Estimating nutritional requirements in clinical practice
PENG guidelines (2011)

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NICE guidelines (2006)

- Prescriptions for nutrition support should take account of:
  - Energy, protein, fluid, electrolyte, mineral, vitamin, trace element and fibre needs
  - Activity levels
  - Underlying clinical condition
  - Prognosis
  - GI tolerance, potential metabolic instability and risk of re-feeding problems
  - Likely duration of nutrition support

- Level of evidence – D (Good Practice Point)
Total Energy Expenditure

- BMR
- DIT
- Activity
Conditions essential for measuring BMR

• Post-absorptive (12 hour fast)
• Lying still at physical and mental rest
• Thermo-neutral environment (27 – 29°C)
• No tea/coffee/nicotine/alcohol in previous 12 hours
• No heavy physical activity previous day
• Gases must be calibrated
• Establish steady-state (~ 30 minutes)

* If any of the above conditions are not met = Resting Energy Expenditure (REE)
Basal Metabolic Rate

Equations for estimating BMR in health

• Harris Benedict Equations (1919)

• Schofield Equations (1985)

• Oxford equations (2005)
Harris Benedict (1919)

- Data collected between 1909 and 1917

- Study population
  - **Male** n = 136
    - Age 27 (± 9) years
    - BMI 21.4 (± 2.8) kg/m²
  - **Female** n = 103
    - Age 31 (± 14) years
    - BMI 21.5 (± 4.1) kg/m²

- Tends to overestimate in healthy individuals ([Daly 1985, Owen 1986, Owen 1987])
Schofield (1985)

- Developed in the 1980’s for WHO/FAO expert consultation

- Database of 114 studies; 7173 subjects
  - North European and American
  - Italian
  - Asians
  - mixed group

- Studies carried out 1914→1980 (including HB data)

- SE (Schofield, 1985):
  - 153-164kcal/d ♂
  - 108-119kcal/d ▃
Henry (2005)

- Database of 10,552 BMR values (included studies from 1914 to 2005)
- More rigorous examination of methodology and only included papers where measurement conditions met criteria for BMR
- Included greater number of elderly subjects (534 ♂: 340 ♀)
- Developed equations using weight alone or using height and weight
- Excluded
  - Italian high altitude data
  - excluded malnourished/ sick
  - screened data and excluded outliers

- Schofield tends to overestimate due mainly to the Italian data:
  - 47% of Schofield database
  - higher BMR/kg than any other group

- Historically, measurement of BMR was used to diagnose thyroid disorders whereas recent data derived from studies designed to measure BMR

- Database contains a more representative sample of the world population
### Schofield (1985) vs. Henry (2005)

<table>
<thead>
<tr>
<th>Age</th>
<th>Weight (kg)</th>
<th>BMR (Henry) kcal/day</th>
<th>BMR (Schofield) kcal/day</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-30 male</td>
<td>75</td>
<td>1738</td>
<td>1819</td>
<td>+ 4.5</td>
</tr>
<tr>
<td>18-30 female</td>
<td>60</td>
<td>1335</td>
<td>1374</td>
<td>+ 2.8</td>
</tr>
<tr>
<td>30-60 male</td>
<td>75</td>
<td>1648</td>
<td>1740</td>
<td>+ 5.3</td>
</tr>
<tr>
<td>30-60 female</td>
<td>60</td>
<td>1272</td>
<td>1346</td>
<td>+ 5.5</td>
</tr>
<tr>
<td>60+ male</td>
<td>75</td>
<td>1517</td>
<td>1495</td>
<td>- 1.5</td>
</tr>
<tr>
<td>60+ female</td>
<td>60</td>
<td>1172</td>
<td>1220</td>
<td>+ 3.9</td>
</tr>
</tbody>
</table>
SACN (2011) report on Energy Requirements

- Recommended use of Henry’s BMR equations for healthy populations (and individuals?)

- No specific recommendations for energy requirements in illness and injury

- SACN used additional data* and found better predictive accuracy using Height + Weight (than using weight alone)

- PENG recommends:
  - Henry (2005) equations for predicting BMR
  - Weight alone and Height + Weight equations
    - in the clinical setting height can be difficult to obtain
    - use of surrogates may introduce sufficient error to negate the advantage of including height

*US DRI DLW database
Measured Energy Expenditure

Health

Disease

BMR

DIT

Activity

REE

TEE

BMR + Stress

Activity

DIT
PENG guidelines (2011)

1. Estimate BMR using Henry (2005)
2. Adjust for metabolic stress
3. Adjust for activity and DIT
4. Add/subtract for weight change?
Criticisms of the PENG guidelines
BMR and stress factors

• Inappropriate use of stress factors:
  – most were derived from studies using Harris Benedict Equations
  – use with other equations leads to inaccuracies
  – i.e. 20% of BMR (HB) $\neq$ 20% of BMR (Schofield)

• Use of static variables (weight)
  – weight often inaccurate
  – does not reflect changes in body’s physiology such as respiratory rate or temperature

(Taylor, 2007)
Criticisms of the PENG Guidelines

ICU

• Are the equations relevant to your clinical group? (IJEE burns, trauma, post surgical)

• Respiratory rate, temp etc can be taken into consideration when adding a stress factor

• Benefits of a complicated formula versus a more simple approach

• 25kcal/kg might be most accurate (Reid, 2007)

• Aims of nutritional support in critically ill patients
  • meeting measured energy requirements?
  • preservation of lean body mass vs. risks of overfeeding?
Metabolic state

- Catabolic
- Anabolic

Graph showing time (hours) vs. metabolic state with labeled points:
- Injury
- Necrobiosis and death
- Catabolic peak
- Anabolic state
Metabolic state

- ↑ CRP and ↓ albumin
- ↑ White cell count
- ↑ blood urea and glucose levels
- ↑ temperature
- ↑ Heart rate
- Poor appetite
- Oedema
- Fatigue

How do indicators of metabolic state translate to “stress factors”?  

