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Comparison of mobile application and bioelectrical impedance analysis in body composition measurement

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Abstract

Introduction: Smartphone-based anthropometry offers a low-cost, high-throughput approach to body composition assessment, but agreement with established field methods requires careful evaluation.

Objectives: We assessed agreement between an image-based mobile application (LeanScreen within PostureScreen Mobile) and a multi-frequency, segmental bioelectrical impedance analyzer (TANITA MC-180) under standardized pre-test conditions in sedentary young adults.

Methods: In a cross-sectional study, 40 participants (57.5% women; aged 18–30 years) underwent same-day assessments by both methods following strict pre-analytic controls. Outcomes assessed included waist-to-hip ratio (WHR), body fat percentage (%BF), fat-free percentage (%FF), fat body mass (FBM), fat-free mass (FFM), and basal metabolic rate (BMR). Agreement was evaluated using paired t-tests, Pearson correlations (95% confidence intervals), Bland–Altman analyses, and intraclass correlation coefficients (ICCs) with a two-way mixed-effects absolute agreement model.

Results: Mean paired differences were small and not statistically significant for all outcomes. Linear associations were very high ($r = 0.943–0.995$; $p < 0.001$), with the highest for BMR ($r = 0.995$) and FFM ($r = 0.993$). Bland–Altman analyses showed small mean biases and clinically acceptable limits of agreement (LoA) for WHR, %BF, %FF, FBM, and FFM, with no evidence of proportional bias. For BMR, bias was near-zero with acceptable LoA (–74.1 to 72.7 kcal/day), but a small proportional bias was detected ($\beta 1 = 0.068$; $p < 0.001$). Absolute agreement was excellent, as indicated by the ICC (3,1) values: BMR (0.993), FFM (0.990), FBM (0.989), %FF (0.967), %BF (0.967), and WHR (0.938).

Conclusion: Under controlled conditions, LeanScreen and BIA TANITA showed high agreement for body composition estimates, supporting their use for population-level comparisons and screening. For individual-level decisions near clinical cut points, corroboration with repeated measures or a reference method is advisable. These findings support protocolized smartphone anthropometry as a practical, field-based approach for body composition assessment in young adults, while criterion-validation studies remain necessary to determine absolute accuracy.

Keywords: Anthropometry; Bioelectrical impedance analysis; Body composition; Cross-sectional study; Mobile applications; Smartphones

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1. Introduction

Excess adiposity is a key driver of type 2 diabetes and cardio-/cerebrovascular diseases; consequently, practical and accurate assessment of body composition is essential for risk stratification, screening, and monitoring.[1] Body mass index (BMI) and waist-to-hip ratio (WHR) are widely used for their low cost and feasibility, yet they only indirectly approximate adiposity and fat distribution. More direct approaches (e.g., skinfolds, bioelectrical impedance analysis [BIA], dual-energy X-ray absorptiometry [DXA], hydrostatic weighing, and air-displacement plethysmography) differ in accuracy, feasibility, and cost across settings. The choice of method therefore entails balancing purpose, accessibility, and expected accuracy while standardizing pre-test conditions.[2–4]

The LeanScreen mobile application promises low cost, speed, and non-contact landmarking suitable for primary care and workplace/community programs. However, because it typically relies on circumference-based regressions and user-dependent photographic landmarking, they are sensitive to camera angle, clothing, and operator decisions; rigorous evaluation of agreement with existing field methods, and ultimately validation against criterion methods, is required before supporting individual-level decisions.[5–7] In contrast, BIA, particularly multi-frequency, segmental BIA, remains widely used in field and clinical settings due to its portability and high throughput. Multi-frequency approaches can better account for body–water distribution than single-frequency systems and, under standardized pre-test conditions, have shown good agreement with criterion methods such as DXA for fat mass and fat-free mass.[2,8,9] Specifically, multi-frequency, segmental TANITA analyzers (including MC-series platforms using hand-to-foot configurations) have been reported to correlate strongly with DXA-derived estimates of % body fat, fat mass, and fat-free mass in adults, supporting their utility as a practical comparator in applied research when strict measurement controls are implemented.[9,10] Nevertheless, BIA estimates remain sensitive to hydration status, recent exercise, and recent food or fluid intake, as well as electrode contact and device-specific algorithms. These factors may influence classification near clinical thresholds if pre-test controls are not enforced.[2,8]

Comparing a mobile, image-based tool with a standardized multi-frequency BIA device under controlled conditions addresses an important evidence gap regarding agreement between practical field methods used in applied settings. Beyond average agreement, decisions often hinge on small differences near cut points and on detecting minimal clinically important changes over time—both of which are influenced by reporting resolution, systematic method bias, and pre-test controls. This study directly compares an image-based mobile application (LeanScreen) with a multi-frequency BIA device (TANITA MC-180) to inform fit-for-purpose tool selection for screening, classification, and longitudinal monitoring, and to guide protocol, training, and quality assurance in field applications.[2–5,7] We aim to compare body composition estimates obtained from an image-based mobile application (LeanScreen) and a multi-frequency, segmental BIA device (TANITA MC-180) under standardized pre-test conditions. We hypothesize that the mobile application would show acceptable agreement with BIA for screening and monitoring purposes, yet exhibit small but systematic differences around clinical cut points.

2. Material and methods

2.1. Study design and ethics

This study was designed as a method-comparison/agreement study between two field-based body composition assessment tools and did not include a criterion-related method. This cross-sectional methodological study was conducted in accordance with the Declaration of Helsinki. All participants received verbal and written information about the study and provided written informed consent prior to enrollment. The written informed consent process explicitly addressed the use of digital photography, including data storage, de-identification procedures, and access controls. Participants were informed that their images would be used solely for body composition analysis and that no identifiable facial features would be captured or stored. The protocol was reviewed and approved by the Scientific Research and Publication Ethics Committee of Cyprus International University.

