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Comparison of Techniques for Tracking Body Composition Changes across a Season in College Women Basketball Players

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ABSTRACT

International Journal of Exercise Science 11(4): 425-438, 2018. Body composition assessment has become an integral part of athletes' training schedules. Questions remain concerning the accuracy of various methods to track body composition changes over a competitive year cycle. The purpose of this study was to compare various methods of tracking body composition across a college women's basketball season. Fourteen Division II women (age = 20.1 ± 1.2 y) were measured prior to the season (T1), after pre-season conditioning (T2), at mid-season (T3), and at the end of the season (T4) using skinfolds (SKF), two bioelectric impedance analysis (BIA) devices, and dual-energy x-ray absorptiometry (DXA). BIA devices were hand-to-hand (H-BIA) and foot-to-foot (F-BIA) single-frequency models. SKF were used to estimate %fat using four prediction equations. A method x trial factorial ANOVA on %fat with repeated measures over the second factor indicated that all methods except the Durnin-Womersley SKF equation were significantly lower than DXA. Across trials, DXA %fat at T1 (25.3 ± 4.7%) was significantly higher than at T2 (24.3 ± 4.6%), T3 (24.6 ± 4.6%), and T4 (24.4 ± 5.1%). Agreement between DXA and the other methods were moderate (r = 0.48 – 0.86). Rank-order correlations of DXA with the other methods to compare team order indicated H-BIA (rho = 0.67 – 0.78) and F-BIA (rho = 0.62 – 0.77) provided comparable agreement, with SKF methods having lower agreement for team order (rho = 0.46 – 0.73). Compared to the DXA standard, a foot-to-foot BIA device may provide adequate but significantly lower relative tracking of %fat across a women's basketball season.

KEY WORDS: Anthropometry, skinfolds, DXA, bioelectrical impedance analysis

INTRODUCTION

Training for most college sports has become a year-round process and typically follows a cyclic pattern of pre-season general fitness preparation which moved into more specific early season conditioning, and finally evolves to a late season balance of activity and recovery (27,33,48). In basketball, programs begin with general aerobic conditioning and resistance training, progressing to sport-specific fundamentals prior to the official game season. Once the competitive season starts, the volume of resistance training is typically reduced significantly in favor of more aerobic conditioning (23,27,33,48,61). As the major part of the competitive season progresses, many teams reduce their conditioning work since several games a week are thought to provide sufficient stimulus to maintain a fitness level (18,19) and avoid physical and mental fatigue (33). However, due to variations in playing time, not all players may maintain a high level of fitness across the competitive year which may affect their body composition (18,19).

Of the studies involving basketball, only a few have considered body composition of players as an integral part of the overall yearly training plan. Siders, Bolonchuk, and Lukaski (51) were among the first to note that women basketball players lost a significant amount of fat mass (FM) while gaining a significant amount of fat-free mass (FFM) over a competitive season when measured by hydrostatic weighing. Nunes et al. (38) reported no change in %fat in elite women basketball players but did show a significant decrease in the total of four skinfolds over a 50-day preseason conditioning period. Ladwig et al. (31) observed a 1.8% decrease in %fat in Division-I women over an entire season determined by air displacement plethysmography (ADP), accompanied by a 0.9% decrease in body mass which would suggest a gain in FFM. In theory, gains in muscle mass and losses in FM would be beneficial to players over the duration of a competitive year. Due to the importance of determining components of body composition and the scarcity of studies showing patterns of change across a season of training and competition in women basketball players, it seems important to evaluate the fluctuations that might occur in FFM, FM, and %fat in college players.

However, with so many methods of assessing body composition available, it may be difficult for individuals involved in the training of players to decide which one to use to provide accurate tracking of important changes across a season. The major concern would be to select a procedure with the greatest sensitivity that would provide the best representation of body composition changes throughout the yearly cycle. The difficulty with selecting such a measurement procedure revolves around the acceptance of a "gold standard" method that is agreed upon by the majority of users (22,43).

