

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