2.2. Participants and setting

Sedentary university students aged 18–30 years were recruited from Cyprus International University via posters, class announcements, and departmental mailing lists. Individuals were eligible if they were between 18 and 30 years of age, reported a sedentary lifestyle, were not using any prescription medications, were able to stand unaided and follow instructions, and provided written informed consent. Sedentary status was operationally defined using the International Physical Activity Questionnaire (IPAQ), and all included participants were classified in the "low physical activity" category according to standard IPAQ scoring criteria. Individuals were excluded if they had a diagnosed illness or a history of surgery within the previous six months; had a serious chronic condition (e.g., hypertension, cancer, diabetes, morbid obesity); were pregnant; had metallic implants (e.g., plates/pins);

reported any use of prescription medications; or failed to meet standardized pre-test hydration requirements, which included maintaining usual fluid intake for 24 h and refraining from alcohol for 24 h and caffeine for 12 h prior to assessment. Female participants were excluded if they were actively menstruating to minimize potential variability in BIA measurements related to hormonal fluctuations. Eligibility was verified using a standardized screening interview and checklist.

2.3. Sample size and power

A priori power analysis using G*Power 3.1.9.2 (test family: *t*-tests; statistical test: means– difference between two dependent means, two-tailed), informed by prior studies[7,11] reporting clinically meaningful between-method differences for non-laboratory body composition tools, assumed an effect size of $d = 0.55$, $\alpha = 0.05$, and a desired power of 0.95 ($1–\beta = 0.95$). The analysis indicated that a minimum of 32 participants was required to detect a statistically and practically meaningful difference. To accommodate potential exclusions (e.g., protocol deviations, inadequate image quality), a 20% over-recruitment margin was planned; accordingly, the total target sample size was set at 40 participants, and the study was completed with 40 participants enrolled. This sample provided adequate precision for primary agreement metrics, including narrower confidence intervals for Bland–Altman limits of agreement (LoA) and intraclass correlation coefficients (ICC).

2.4. Design and within-participant measurement protocol

All included participants underwent both assessment methods— the LeanScreen application and multi-frequency, segmental BIA (TANITA MC-180, TANITA, Japan)—on a single visit under standardized conditions. To minimize order effects, the sequence of methods (BIA first vs. LeanScreen first) was randomized in a 1:1 ratio using a computer-based randomizer (www.randomizer.org), with allocation concealed in sequentially numbered, opaque envelopes opened immediately before measurement. Given the nature of the procedures, assessors were not blinded to the device in use; however, the data analyst was blinded to method identity by labeling datasets as "Method A" and "Method B" during primary analyses.

2.5. Pre-test standardization

To reduce pre-analytic variability, participants were scheduled for the morning after an overnight fast of at least eight hours. They refrained from vigorous exercise and alcohol for 24 h and from caffeine for 12 h, voided their bladder within 30 min prior to measurement, removed metal accessories, and wore light, form-fitting clothing. All assessments were conducted in a temperature-controlled room (22–24 °C) by trained assessors in accordance with a written standard operating procedure. No food or fluids were permitted between the two methods, and a seated rest of at least five minutes was observed between methods.

2.6. Data collection and outcome measures

A structured case report form documented age, sex, height, body mass, medication use, smoking status, and relevant medical history. Height was measured to the nearest 0.1 cm with a wall-mounted stadiometer, and body mass to the nearest 0.1 kg with a calibrated digital scale; BMI was calculated as kg/m^2.

2.7. Physical activity assessment

Participants' physical activity levels were assessed using the IPAQ–Short Form (IPAQ-SF), Turkish version, which has demonstrated acceptable validity and reliability in Turkish adults.[12] The IPAQ-SF comprises seven items capturing time spent in the last seven days in vigorous-intensity activity, moderate-intensity activity, walking, and sitting. Activity volumes were expressed as metabolic equivalent of task (MET)-min/week using standard MET values assigned by the IPAQ scoring protocol: 8.0 METs for vigorous activity, 4.0 METs for moderate activity, 3.3 METs for walking, and 1.5 METs for sitting. The total physical activity score was computed as the sum of MET-min/week for vigorous, moderate, and walking activities (sitting is reported separately and not included in the total). Based on established thresholds, participants were categorized as low/inactive (<600 MET-min/week), moderate (600–3,000 MET-min/week), or high (>3,000 MET-min/week).[13]

2.8. Body composition assessment

Body composition was measured using two methods on the same day under standardized pre-test conditions.

A multi-frequency, segmental BIA analyzer (TANITA MC-180) was used according to manufacturer instructions and international recommendations for BIA measurement.[2,14] The device operates with a segmental, multi-frequency (5, 50, and 250 kHz) hand-to-foot electrode configuration and provides whole-body and segmental estimates of body composition. The analyzer was used in the standard adult mode appropriate for non-athletic populations, and the software/firmware remained unchanged throughout the study period.[9,10] Participants were assessed barefoot with both feet contacting the footplate electrodes and both hands contacting the hand electrodes while standing upright and motionless until the measurement was completed. Device inputs (age, sex, and height) were verified by a second assessor. Primary outcomes included WHR, body fat percentage (%BF), fat mass (kg), fat-free mass (FFM), fat-free percentage (%FF), and basal metabolic rate (BMR), as reported by the device; where available, segmental composition indices were recorded. BMR values reported by the device are algorithm-derived estimates based on anthropometric and body composition inputs rather than direct physiological measurements. Output data were exported via the manufacturer's software into the study database and cross-checked by two independent assessors to minimize entry or transcription errors. The device was maintained and calibrated in accordance with institutional quality-control procedures.

An image-based mobile application (LeanScreen), implemented within the PostureScreen Mobile application (version 15.6; PostureCo, Inc., United States), was used to estimate body composition and circumferences from two-dimensional photographs captured with a smartphone. Following procedures described in prior studies[5,7,15–17], all images were captured using a single smartphone model (iPhone 17, Apple Inc., United States) running iOS 26.3.1 to ensure consistency throughout the study period. Standardized anterior and right-lateral images were taken at a fixed distance of approximately 3 m in front of a plain background, with participants standing in a neutral posture (feet shoulder-width apart, arms relaxed). To ensure participant anonymity, images were framed or digitally cropped to exclude facial features. All digital files were de-identified upon capture and assigned a unique alphanumeric code. Data were stored on a secure, password-protected institutional server with access strictly limited to the primary investigators. In accordance with institutional data retention policies, all raw images will be permanently deleted five years after the completion of the study analysis.