For over six decades, hydrostatic (underwater) weighing has been widely accepted as a primary standard for evaluating the two major components of body composition (i.e., FM and FFM) based on the density of human tissue. The problem with this approach may be the assumption of constant density of lean tissue (1,35,45,58). Despite the variability in density of FFM, underwater weighing has often been used as the criterion for judging the correlations with various subcutaneous skinfold measurements. Over time, a number of prediction equations have been developed to estimate body density or %fat in athletes due to the convenience of skinfold measurement (12,14,26,34,40,53,54,57,59).

In the 1980's, bioelectrical impedance analysis (BIA) emerged as a convenient and popular technique for assessing body composition. Currently, the most frequently used BIA devices are single-frequency (50 kHz) apparatuses that emit an imperceptible electrical current that travels through the water compartment of the body to assess the degree of resistance to current flow. The major portion of body water is located in muscle, which offers less impedance to current flow, and therefore, greater current flow serves to indicate a greater FFM (21). Estimated FFM is then utilized to calculate %fat. Most of these devices require the input of gender, age, height, and body weight, and some have a setting for athletes to allow estimation of %fat through their proprietary equations specific to each device.

The method now widely accepted as an accurate technique for assessing regional and global body composition components is dual-energy x-ray absorptiometry (DXA) (16,17,22,28,36,42,43,44). This approach uses a low-dose x-ray to evaluate the different densities of tissues (21,22,36) and has become one of the most widely accepted techniques for assessing body composition in athletes (2,28,46,57). A major drawback to this method is the exorbitant cost of the device, which makes it unavailable to many athletic teams. However, if an acceptable method could be found that compared well with DXA at all points across a training cycle, it would expedite assessment of body composition to avoid unnecessary constraints on the time of college women basketball athletes and yet provide meaningful data to aid in maintaining high-level performance throughout the long season. Thus, the purpose of this study was to compare selected methods of tracking body composition across a college women's basketball season compared to DXA as a standard.

METHODS

Participants

Fourteen members of a Division II women's basketball team (age = 20.1 ± 1.2 yrs, height = 175.5 ± 5.7 cm) volunteered to participate. The study was approved by the Institutional Review Board for the use of human subjects, and all participants provided written informed consent to participate in accordance with the ethical standards of the Helsinki Declaration.

Protocol

Each player was measured prior to the season (T1), after pre-season conditioning (T2), at mid-season (T3), and at the end of the season (T4). Measurements were made approximately every five weeks between 15:00 and 17:00 hours each time, with players having not engaged in strenuous physical activity for a minimum of six hours prior to measurement (36). Although hydration was not measured, players indicated they had consumed water throughout the day but had not eaten for at least three hours prior to measurement (20). Players were dressed in shorts and T-shirts at each test session. This measurement protocol was assumed to be the more typical approach to measuring athletes who maintained a regular college schedule.

Skinfolds (SKF) were measured on the right side of the body at the biceps, triceps, subscapular, suprailiac, abdominal, and thigh sites according to the procedures given by Norton et al. (37). Three measurements were taken at each site by the same technician who had 14 years of experience using Lange calipers (intra-rater reliability, ICC>0.94), and the average at each site was used for analysis. SKF were used to predict %fat using equations developed by Durnin and Wormsley (D-W) (12), Jackson, Pollock, and Ward (J-P)(9), as well as on NCAA Division-I (59) and Division-II athletes (34). The Warner et al. (59) equation was the only one developed using DXA; all others were developed using underwater weighing as the criterion.

Single-frequency bioelectric impedance analysis (BIA) was used to determine %fat from a hand-to-hand model (H-BIA, Omron, model 306C, Hoffman Estates, IL) and a foot-to-foot model (Tanita 521, Tanita Corp, Arlington Heights, IL). Each was an inexpensive, commercially available model with an athletic setting widely used to assess %fat.

