Body composition: advantages and limits

Kopenhagen 2010

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MESSAGES

Body composition:

1. Integrates energy and protein “Intakes - Losses - Needs”
2. Is correlated with nutritional risks and clinical outcome
3. Is contributive to document the efficiency of nutrition support
4. Allows to tailor treatments to patient’s characteristics
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Body composition (BC) changes with Deltas (Intakes - Losses - Expenses) over Time.
Undernutrition

Women 30 yr, 60 kg / 173 cm, healthy. Pneumonia.

Temperature: J1 - 6 d.

INTAKES: {iv : G5% 1.5 L = 300 kcal, po: 540 kcal} x 6 d. 5'050 kcal

NEEDS: {60 kg x 25 kcal + 30% (3d) + 20% (2d)} x 6 d. 11'400 kcal

DEFICIT: 6'350 kcal

50 %: 3'200 / 4 = 800 g protein ~ 4.0 kg lean tissue

50 %: 3'200 / 7 = 460 g fat ~ 0.5 kg fat tissue

Water retention: 3.5 kg

Measured BW loss: 1 kg

Tissue loss: 4.5 kg
<table>
<thead>
<tr>
<th>Body Weight loss (%)</th>
<th>Protein loss * (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>11.2 - 16.8</td>
</tr>
<tr>
<td>10</td>
<td>15.2 - 20.8</td>
</tr>
<tr>
<td>15</td>
<td>19.2 - 24.8</td>
</tr>
<tr>
<td>20</td>
<td>23.0 - 29.0</td>
</tr>
<tr>
<td>25</td>
<td>26.8 - 33.2</td>
</tr>
</tbody>
</table>

Body composition measurements during wasting diseases


70 kg

- Minerals = 5%
- Water = 39.0 kg (55%)
- Protein = 10.5 kg (15%)
- Fat = 16.8 kg (24%)
- Glycogen = 0.6%

Fat-Free Mass (FFM)  
Lean Body Mass (LBM)

Fat Mass (FM)
Contribution of body composition to nutritional assessment at hospital admission in 995 patients:

A controlled population study

Body Mass Index (kg/m$^2$): MEN at Hospital Admission

Fat - Free Mass (kg):
MEN at Hospital Admission

controls, n = 619
patients, n = 471

Kyle U. et al.
Brit J Nutr 2001
86: 725-731
Methods to measure Body Composition
Atomic
C, H, O, N, P, K, ...

Molecular
Protein
Lipid
Water

Cellular
ICF
ECF
Cell mass

Tissue-systems
Blood
Bone
Adipose tissue
Skeletal
Muscle

Whole body

Complexity
Invasiveness
Cost

Anthropogammametry
Total Body $^{40}$Potassium

Pierson RN et al.
Am J Physiol 1984, 246: F234-F239
Skinfolds

Sites
- triceps, biceps, subscapular, suprailiac, abdominal, thigh
- Fat Mass

Limitations
- Equations
- References
- Interobserver variability
- ...
- Age
- Obesity

? FM underestimation
Dual X-ray Absorptiometry (DEXA)

Assessment of whole-body composition with DEXA
Slosman DO et al. Radiology 1992, 185: 593-8
Dual X-ray Absorptiometry (DXA)

Fat Mass  Lean Body Mass  Total Mass
Dual X-ray Absorptiometry (DEXA)

Limitations

• Calibration
  • CV: FFM 0.7, FM 1.9 %
  • Precision: FFM 1.2, FFM 2.0 %
• Equations: hydration, extreme BMIs
• Cost
• X-rays exposure

Slosman DO et al. Radiology 1992, 185: 593-598
Bioelectrical Impedance Analysis (BIA)
OHM's Law:

Impedance \( (Z) \) = \( (L^2) \times \text{Volume} \)
From the modelisation of the whole body, we can derived body composition parameters

\[
\text{Fat-free mass} = K_1 \times K_2 \times \frac{(W \times P)}{Z} \times L^2
\]

\(K_1, K_2 = \text{constants; } W = \text{specific electrical conductivity; } P = \text{density}\)
Resistance (R) = Opposition of a conductor to an alternating current

<-> total water & electrolytes
  (e.g. Traffic speed limit)

Reactance (Xc) = Opposition which a condenser offers to an alternating current

<-> cell membranes are mini condensers
<-> cell mass
  (e.g. Traffic lights)