The smartphone camera was positioned at approximately waist-to-chest height on a stable tripod, aligned perpendicular to the participant, and standard camera settings (no digital zoom or portrait effects) were used to minimize optical distortion. A single smartphone model was used for all assessments, and the application version remained consistent throughout the study period. Lighting conditions were kept consistent using ambient indoor lighting in a controlled environment, and a plain, non-reflective background was used to enhance landmark visibility and reduce visual noise. Participants were instructed to stand upright with weight evenly distributed, arms relaxed at the sides, and to maintain a normal breathing phase (end of gentle expiration) during image capture to minimize variability in abdominal and thoracic dimensions. Tight-fitting clothing or, where feasible, minimal, form-fitting clothing was used to ensure visibility of anatomical landmarks. Photographic landmarking was performed by a single trained operator, who also conducted all LeanScreen image acquisitions, according to in-app instructions (e.g., shoulders, waist, hips), to minimize operator-related variability during data collection. Image quality was reviewed immediately after capture; if images were blurred, misaligned, or landmarks were not clearly visible, repeat captures were performed. Two consecutive image captures were obtained; if %BF values differed by more than 1.0 percentage point, a third image was acquired and the median value recorded. The number of retakes was minimal and did not systematically affect the measurement workflow.

2.9. Statistical analysis

All analyses were conducted using IBM Statistical Package for Social Sciences Statistics (version 27.0). Data were first assessed for normality using the Shapiro–Wilk test, which indicated that all variables were approximately normally distributed. For within-subject comparisons between the two measurement methods (TANITA BIA vs. LeanScreen), paired-samples *t*-tests were performed. Linear associations between methods were examined using Pearson correlation coefficients with 95% confidence intervals (CIs).

Method agreement was evaluated using Bland–Altman analysis, including estimation of mean bias and 95% LoA (mean difference ± 1.96 × standard deviation of the differences) and visualization with Bland–Altman plots. Normality of the paired differences was verified for each variable using Shapiro–Wilk tests and visual inspection of Q–Q plots to support the assumptions underlying LoA estimation. Proportional bias was assessed by ordinary least squares (OLS) regression of the difference on the mean (difference = $\beta 0 + \beta 1 \times$ mean), and we reported the regression slope ($\beta 1$), its 95% CI, and *p*-value. Heteroscedasticity was evaluated by visual inspection of residuals versus fitted values; when present, it was noted that fixed LoA may vary across the measurement range (e.g., for BMR with a significant slope), and the linear trend was reported accordingly.

To contextualize the clinical relevance of the Bland–Altman LoA, we predefined a priori clinical acceptability thresholds based on established literature and typical field-assessment variability. For %BF, thresholds of ±3.0% to ±5.0% were used[18,19]; for FM and FFM, ±2.0 kg to ±3.5 kg[11,20]; for WHR, ±0.03 to ±0.05 units[6,19]; and for BMR, ±100 to ±150 kcal/day.[2,14] Methods were considered to demonstrate sufficient agreement for screening and group-level monitoring if the 95% LoA fell within these clinically relevant bounds.

Inter-method reliability was quantified via ICC using a two-way mixed-effects model with an absolute-agreement definition: single-measures ICC (3,1) and average-measures ICC (3,k), each with 95% CIs. No multiplicity correction was applied; emphasis was placed on effect sizes and confidence intervals. Statistical significance was set at $p < 0.05$ (two-tailed).

3. Results

A total of 98 individuals were screened for the study. Forty individuals who met the inclusion criteria were included in the study (Figure 1). Of the 40 participants, 23 (57.5%) were women, and 17 (42.5%) were men.

Table 1 summarizes the demographic and anthropometric characteristics of the study participants, alongside their physical activity levels. The study consisted of 40 individuals with an average age of 21.95 ± 1.93 years. Participants had a mean height of 170.25 ± 8.07 cm and a mean body weight of 71.59 ± 18.82 kg, resulting in a mean BMI of 24.52 ± 5.45 kg/m^2. Physical activity, as assessed by the IPAQ, showed a mean score of 386.77 ± 124.98 MET-min/week. To account for potential skewness in physical activity data, we also report a median score of 405.50 MET-min/week, with an interquartile range of 310.00–480.00 MET-min/week. Based on these scores, 100% (n = 40) of the participants were classified in the "low" physical activity category according to standard IPAQ thresholds (Table 1).

Paired-samples t-test results comparing body composition parameters between the two measurement methods are presented in Table 2. Across all outcomes—%BF, %FF, FBM (kg), FFM (kg), WHR, and BMR (kcal)—mean differences were small in magnitude and not statistically significant ($p > 0.05$), with 95% CIs for the mean differences spanning zero. Central tendency and dispersion were highly similar between TANITA BIA and LeanScreen across all parameters. These findings indicate no material systematic offsets between methods at the group level for the assessed metrics.