Dual-energy x-ray absorptiometry (DXA) was used as the criterion body composition method (General Electric Lunar iDXA, Fairfield, CT). Each player was positioned on the scanning table with hands in a prone position adjacent to the side. They removed their shoes and any metal jewelry, watches or other objects prior to measurement. Each scan required approximately 7 minutes.

Statistical Analysis

SPSS (Verison 24, IBM) was used to perform a device by test period multi-factorial ANOVA with repeated measures across the second factor to evaluate differences in each body composition component for the seven test methods. If Mauchly's test of sphericity was significant, the Greenhouse-Geisser adjustment was applied. *Post hoc* testing was performed using the Bonferroni correction for multiple trials. Pearson correlation coefficients were used to evaluate the relationship among different prediction methods compared to DXA. Rank-order correlations were used to evaluate the relative position of player %fat values compared to other members of the team at each test period. The Bland-Altman procedure was used to assess bias between predicted and actual measurements and 95% limits of agreement (LoA) (4). A significant level of $p<0.05$ was utilized throughout the analysis process. Power for all analyses was greater than 0.91.

RESULTS

Team analysis showed no significant change in body mass ($p=0.61$) over the course of the training year (Table 1). Eight players lost body mass (3.2 ± 1.4 kg, -4.3 ± 1.7%) while six players gained (3.0 ± 2.2 kg, 4.2 ± 3.1%). Lean mass (LM) measured from DXA increased significantly ($p<0.01$) in 12 players (1.9 ± 1.3 kg, 3.9 ± 2.5%) during the pre-season conditioning period and then showed minor, non-significant declines (-1.3 ± 1.2 kg, -2.7 ± 2.6%) until the end of the season (Figure 1). Post-season LM was within 1.0 ± 4.6% of pre-season value ($p<0.05$). FM declined nonsignificantly ($p = 0.08$) after conditioning (-1.1 ± 1.4 kg, -5.5 ± 6.8%), followed by small gain (0.4 ± 2.0 kg, 2.4 ± 10.6%) by the end of the season. Percent fat (%fat) decreased significantly ($p<0.001$) from T1 to T2 (1.8 ± 1.5%) and increased non-significantly ($p = 0.18$) between T3 and T4 (0.9 ± 2.3%).

Difference among devices ($F = 16.20$, $p<0.001$) and across trial periods ($F = 6.18$, $p<0.001$) for tracking %fat throughout the season were significant. The device by time interaction was not significant ($F = 0.78$, $p=0.72$). *Post hoc* tests found four of the prediction methods produced estimates that were significantly lower ($p<0.01$) than DXA (Figure 2). F-BIA and D-W skinfold prediction were not significantly different from DXA ($p>0.05$), with D-W slightly overestimating %fat (M ± SD = 1.6 ± 2.5%) and F-BIA underestimating %fat (M ± SD = -3.3 ± 2.4%). When D-W predicted %fat values for each time point were compared to DXA, with

Bonferroni correction for multiple trials, only the mid-season estimate was significantly different from DXA (p<0.002).

Table 1. Body composition components across a basketball season measured by DXA (n = 14).

	T1	T2	T3	T4
Body Mass (kg)	72.1±6.2	72.4±6.0	71.7±6.3	71.6±6.5
Lean Mass (kg)	49.1±3.4	50.6±3.7[a]	50.5±4.1	49.6±4.8
Fat-Free Mass (kg)	52.1±3.8	53.7±4.0*	53.4±4.1	52.5±4.9
Fat Mass (kg)	19.8±3.5	18.7±3.5	18.5±3.7	19.0±5.8
%fat	28.5±3.4	26.8±3.5	26.4±3.7	27.4±4.2
□6SKF[§] (mm)	105.3 ± 18.1	101.7 ± 20.8	104.4 ± 23.8	101.7 ± 21.0

Legend: T1 = Pre-Season, T2 = Conditioning, T3 = Mid-season, T4 = Post-Season.
[§]Σ6SKF = biceps+triceps+subscapular+suprailiac+abdominal+thigh, [a]Significantly different from other time periods (p<0.05)

