In-Depth Notes

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COSMED Links
COSMED Homepage
http://www.cosmed.com
BOD POD Homepage
http://www.bodpod.com

ADP vs DXA
Learn more

Air Displacement Plethysmography (BOD POD)
Principles
• Estimates body composition from body density: \( D = \frac{\text{Mass}}{\text{Volume}} \)
• Mass – Measured on a scale on land
• Volume – Measured by air displacement plethysmography in the BOD POD chamber
• Computing Density to %BF – Established equations are used that incorporates measured densities of fat and fat-free mass. For example:
  \[
  \begin{align*}
  \text{density of fat} &= 0.9007 \text{ g} \cdot \text{cm}^{-3} \\
  \text{density of fat-free} &= 1.100 \text{ g} \cdot \text{cm}^{-3}
  \end{align*}
  \]
• The more dense a body is, the lower the percentage of body fat; the less dense a body is, the higher the body fat.
• Subject can breathe normally during the test.
• Thoracic Gas Volume (TGV) is accounted for instead of RV.

Research/Literature
Several studies have compared the BOD POD with Multi-compartment Models, and the average of the study means indicates that the BOD POD and Multi-Compartment Models agree within 2%BF. (1-5)
• “The mean bias between BOD POD and 4-compartment model was 0.5%. The regression between fat mass by the 4-compartment model and by BOD POD did not significantly deviated from the line of identity. BOD POD is the only technique that can accurately, precisely, and without bias estimate fat mass in 9- to 14-yr-old children.” (5)
• “The average of the study means indicates that the BOD POD and underwater weighing agree within 1%BF for adults and children.” (1)

COSMED Position
Percent fat results obtained form the BOD POD have not been shown to be statistically different than results from Multi-Compartment Models. Because the BOD POD and Underwater Weighing (gold standard technique) compare favorably with Multi-Compartment Model results, they also compare favorably with each other when proper protocol is followed.

Dual-Energy X-Ray Absorptiometry (DXA)
Principles
• Dual Energy X-Ray Absorptiometry or “DXA” (previously DEXA) is a means of measuring Bone Mineral Density (BMD).
• Two x-ray beams with differing energy levels are aimed at the patient’s bones. (Figure 1)
• X-rays attenuation (R) from going through a subject is measured. Attenuation is a function of:
  - Initial X-rays energy levels (instrument dependant)
  - Attenuation coefficients, R (tissues dependant)
  - Path length (subject thickness dependant)
• DXA uses a 2-compartment model (Figure 2). One half of the block tissue contains only soft tissue, the other half contains both soft tissue and bone. As the dual energy X-ray beams pass through the “Soft Tissue Pixel” (Fat Mass +
Lean Soft Tissue Mass), the mass of the two components of this pixel can be determined. As well, as the dual energy X-ray beams pass through the “Bone + Soft Tissue Pixel”, even in this case the mass of its two components can be determined.

- The DXA assumption is that the composition of the soft tissue over the bone is nearly the same as the composition of the soft tissue pixel containing no bone (in general not true). For example, if the total soft tissue mass of the soft tissue pixel is 10 grams, and it contains 2 gr. of fat, then the percent fat of the soft tissue pixel is 20%. In the total mass of soft tissue in the bone pixel is 5 gr, and the composition of the bone pixel soft tissue is hypothesized equal to the composition of adjacent soft tissue pixel, then the composition on the soft tissue in the bone pixel is also 20%. Therefore, the Fat Mass of the soft tissue in the bone pixel is 1 gr (20% of 5 gr).

- DXA is the most widely used and most thoroughly studied bone density measurement technology.

- The DXA technique involves a small amount of radiation, and is usually administered by a department qualified to use radiation for medical imaging.

- Subject thickness is assumed.