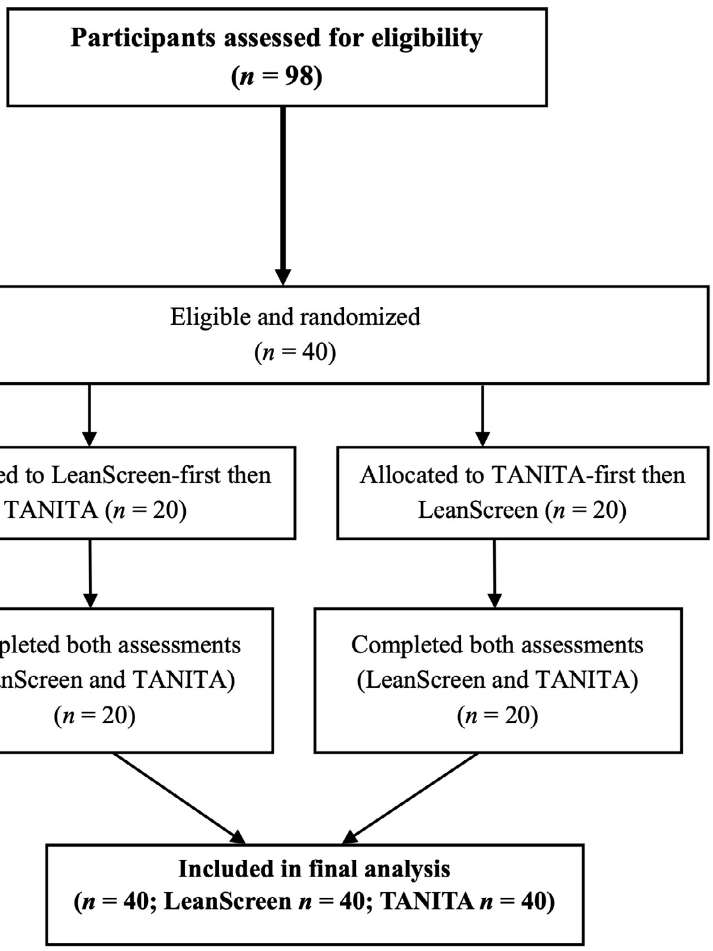

Figure 1. Flow chart of the individuals included in the study

Table 1. Participants' age, anthropometric characteristics, and IPAQ scores

Parameters	*n*	Mean ± standard deviation	Median (Min–max)
Average age (years)	40	21.95 ± 1.93	21.00 (19.00–27.00)
Height (cm)	40	170.25 ± 8.07	171.50 (153.00–187.00)
Body weight (kg)	40	71.59 ± 18.82	65.10 (40.20–126.80)
BMI (kg/m^2)	40	24.52 ± 5.45	23.60 (16.30–43.80)
IPAQ (MET-min/week)	40	386.77 ± 124.98	405.50 (99.00–598.00)

Abbreviations: BMI: Body mass index; IPAQ: International physical activity questionnaire; MET: Metabolic equivalent of task.

Table 2. Comparison of body composition parameters measured by BIA Analyzer and LeanScreen

Variables	Group	*n*	Mean ± SD	Median (Min–max)	Cohen's *d*	95% CI (Lower–Upper)	p^{ϕ}
%BF	TANITA BIA	40	25.09 ± 8.55	24.31 (9.20–47.30)	−0.126	−0.565 – 0.313	0.742
	LeanScreen	40	26.15 ± 8.22	25.98 (10.95–46.24)			
%FF	TANITA BIA	40	74.91 ± 8.55	75.69 (52.70–90.80)	0.126	−0.313 – 0.565	0.742
	LeanScreen	40	73.85 ± 8.22	74.02 (53.76–89.05)			
FBM (kg)	TANITA BIA	40	18.83 ± 10.66	17.25 (5.30–57.80)	−0.072	−0.510 – 0.367	0.854
	LeanScreen	40	19.59 ± 10.57	18.75 (4.40–56.50)			
FFM (kg)	TANITA BIA	40	52.76 ± 11.12	49.80 (34.90–82.10)	0.070	−0.369 – 0.508	0.887
	LeanScreen	40	51.99 ± 10.80	49.50 (35.30–79.50)			
WHR	TANITA BIA	40	0.88 ± 0.06	0.87 (0.78–1.06)	−0.115	−0.554 – 0.324	0.958
	LeanScreen	40	0.88 ± 0.06	0.88 (0.77–1.04)			
BMR (kcal/day)	TANITA BIA	40	1,627.55 ± 327.75	1,541.00 (1,115.00–2,527.00)	−0.002	−0.440 – 0.436	0.750
	LeanScreen	40	1,628.26 ± 306.24	1,559.50 (1,156.00–2,465.00)			

Note: $^{\phi}$: Paired-samples *t*-test.

Abbreviations: %BF: Body fat percentage; %FF: Fat-free percentage; BIA: Bioelectrical impedance analysis; BMR: Basal metabolic rate; FBM: Fat body mass; FFM: Fat-free mass; SD: Standard deviation; WHR: Waist-to-hip ratio.

In Table 3, we present the results of Pearson correlation analyses examining the associations between body composition outcomes measured by the two methods. Across all comparisons, Pearson correlations between TANITA BIA and LeanScreen were very high to near-perfect (r = 0.943–0.995; all $p < 0.001$), indicating strong linear association and consistent ranking of individuals across methods. Specifically, BMR (r = 0.995) showed the highest correlation, indicating nearly identical relative measurements across devices. Similarly, mass-based indices such as FFM (r = 0.993) and FBM (r = 0.992) also showed exceptionally strong correlations. Percentage measures, including %FF (r = 0.974) and %BF (r = 0.974), along with WHR (r = 0.943), consistently exhibited excellent correlations. These findings collectively support a high degree of concordance between the BIA Analyzer and LeanScreen devices for all assessed body composition parameters.

Bland–Altman analysis for WHR (difference defined as TANITA BIA–LeanScreen) demonstrated a small negative mean bias of −0.007 (95% CI: −0.013 to −0.001), with 95% limits of agreement (LoA) from −0.045 to 0.032. This indicates that, on average, LeanScreen yields slightly higher WHR values than the TANITA BIA, though the difference is minimal. The limits indicate generally good agreement between methods, although a small number of observations lie outside the LoA, suggesting occasional larger discrepancies (Figure 2). Regression of differences on the mean indicated no evidence of proportional bias (slope = 0.031, p = 0.583).

For FFM, FBM, %FF, and %BF (differences defined as TANITA BIA–LeanScreen), Bland–Altman analysis showed small systematic differences between devices. FFM

Table 3. Correlations between body composition measured by BIA Analyzer and LeanScreen

Variables compared	*n*	*r*	95% confidence interval (Lower–upper)	*p*-value
TANITA BIA %BF vs. LeanScreen %BF	40	0.974	0.952 – 0.986	<0.001*
TANITA BIA %FF vs. LeanScreen %FF	40	0.974	0.952 – 0.986	<0.001*
TANITA BIA FBM (kg) vs. LeanScreen FBM (kg)	40	0.992	0.984 – 0.996	<0.001*
TANITA BIA FFM (kg) vs. LeanScreen FFM (kg)	40	0.993	0.986 – 0.996	<0.001*
TANITA BIA WHR vs. LeanScreen WHR	40	0.943	0.895 - 0.970	<0.001*
TANITA BIA BMR (kcal/day) vs. LeanScreen BMR (kcal/day)	40	0.995	0.991 – 0.998	<0.001*

Abbreviations: %BF: Body fat percentage; %FF: Fat-free percentage; BIA: Bioelectrical impedance analysis; BMR: Basal metabolic rate; FBM: Fat body mass; FFM: Fat-free mass; SD: Standard deviation; WHR: Waist-to-hip ratio.