Difference among devices (F = 16.20, p<0.001) and across trial periods (F = 6.18, p<0.001) for tracking %fat throughout the season were significant. The device by time interaction was not significant (F = 0.78, p=0.72). *Post hoc* tests found four of the prediction methods produced estimates that were significantly lower (p<0.01) than DXA (Figure 2). F-BIA and D-W skinfold prediction were not significantly different from DXA (p>0.05), with D-W slightly overestimating %fat (M ± SD = 1.6 ± 2.5%) and F-BIA underestimating %fat (M ± SD = -3.3 ± 2.4%). When D-W predicted %fat values for each time point were compared to DXA, with Bonferroni correction for multiple trials, only the mid-season estimate was significantly different from DXA (p<0.002).

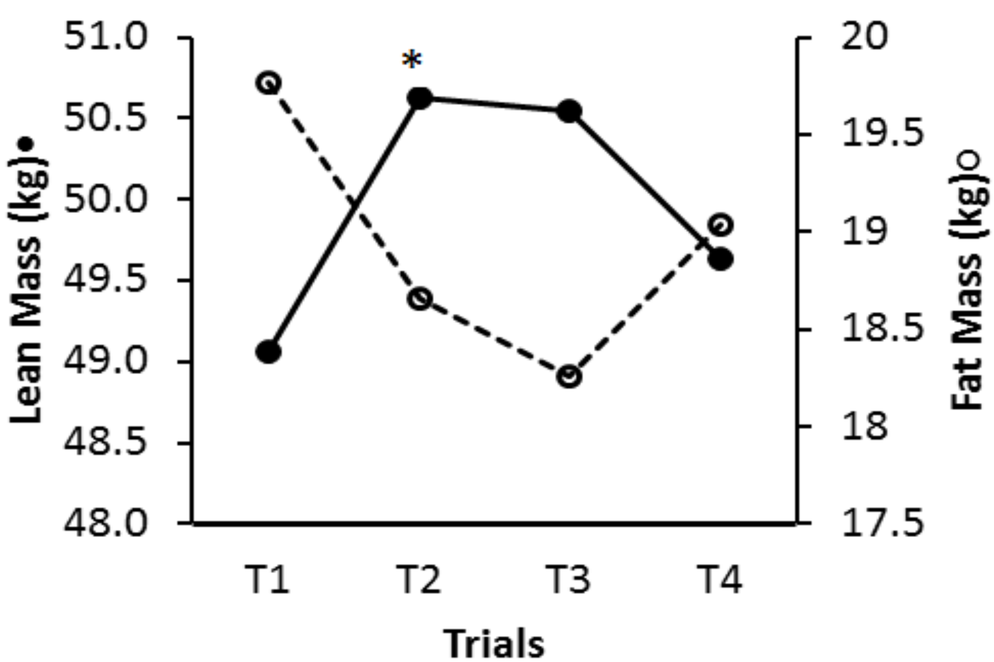

Figure 1. Comparison in lean mass (●) and fat mass (○) across a basketball season (n = 14). *p<0.05