Impedance (Z) = \( \sqrt{R^2 + Xc^2} \)
Signal frequencies

Frequency:
5 kHz
50 kHz
> 100 kHz
BIA - measured parameters

- Impedance $Z$ ($\Omega$)
- Resistance $R$ ($\Omega$)
- Reactance $Xc$ ($\Omega$)
- Phase angle

$Xc$
Single prediction equation for BIA in adults
(20-94 yrs, 17.0 - 33.8 kg/m²)

\[
FFM = -4.104 + \left(0.518 \times \text{height}^2 / \text{resistance}\right) + (0.231 \times \text{weight}) + (0.130 \times \text{reactance}) + (4.229 \times \text{sex (men = 1, women = 0)})
\]

\[
Y = 1.423 + 0.973 \times x, \quad r=0.986
\]

SEE = 1.72 kg, TE = 1.74 kg
Single prediction equation for BIA in adults (20-94 yrs, 17.0 - 33.8 kg/m²)

Y = 1.423 + 0.973 * x, r=0.986
SEE = 1.72 kg, TE = 1.74 kg
Body composition by BIA

Precision
EE 1.7 - 2.7 %

Reproducibility
CV 1.8 - 2.9 %

Lukaski H.C. Am J Clin Nutr 1985: 41, 810
Jackson AS. J Appl Physiol 1988: 64, 529
Pichard C. Nutrition 2000: 16, 245

r = 0.999, 1 subject within 1 week (n = 29)
r = 0.977, 1 month (n = 40)

CV 2.5%

Relevant for:
- Initial assessment
- Follow-up
Relevance of BC measurements
MESSAGES

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Lean body reserves & Length of Stay
Fat-Free Mass Index at hospital admission is associated with increased LOS: a prospective controlled population study (N = 996)  
Fat-Free Mass Index at hospital admission is associated with increased LOS: a prospective controlled population study (N = 996)

Fat-Free Mass Index at hospital admission is associated with increased LOS: a prospective controlled population study (N = 996) Pichard C et al. Am J Clin Nutr 79, 2004: 613-8
Fat-Free Mass Index at hospital admission is associated with increased LOS: a prospective controlled population study (N = 996)


Length of stay: low vs. normal FFMI

3 - 6 d: OR 3.8, CI 1.6 - 8.9

= 12 d: OR 5.6, CI 3.1-10.4

Fat-free mass index
LOS is increased if body protein reserves are decreased.
Respective contribution of FFM & FM in the LOS
Increased length of hospital stay in underweight and overweight patients at hospital admission:

A controlled population study (1707 patients/1707 volunteers)

BIA Reference Values

• Caucasian Population
• Age 15 - 98 yrs
• BMI 17.0 - 33.8 kg/m²
Percentiles Fat-free Mass in 5225 Volunteers
(15 - 98 years, 16.0 - 47.1 kg/m²)
Percentiles Percent Fat Mass in 5225 Volunteers
(15 - 98 years, 16.0 - 47.1 kg/m²)
Home care combining oral nutritional supplement, exercise and androgen substitution in malnourished patients with chronic respiratory failure: a prospective controlled multicenter trial

N Cano, C. Pison, et al.
Study design

126 malnourished patients, 8 centers

Education for health (n=62)

Education for health + ONS, rehabilitation, testosterone
For 90 days (n=60)

- Follow-up: 15 months (including 3-month treatment)
- days 0, 90: nutritional status, respiratory function,
- months 9, 15: exercise capacity & QoL
- survival assessment
Patient selection

Stable patients $\text{PaO}_2 < 8 \text{ kPa}$

$\text{BMI} < 21$ or $\text{BW loss} > 10\%$ within 6 months

or $< 63\% \text{ IBW (women)}, < 67\% \text{ IBW (men)}$ (Schols 95)

or $\text{FFM (BIA)} < 25 \text{ percentile}$
Home care combining oral nutritional supplement, exercise and androgen substitution in malnourished patients with chronic respiratory failure: a prospective controlled multicenter trial

N Cano et al.

