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Validity of a Novel Smartphone-Based 3D Application for Body Fat Percentage Measurement

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Introduction

Body composition is a valuable metric for evaluating comprehensive health and fitness, providing insight into acute and long-term responses to dietary modifications and physical activity (Castro et al., 2020). Standard assessments of body composition measure total body mass using a two-category model: fat mass and fat-free mass, which comprises muscle, water, organs, and bones (Holmes & Racette, 2021). Adverse changes in body composition, such as muscle wasting and elevated adiposity, are associated with poor clinical outcomes and higher risks of mortality (Santanasto et al., 2017). Most relevant to public health at the global scale, however, is the development of obesity, which carries significant cardiometabolic risk and is closely associated with downstream health complications (Bray et al., 2018).

Considering the importance of body composition in both clinical and fitness contexts, numerous methods are available for its measurement. Self-weighing with commercially available scales can provide a general, albeit limited, indication of overall body composition through body weight (Zheng et al., 2014). Body mass index (BMI) measures weight relative to height but does not differentiate between lean and fat mass, leading to inaccuracies in obesity diagnoses (Okorodudu et al., 2020). Alternative measures include abdominal circumference measurement, waist-to-hip ratio, and skinfold measurements, all of which are subject to considerable variability in both execution and interpretation (Duren et al., 2008). Well-validated measures, such as dual-energy x-ray absorptiometry (DXA), bioelectrical impedance analyzers (BIA), computed tomography, and magnetic resonance imaging, may offer more accurate assessments of body composition. However, these methods are limited by high costs, time consumption, the need for expert involvement, and their applicability to specific demographics. Furthermore, these methods lack ecological validity as they are not administered in real-world conditions and everyday environments beyond the confines of laboratories or clinics, which consequently limits their practicality and accessibility.

To enhance accessibility to body composition assessments, the marketplace has recently introduced numerous technological advancements aimed at facilitating digitally based anthropometric measurements. From three-dimensional imaging scans (Tinsley et al, 2024; Florez et al., 2024) to integrated two- and three-dimensional modeling (Neufeld et al., 2020), these modern alternatives have demonstrated promising results in accurately evaluating body composition. Overall, some of these app-based measurements have shown relative agreement with traditional methods, including DXA and BIA. However, given that these platforms are still in their nascent stages, further validation is necessary to ensure their accuracy. This present study assesses the accuracy and validity of *Visualize Me* (Visualize Inc., Tokyo, Japan), an application that uses depth mapping and infrared scanning for detailed body composition analysis, against criterion-BIA measurements.

Methods

Participants

Eighty-eight apparently healthy participants (60 male, aged 20.1 ± 1.1 yrs; BMI 23.2 ± 1.2 kg/m^2) within the surrounding community of University of California, Los Angeles volunteered to participate in this study. Written informed consent and ethical approval (IRB: 11-003190) was obtained from all pilot participants for a priori power analysis determination at UCLA. Off-site participants gave written consent and approval from a single IRB (sIRB: BRANY, NY, USA) for all data collection. Research practices were conducted in accordance with the ethical principles documented in the Declaration of Helsinki.

Testing Procedures

Body mass and Height: Body mass and Height: Body mass was measured on a calibrated medical scale (accuracy ±0.1 kg), and height was determined using a precision stadiometer (Seca, Hanover, MD, United States; accuracy ±0.01 m). In a fasted state and after voiding their bladder, participants were instructed to remove unnecessary clothing and accessories prior to being weighed, as well as remove their shoes prior to taking height measurements.

Body Composition: Body fat percentage was measured using a validated octipolar, multi-frequency, multi-segmental bioelectrical impedance analyzer (BIA) (InBody Co., Seoul, Korea Republic) (Dolezal et al., 2013). To ensure accuracy, participants adhered to standard pre-measurement BIA guidelines recommended by the American Society of Exercise Physiologists (Heyward, 2001). Briefly, the test was performed after at least 3 hours of fasting and voiding, with participants instructed to remain hydrated and not exercise 2 hours before testing. After investigators explained the procedure, the participant stood upright with their feet on two metallic footpads while holding a handgrip with both hands. The instrument measured resistance and reactance using proprietary algorithms. Another group of approximately 22 participants were measured using DXA, but their data is not included in this report.