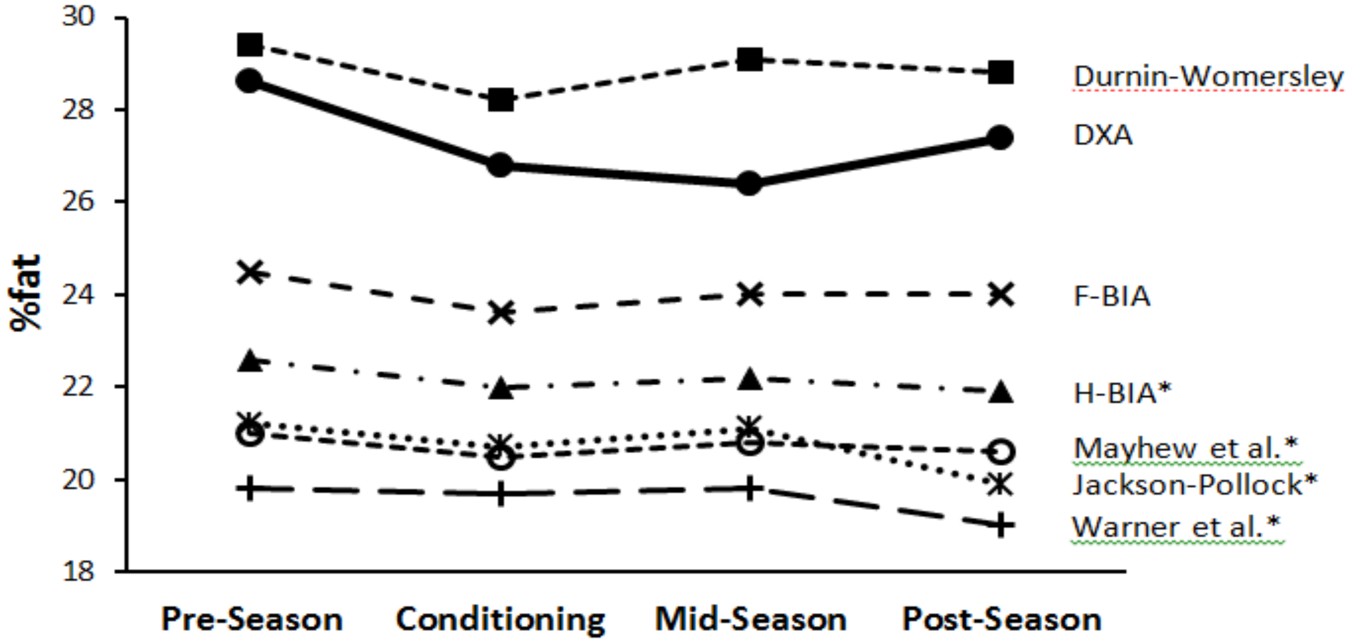

Figure 2. Changes in %fat across a season with different measurement techniques. Durnin-Womersley equation (12), DXA = dual-energy x-ray absorptiometry, F-BIA = foot-to-foot BIA, H-BIA = hand-to-hand BIA, Mayhew et al. equation (34), Jackson-Pollock equation (26), Warner et al. equation (59). *$p<0.05$.

Comparison of each prediction method with DXA at each test period produced correlations ranging from 0.48 to 0.86, providing coefficients of determination of 23% to 74% (Table 3). No single prediction technique had the consistently highest correlation with DXA %fat across the four test periods. Rank-order correlations between DXA and each prediction technique were significant at every test period (Table 3). Values were moderately high for F-BIA at T1 and T4 but not at T2 and T3. Correlations between the D-W equation and DXA were moderate at all test periods. There was very little difference between the team rankings between H-BIA and F-BIA compared to DXA. Rank-order values were lower for J-P and D-W equations at all test periods except for J-P at T2. F-BIA produced a better tracking pattern for %fat in team rankings compared to DXA than the other methods (Figure 2), with low standard errors of estimate (2.1 to 2.7%), despite showing average %fat values that were 2.5 to 4.1% lower than DXA. The remaining patterns were different at specific time points that would reduce their ability to track DXA %fat accurately across a competitive season (Figure 2). The lowest bias and smallest LoA were registered by the Durnin-Wormsley skinfold prediction (Table 4). Bias calculations for the remaining methods illustrated the large underprediction of %fat at each test period compared to DXA.

Since skinfolds are a widely used method for assessing body fat, the sum of 3 trunk skinfolds, 3 limb skinfolds, total SKF, and a limb:trunk ratio were compared to assess their accuracy to track %fat change over the season. The correlations between limb and trunk SKF sums were significant but moderate at each time point (Table 5); however, the changes in both limb and trunk sums followed a similar pattern which was different from the pattern of DXA %fat (Figure 4a). Total SKF coincided with DXA %fat only at T1 and T2. The pattern for limb:trunk SKF ratio compared to DXA %fat was somewhat more consistent (Figure 4c), but the correlations at each time point were not significant (Table 5). This would suggest that these SKF measurements in various combinations may not offer an adequate means of tracking %fat changes across the year in women basketball players when compared to a laboratory standard.