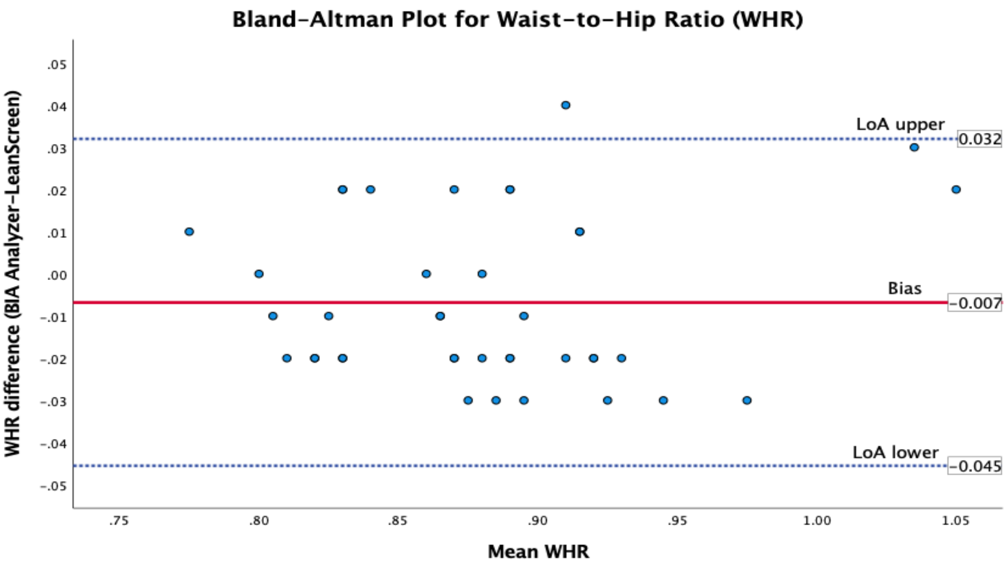

Figure 2. Bland–Altman plot for waist-to-hip ratio (WHR) comparing TANITA bioelectrical impedance analysis (BIA) and LeanScreen (*n* = 40). The solid line represents the mean bias, and the dashed lines represent the 95% limits of agreement (LoA).

exhibited a positive mean bias of 0.765 kg (95% CI: 0.324 to 1.206) with 95% LoA from −1.938 to 3.468 kg. The lower limit fell within the predefined ±3.5 kg threshold, while the upper limit approached but did not exceed this boundary (3.468 kg), indicating agreement within the expected range for field methods.

Fat body mass showed a corresponding negative mean bias of −0.765 kg (95% CI: −1.206 to −0.324), with a 95% LoA of −3.468 to 1.938 kg. Both limits were within the predefined ±3.5 kg threshold, supporting acceptable agreement for fat mass estimation at the group level. %FF demonstrated a positive mean bias of 1.061% (95% CI: 0.445 to 1.677) with 95% LoA from −2.714 to 4.836%. These limits were within the predefined ±5.0% threshold, indicating agreement consistent with expected variability for percentage-based estimates.

Similarly, %BF showed a negative mean bias of −1.061% (95% CI: −1.677 to −0.445), with a 95% LoA of −4.836 to 2.714%, which remained within the predefined ±5.0% clinical threshold. Across these parameters, most paired measurements fell within the LoA, with only a small number of observations outside the limits and no evidence of systematic outliers. Regression analysis indicated no proportional bias for any of these variables (FFM slope = 0.029, $p = 0.148$; FBM slope = 0.008, $p = 0.706$; %FF slope = 0.040, $p = 0.285$; %BF slope = 0.040, $p = 0.285$) (Figure 3).

Bland–Altman analysis for BMR (difference defined as TANITA BIA−LeanScreen) showed a near-zero mean bias of −0.708 kcal/day (95% CI: −12.681 to 11.266 kcal/day), with 95% LoA from −74.079 to 72.664 kcal/day. These limits

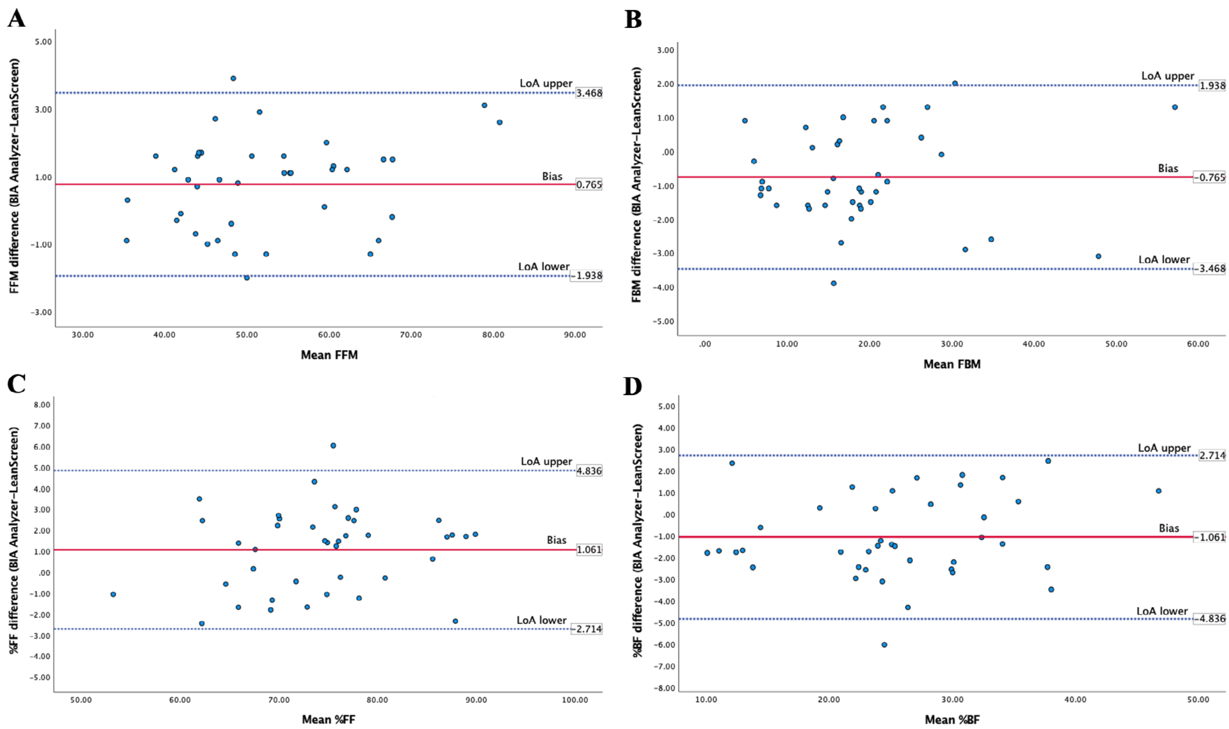

Figure 3. Bland–Altman plots comparing TANITA bioelectrical impedance analysis (BIA) and LeanScreen for (A) fat-free mass (FFM), (B) fat body mass (FBM), (C) fat-free percentage (%FF), and (D) body fat percentage (%BF) (n = 40). Solid lines indicate mean bias; dashed lines indicate 95% limits of agreement (LoA).