Mobile BF% Application: Following the BIA measurements, body fat percentage was determined using the Body Fat Mobile Application ("Visualize Me", Visualize Inc., Tokyo). This application employs the True Depth camera system (Apple Inc., Cupertino, CA) to obtain body measurements through a combination of depth mapping and infrared scanning technologies (Figure 1). According to the company, a 30-second scan facilitates measurements of the user's neck, chest, waist, and hip circumferences, which are subsequently processed through proprietary AI models to validate measurement accuracy. Body fat percentage is then calculated by incorporating these measurements into the US Navy circumference method formula (CITATION NEEDED FROM COMPANY).

Participants began by removing any loose upper-body clothing, excluding bras and tight-fitting shirts, for the measurements. The smartphone equipped with the application was initially provided by the staff to the participant. Upon prompt, the participant entered their sex and height, then pressed the 'scan' button. Subsequently, the app delivered an instructional audio prompt. Two photographs were then taken: a front profile with the smartphone held in both hands to capture the shoulders and waist (excluding the face), and a side profile with the smartphone held in one hand to capture the side of the shoulder and waist. Participants subsequently adjusted a circle on the screen to mark the position of their belly button on the frontal image. To ensure impartiality, neither the staff nor the participants were permitted to access their body fat percentage results from this measurement or the subsequent BIA assessment. The test was conducted twice, with results documented by an independent, unblinded associate.

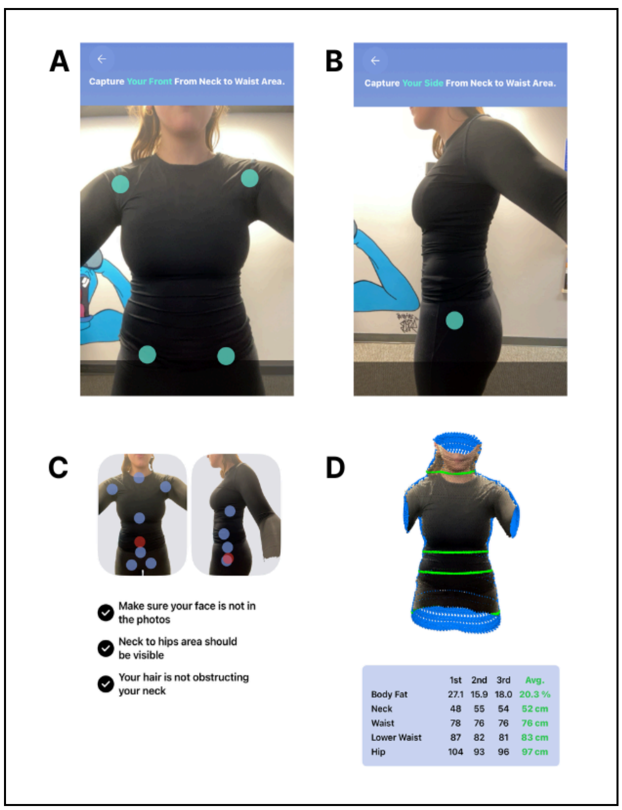

Figure 1. Depiction of front view (A) and side view (B) postures for thorough body composition evaluation via the smartphone application. Quality assurance and precise measurement guidelines are provided during the assessment

process (C). Triplicate measurements are averaged using proprietary software to produce an estimation of body fat percentage (D).

Data Analysis

Convergent validity was evaluated to ascertain whether the smartphone application recorded body fat percentages comparable to those obtained by the criterion measure, Bioelectrical Impedance Analysis (BIA). Strong convergent validity is determined by a Pearson correlation coefficient (*r*) greater than 0.70 (Abma et al., 2016), indicating that a novel measure produces data consistent with a similar, well-established measure. Group agreement between each measurement pair (*i.e.,* smartphone application versus BIA) was determined through bias and limits of agreement (LoA) (Bland & Altman, 1986). The former evaluates the average difference between concurrent measurements across a sample, whereas the latter indicates the outer extremes for the potential difference between two measurements (i.e. 95% LoA) (Giavarina, 2015; Bland & Altman, 1999). Normality assessment was conducted using Shapiro-Wilk tests (Ghasemi & Zahediasl, 2012), followed by determination of the Spearman rank correlation coefficient to identify monotonic association (Schober et al., 2018).