Table 3. Pearson correlation coefficients and rank-order correlations between DXA and each prediction techniques in college women basketball players (n = 14).

Technique	T-1		T-2		T-3		T-4	
	r	rho	r	rho	r	rho	r	rho
F-BIA	0.79*	0.77*	0.71*	0.65*	0.73*	0.62*	0.79*	0.74*
H-BIA	0.82*	0.75*	0.81*	0.67*	0.74*	0.71*	0.86*	0.78*
Durnin-Wormsley equation	0.64*	0.46	0.77*	0.65*	0.75*	0.53*	0.60*	0.60*
Jackson-Pollock equation	0.66*	0.52	0.77*	0.73*	0.75*	0.66*	0.60*	0.56*
Warner et al. equation	0.48*	0.28	0.77*	0.64*	0.75*	0.66*	0.65*	0.64*
Mayhew et al. equation	0.60*	0.48	0.83*	0.63*	0.77*	0.60*	0.68*	0.66*

Legend: T1 = Pre-Season, T2 = Conditioning, T3 = Mid-season, T4 = Post-Season. *p<0.05

Table 4. Bias and 95% limits of agreements for %fat between prediction techniques and DXA across a season (n = 14).

Technique	T-1		T-2		T-3		T-4	
	Bias	LoA	Bias	LoA	Bias	LoA	Bias	LoA
F-BIA	-4.1	-9.3 to 1.2	-3.2	-9.2 to 2.8	-2.5	-7.9 to 2.9	-3.4	-9.6 to 2.9
H-BIA	-5.9	-10.0 to -1.9	-4.8	-8.9 to -0.7	-4.3	-9.4 to 0.7	-5.4	-9.6 to -1.2
Durnin-Wormsley equation	0.9	-4.4 to 6.2	1.4	-3.8 to 6.6	2.6	-2.4 to 7.6	1.5	-5.2 to 8.2
Jackson-Pollock equation	-7.4	-12.8 to -2.1	-6.1	-10.1 to -2.1	-5.3	-10.6 to -0.1	-7.5	-14.3 to -0.7
Warner et al. equation	-8.8	-14.8 to -2.8	-7.1	-11.5 to -2.7	-6.7	-11.6 to -1.8	-8.3	-14.5 to -2.1
Mayhew et al. equation	-7.6	-12.8 to -2.3	-6.3	-10.3 to -2.4	-5.7	-10.5 to -0.8	-6.7	-12.8 to -0.7

Table 5. Pearson correlation coefficients and rank-order correlations of skinfold combinations with DXA %fat across a season (n = 14).

	T1		T2		T3		T4	
	r	rho	r	rho	r	rho	r	rho
Limb SKF Total (mm)	0.48	0.26	0.73*	0.48	0.68*	0.54*	0.43	0.35
Trunk SKF Total (mm)	0.63*	0.60*	0.71*	0.58*	0.66*	0.57*	0.59*	0.57*
Total SKF (mm)	0.68*	0.59*	0.82*	0.63*	0.73*	0.59*	0.63*	0.56*
Limb:Trunk Ratio	-0.13	-0.22	-0.11	-0.11	-0.18	-0.17	-0.27	-0.27

Legend: T1 = Pre-Season, T2 = Conditioning, T3 = Mid-season, T4 = Post-Season. *p<0.05

DISCUSSION

The main objective of this study was to evaluate the potential of selected prediction techniques to track changes in body composition of college women basketball players across a competitive season compared to a laboratory standard (i.e., DXA). Previous studies have divided the competitive year into two or three parts (11,19,23,31,33,56). The current study is unique in that it divided the competitive year into four phases, more typical of the way coaches approach their training program. Since college basketball has one of the longest seasons of any sport, care must be taken to maintain high levels of conditioning, prevent fatigue, and insure factors that lend themselves to good performance. Changes in body composition (i.e., loss of LM and gain in FM), although subtle, could influence performance, especially in the latter part of the season.

