Reliability and Validity of an iPad App and 3D Body Scanner to Measure Body Fat

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ABSTRACT
Background: Novel and innovative imaging methods to rapidly estimate body fat percentage (%BF) have made their way into fitness centers and clinicians’ offices. The purpose of this study was to evaluate the test-rest test-retest reliability of the %BF estimation from a two-dimensional iPad application (2D APP) and a three-dimensional body scanner (3D SCAN), and compare both imaging methods to the %BF estimation from air displacement plethysmography (Bod Pod). Methods: Seventy-nine adults (37 female, 42 male) varying widely in age (32.9 ± 12.4, 18-65 y) and body mass index (25.0 ± 4.9, 18.2-41.8 kg/m²) volunteered to be measured twice with the 3D SCAN and the 2D APP. A Bod Pod measurement served as the criterion. The 3 testing methods were all completed in the same session lasting about 1 hr. Results: Test-retest reliability was excellent for both the 2D APP (ICC = 0.993; 95% CI: 0.989 to 0.996) and the 3D SCAN (ICC = 0.993; 95% CI: 0.989 to 0.995) with the standard error of measurement < 1% BF for both methods. Although the 3 methods were highly correlated with each other (r = 0.927 to 0.932), the mean %BF estimations were significantly different (p < 0.001). The 2D APP (19.9 ± 8.2% BF) underestimated the Bod Pod value (21.9 ± 9.4% BF), and the 3D SCAN (24.0 ± 6.8% BF) overestimated it. Additionally, the standard error of estimate and total error exceeded 4% BF for both 2D APP and 3D SCAN, and both methods tended to overestimate lean participants and underestimate fat participants. Conclusions: Although highly reliable, neither the 2D APP nor 3D SCAN provided valid estimates of %BF compared to the Bod Pod. More research is needed to determine if the algorithms associated with the imaging devices can be modified to improve the accuracy of the %BF estimates.

METHODS
Subjects: 79 subjects (37 female, 42 males, 32.9 ± 12.4, 18-65 y; BMI 25.0 ± 4.9, 18.2-41.8 kg/m²) Measurement protocol: Each subject was measured twice by the 3D SCAN and 2D APP. A single measurement by the Bod Pod served as the criterion.

Equipment & Procedures: 1) Height and weight were measured. 2) Bod Pod Air Displacement Plethysmography (Figure 1) with measured thoracic gas volume was used to determine body density (Db). 3) Siri formula was used to convert Db to %BF. 4) Posture Co. LeanScreen 2D APP (See Figure 2) 5) Fit3D Body Scanner (See Figure 3)

Statistical Analyses: 1) Means ± SD were calculated for all variables. 2) Test-retest reliability of the app and scanner were assessed with intraclass correlation (ICC) and standard error of measurement (SEM). 3) 2D APP and 3D SCAN validity was assessed against the Bod Pod with repeated measures ANOVA, linear regression, and Bland-Altmann plots.

RESULTS
Descriptive characteristics of the sample are in Table 1. • Test-retest reliability for both 2D APP and 3D SCAN were identical (ICC= 0.993, SEM <1% BF). • All 3 methods highly correlated (r = 0.857 to 0.923). • Mean %BF estimations were significantly different (p = 0.001) with the disparity between methods greater for males than females (Figure 4-top right). 2D APP: 19.9 ± 8.2% BF, SEE >4% BF (Figure 4-top left) 3D SCAN: 24.0 ± 6.8% BF; SEE >4% BF (Figure 4-middle) Bod Pod: 21.9 ± 9.4% BF Systematic bias of error scores for both the app and scanner (Figure 4-bottom left and right)

Table 1. Mean ± SD of the study sample

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female (n = 37)</td>
<td>32.9 ± 13.1</td>
<td>166.0 ± 7.6</td>
<td>66.4 ± 13.4</td>
</tr>
<tr>
<td>Male (n = 42)</td>
<td>33.2 ± 11.9</td>
<td>179.3 ± 8.0</td>
<td>82.6 ± 13.2</td>
</tr>
<tr>
<td>Total (N = 79)</td>
<td>32.9 ± 12.4</td>
<td>173.0 ± 10.2</td>
<td>75.0 ± 15.5</td>
</tr>
</tbody>
</table>

SUMMARY and CONCLUSIONS
There was excellent test-retest reliability for both the 2D APP and the 3D SCAN. • All 3 methods were highly correlated; however, the mean %BF of the app and scanner were significantly different than the Bod Pod with the 2D APP underestimating and the 3D SCAN overestimating %BF. • Both methods had a systematic bias: overestimating lean participants and underestimate fat participants • The 2D APP and 3D SCAN are both very reliable, however, neither provided valid estimates of %BF compared to the Bod Pod. • More research is needed to test the algorithms associated with imaging devices to see if they can be modified to be more accurate.