A note on exclusionary data for this study: Data that is intentionally excluded from the aforementioned data analysis helps preserve the integrity and validity of the research by ensuring that only relevant, reliable, and appropriately collected data are considered. For transparency, the following list the reasons and number of participant data that were excluded for analysis in this study:

- Participant non-eligibility – did not meet inclusion criteria (*e.g.,* wrong age group, underlying health issues, etc.) **n=3**
- Missing or Incomplete data – if critical data points are missing **n=5**
- Outliers – Extreme values that may skew results, which were identified statistically in this study **n=4**
- Protocol Violations – Did not follow study protocols (*e.g.,* BIA measure prerequisites not met **n=8**
- Data Entry or Measurement Errors – Mistakes in recording or technical failures (*e.g.,* app crashes) **n=18 (we retested and retained 12 of them)**
- Bias or Confounding Factors – Data that introduces bias or confounds the study's results (*e.g.,* staff unblinded themselves) **n=1**

Results

Shapiro-Wilk tests demonstrated that both distributions deviate significantly from normality. Spearman's rank correlation coefficient was calculated due to non-normal distributions, resulting in **0.92 (95% CI: 0.88, 0.95), indicating a very strong correlation between the two BF% measures**. The bias observed between the two devices (Figure 2) was 0.2% (95% CI: -0.1, 0.5) with LoA spanning from -2.9% (95% CI: -3.4, -2.3) to 3.2% (95% CI: 2.7, 3.8).

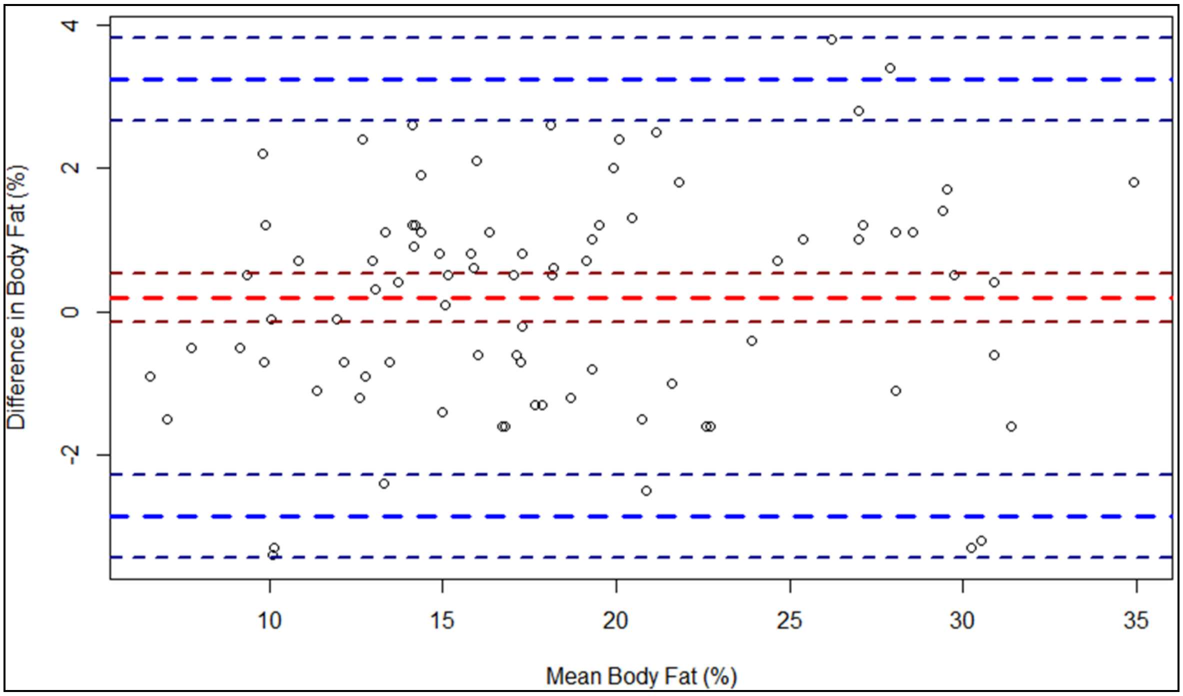

Figure 2. The Bland-Altman plot shows the difference in body fat measurements between the app and criterion methods against the average of the two measurements. The smaller dashed lines next to each larger dashed line indicate the 95% confidence interval.

