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Original Research

New Multisite Bioelectrical Impedance Device Compared to Hydrostatic Weighing and Skinfold Body Fat Methods

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ABSTRACT

International Journal of Exercise Science 13(4): 1718-1728, 2020. The purpose of this study was to compare the Skulpt Chisel™ to seven-site skinfold (SKF) and hydrostatic weighing (HW) body fat percentage (%BF) estimates. Twenty-six participants (aged 24 ± 4 years; BMI 23.1 ± 3.5 kg·m^{-2}) were assessed. Significant differences in %BF estimates were found for all methodological pairings; $p < 0.05$. The SKF method underestimated %BF compared to HW (-2.52 ± 3.42 %BF). The Skulpt Chisel™ overestimated %BF compared to both HW (3.38 ± 6.10 %BF) and SKF (5.90 ± 5.26 %BF). Limits of agreement comparing HW to Skulpt Chisel™ indicated a difference between 95% confidence interval bounds (Upper bound: 5.84 %BF, Lower bound 0.92 %BF) and for HW to SKF (Upper bound: -1.14 %BF, Lower bound: -3.91 %BF). Regression analysis showed no significant bias for any methodological pairing; ($p > 0.05$). In conclusion, the Skulpt Chisel™ method should be used with caution when evaluating %BF of adults with similar demographics reported in this study.

KEY WORDS: *Body fat percentage, Skulpt Chisel™, body composition methodology, evaluation, validity, measurement*

INTRODUCTION

Excess body fat and loss of lean mass increase risk of illness, thereby leading to higher health care costs, disability, and a lower quality of life (23, 29, 31). The ability to track changes in body composition, rather than body weight, requires a valid, reliable method to estimate body fat and lean mass (1, 4, 15, 23, 32).

Several methods exist to accurately assess and track body composition changes. Some of the most accurate laboratory methods include hydrostatic weighing (HW) at measured residual lung volume, dual-energy X-ray absorptiometry (DXA), and magnetic resonance imaging (MRI) (34). Skinfold (SKF) and bioelectrical impedance analysis (BIA) field method assessments require less technician expertise, are accessible, affordable, and easier to transport than the aforementioned laboratory-based methods. However, this practicality often limits accuracy and precision (11). Skinfold measurements are done with calipers to measure subcutaneous fat thickness at specific anatomical sites. Formulas are then used to calculate body density from the SKF values (12, 19, 20), with body density being subsequently converted to percent body fat (%BF) (35). Bioelectrical impedance analysis uses a weak electrical current to measure conductance and resistance of body tissues. Muscle tissue and water, constituents of fat free mass, have lower resistance, and consequently, greater electrical conductance compared to fat tissue (21).

These field methods are not without limitations. Skinfolds require experienced technicians to perform the test reliably and accurately. Skinfold thickness measurements may also cause discomfort during testing due to pinching of the measurement sites. Skinfold measurements have been shown to be less accurate in obese populations, limited by inaccessible measurement sites or because the skinfold thickness may exceed caliper measuring capacity (11, 22). Also, sites that are difficult to measure may occur with substantial weight loss that leaves excess skin tissue.

Bioelectrical impedance analysis assessments may not require a trained technician; however, there are important guidelines to follow for accurate and reliable results (16, page 94). Several assumptions are required as BIA %BF estimates rely on electrical conductance (9, 25, 30). These assumptions include (a) the participant is euhydrated, (b) body tissues have uniform resistance to the electrical current, and (c) the body is a perfectly cylindrical conductor uniform in cross-sectional area and length (8, 9, 25, 30). As BIA estimates lean mass to determine fat mass, an under- or overestimation can occur for estimates of %BF (body fat mass = total mass – lean mass) depending on the hydration status of the lean mass (9, 30). For example, hyperhydration may alter electrical current conduction, reducing resistance and underestimating %BF (2). In contrast, hypohydration may increase resistance and lead to over-estimated %BF values (2). Another assumption includes the cross-sectional area and length of the arms, trunk, and legs; longer limbs or a body segment with a smaller cross-sectional area increase resistance to electrical conductance thereby overestimating %BF (30). However, in comparison to SKF assessment, BIA may be a better field test for obese individuals (11), as the error of BIA does not become greater across increasing body fatness (27).

