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Comparison of Body Composition Assessment Methods in Breast Cancer Survivors

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Accurate and reliable assessment of body composition often is an integral component in the identification of clinically high-risk populations and is used in an attempt to prevent and manage certain chronic diseases (Heyward, 2006). Breast cancer survivors are a clinical population who frequently experience extremely altered body composition (e.g., changes in body fat [BF] percentage, muscle mass, bone mineral density) after diagnosis and treatment. Because of these alterations, it can be beneficial and clinically appropriate for body composition monitoring to be conducted during and after treatment in breast cancer survivors.

At-Risk Population

Breast cancer survivors have been reported to experience sarcopenic obesity, defined as increased weight without concomitant gain in lean tissue (Herber et al., 1996). Sarcopenic obesity often is a side effect of adjuvant chemotherapy and is associated with reduced energy and physical activity levels, although controversy remains whether this outcome is in some part related to adjuvant endocrine hormone therapy such as tamoxifen and aromatase inhibitors (Denmark-Wahnefried, Rimer, & Winer, 1997; Denmark-Wahnefried, Winer, & Rimer, 1993; Kroenke, Chen, Rosner, & Holmes, 2002). Such weight gain has important long-term health implications for breast cancer survivors, particularly because it usually occurs with concomitant increases in BF that have been associated with disease recurrence (Rooney & Wald, 2007). A systematic review by Rock and Denmark-Wahnefried (2002) determined that increased body mass index (BMI) was a significant risk factor for breast cancer recurrence and was associated with poorer survival rates. An increased BF percentage in breast cancer survivors is associated with increased risks of other comorbidities, including hypertension, diabetes, osteoarthritis, and car-

Purpose/Objectives: To examine and compare the reliability of four body composition methods commonly used in assessing breast cancer survivors.

Design: Cross-sectional.

Setting: A rehabilitation facility at a university-based comprehensive cancer center in the southeastern United States.

Sample: 14 breast cancer survivors aged 40–71 years.

Methods: Body fat (BF) percentage was estimated via bioelectric impedance analysis (BIA), air displacement plethysmography (ADP), and skinfold thickness (SKF) using both three- and seven-site algorithms, where reliability of the methods was evaluated by conducting two tests for each method (test 1 and test 2), one immediately after the other. An analysis of variance was used to compare the results of BF percentage among the four methods. Intraclass correlation coefficient (ICC) was used to test the reliability of each method.

Main Research Variable: BF percentage.

Findings: Significant differences in BF percentage were observed between BIA and all other methods (three-site SKF, $p < 0.001$; seven-site SKF, $p < 0.001$; ADP, $p = 0.002$). No significant differences ($p > 0.05$) in BF percentage between three-site SKF, seven-site SKF, and ADP were observed. ICCs between test 1 and test 2 for each method were BIA = 1, ADP = 0.98, three-site SKF = 0.99, and seven-site SKF = 0.94.

Conclusions: ADP and both SKF methods produce similar estimates of BF percentage in all participants, whereas BIA overestimated BF percentage relative to the other measures. Caution is recommended when using BIA as the body composition method for breast cancer survivors who have completed treatment but are still undergoing adjuvant hormonal therapy.

Implications for Nursing: Measurements of body composition can be implemented very easily as part of usual care and should serve as an objective outcome measure for interventions designed to promote healthy behaviors among breast cancer survivors.

diovascular disease (Denmark-Wahnefried et al., 1997). Other adverse consequences associated with weight gain include psychological distress, loss of self-esteem, anxiety concerning appearance, body image concerns, and

reduced quality of life (Denmark-Wahnefried et al., 1997). Therefore, monitoring and attempting to maintain ideal body weight and body composition in breast cancer survivors can play an important role in reducing the risk of recurrence and improving overall health and well-being.