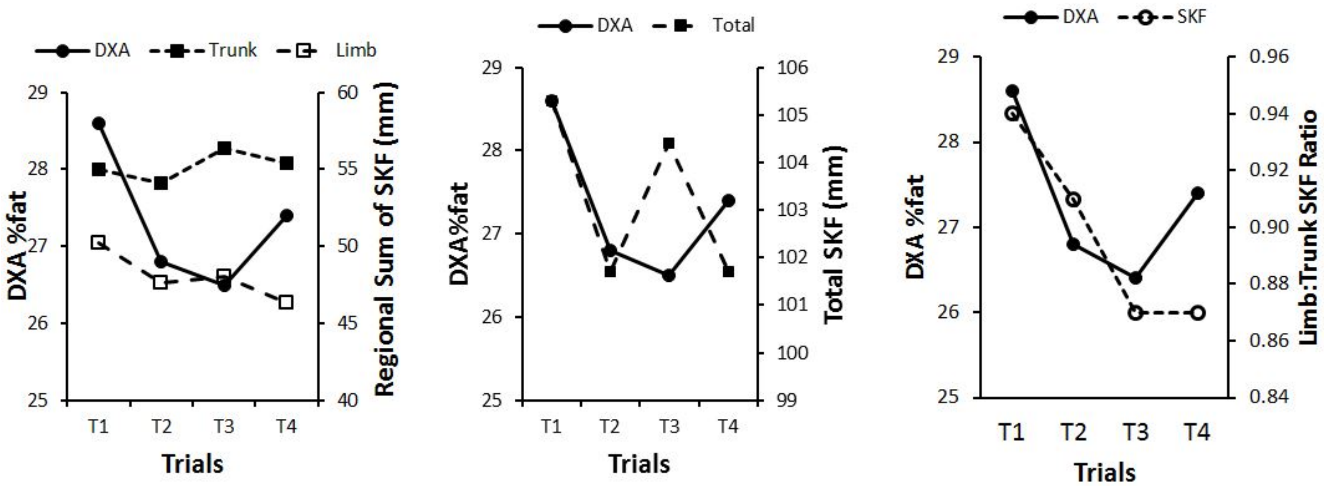

Figure 4. Comparison of sum of regional skinfolds (a), sum of all skinfolds (b), and limb:trunk skinfold ratio (c) for tracking %fat change over a competitive season.

In the current study, the criterion method of DXA showed a distinct pattern of LM and FM cycling during the year-long season. Greater emphasis on resistance training during the pre-season conditioning period resulted in LM gains in most players in five weeks. The transition to more aerobic on-court time and less resistance training by mid-season may have contributed to the slight decrease in FM with maintenance of LM (5). The return of LM to approximately the pre-season level by the end of the season could reflect the continued decrease in resistance work, while the slight gain in FM could be due to reduced aerobic work during late-season practice sessions, especially among those who did not play a majority of the time in games (19).

The changes in body composition components in the current players were similar to those previously noted in other women athletes (5,11,31,51,56). Carbuhn et al. (5) found Division I basketball players gained 3.7% LM from pre-season to mid-season and lost 2.9% by the post-season when measured by DXA. In a pre-to-post season comparison, Stanforth et al. (56) noted that basketball players were stable in LM but lost 5.0% FM when measured by DXA. Siders et al. (51) showed a 2.6 kg drop in FM and 2.0 kg gain in FFM across a season that maintained a stable body mass when measured by hydrostatic weighing. Ladwig et al. (31) noted a nonsignificant decrease in %fat across a season but measured only at pre-season and post-season, which may have masked fluctuations throughout the season. These changes in body composition from previous studies matched closely the 3.1% pre-season gain in LM and 2.0% loss by season's end in the current players. It would be beneficial to establish if connections between body composition changes and performance-based criteria exist. This might provide a stronger case for routine assessment of body composition throughout the season to guide conditioning and influence player performance potential.