A new commercially available compact BIA device (Skulpt Chisel™) operating under the "full scan" option uses 12 anatomical sites on each side of the body (24 different measurement sites total) to estimate %BF (26). Like other commonly used BIA devices such as the Omron™ or Tanita™, the Skulpt Chisel™ allows an individual to conduct their own assessments in the privacy of their own home, removing the need of a trained technician. Also, the Skulpt Chisel™ uses Bluetooth™ technology to interface with smartphones (android™ and iPhone™) for easy tracking of %BF estimates over time. Possible limitations exist using the Skulpt Chisel™ that include the time required to measure all 24 anatomical sites. Further, difficulty with measurements may occur depending on the amount of body hair covering the measurement site (26). Finally, another concern is if an individual lacks joint mobility making performing some of the measurements without a technician present difficult.

It was anticipated that there would be a significant device-dependent difference in %BF estimations; therefore, the purpose of this study was to compare %BF estimates using three different methods: the Skulpt Chisel™ (BIA), SKF, and HW with measured residual volume. A secondary objective of this study was to investigate bias between the three %BF assessment methods.

METHODS

Participants

Body composition of twenty-six participants (13 males, 13 females) was assessed in the following order: the BIA Skulpt Chisel™ device, Jackson et al. (20) and Jackson and Pollock (19) seven site SKF thicknesses, and HW with measured residual volume. A non-randomized assignment was chosen due possible residual tissue moisture from HW assessments influencing BIA and SKF thickness measurements. All body composition assessments were completed within a single two-hour visit to the university's exercise physiology lab. Urine pregnancy tests were given to all female participants as pregnancy was an exclusion criterion as well was any participant with a medically implanted electronic device. All participants were instructed to follow standard pre-test guidelines regarding exercise, pre-test food and beverage consumption, (16, page 94), and caffeine (36) before %BF testing. Prior to any data collection, all participant concerns were addressed, and written consent was obtained. This study was approved by university's Institutional Review Board and was in compliance with the Declaration of Helsinki (37). This research was carried out in accordance to the ethical standards of the International Journal of Exercise Science (28).

Protocol

Height measurements were taken without shoes using a stadiometer (SECA, seca 216, Chino, CA, USA). Prior to weight measurements, all participants were asked to void their bladder and bowels. Nude body weight was obtained using a digital scale (Cardinal DETECTO 758C, Webb City, MO) in a private room. Participant demographic data are shown in Table 1.

Table 1. Descriptive Characteristics of the Sample (Mean ± SD)

Variable	Male (*n* = 13)	Female (*n* = 13)	Total Sample (*N* = 26)
Height (cm)	176.9 ± 4.3	162.9 ± 7.2	169.9 ± 9.4
Weight (kg)	74.8 ± 11.1	58.3 ± 7.9	66.8 ± 12
Age (yrs)	25 ± 4	24 ± 5	24.4 ± 4
BMI (kg/m^2)	23.9 ± 3.7	21.9 ± 3.0	23.1 ± 3.5
HW %BF	14.4 ± 7.1	21.6 ± 8.1	18.0 ± 8.3
SKF %BF	11.1 ± 5.6	19.9 ± 5.3	15.5 ± 7.0
Skulpt Chisel™ %BF	19.8 ± 7.5	23.0 ± 6.3	21.4 ± 7.0

cm – centimeters, m – meters, kg – kilograms, BMI – Body Mass Index, HW %BF - Hydrostatic Weighing Body Fat Percentage, SKF %BF - Seven Site Skinfolds Body Fat Percentage, %BF - Body Fat Percentage.

Participants were asked to change into dry swim wear or shorts and a t-shirt. The bioelectrical impedance device (Skulpt Chisel™) "full scan" assessment was performed with participants standing in an upright position according to the manufacturer's step-by-step instruction (i.e.

pictures of where to place the Skulpt Chisel™ with captions naming the measurement site) provided via the phone application "Skulpt" (app version 2.9.7; firmware version 2.4.1.47). As step-by-step manufacturer instructions were followed with each assessment, user variability of the Skulpt Chisel™ device was minimized. The "full scan" function %BF estimate assesses 24 measurement sites, 12 sites on each side of the body. Only one measurement was taken at each site as per the phone application instruction; there was no criterion provided for measurement variance. At the discretion of the participant, any Skulpt Chisel™ measurement site that the participant was not comfortable having the technician measure was skipped or privacy was provided to the participant, allowing the participant to perform that measurement after instruction on how to use the device. A total body %BF value was provided based on a proprietary algorithm following the completion of electrical conductance measurements at the 24 separate anatomical sites.