Methods of assessing body composition in clinical settings should be accurate, reliable, and easy to perform. True measurement of body composition requires direct tissue assessment, but valid and reliable measurements of body composition in healthy populations can be accomplished through noninvasive methods such as hydrodensitometry underwater weighing (HD), dual energy x-ray absorptiometry (DEXA), bioelectric impedance analysis (BIA), air displacement plethysmography (ADP), skinfold thickness (SKF), or anthropometric measurements. The HD method, based on the classic two-compartment model of the body (the assumption that the body can be separated into two chemically different compartments for analyses of its composition—fat mass and fat-free mass) has been long considered the gold standard of body composition assessment. Three- and four-compartment model-based methods for estimates of body composition constituents have been used as standard reference because expansion of the compartments increases the precision and reduces the number of biologic assumptions made by the two-compartment method (Aleman-Mateo et al., 2007; Fuller, Jebb, Laskey, Coward, & Elia, 1992; Ginde et al., 2005). The three-compartment model (e.g., DEXA) includes the analyses of fat mass, total body water, and fat-free dry mass and is based on measurements of body density and total body water assuming a constant mineral-to-protein ratio of 0.35. Because of the variability of total body water among individuals, the three-compartment model was designed to account for such variability with the goal of further increasing accuracy from the two-compartment model. In an attempt to increase accuracy even more, the four-compartment model was developed to account for total body water, bone mineral, non-bone mineral, and protein. In theory, the four-compartment model appears to be a more valid method than the three-compartment model because it accounts for biologic variations in total body water and bone mineral content; however, more research is needed to confirm or refute this supposition. Although three- and four-compartment models account for potential biologic variations among individuals, as explained earlier, and perhaps provide more precise analyses of body composition, these methods usually are expensive or are highly complex requiring measurement of multiple variables (e.g., body density, mineral density, total body water) from independent tests. Subsequently, these complex methods can impose greater financial and time burdens on breast cancer survivors who already spend a significant amount of money and time treating their disease,

thus compromising the feasibility and practicality of employing these types of measurements in clinical settings. In addition, some of the more complex methods, even two-compartment methods, may not be suitable for use in certain cancer populations. For example, with HD, submerging breast cancer survivors—who have recently undergone surgery or still have a port inserted for the administration of adjuvant therapy—in water may increase the risk for infection.

Clear potential clinical benefits to having accurate, reliable, and practical determination of body composition in breast cancer survivors are apparent. However, feasibility, cost effectiveness, potential barriers, reliability, and comparability of different body composition methods have not been evaluated thoroughly in this population. In this study, focus was placed on the last of these issues. Therefore, the purpose of the study was to examine and compare the reliability of four body composition methods commonly used in assessing breast cancer survivors who have completed cancer treatment within the previous six months.

Methods

The current study employed a one-group design with multiple measures of body composition. The BF percentage was estimated from measurements taken on the same day via four methods: three-site SKF, seven-site SKF, ADP, and BIA. Fourteen women, aged 40–71 years, who were diagnosed with breast cancer, stages I–III, and had completed their treatment (surgery, chemotherapy, and/or radiation) for breast cancer within the previous six months, participated in the study. Seven women were Caucasian, five were African American, one was Hispanic, and one was Asian. All 14 had surgery, 9 had chemotherapy and radiation, 1 received chemotherapy only, and 4 received radiation only. Eleven of the 14 were receiving hormone therapy at the time of the study. None of the participants had signs of or had been diagnosed with lymphedema.

Verbal and written explanations of the protocol, pre-test guidelines, body composition assessment methods, and location and duration of testing were provided to each participant, and all signed written consent forms prior to taking part in the study. The study was approved by the University of North Carolina–Chapel Hill's biomedical institutional review board.

Demographic information, cancer history, and adjuvant cancer therapy were recorded for each participant. All followed strict pre-assessment guidelines, which involved no eating four hours prior to testing, voiding prior to testing, no exercising 12 hours prior to testing, no consumption of alcohol 48 hours prior to testing, and no diuretic medications seven days prior to testing. Participants also were advised to maintain normal hydration prior to reporting to the authors'

Table 1. Physical Characteristics of Breast Cancer Survivors

Characteristic	$\bar{X}$	SD	Range
Age (years)	52.4	8.9	43–71
Height (cm)	163.6	5.8	152.4–170.2
Weight (kg)	73.1	19.4	45.1–120
Body mass index (kg/m ²)	27.5	6.2	19.5–41.2
Waist-to-hip ratio ^a	0.77	0.05	0.72–0.89

N = 14

^a Waist circumference (cm) divided by hip circumference (cm)

laboratory and to avoid consumption of caffeine on the day of testing. Pre-assessment guidelines were reviewed with each participant prior to testing and, if any of the guidelines were not followed, the tests were rescheduled.

Assessment Protocols

Anthropometric measures: Body weight was determined with an electronic scale to the nearest 0.01 kg. Prior to measuring each breast cancer survivor, two standard 10 kg weights were used to calibrate the scale. Height was measured to the nearest 0.1 cm with a portable stadiometer.