Multivariate Cox analysis for SURVIVAL

- Intervention group  RR: 0.18 [0.04-0.79]  95% CI  p< 0.02
- + 1 kg FFM / m²  RR: 0.05 [0.002-0.07]  95% CI  p< 0.05
Body Composition provides Health Care Givers with:

Objective data

Initial assessment & Follow-up
Guidelines

ESPEN Guidelines On
Bioelectrical Impedance Analysis

Free at: www.espen.org
Review of principles & methods.  
Clin Nutr 2004 
23: 1226-1243

Utilisation in clinical practice. 
Clin Nutr 2004 
23: 1430-1453
Bioelectrical impedance analysis

SUMMARY

- Non-invasive, relatively inexpensive, no ionizing radiation, very limited inter-observer variations
- Works well: healthy subjects & chronic diseases (validated BIA equation for age, sex, race), if BMI 16 - 34 kg/m2
- Not recommended: abnormal hydration
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ACUTE COLITIS

Total body protein (% normal)

-4 0 4 20 40 weeks

Controls, n= 5

ACUTE COLITIS

Total body protein (% normal)

-4 0 4 20 40 weeks


TPN, at hospitalization, n = 5

Controls, n = 5

critical protein loss
Energy expenditure in anorexia nervosa: can FFM as measured by BIA predict energy expenditure in hospitalized patients?

Longitudinal follow-up of body composition in 82 hematopoietic stem cell transplant patients

Kyle UG et al. Bone Marrow Transplantation 2005; 35: 1171-1177
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Body Composition measurements in oncology
BIA phase angle in clinical practice: implications for prognosis in 52 advanced colorectal cancer


Survival stratified by phase angle categories

- 5.57 (dashed line)
- > 5.57 (solid line)

95% CI: 21.9, 58.8
P < 0.0001
Sarcopenic obesity is an independent predictor of survival (HR 4.2 [2.4 - 7.2], p<0.0001)

... links body composition, especially sarcopenic obesity, to clinical parameters (functional status, survival, and potentially, chemotherapy toxicity)
Sarcopenia as a determinant of chemotherapy toxicity and time to tumor progression in metastatic breast cancer patients receiving capecitabine treatment

<table>
<thead>
<tr>
<th></th>
<th>Sarcopenic (n = 14)</th>
<th>Non-sarcopenic (n = 41)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toxicity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>7 (50.0%)*</td>
<td>8 (20%)*</td>
<td>0.03</td>
</tr>
<tr>
<td>Absent</td>
<td>7 (50.0%)*</td>
<td>33 (80%)*</td>
<td></td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>65.6 (11.4)</td>
<td>71.4 (16.7)</td>
<td>0.23</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>24.6 (4.0)</td>
<td>27.8 (5.7)</td>
<td>0.06</td>
</tr>
<tr>
<td><strong>BSA (m²)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.7 (0.2)</td>
<td>1.8 (0.2)</td>
<td>0.42</td>
</tr>
<tr>
<td><strong>Lumbar skeletal muscle index (cm²/m²)</strong></td>
<td>35.0 (3.3)</td>
<td>47.4 (5.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Whole body lean mass (kg)</strong></td>
<td>34.0 (3.3)</td>
<td>42.5 (5.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Mg capecitabine / kg FFM</strong></td>
<td>104.2 (16.1)</td>
<td>86.9 (13.7)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>
A practical and precise approach to quantification of body composition in cancer patients using computed tomography images acquired during routine care


Aim: to evaluate clinically accessible methods to achieve practical and precise measures of body composition in cancer patients.

DXA-FM and -FFM performed in 50 cancer patients and compared with BIA, DXA, CT-scan available in patients' medical records.

BIA overestimated or underestimated FFM vs. DXA (up to 9.3 kg difference). Significant FFM changes over time detected with DXA in a subset of 21 patients (+2.2 +/- 3.2%/100 days, p = 0.003) was beyond the limits of detection of BIA.

Regional analysis of FM and FFM at the 3rd lumbar vertebra with either DXA or CT predicted FM and FFM (r = 0.86-0.94; p < 0.001).

CT scan provided detail on specific muscles, adipose tissues and organs, not provided by DXA or BIA. CT presents great practical significance due to the prevalence of these images in patient diagnosis and follow-up.
Sarcopenia significant predictor of chemotherapy toxicity: Fluoropyrimidines

Body composition as an independent determinant of 5-fluorouracil-based chemotherapy toxicity

Sarcopenia as a determinant of chemotherapy toxicity and time to tumor progression in metastatic breast cancer patients receiving capecitabine treatment
Sarcopenia

- Physical disability
- Falls
- Extended hospitalization
- Infectious, non-infectious complications
- Mortality in cancer patients
- *Treatment toxicity in cancer patients*