Multiple highly skilled technicians, trained by the same body composition assessment expert, used the same techniques to take SKF measurements. All SKF measurement locations were taken on the right side of the body. Skinfold thicknesses (Lange Skinfold Caliper, Cambridge Scientific Industries Inc., Cambridge, Maryland) in millimeters (mm) were measured at the triceps, chest, abdomen, suprailiac, thigh, subscapular, and midaxillary sex-specific anatomical sites with fold direction based on the Jackson et al. (20) and Jackson and Pollock (19) SKF methods. All measurements were performed twice in rotational order. If the two SKF thicknesses differed by more than 2mm at a site, a third measurement was taken, and the two closest measurements were averaged for that site (32). Sex-specific seven-site equations were used to calculate body density (19,20). The Siri equation (%BF = [(4.95/body density) - 4.95)] x 100) was used to estimate %BF from body density (33).

Dry land residual lung volume was measured with participants in a seated position using a 100% oxygen dilution technique (ParvoMedics TrueOne 2400, ParvoMedics Inc., UT). Multiple trials were conducted until two residual volume values were within 5%. These two trials were averaged and used to adjust body volume. A chair made of polyvinylchloride pipe was suspended from a 9-kg scale (Chatillon 1309DD-H, Columbia, MD). Prior to measuring the participants' underwater weight, the water temperature and tare weight of the chair plus any additional weight were recorded. Participants were asked again to void their bladder and bowels if needed, change into swimwear and shower before entering the HW tank. Participants were instructed to remove any air trapped in the swimsuit and hair before sitting on the chair and receiving instruction regarding the maximal exhalation maneuver. Participants exhaled as much air as possible while being completely submerged underwater. Multiple trials were performed until three underwater weight measurements within ± 0.1kg were obtained. These three values were then averaged. Water density was adjusted based on water temperature. Although gastric gas volumes may range between 30 ml to 200 ml (24), gastric volume was assumed to be 100 ml for calculations of body density. To decrease variability, participants were instructed to refrain from eating gas-producing foods 24 hours prior to the testing session. Body density values were calculated as follows:

$$Body\ Density = \frac{Weight\ in\ Air}{\left(\frac{Weight\ in\ Water - Net\ Underwater\ Weight}{Density\ of\ Water}\right) - (Residual\ Volume + 0.001)}$$

All body density values were converted to %BF using the Siri equation (33).

Statistical Analysis
Sample size was based on an *a priori* power analysis using G*Power software version 3.1.9.4 (13,14). Power was set to 0.80 with an alpha-value of 0.05. Effect size was assumed to be 0.5 for *a priori* analysis providing a required sample size of 27 for the study to be properly powered. The power of the study was confirmed using a post-hoc power analysis using G*Power software version 3.1.9.4 (13,14). Following the recruitment and completion of 26 participants, an alpha value of 0.5 and the smallest effect size for all methodological comparisons was used to calculate the statistical power. This provided a statistical power of 0.81 with a calculated effect size of 0.56 comparing HW to SKF methods. As data were paired, effect sizes were calculated by using the mean difference divided by the standard deviation of the difference (7).

Multiple one sample t-tests were performed to investigate statistical differences for mean %BF values when comparing Skulpt Chisel™ and SKF to the HW reference method. A Cronbach's alpha and intraclass correlation (ICC) were performed to quantify inter-rater reliability for SKF and Chatillon scale measurements. Bland-Altman plots (3) with a linear least squares regression and Pearson's correlation coefficient analyses (10,16,17) were used to investigate bias (i.e. systematic difference between two measurements) and limits of agreement (i.e. the 95% confidence interval of the difference between measurement methods) between %BF methods (16). Skipped or missing values from Skulpt Chisel™ measurements did not preclude the proprietary equation estimation of total %BF, and all Skulpt Chisel™ %BF values were used in the data analysis. All statistical tests were performed using IBM SPSS Statistics for Windows (Version 19.0. Armonk, NY); significance was set at $p < 0.05$.