The assessment of body composition was conducted using four methods in the following order: three-site SKF, seven-site SKF, BIA, and then ADP. Repeated measures (test 1 and test 2) were made for each participant. Immediately after completing test 1 measurements, test 2 measurements were taken for each method in the same order. The following is a brief description of the procedures for each of the methods used in the study.

Skinfold measurement: SKF was assessed to the nearest 0.1 mm at three sites and seven sites, as described in Heyward (2006). A Lange Skinfold Caliper was used for all skinfold measures. To enhance the consistency of the measurements, all skinfold measurements were performed by the same research team member, who was an experienced body composition technician. Three measurements were taken at each site for both the three-site SKF and seven-site SKF models following standardized procedures (Heyward, 1998). The results

of two measurements, which were within 1 mm of each other, were used for the estimation of BF percentage using the three-site SKF and seven-site SKF population-specific equations proposed by Jackson and Pollock (1985). The validity of SKF using DEXA as the reference method ranged from 0.75–0.89 for racially diverse obese and nonobese women (Erselcan, Candan, Saruhan, & Ayca, 2000; Jackson, Pollock, Graves, & Mahar, 1988). Reported reliability using SKF by experienced testers is very high (intraclass correlation coefficient [ICC] = 0.99) (Erselcan et al., 2000; Jackson et al., 1988).

Bioelectric impedance analysis: BIA is a method of body composition assessment that uses a low level of electric current that travels through the body with the goal of measuring the resistance to current flow, allowing for the estimation of total body water. Because fat-free mass has a relatively large water content (about 73% water), by estimating total body water, fat-free mass and the BF percentage both can be predicted (Heyward, 2006). Because BIA relies on total body water for the determination of body composition, hydration status can significantly influence the accuracy of determining body composition using this method. Body resistance was measured according to standard procedures, on the right side of the body, after participants rested in a supine position using a Bodystat® QuadScan 4000 multifrequency device that measures impedance at frequencies from 5 KHz–200 KHz. All jewelry and metal objects were removed so as to not interfere with the electric impedance. Hydration levels including total body water, intracellular fluid (ICF), and extracellular fluid (ECF) were computed by the Bodystat QuadScan 4000 and recorded from the device. The validity of BIA using DEXA as the reference method ranged from 0.84–0.96 in comparable groups of women (Pineau, Guihard-Costa, & Bocquet, 2007). The reliability (ICC) of BIA ranged from 0.97–0.99 (Jackson et al., 1988).

Air displacement plethysmography: Repeated measures of body composition were obtained using the Bod Pod®, with identical protocols being applied during both tests. Before testing, the Bod Pod was warmed up and calibrated using a 50.1 L cylinder. Participants were required to wear spandex or lycra shorts and a tank top, along with a swimming cap. A predicted thoracic

Table 2. Descriptive Data of the Results Obtained for the Determination of Body Fat Percentage

Method	Test 1				Test 2			
	$\bar{X}$	SD	95% CI	Range	$\bar{X}$	SD	95% CI	Range
Three-site skinfold thickness	30.2	6.9	26.2–34.2	19.4–42.3	29.9	7	25.9–34	19.2–42.1
Seven-site skinfold thickness	29.4	7	25.4–33.5	18.5–41.2	29.9	6.5	26.2–33.7	18.1–40.6
Bioelectric impedance analysis	38.3	6.6	34.5–42	28–52.4	38.4	6.5	34.6–42.1	28.4–52.4
Air displacement plethysmography	30.9	10.1	25.1–36.7	15.5–49.8	31.2	9.3	25.8–36.5	17.2–47

CI—confidence interval

Table 3. ICC and SEM for Each Method of Estimating Body Fat Percentage

Method	ICC	SEM
Three-site skinfold thickness	0.99	0.51
Seven-site skinfold thickness	0.94	1.78
Bioelectric impedance analysis	1	1.12
Air displacement plethysmography	0.98	1.31

ICC—intraclass correlation coefficient; SEM—standard error of measurement

gas volume and the Siri (1956) equation, both inbuilt to the Bod Pod software, were used for the calculation for body density and BF percentage. The validity of ADP using DEXA as the reference method was 0.91 or greater (Sardinha, Lohman, Teixeira, Guedes, & Going, 1998; Wagner, Heyward, & Gibson, 2000). Reported reliability using the Bod Pod for between-day, test-retest situation was $R \geq 0.9$ (Sardinha et al., 1998).