Discussion

The primary objective of this study was to assess the validity of a novel smartphone application's body fat measurements in comparison to a criterion body fat measure. The results indicate that body fat measurements were highly comparable between both methods. The Spearman's rank correlation exceeded the threshold of 0.90, demonstrating a very strong correlation in body fat percentage between the *Visualize Me* smartphone application and criterion BIA. Additionally, there was negligible bias and a small error margin of less than 3% between the measurements. These findings are promising for the potential effectiveness of this application in providing accurate and accessible body composition assessments.

Current research in this field

Recent advancements in anthropometric measurements via digital platforms have demonstrated promising preliminary results, although absolute accuracy remains forthcoming. For instance, mobile phone-based three-dimensional optical imaging has been employed to measure abdominal circumference, subsequently incorporated into a novel single-site body fat estimation equation devised by the United States military (Florez et al., 2024). When compared to DXA, measurements of BF percentage, fat mass, and fat-free mass showed no significant discrepancies between the two methods. Nevertheless, notable proportional bias was detected among participants with exceptionally low or high body fat percentages. Another application, which reconstructed three-dimensional avatars based on smartphone camera scanning, showed a strong correlation with DXA measurements (r = 0.90) without proportional bias (Tinsley et al., 2024). Unlike the one-site method, this application utilized a range of visual data through a full 360-degree rotation of the subject.

Sex-related differences

The distribution of adipose tissue within the body is influenced by a variety of factors. Adipose tissue primarily resides beneath the skin, known as subcutaneous adipose tissue (SCAT), and around internal organs, referred to as visceral adipose tissue (VAT) (Frank et al., 2018). Sex-related differences have been observed in adipose tissue distribution. In premenopausal women, there is a higher prevalence of gluteofemoral and abdominal SCAT compared to age-matched men (Karastergiou et al., 2012). The distinction between premenopausal and postmenopausal states is critical, as postmenopausal women exhibit a central body pattern favoring adipose tissue accumulation (Ley et al., 1992). Consequently, the diverse locations of adipose tissue necessitate multiple measurement approaches.

Ecological value of Visualize Me app

The current application presents several advantages. It features multi-angle depth capture, including front and side views, which facilitates a range of measurements. As previously noted, data collected from various perspectives of a participant can contribute to preventing inaccuracies. Furthermore, the different measurement locations enable a more comprehensive evaluation of adipose tissue. While the one-site method is relatively accurate, it may not fully account for the complex distribution of adipose tissue, particularly in relation to the sex and age of the individual being assessed. Lastly, the convenience, low-cost and accessibility of smartphone applications stand out as its primary strengths. Providing accessible body composition scans through picture taking, akin to the current trend of Generation Xers penchants for selfies, without sacrificing accuracy, possesses the potential to significantly enhance awareness in the public health and fitness landscapes where adult and childhood obesity is rampant.

The limitations of this study include the homogeneity of participant demographics and potential user errors with the application. Since the data was collected exclusively from college-aged, apparently healthy individuals, interpretations should be confined to this specific population. Further validation of measurement accuracy is required across a broader and more diverse population, including pediatric and geriatric subjects. Although the application provides audible measurement guidelines, camera angles and user errors in positioning may have led to some discrepancies in data capture.

Conclusion

The *Visualize Me* application is an accurate and user-friendly tool for evaluating body fat percentage. Furthermore, due to the application's advanced ecological design, it requires minimal resources to function effectively at virtually any location. It delivers immediate and precise body fat percentage measurements using proprietary depth mapping and infrared scanning technologies from the smartphone camera.