SKF assessment has been used as a convenient method for evaluating body composition in athletes for some time (11,24,40,41). One drawback to their use is the difference among testers that could provide significantly different estimates of %fat (3,30,39). Even though the same experienced tester performed all SKF measurements in the current study, tracking patterns for SKF prediction equations (Figure 2) as well as sum of SKF (Figure 4) showed a dissimilar pattern to DXA. Thus, while the limb:trunk SKF ratio pattern would appear to track group %fat in college women basketball players (Figure 4c), it is less accurate for determining individual %fat values given the low correlations with the DXA pattern (Table 5). Sinning and Wilson (54) noted that women athletes might have higher FFM density than the assumed average value, which would affect any SKF equations that predict density to estimate %fat. Greater investigation among different testers and with various combinations of SKF totals or ratios may be needed to determine the best approach for tracking changes in body composition using this method (52).

Some studies have shown BIA to be an adequate method for assessing body composition of female athletes (6,16,42,47). While their devices were single-frequency instruments, they typically used a four-electrode configuration which may provide a better estimate of %fat than the simple limb-to-limb devices used in the current study. Although the BIA devices utilized in this study had athlete designations, it is possible that the proprietary equations utilized in each do not adequately represent the college female athletic population and need to be re-evaluated. Other studies have indicated many BIA devices underestimate %fat compared to laboratory techniques (8,13), a fact partly supported in this study. Thus, until better algorithms can be developed, the precision for tracking changes across a training season with BIA devices remains in question.

Laboratory studies on athletes are not without their limitations. Coaches' plans and game schedules often restrict when and how athletes can be measured (56). While hydration has been shown to be a factor in body composition measurement (36), other studies have suggested that neither hydration status (9,10,20), exercise (15), nor a small amount of food (20) consumed prior to measurement affected either BIA devices or DXA. Furthermore, some sources have indicated that athletes are not always euhydrated prior to training sessions (25,29,55,60). A study of football players found that as much 83% of the team was above the dehydration standard when arriving for morning practice (25). By afternoon practice, 70% of players were rehydrated. Volpe et al. (60) noted that fewer women than men were hypohydrated prior to practice, although the 28% recorded was significant.

Ascribing changes in body composition strictly to the effects of training procedures disregards the effect of the athlete's diet across the season (49). Previous investigation has shown that women athletes may have lower energy intake levels compared to their energy output (7). Furthermore, women athletes may be more prone to irregular eating habits especially during the competitive season (50). Additional investigation assessing both training and eating patterns might shed more light of the mechanisms of fluctuations in body composition of women athletes across a competitive year.

In summary, this is one of the first studies to divide the basketball season into four commonly observed periods of a competitive year to analyze body composition changes by various methods. The changes in LM and FM as determined by DXA can be considered typical of what happens to women athletes in this sport due to the multidimensional nature of their training. When there is a heavy emphasis on resistance training, LM is likely to increase, and FM is likely to remain stable or decrease slightly. As training transitions to more of an aerobic nature, LM is likely to revert to its previous level and FM may decrease thus maintaining a stable body mass. In the final stages of the competitive season when much of the practice sessions is spent on technique work with little emphasis on conditioning, FM may increase. Given the fluid nature of body composition changes, our findings agree with those of Silva et al. (52) that although prediction methods may have acceptable correlations with actual measurement of %fat, the wide limits of agreement for most techniques highlight the difficulty of accurately assessing the pattern of changes in components across a competitive season. Of the methods surveyed, F-BIA might be acceptable as a means of tracking the pattern of %fat change over a basketball season as registered by DXA. Further research may be required to isolate a convenient method that provides accurate longitudinal tracking for women athletes throughout a long-term training cycle.

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