Statistical analysis: Descriptive statistics were computed for each anthropometric measure of the participants and for BF percentage estimated from all four methods. ICC between test 1 and test 2 for each body composition method was computed. In addition, a one-way within-subject analysis of variance with post-hoc pair-wise comparisons using the Sidak method was used to determine whether the four methods produced statistically significant different estimates of BF percentage. The Sidak test was chosen because it affords strict control of family error rate for multiple pair-wise comparisons. The dependent variable in the analysis of variance was the mean BF percentage from test 1 and test 2 estimates for each participant.

Results

Means and standard deviations for age and anthropometric measures of the participants are presented in Table 1. Mean BMI was 27.5 kg/m² and, of the 14 participants in the study, five were classified as normal weight (BMI less than 25), four as overweight (BMI of 25–29), and five as obese (BMI of 30 or higher). Descriptive data for test 1 and test 2 performed for the determination of BF percentage using three-site SKF, seven-site SKF, BIA, ADP, as well as 95% confidence interval are presented in Table 2. Table 3 presents ICCs and standard error of measurement for each method.

The omnibus analysis of variance comparing the four body composition methods for determining BF percentage was significant ($p = 0.037$). Post-hoc pair-wise comparisons revealed a significant difference between BIA and all other techniques. The BF percentage estimate from the BIA method was greater compared to the other three methods (three-site SKF, $p < 0.0005$; seven-site SKF,

$p < 0.0005$; ADP, $p = 0.002$). No significant differences were observed between BF percentage estimated by three-site SKF and seven-site SKF ($p = 0.99$), three-site SKF and ADP ($p = 0.971$), and seven-site SKF and ADP ($p = 0.936$).

Discussion

Of the four body composition methods examined, only BIA produced a statistically significant different BF percentage estimate compared to the other methods. Specifically, an approximately 8%–10% larger estimate of BF percentage was found with the BIA method. The results suggest that this large overestimation of body fat levels with the BIA may be principally attributed to the altered hydration levels of the participants from the types of treatment they were undergoing (i.e., hormone therapy) during the study; 11 of the women were undergoing hormone therapy (10 receiving tamoxifen and one receiving anastrozole) at the time of the study. Zhang et al. (1994) noted that such hormone therapy can impact water balance and, therefore, supports the authors' view that hydration status influences the accuracy of estimating BF percentage through BIA. In the current study, participants recorded lower than normal mean total body water values as well as below normal ICF levels, indicative of a dehydrated state. Table 4 contains percentages for total body water, ICF, and ECF obtained through the BIA analysis. Participants had a mean total body water of about 47%, slightly below the normal level (typically 50%–60%), which also has been previously reported by Isenring, Bauer, Capra, and Davies (2004) in patients with cancer. One participant had a level of 35%, well below the normal level. BIA results also determined that all participants had less than adequate, below-normal ICF levels. Conversely, ECF for all participants was within the normal range.

This altered hydration status would substantially influence the whole-body resistance (a key component in BIA analysis) and estimations of fat-free mass and, therefore, BF percentage via the BIA method. A participant's dehydration would increase the resistance response resulting in an underestimation of fat-free mass or lean muscle tissue, conversely leading to an

Table 4. Hydration Levels of Breast Cancer Survivors Estimated Via Bioelectric Impedance Analysis

Characteristic	$\bar{X}$	SD	Range	Norm
Total body water	47.6	6.9	35.6–57.4	50–60
Intracellular water	25.7	1.9	22.1–29.6	30–35
Extracellular water	22.7	3.2	17.5–28.7	20–25

N = 14

Note. All characteristics are measured in percentage of liters.

overestimation of fat mass (Heyward, 1998; Kushner, Schoeller, Fjeld, & Danford, 1992).

The estimated BF percentage associated with the BIA was 8%–10% larger in value when compared to the other methods in the study. To examine the difference across the values observed for the BIA versus the other methods, scatter plots of the BF percentage results were constructed. A review of Figure 1 reveals that almost all of the plotted data points are above the line of identity, suggesting that BF percentage, as determined by the BIA, appears to overestimate body fat when compared to the other three methods. In addition, the overestimation of BF percentage associated with the BIA is across the entire range of BF percentage observed for the participants and not delimited to percentages near the sample mean responses. This finding suggests that the BIA method, specifically because of the influence of hydration status sensitivity, may not be as reliable in the estimation of BF percentage in breast cancer survivors recovering from treatment or undergoing hormone therapy at the time of measurement.