*The emerging role of computerized tomography in assessing cancer cachexia. Prado CM, Birdsell LA, Baracos VE. Curr Opin Support Palliat Care 2009 Aug 6*
Chemotherapy & BC

- « Era of sarcopenic obesity »

- Optimal dosage of chemotherapy agents
- Better prevention of side effects
- Improved cost-efficiency
Simplification of Body Composition
Complexity

Gain of knowledge

Science

simplification

Clinical Practice
## Body Composition

**Interpretation:**

**Contribution of fat-free mass index & body fat mass index**

Kyle UG, et al.  
*Nutrition* 2003, 19: 597-604

<table>
<thead>
<tr>
<th>BMI</th>
<th>FFMI</th>
<th>BFMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg/m²</td>
<td>kg/m²</td>
<td>kg/m²</td>
</tr>
<tr>
<td><strong>MEN</strong> n=2982 (18-98)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.0</td>
<td>21.7</td>
<td>8.3</td>
</tr>
<tr>
<td>27.8</td>
<td>20.9</td>
<td>6.9</td>
</tr>
<tr>
<td>25.0</td>
<td>19.8</td>
<td>5.2</td>
</tr>
<tr>
<td>20.0</td>
<td>17.5</td>
<td>2.5</td>
</tr>
<tr>
<td>18.5</td>
<td>16.7</td>
<td>1.8</td>
</tr>
<tr>
<td><strong>WOMEN</strong> n=2647 (18-98)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.0</td>
<td>18.2</td>
<td>11.8</td>
</tr>
<tr>
<td>27.3</td>
<td>17.5</td>
<td>9.8</td>
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<tr>
<td>25.0</td>
<td>16.8</td>
<td>8.2</td>
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<tr>
<td>20.0</td>
<td>15.1</td>
<td>4.9</td>
</tr>
<tr>
<td>18.5</td>
<td>14.6</td>
<td>3.9</td>
</tr>
</tbody>
</table>
Body Composition measurements:
Interpretation finally made easy for clinical use

“...The use of percentiles and height-normalized FFM and FM permit the classification of patients... and risk evaluation”
Body composition in the future...


Kindly provided by Pr A Laviano
Body composition machine in 20...

**Compartment:**
- Lean mass: P90
- Fat mass: P10

**Molecular:**
- CrP: P90

**Residues:**
- Explosive agents
- "Martini on the rock"

**Functions:**
- Muscular: ATP, P97
- Sexual: P out of range
Conclusion
Why is malnutrition underrecognized?
Published papers about BIA

1972 : 7
1982 : 11
1992 : 103
1996 : 236
2000 : 351
2004 : 880
2008 : 1051
2009 (August) : 543
Body Composition « added value »:

- Measurable facts
  - Objective initial assessment
  - Follow-up, $/ kg FFM
- Optimal treatment
- Printed report
- Credibility
- Institutional visibility
<table>
<thead>
<tr>
<th>Ursula Kyle</th>
<th>Maike Kruseman</th>
<th>Laurence Paniagua</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yves Dupertuis</td>
<td>Ariane Paoloni</td>
<td>Nicole Pittet-Weimer</td>
</tr>
<tr>
<td>Véronique Karsegard</td>
<td>Patrizia Nardo</td>
<td>Osman Ratib</td>
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<tr>
<td>Marina Schutz</td>
<td>Comasia Raguso</td>
<td>Daniel Slosman</td>
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<tr>
<td>Gaëlle Benais-Pont</td>
<td>Lynne Thadikkaran</td>
<td>Raymond Miralbell</td>
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<tr>
<td>Ghita Benzakour</td>
<td>Ronan Thibault</td>
<td>Abdelkarim Allal</td>
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<tr>
<td>Linda Belabed</td>
<td>Philippe Jolliet</td>
<td>Philippe Nouet</td>
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<tr>
<td>Fang Cai</td>
<td>Marc Fathy</td>
<td>Bruno Robert</td>
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<tr>
<td>Patrice Darmon</td>
<td>Franz Buchegger</td>
<td>Dominique Wohlwend</td>
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<tr>
<td>Laurence Genton</td>
<td>Didier Hans</td>
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<td>Virginie Granci</td>
<td>Maryse Jaunin</td>
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<tr>
<td>Nathalie Jacquelin-Ravel</td>
<td>Noury Mensi</td>
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<tr>
<td>Michel Kossovsky</td>
<td>Sophie Namy</td>
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