RESULTS

All participants stated they adhered to pre-test guidelines; all but one participant completed all testing in one visit. This participant adhered to pre-test guidelines, but the Skulpt Chisel™ measurement for total %BF provided an "N/A" value. Due to time constraints, this participant returned for a second visit on a separate day having adhered to all pre-test guidelines to have a Skulpt Chisel™ %BF measurement recorded. The Cronbach's alpha, a measurement of consistency between technicians measuring the triceps site only for SKF and Chatillon scale measurements, were 0.28 (range: 4mm to 5.5mm) and 0.917 (range: 7.45kg to 7.55kg), respectively. No Cronbach's alpha score was calculated for the Skulpt Chisel™ as participants performed their own gluteal measurements. The ICC, another inter-rater reliability measure, was 0.71 for the Chatillon scale and 0.34 for SKF measurements.

A significant mean difference for %BF was found comparing the Skulpt Chisel™ and Jackson et al. (1978, 1980) seven-site skinfold methods ($t_{25} = 5.73$; *Mean Difference* = 5.90; *SD* = 5.26; 95%CI = 3.78 to 8.03; $p \leq 0.05$), showing a greater %BF estimation using the Skulpt Chisel™ (Figure 1).

Compared to HW, a significant mean difference was found for the Skulpt Chisel™ (t_{25} = 2.826; *Mean Difference* = 3.38; *SD* = 6.10; 95%CI = 0.92 to 5.84; $p \leq 0.05$), again showing higher %BF estimation (Figure 1). A significant mean difference was found comparing the Jackson et al. (1978, 1980) seven-site skinfold to HW (t_{25} = -3.758; *Mean Difference* = -2.52; *SD* = 3.42; 95%CI = -3.91 to -1.14; $p \leq 0.05$) showing a lower %BF estimate (Figure 1). Pearson's *r* correlation values were calculated for HW and SKF (r = -0.369; $p > 0.05$), HW and Skulpt Chisel™ (r = 0.243; $p > 0.05$), and for SKF and Skulpt Chisel™ (r = -0.026; $p > 0.05$). There were no significant biases comparing HW to SKF ($F_{1,24}$ = 3.972; $p > 0.05$) (Figure 2), HW to Skulpt Chisel™ ($F_{1,24}$ = 1.50; $p > 0.05$) (Figure 3A), and Skulpt Chisel™ to SKF ($F_{1,24}$ = 0.016; $p > 0.05$) (Figure 3B).

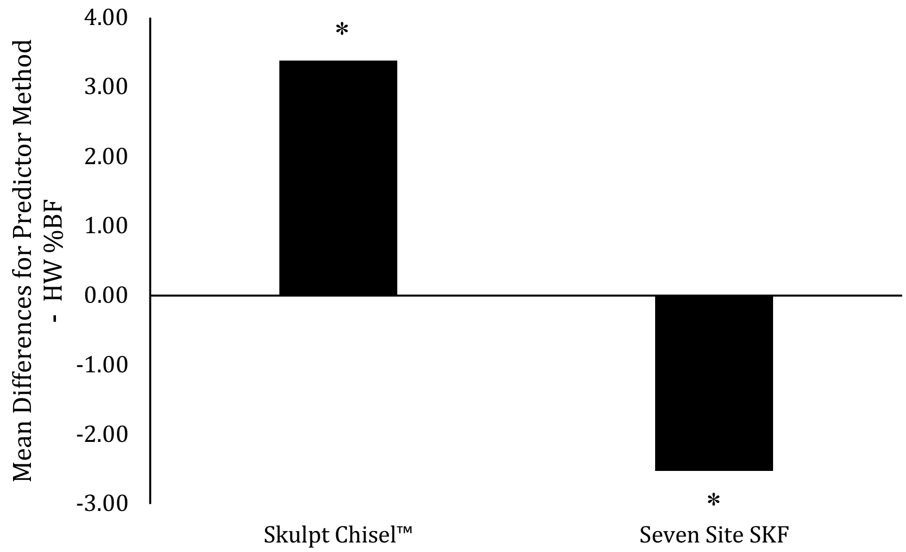


Figure 1. Mean body fat percent difference standardized to hydrostatic weighing (N=26). Skulpt Chisel™ "full scan" 24 site measurement. Seven-site skinfold (SKF) = Jackson et al. (20) and Jackson and Pollock (19) seven-site skinfold measurement methods. *Significantly different (p <0.05) compared to hydrostatic weighing.