Scatter plots with a line of identity also were constructed to examine BF percentage estimates between ADP, three-site SKF, and seven-site SKF methods. Figure 2 reveals that these methods are all in good agreement (i.e., the compared BF percentage values lie very close to the line of identity) with very similar BF percentage estimates from the ADP, three-site SKF, and seven-site SKF methods. However, two participants deviated in a noteworthy fashion from the line of identity as depicted in Figures 2b and 2c. Specifically, those two outlier participants had the highest body mass in the sample of participants tested, with body masses of 88.6 kg and 120 kg. Previous research has found that obese individuals have a greater likelihood for measurement error when using SKF techniques (Heyward, 1998; Jackson & Pollock, 1985) because, oftentimes, the large body size of obese individuals inhibits the jaws of the SKF caliper and may cause the instrument to slip off the fold during measurement or, in some extreme cases, the individual skin fold exceeds the maximum capability of aperture of the caliper. That may explain, in part, the discrepancy in the results obtained between three-site SKF, seven-site SKF, and ADP for those two participants. Therefore, using SKF methods for the assessment of body composition in breast cancer survivors who have large body mass is not recommended (Heyward, 1998; Jackson & Pollock, 1985).

A very-high degree of agreement between body composition measures is found in previous research (Aleman-Mateo et al., 2007; Bentzur, Kravitz, & Lockner, 2008; Ginde et al., 2005) for ADP, HD, and DEXA scans, as well as the three-site and seven-site SKF methods (Heyward, 1998). The results of the current study suggest this also is the case when using the three-site and seven-site SKF and ADP methods for the assessment of

Figure 1a.

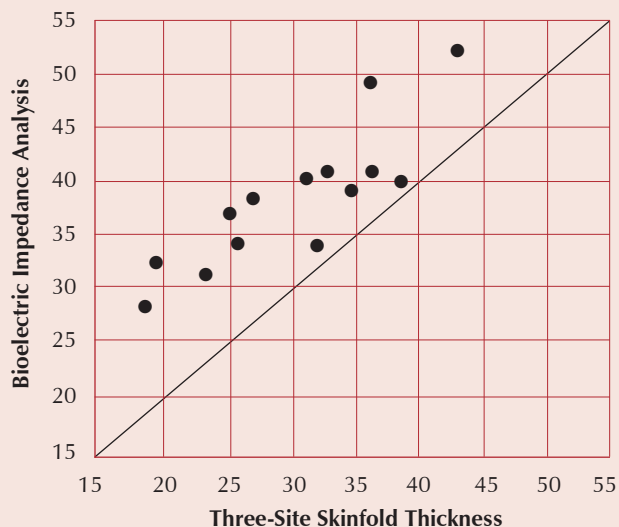


Figure 1b.

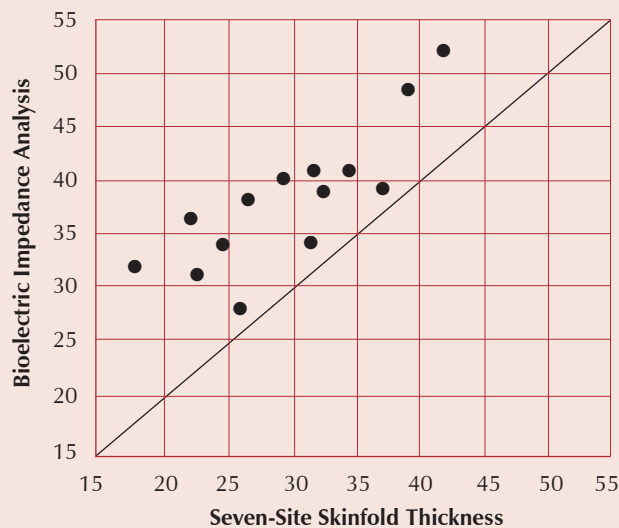
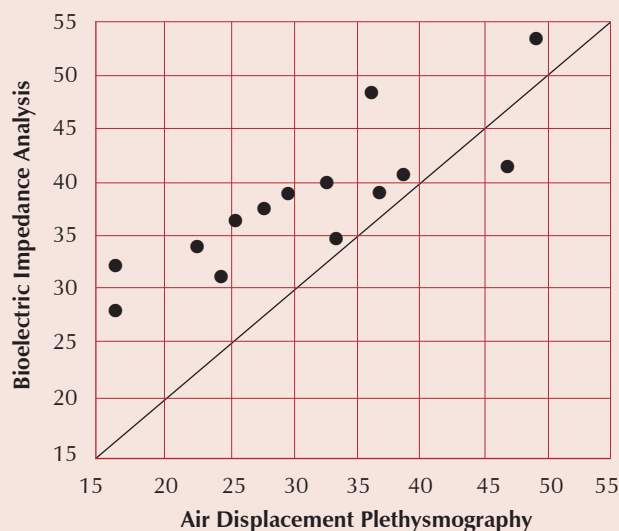