Research/Literature
- DXA can only estimate two compartments (5-8).
  - Bone compartment results are directly derived from actual measurements. On the other hand, soft tissue results are only in part derived from actual measurements.
  - In pixels containing only fat and non-bone fat free mass DXA can estimate both. In pixels containing bone, fat and non-bone fat free mass (50% of a DXA scan), DXA can estimate only bone and non-bone tissue. The amounts of fat and non-bone fat free mass are, therefore, “guesstimated” in these pixels. The amounts of fat and non-bone fat free mass are derived making empirically derived assumptions on the proportions of fat and non-bone fat free mass in various regions of the body.
  - **DXA is NOT a 3-compartment technology.** It estimates bone in every pixel and in 50% of pixels guesses the proportions of fat and non-bone fat free mass.

DXA Limits
Subject Types
- Subject size: Weight: 136 kg (159 kg in one new system); Height: 203 cm. Accuracy worsens at lower and upper size limits and is also negatively affected by body thickness.
- Limitations in younger children, lean people, the elderly, the disabled and the diseased.
- In the BOD POD measurement accuracy is unaffected by size (Weight: 250 kg; Height: 214 cm) and is performed on wide range of subject types including children, the elderly, the diseased and the disabled.

Radiation Exposure
By a certified DXA engineer
- Yearly costs between $7,000 and $12,000
- BOD POD has a little maintenance required, with yearly costs below $3,500

Maintenance Costs
- Required radiography license
- Skilled technician
- Signage to be used in the room and on the machine indicating that radiation (x-ray) is in use
- Cannot be used in pregnant women
- Cannot measure periodically for monitoring progresses
- Bod Pod doesn’t have the above limitations.
Accuracy

• Body thickness
  - "Body thickness may have a considerable influence on the estimates of soft tissue mass by DXA. The assessment of soft tissue in both thin and thick tissue regions appears to be subject to significant errors, leading to over- or under-estimates of %BF." (9-13)
  - Laforgia et al (24) compared DEXA (Lunar Prodigy) with a reference 4-compartment technique in obese men and women. Although there was a good degree of correlation, individual data was associated with large prediction errors and these errors were associated with tissue thickness indicating that DEXA was not able to accurately account for beam hardening in obese cohorts.
  - Van der Ploeg et al (25) compared DEXA (Hologic) with a reference 4-compartment technique in 152 healthy adults. They report that DEXA tends to progressively underestimate the % body fat for leaner individuals when compared to the reference technique. They attribute this bias to beam hardening errors introduced due to differences in anterior-posterior tissue thickness.

• Movements
  - Any movement during DXA whole body scan will lead to invalid test results. This is particularly important for the use of DXA in infant population in which compliance with a test protocol cannot be expected. (7)

• Variations in regional composition
  - “DXA has been suggested for the assessment of regional soft tissue composition. However, it accuracy has been questioned based on findings from several previous studies, suggesting significant underestimation of truncal fat.” (14-17)

Manufacturer

• “Contributing to the uncertainty regarding DXA validity is the variability among manufacturers of DXA instruments in the methods of calibration, data acquisition, and data analysis. Comparisons of whole-body soft tissue measurements between three commercial DXA systems showed that there were significant mean differences of %BF between DXA instruments of 3 – 6 %BF. These findings indicate that DXA systems from different manufacturers are not interchangeable in measurements of individual subjects.” (18, 19)
  - Differences present were sex-dependent, and were found to be greater at higher levels of fat free mass.
  - Bias was also greater in men with higher % body fat levels.
  • “Consistent discrepancies of 1.7 – 5.3 %BF in the estimates of %BF were shown between two identical DXA machines, indicating that even identical models of DXA from the same manufacturer may not provide comparable body composition estimates.” (20, 21)

• Large variability across technology: pencil beam & fan beam.
  - DEXA instruments have moved from utilizing pencil-beam to fan-beam x-rays that allows faster scanning times.
  - Plank et al (26) reports that within the two categories of beam geometry, differences in both hardware and software exists and results from one instrument are not necessarily the same as those from another.
  • “A larger fat mass (1.5 kg) and percent fat (2.0 %BF), and a lower lean mass (1.1 kg) was observed with DXA software version 3.6R compared with version 3.4, suggesting that significant differences exist in body composition measurements from different DXA software packages within the same manufacturer.” (22)