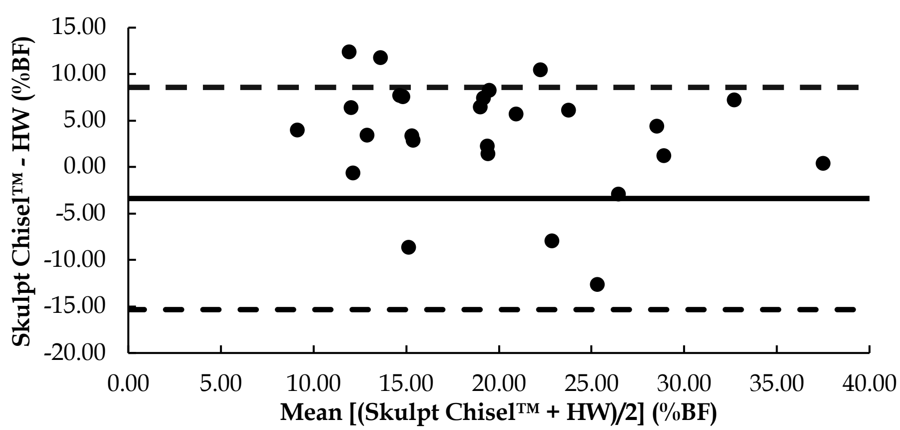
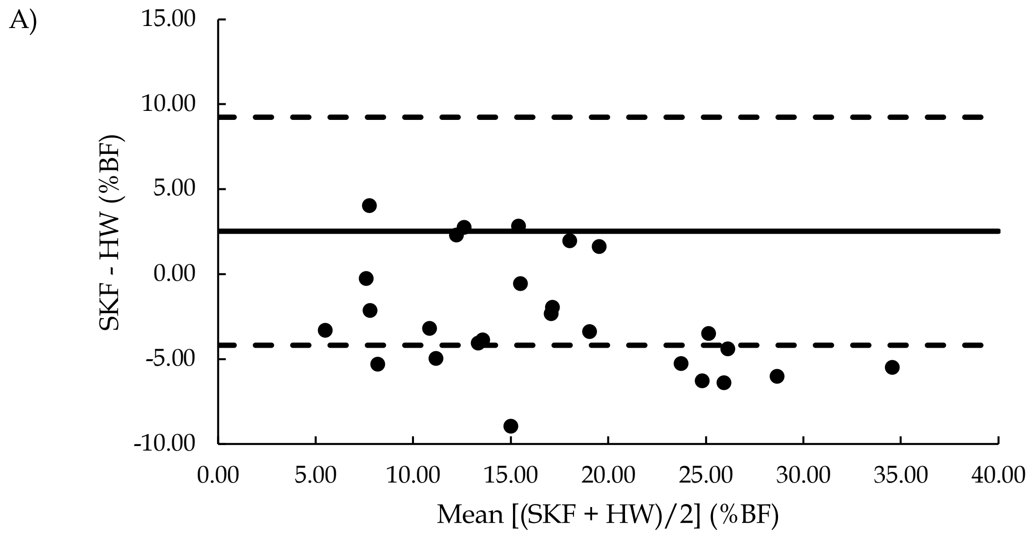


Figure 2. Bland-Altman analysis plot of individual differences between Skulpt Chisel™ and Hydrostatic Weighing (HW) and the mean of the two measurements. The solid line is the mean difference of -3.38 units represented by the gap between the X axis, corresponding to a zero difference, and the parallel line to the X axis at -3.38 units with the representation of the limits of agreement (dotted lines), from -1.96*sd* to +1.96*sd*. Pearson's *r* correlation coefficient value (r = 0.243; $p > 0.05$), (N = 26)