Figure 1c.



Note. Values on the x- and y-axis are body fat percentage.

Note. The 45° black line represents the line of identity.

Figure 1. Bioelectric Impedance Analysis Comparison

Figure 2a.

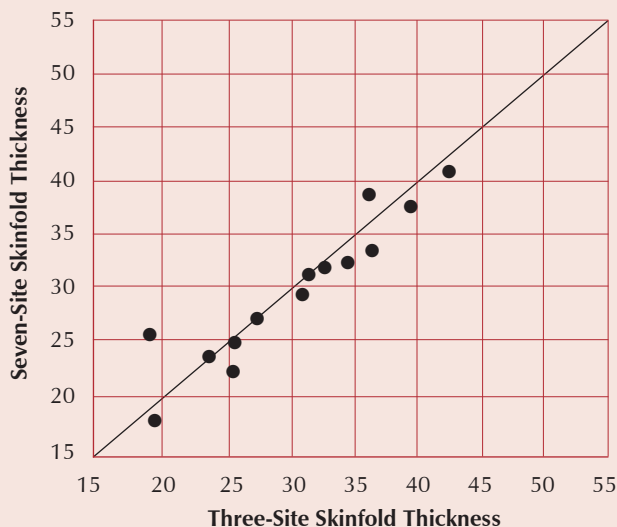


Figure 2b.

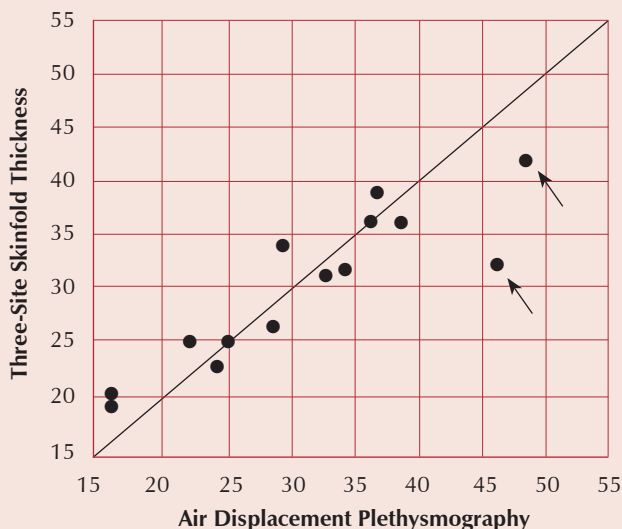
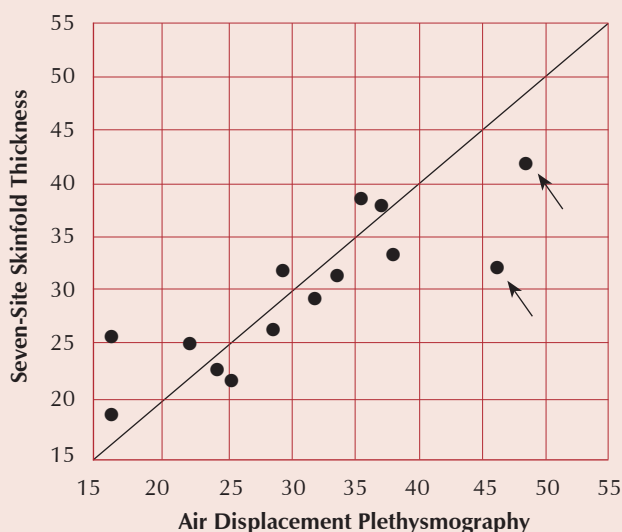


Figure 2c.



Note. Values on the x- and y-axis are body fat percentage.
Note. The 45° black line represents the line of identity.