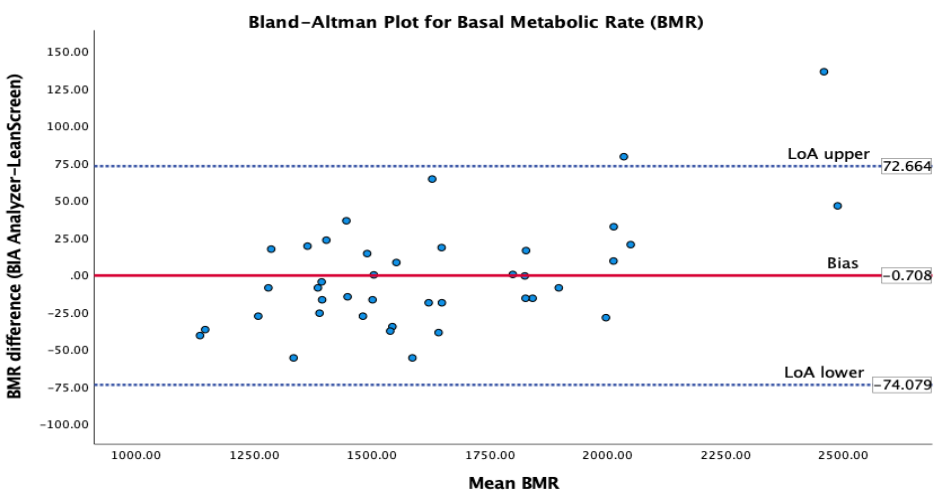

Figure 4. Bland–Altman Plot for basal metabolic rate (BMR) comparing TANITA bioelectrical impedance analysis (BIA) and LeanScreen (n = 40). Solid lines indicate mean bias; dashed lines indicate 95% limits of agreement (LoA).

fell entirely within the predefined ±150 kcal/day clinical acceptability threshold, indicating strong concordance between the two field methods for group-level metabolic estimates. It should be noted that BMR values from both methods were derived using predictive algorithms based on similar input variables (e.g., body mass, height, and composition); therefore, the observed agreement reflects concordance between estimation models rather than direct measurement of metabolic rate.

Most observations fell within the LoA; however, a small number of points lay beyond these limits, indicating occasional larger discrepancies without a consistent pattern of outliers (Figure 4). While the overall agreement was strong, the proportional bias was small but statistically significant ($\beta1 = 0.068$, $p < 0.001$) in an OLS regression of the difference on the mean. This suggests that differences between LeanScreen and BIA may increase slightly at higher mean BMR values; therefore, the fixed LoA should be interpreted in light of this linear trend.

All Bland–Altman agreement parameters, including mean bias with 95% CIs, LoA, and proportional bias estimates (β1 and *p*-value) are summarized in Table 4.

Across all metrics, TANITA BIA and LeanScreen demonstrated very high to excellent absolute agreement based on a two-way mixed-effects, absolute-agreement ICC model. Single-measures ICC (3,1) values are reported in the text, and both ICC (3,1) and average-measures ICC (3,k) with 95% CIs are presented in Table 5. Agreement was strongest for BMR (ICC [3,1] = 0.993, 95% CI: 0.987–0.996) and FFM (ICC [3,1] = 0.990, 95% CI: 0.973–0.995), indicating very strong agreement between methods. FBM likewise showed excellent agreement (ICC [3,1] = 0.989, 95% CI: 0.971–0.995). Percentage-based indices exhibited slightly greater variability yet retained very high agreement, with %FF and %BF each at ICC (3,1) = 0.967 (95% CI: 0.914–0.985). WHR also reached a very high level of agreement (ICC [3,1] = 0.938, 95% CI: 0.881–0.967). By convention, we interpret ICCs > 0.90 as excellent and 0.75–0.90 as good; consequently, these results demonstrate strong absolute agreement between the two field methods at the group level under standardized conditions, consistent with Bland–Altman findings where the 95% LoA fell within our predefined clinical benchmarks.

The distribution of participants across general %BF and WHR-based health risk categories according to

Table 4. Bland–Altman agreement analysis between TANITA bioelectrical impedance analysis and LeanScreen

Metric	Mean bias (95% confidence interval)	Lower LoA	Upper LoA	Proportional bias (β1)	*p*-value
FFM (kg)	0.765 (0.324 to 1.206)	−1.938	3.468	0.029	0.148
FBM (kg)	−0.765 (−1.206 to −0.324)	−3.468	1.938	0.008	0.706
%FF	1.061 (0.445 to 1.677)	−2.714	4.836	0.040	0.285
%BF	−1.061 (−1.677 to −0.445)	−4.836	2.714	0.040	0.285
WHR	−0.007 (−0.013 to −0.001)	−0.045	0.032	0.031	0.583
BMR (kcal/day)	−0.708 (−12.681 to 11.266)	−74.079	72.664	0.068	0.001*

Abbreviations: %BF: Body fat percentage; %FF: Fat-free percentage; BIA: Bioelectrical impedance analysis; BMR: Basal metabolic rate; FBM: Fat body mass; FFM: Fat-free mass; LoA: Limits of agreement; WHR: Waist-to-hip ratio.