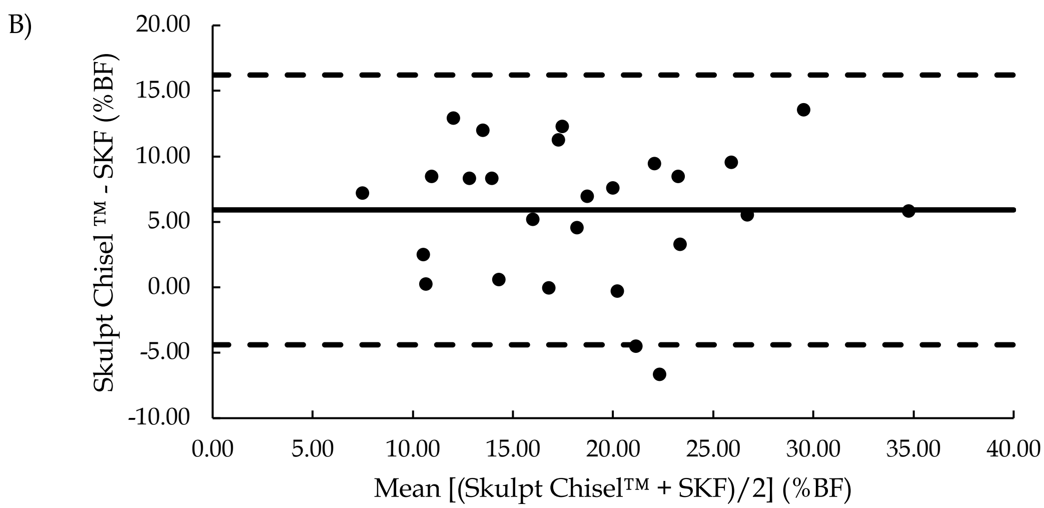


Figure 3. A) Bland-Altman plot of individual differences between Jackson et al. (20), Jackson and Pollock (19) seven-site skinfolds (SKF) and Hydrostatic Weighing (HW) and the mean of the two measurements. The solid line is the mean difference of 2.52 units represented by the gap between the X axis, corresponding to a zero difference, and the parallel line to the X axis at 2.52 units with the representation of the limits of agreement (dotted lines), from -1.96*sd* to + 1.96*sd*. Pearson's *r* correlation coefficient value (r = -0.369; p > 0.05), (N = 26). B) Bland-Altman analysis plot of individual differences between Skulpt Chisel™ and Jackson et al. (19,20), seven-site SKF and the mean of the two measurements. The solid line is the mean difference of 5.91 units is represented by the gap between the X axis, corresponding to a zero difference, and the parallel line to the X axis at 5.91 units with the representation of the limits of agreement (dotted lines), from -1.96*sd* to +1.96*sd*. Pearson's *r* correlation coefficient value (r = -0.026; p > 0.05), (N = 26).

DISCUSSION

The purpose of this study was to compare %BF estimates for the Skulpt Chisel™ "full body" scan (BIA) and seven-site SKF methods (19, 20) as compared to each other and HW with measured residual volume. A secondary objective of this study was to investigate bias between the three %BF estimation methods. The main finding is that significant differences for %BF were found when comparing HW to the Skulpt Chisel™ and the SKF (19 ,20) methods. Data from the present study shows an overestimation of 3.38 %BF using the Skulpt Chisel™ method and an underestimation by 2.53 %BF using Jackson et al. (20) and Jackson and Pollock (19) skinfold methods compared to HW (Figure 1). Further, regression analysis demonstrated no bias in %BF estimation for each method pairing (Figures 2, 3A, and 3B). In contrast, the significant overestimation of HW %BF by the Skulpt Chisel™ might be explained by the propagation of error, characterized as the increase in measurement error dependent on the number of measurements taken. Because the Skulpt Chisel™ "full body" scan requires 24 different measurements, the error produced by each measurement may have contributed to the overestimation of %BF. However, this may not be the case as no measurement bias was found using the Bland-Altman technique comparing the Skulpt Chisel™ to HW (Figure 3). Although the current study did not use the Skulpt Chisel™ "quick scan" function, a three measurement site protocol, results of a previous research study using the Skulpt Chisel™ showed no difference in mean %BF comparing the "quick scan" function to the 24-site "full scan" function (26). Additionally, age, weight, height, and BMI sample demographics between the current study and the McLester et al., (26) study were similar, thereby suggesting that there was no evidence for a propagation of error.