Figure 2. Comparison of Assessment Methods

body composition in post-treatment breast cancer survivors who have completed treatment within the past six months. Based on the results of the current study, the use of three-site or seven-site SKFs, a relatively cost-effective method for the analyses of body composition, should be considered for the monitoring of body composition in post-treatment breast cancer survivors in clinical settings because of its high agreement with the ADP method and for its high level of reliability when performed by experienced technicians. Because all tests (including the two SKF tests) in this study were performed by the same tester, when performing body composition in clinical or fitness settings where perhaps different technicians will assess the same breast cancer survivor in different occasions, between-tester differences must be accounted for when interpreting the results of the tests (mainly for the SKF methods). Intra- and intertesting reliability should, therefore, be performed among technicians to minimize potential discrepancies in results, thus maximizing precision when monitoring body composition in breast cancer survivors. Of note, however, is that none of the participants in this study were previously diagnosed with lymphedema or were presenting signs of secondary lymphedema at the time of the study. Because some of the symptoms of lymphedema may include swelling and pitting edema, these symptoms could potentially compromise the accuracy of the SKF measurement. The presence of lymphedema, usually detected through significant differences in arm circumference because of swelling (i.e., edema), can make it virtually impossible to precisely assess body composition via SKF in breast cancer survivors experiencing the condition on the right arm (because the procedure is standardized to be performed on the right side of the body). An adjustment could be made using the left arm in these cases, but additional research needs to fully evaluate this possibility. In breast cancer survivors who have been diagnosed with lymphedema in the upper extremities, the use of an alternative method such as the ADP for the assessment of body composition is therefore recommended. Also of note is that none of the participants who took part in the current study complained about the SKF measurement procedure and, therefore, it should not be a problem to implement the technique in this cancer population. One other caveat with this recommendation relates to earlier remarks that it may be inappropriate to use SKF methods with breast cancer survivors who have extremely large body masses.

Limitations

The small sample size is an internal limitation of this study, and findings should be viewed as preliminary and, perhaps, hypothesis generating. However, the fact that all of the participants had undergone chemotherapy and/or radiation treatments, and 11 of the 14 were

undergoing hormone therapy at the time of the study measurements, the study population used in this study can be seen as a very good representation of breast cancer survivors who commonly undergo these types of treatment. A second major limitation was the single-arm design that only included breast cancer survivors. The lack of body composition analyses performed in healthy age-matched controls prevents the authors from drawing definitive comparative conclusions.

Conclusion

In this study, all four body composition methods were observed to have very high reliability. However, the results showed that ADP and the three-site and seven-site SKF methods produce similar estimates of BF percentage in post-treatment breast cancer survivors, whereas BIA concomitantly overestimated BF percentage in relation to the other three methods. In post-treatment breast cancer survivors, because of the possibility of treatment-related water balance disturbances that can significantly influence the outcomes of the BIA technique, caution against the use of BIA should be considered.

Implications for Nursing

Because of the importance of monitoring body composition in patients with cancer, both for survivorship and self-esteem issues, and the existence of comorbidities, healthcare providers need to accurately monitor body composition changes over time. This study examined four methods routinely used to assess body composition in different clinical populations and the notion that BIA, ADP, and SKF methods also may be applicable to post-treatment breast cancer survivors. These preliminary findings suggest that ADP and SKF elicit similar results within an acceptable range (Heyward, 1998; Jackson & Pollock, 1985) and should be considered for routine monitoring of body composition, specifically BF percentage in female breast cancer survivors who have completed treatment for breast cancer within the past

six months. However, healthcare professionals interested in monitoring body composition in breast cancer survivors with large body mass or those presenting with lymphedema should use a body composition technique other than the SKF methods (i.e., ADP until additional research is conducted in this area). Because breast cancer survivors may experience potential water balance alterations from treatment and because these alterations can influence the outcome of the BIA technique, caution should be used when choosing BIA for the monitoring of body composition in this population. Because nurses are skilled healthcare providers, the use of SKF measurement can be very easily implemented as part of usual care and should be used as a tool, not only to monitor body composition, but also as an objective measure for interventions aimed to promote healthier behaviors among breast cancer survivors. Nurses must be trained on how to properly conduct these body composition tests to ensure the most accurate results.

The authors gratefully acknowledge Elizabeth Evans, MA, and Edith Pituskin, RN, for their invaluable editorial assistance in the preparation of this article.

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Digital Object Identifier: 10.1188/11.ONFE283-E290

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