DXA vs other techniques

- “There are limited studies that compared DXA estimates of body composition with other techniques in athletes practicing a variety of sports. Lunar DXA was found significantly underestimated %BF by ~ 4 %fat respect to other three different methods (UWV, TBW AND TBK) in a sample of 12 endurance athletes.” (27)
In a recent study, the accuracy of DXA (Lunar Prodigy) was compared with 4-CM and found that the inconsistent bias of DXA varies according to sex, size, fatness and disease status, indicating that DXA is unreliable for patient case-control studies and for nutrition/health longitudinal studies. (23)

There was a poor agreement between %BF estimates from DXA and the criterion method of 4-compartment in infant population, with mean bias of 4.5 %BF. The study results did not support the use of DXA for body composition assessment in infants. (Ellis et al., unpublished data)

Conclusions
• Biases in DEXA’s accuracy when compared to reference techniques.
• No single correction factor for these biases as they are present in both leaner individuals as well as obese/large individuals where tissue thickness causes beam hardening errors.
• Inter-manufacturer differences observed can be attributed to the different algorithms used.
• Intra-device variations are present due to corrections factors used for beam modification in fan-beam mode DEXA.

COSMED Position
While DXA does a good job of measuring bone density, the measurement of body fat is not as well established according to the research. Percent fat readings measured by DXA have not been shown to agree favorably with the Multi-Compartment Model and, therefore, cannot be considered a gold standard.

<table>
<thead>
<tr>
<th>Measurement Method</th>
<th>BOD POD</th>
<th>DXA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Required</td>
<td>BOD POD Body Composition Tracking System from a single manufacturer.</td>
<td>DXA system from one of three manufacturers, each selling several systems using different configurations of hardware and software, each with different performance characteristics.</td>
</tr>
<tr>
<td>Time Required for Assessment</td>
<td>5 minutes</td>
<td>4-8 minutes (based on scanner speed)</td>
</tr>
<tr>
<td>Subject size limit</td>
<td>Weight: 250 kg; Height: 214 cm (measurement accuracy unaffected by size).</td>
<td>Weight: 136 kg (159 kg in one new system); Height: 203 cm. Accuracy worsens at lower and upper size limits and is also negatively affected by body thickness.</td>
</tr>
<tr>
<td>Required Subject Effort</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Subject Movement Sensitivity</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Subject Types</td>
<td>A wide range of subject types including children, the elderly, the diseased and the disabled.</td>
<td>Limitations in younger children, the elderly, the disabled and the diseased.</td>
</tr>
<tr>
<td>Intra-Device Reliability</td>
<td>Excellent, within ±1 %fat.</td>
<td>Excellent, within ±0.5 – 1.5 %fat.</td>
</tr>
<tr>
<td>Inter-Device Reliability</td>
<td>Excellent, within ±1 %fat.</td>
<td>Large variability across manufacturers, software versions and models, up to ±5 %fat.</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Excellent, within ±2 %fat of reference methods.</td>
<td>Accuracy affected by body thickness, software version, model, and manufacturer.</td>
</tr>
<tr>
<td>On-Going Maintenance</td>
<td>Little maintenance required, with yearly costs below $3,500.</td>
<td>Routine preventive maintenance twice annually by a certified DXA engineer, with yearly costs between $7,000 and $12,000.</td>
</tr>
<tr>
<td>Mobility</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Radiography license required</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Operating Space Required</td>
<td>5.9 m2</td>
<td>Based on model, 7.4 to 9.3 m2 in dedicated shielded room.</td>
</tr>
<tr>
<td>Radiation Exposure</td>
<td>None</td>
<td>Yes, all states require that signage be used in the room and on the machine indicating that radiation (x-ray) is in use. Cannot be used in pregnant women.</td>
</tr>
</tbody>
</table>
References
21. Tataranni PA, Pettitt DJ, Ravussin E. Dual energy X-ray absorptiometry: inter-