Regardless, a 3.38 %BF overestimation, on average, was found using the Skulpt Chisel™ relative to HW; this suggests it is possible to incorrectly categorize an individual as being obese or having more %BF that can be safely lost. Also, an individual below the recommended %BF may be incorrectly categorized by the Skulpt Chisel™ as having a %BF high enough to avoid suspicion of malnutrition or disordered eating. McLester et al. (26) found no difference between the Skulpt Chisel™ and dual-energy X-ray absorptiometry (DXA) which they stated provides evidence for using the Skulpt Chisel™ as a valid measure of %BF. In agreement with McLester et al. (26), Czeck et al. (6), also found no difference comparing the Skulpt Chisel™ to DXA estimates of %BF. The discrepancy between the results of the present study and those of McLester et al. (26) and Czeck et al. (6) would be resolved by a comparison between HW and DXA measurements. A recent study provides evidence that, on average, mean %BF difference estimated by DXA is 1% (90% CI: 0.6% - 1.4%) higher compared to HW (5). This suggests the higher mean %BF from DXA is another possible explanation for the difference between HW and the Skulpt Chisel™ in the present study. This may also explain the absence of %BF differences between DXA the Skulpt Chisel™ as reported by McLester et al. (26) and Czeck et al. (6). Thus, the Skulpt Chisel™ may still be used as a reasonable means to track body composition. Further, the present study reports no bias as the Bland-Altman correlations were not statistically significant, suggesting agreeability between all methodological pairings (Figures 2, 3, and 4). In parallel, Mclester et al. (26) using Bland-Altman analysis, reported no bias between DXA and the Skulpt Chisel™. This suggests a 1%BF difference comparing HW and DXA is not a result of methodological bias.

It was noted in the current study that anatomical sites covered by tattoos could not be measured with the Skulpt Chisel™. Tattoos, particularly those covering large areas, are becoming increasingly popular. Therefore, this may represent an important limitation to the Skulpt

Chisel™ for individuals with inkwork covering multiple measurement sites. In agreement with McLester et al. (26), body hair increased time to perform Skulpt Chisel™ measurements in the present study. Also, in agreement with McLester et al. (26), any difficulty apart from tattoos in measuring anatomical sites using the Skulpt Chisel™ were resolved by applying more water to the electrodes or terminating and restoring the Bluetooth™ connection pairing the Skulpt Chisel™ to the Skulpt phone application. This, however, increases time to perform a full body scan creating an inconvenience for either technicians or individuals to perform measurements with no additional accuracy as opposed to the "quick scan" function according to data provided by McLester et al., (26). Also, in the present study the "full scan" function requires measurement at sites on the upper and lower back that are difficult for an individual with restricted shoulder mobility to complete alone. Further, in one case the Skulpt Chisel™ provided a "N/A" value for total %BF and a measurement site was skipped for two other participants. However, using the "full body" scan, the Skulpt Chisel™ still provided a total %BF value that included the missing measurements. Therefore, the trials with missing values were still included in the data analysis. A possible limitation is that the inclusion of these data with missing site measurements may have had an impact on the %BF estimation of these two participants. Another limitation is that Skulpt Chisel™ uses proprietary prediction formulas to provide a total %BF estimate, reported to be based on site-to-site measurements. Thus, as body density was not provided by the Skulpt Chisel™, there was no possible means to make a direct comparison of total %BF estimations between methodological pairings as both HW and SKF make total %BF estimates from body density with known formulas such as the Siri equation.

In conclusion, this study shows evidence of overestimation of %BF calculation using the Skulpt Chisel™ and underestimation of %BF calculation from seven-site SKF assessments when compared to HW. Since difficulty reaching measurement locations (e.g. individuals with restricted range of motion) using the "full scan" function when alone, the "quick scan" function is suggested for measurement using the Skulpt; although, it is unknown whether tattoos covering one or more of the three sites may lead to errors in measurement. Future research needs to be done to estimate %BF in obese and underweight populations to extend possible application of the Skulpt Chisel™ to track total %BF in that population. Further, based on the data from the current study, caution is suggested if using the Skulpt Chisel™ to assess %BF in a research setting.

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