Table 5. Intraclass correlation coefficients for agreement between TANITA BIA and LeanScreen across body composition parameters

Metric	ICC (Single measures)	95% CI (Lower–upper)	*F* (df1, df2)	*p*-value	ICC (Average measures)	95% CI (Lower–upper)
WHR	0.938	0.881–0.967	34.022 (39, 39)	<0.001*	0.968	0.937–0.983
FFM (kg)	0.990	0.973–0.995	251.904 (39, 39)	<0.001*	0.995	0.986–0.998
FBM (kg)	0.989	0.971–0.995	235.900 (39, 39)	<0.001*	0.995	0.985–0.998
%FF	0.967	0.914–0.985	74.900 (39, 39)	<0.001*	0.983	0.955–0.992
%BF	0.967	0.914–0.985	74.900 (39, 39)	<0.001*	0.983	0.955–0.992
BMR (kcal/day)	0.993	0.987–0.996	286.159 (39, 39)	<0.001*	0.997	0.994–0.998

Abbreviations: %BF: Body fat percentage; %FF: Fat-free percentage; BIA: Bioelectrical impedance analysis; BMR: Basal metabolic rate; FBM: Fat body mass; FFM: Fat-free mass; ICC: Intraclass correlation coefficients; LoA: Limits of agreement; WHR: Waist-to-hip ratio.

measurement methods (TANITA BIA and LeanScreen) are presented in Figure 5. There were no significant differences in categorical classification between devices for either outcome ($p > 0.05$).

4. Discussion

This study compared an image-based mobile application (LeanScreen within PostureScreen Mobile) with a multi-frequency, segmental bioelectrical impedance analyzer (TANITA MC-180) under standardized pre-test conditions in sedentary young adults. Across all outcomes, paired differences were small and not statistically significant, with 95% CIs spanning zero; linear associations were very high (r = 0.943–0.995), and absolute agreement was excellent based on ICC (3,1), particularly for BMR and FFM. Bland–Altman analyses demonstrated small mean biases and acceptable LoA for all metrics. A small but statistically significant proportional bias was detected only for BMR. Collectively, these findings demonstrate that, under controlled conditions, the two methods yield closely aligned estimates suitable for population-level comparisons and screening, while caution is warranted for individual-level decisions near clinical cut points.

In applied community and clinical contexts where rapid, low-burden assessments are needed (e.g., primary care intake, workplace wellness screenings, collegiate health services), our findings suggest that a protocolized smartphone workflow can feasibly complement established field tools, such as multi-frequency BIA. The very high linear associations and excellent absolute agreement observed here, alongside small and clinically acceptable biases for %BF, %FF, FBM, FFM, WHR, and near-zero bias for BMR, support the use of LeanScreen for group-level surveillance, population risk stratification, and longitudinal monitoring under standardized procedures. In practice, this means that programs seeking scalability and cost-efficiency may deploy smartphone anthropometry when strict pre-analytic controls and assessor training are enforced. For individual-level decisions near clinical thresholds (e.g., %BF risk categories or WHR cut points), corroboration via repeat measures or a reference method remains advisable—especially given the small proportional bias noted for BMR at higher values.

Our results align with contemporary evaluations of mobile, image-based anthropometry that report high levels of inter-method agreement with field tools but heterogeneous agreement when benchmarked against laboratory criteria. In a large multidomain validation (n = 240), Neufeld et al.[21] observed consistently high convergent validity for LeanScreen across WHR and %BF relative to conventional methods (Gulick tape, BIA, skinfolds). In that work, LeanScreen showed high agreement for %BF versus BIA/skinfolds with LoA comparable to those between conventional methods themselves; LeanScreen exhibited high agreement for WHR but lower agreement for %BF, while indirect comparisons suggested potential agreement with DXA that merited direct testing. Similarly, MacDonald et al.[20] reported that LeanScreen, Department of Defense circumference equations, and handheld OMRON BIA all underestimated DXA-derived %BF on average and exhibited wide LoA, yet each method demonstrated very high repeatability (ICC > 0.99), illustrating that excellent precision can coexist with systematic bias that matters for interchangeability decisions. These themes are echoed by broader digital anthropometry and smartphone-

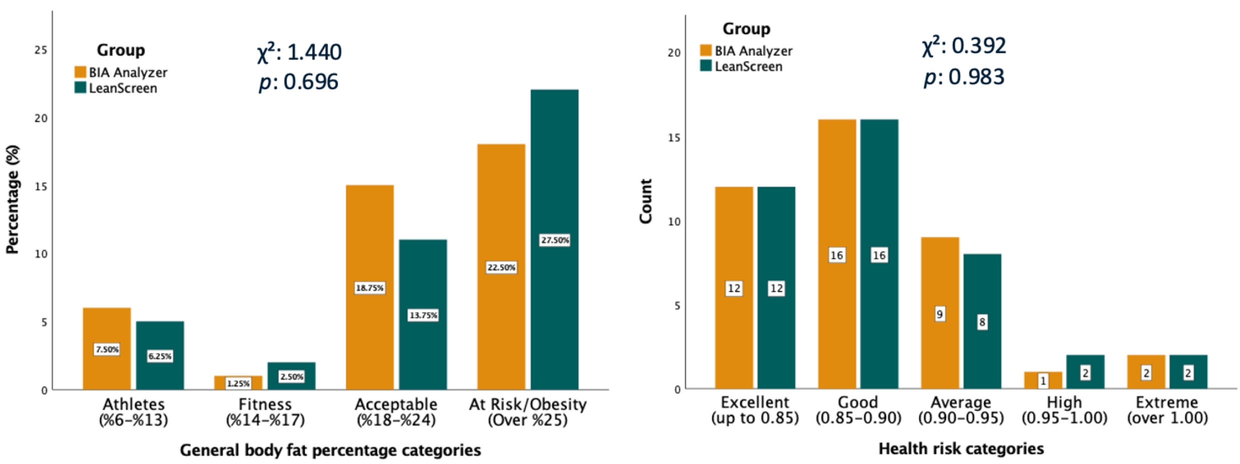

Figure 5. Distribution of participants across general body fat percentage and waist-to-hip ratio (WHR)-based health risk categories by methods

focused validations showing strong validity of two-dimensional/three-dimensional smartphone approaches for circumferences and reasonable agreement for adiposity versus DXA and field methods, with some studies noting performance that can match or outperform consumer BIA devices for girth estimates.[19,22,23] Classic anthropometric reviews further emphasize that agreement and validity are context-dependent and sensitive to protocolization and operator skill.[24]

Independent LeanScreen studies provide additional nuance. Marx et al.[15] reported a high correlation between LeanScreen %BF and air-displacement plethysmography (r = 0.82), but substantial individual-level variability (standard error of the estimate ≈ 5.1 % points) and systematic bias at distributional extremes. For WHR, agreement with manual measurement was high (r = 0.83; standard error of the estimate≈0.04).[6] In line with those findings, population and athlete-focused comparisons of BIA and skinfolds show that methods can yield similar mean %BF while exhibiting non-trivial LoA and method-specific deviations that are consequential for individual classification.[18,25] Recent smartphone photogrammetry work similarly demonstrates that two-dimensional image-based predictions of anthropometry and %BF can approach criterion methods under disciplined protocols, while still requiring careful interpretation against clinical thresholds due to variance structure and LoA considerations.[19] Taken together with our findings—very high r and ICC, small mean biases, and clinically acceptable LoA under a disciplined protocol—this literature supports a pragmatic conclusion: protocolized imaging and assessor training can mitigate variability and bias observed in less controlled settings, enabling group-level applications and screening, whereas individual-level classification at cut points should be corroborated.

Agreement patterns across outcomes in our study were largely favorable. For %BF, %FF, FBM, FFM, and WHR, mean biases were small and proportional bias tests were non-significant, supporting homoscedastic residuals and the use of fixed LoA across their observed ranges. Based on our predefined clinical acceptability thresholds, the 95% LoA for %BF (−4.836 to 2.714%) and WHR (−0.045 to 0.032) were within the ±5.0% and ±0.05 unit ranges, respectively, supporting the use of LeanScreen for screening and group-level risk stratification. For FFM, although the mean bias was small (0.765 kg), the upper LoA (3.468 kg) approached the ±3.5 kg limit, suggesting that while agreement is strong for population monitoring, individual-level mass estimates may show wider variance. The BMR LoA (−74.1 to 72.7 kcal/day) were well within the ±150 kcal/day threshold, further reinforcing the concordance between methods for metabolic estimates.[6,18–20] BMR also showed a very strong linear association (r = 0.995; p < 0.001) and near-zero mean bias; however, because BMR is derived from predictive algorithms rather than measured directly, this agreement reflects concordance between estimation models rather than physiological metabolic measurement. The narrow LoA may partly reflect shared input variables across methods. Notably, a small but significant proportional bias ($\beta 1$ = 0.068, p < 0.001) indicates slightly increasing differences at higher BMR values, suggesting that estimates at the upper range should be interpreted with caution and, where relevant, confirmed with repeated or standardized approaches. While ICC (3,1) values reinforced excellent absolute agreement, LoA provide complementary insight into the extent of agreement between methods; together, these findings indicate strong practical agreement at the group level under standardized conditions.

Two protocol features likely contributed to the high agreement observed: strict pre-test standardization (fasted morning assessments; controlled recent exercise, caffeine, alcohol; bladder voiding; ambient temperature control) and a disciplined imaging workflow (fixed distance/background, neutral posture, tight-fitting clothing, trained landmarking, and a median-rule across repeated captures). These align with established recommendations for minimizing pre-analytic variance in BIA and anthropometry and mirror best practices in recent digital anthropometry evaluations.[19,21] For field adoption, checklist-based protocol enforcement and periodic assessor retraining are advisable to sustain precision and limit edge-of-range biases noted in studies with less controlled procedures.[4,6,20,21]

Strengths include randomized measurement order, analyst blinding to method identity, rigorous pre-test controls, and comprehensive agreement profiling (paired tests, Pearson correlations with CIs, ICCs with explicit model specification, and Bland–Altman analyses with proportional bias testing). However, several limitations must be acknowledged. First, the study was restricted to a narrow demographic of young, sedentary adults (aged 18–30), which significantly limits the generalizability of these results to older, athletic, or clinical populations with different body habitus. Second, the absence of a laboratory criterion method—such as DXA—precludes the assessment of absolute measurement accuracy. Importantly, because no criterion reference method was included, these findings should be interpreted strictly as inter-method agreement between field tools and not as evidence of criterion validity. While a single trained operator performed all LeanScreen assessments to minimize procedural variability, the lack of quantified inter-rater and intra-rater reliability remains a limitation for multi-operator settings. Prior evidence indicates that LeanScreen can show systematic differences versus DXA with wide LoA under typical conditions, although high repeatability is often observed and WHR agreement with tape is consistently high.[19–21,25] These considerations contextualize our findings and reinforce the need for future criterion-based validation across varied populations and settings.

Future research should include criterion validation (e.g., DXA) of current LeanScreen implementations across diverse populations and settings, with explicit evaluation of variance structure and proportional bias where present (e.g., BMR). Direct DXA comparisons for smartphone-native three-dimensional and advanced two-dimensional workflows—without external sensors—are particularly salient given indications of strong agreement for circumferences and plausible %BF agreement when protocols are enforced.[19,21–23] Calibration strategies (e.g., regression-based adjustments) and repeat-measure protocols may further enhance individual-level decision accuracy near clinical cut points. As mobile photogrammetry evolves, rigorous protocolization combined with assessor training will likely determine whether smartphone anthropometry consistently matches established field methods for group-level monitoring and screening.[4,6,20,21]

5. Conclusion

Under standardized conditions in sedentary young adults, LeanScreen within PostureScreen Mobile showed high agreement with a multi-frequency segmental BIA device for %BF, %FF, FBM, FFM, WHR, and BMR. These findings support its potential utility as a practical, field-based method for group-level screening and monitoring. However, because this study assessed agreement between two field methods rather than criterion validity, the results should not be interpreted as evidence of absolute accuracy, and individual-level decisions near clinical thresholds should be supported by repeated or confirmatory assessment.

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Conflict of interest

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Author contributions

Conceptualization: All authors
Data curation: All authors
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Methodology: All authors
Writing–original draft: Mehmet Miçooğulları
Writing–review & editing: All authors

Ethics approval and consent to participate

The study was approved by the Scientific Research and Publication Ethics Committee of Cyprus International University (Approval number: -020-2754), and written informed consent was obtained from all participants.

Consent for publication

All participants provided written informed consent for their data to be published.

Availability of data

The data files used in this study are available from the corresponding author and can be made available to anyone upon reasonable request.

Further disclosure

AI tools were used only to edit language and paraphrase text to make it clearer and grammatically correct. The study design, data collection, analysis, and interpretation were completed by the authors.

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