In the presence of an inflammatory response it is very difficult to achieve weight gain and other clinical benefits with nutritional support alone.
Stress (fudge) factors

- Limited by the published data (ICU predominates)

- Advances in medical interventions and patient care
  - Wound care/ antipyretics/ ventilation and sedation
  - Hyperalimentation
  - Retrospective data
  - Include DIT/ movement

- Derived from HB not Schofield Equations

- Tend to overestimate for current practice .:. need to be used with caution, especially in ventilated patients in ICU
Physical activity (Hospital)

• Illness and injury are usually accompanied by a decrease in physical activity.

• Physical activity is unlikely to exceed ~ 20% total energy expenditure in hospitalised patients.

• In some hospitalised patients however, physical activity may be increased due to:
  – Abnormal neuro-muscular function e.g. brain injury, Parkinson’s disease, cerebral palsy, motor neurone disease.
  – Prolonged and active physical therapy.
  – The increased effort involved in moving injured or painful limbs.
Physical activity (Community)

- Energy expended in physical activity affected by intensity and duration of the activity and also BMI and physical fitness of the individual.

- Free living individuals in the community are likely to be more active than hospital patients although some patients e.g. on home ANS, may have similar activity levels to healthy individuals.

- Housebound or nursing home patients will have similar activity levels to hospital patients.

- For patients considered to have activity levels nearer to healthy individuals, a PAL should be added rather than a combined factor for physical activity and diet induced thermogenesis (DIT).

- PALs include a factor for DIT and assumes normal neuro-muscular function.
Diet-induced thermogenesis

- Main determinant of DIT is the energy content of the meal, followed by the protein content.

- In healthy subjects with a mixed diet, DIT represents about 10% of the total amount of energy ingested over 24 hours.

- Lack of evidence on how DIT might vary with feeding route (enteral or parenteral) or clinical condition (e.g. malabsorption states).

- Continuous infusion of nutrients does not significantly increase resting energy expenditure over fasting level.

- Feed given as a bolus has a similar effect to a meal resulting in an increase in BMR of 8 – 10%.
Disease-specific equations

- Use a combination of static measurements and physiological parameters e.g. body surface area, age, temperature, respiratory rate and tidal volume (Swinamer et al. 1990)

- No guidelines on how frequently requirements should be reviewed and amended in the light of physiological changes

- No evidence that amending feeding regimens in response to changes in these variables results in better outcomes (yet)

- Open to similar criticisms regarding validity and applicability to individuals
Generic equations

- Based on energy value per kg body weight (kcal/kg) e.g. ESPEN (2009), NICE (2006), ASPEN (2002)
- Different cut-offs recommended for similar disease states
- Originally derived for ICU patients yet no references to original work explaining how values were derived
- No validation studies
- Do not account for changes in energy expenditure with age, gender or metabolic state
- Unclear for people who are obese or underweight whether requirements should be calculated using actual or ideal body weight
- No defined criteria for when to use 20, 25, 30 or 35 kcal/kg/day
## Generic guidelines

<table>
<thead>
<tr>
<th>Energy</th>
<th>Protein</th>
<th>♀; 75 years; 70kg; hospitalised with acute exacerbation of COPD (Day 3; to be discharged today)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMR + stress + activity/DIT(^1)</td>
<td>1.0 - 2.0 g protein/kg/day(^1)</td>
<td>1,750 kcal/day 70 – 140 g protein/day (Day 3 :: no stress factor added)</td>
</tr>
<tr>
<td>25 - 35 kcal/kg/day(^2)</td>
<td>0.8 - 1.5 g protein/kg/day(^2)</td>
<td>1,750 – 2,450 kcal/day 56 – 105 g protein/day</td>
</tr>
<tr>
<td>20 - 35 kcal/kg/day(^3)</td>
<td>0.8 - 2.0 g protein/kg/day(^3)</td>
<td>1,200 – 2,450 kcal/day 56 – 140 g protein/day</td>
</tr>
</tbody>
</table>

\(^1\) PENG guidelines (2011)

\(^2\) NICE guidelines (2006) for patients who are not severely ill or injured, nor at risk of re-feeding syndrome

\(^3\) ASPEN guidelines (2002) for unstressed adult patients with adequate organ function
Micronutrients in health

• Recommended intakes (DoH, 1991) are levels required to prevent deficiency in healthy populations.

• Applicability to ill or injured individuals?

• RDA – the average amount of nutrient that should be consumed per head in a group of people.

• Requirements differ in health due to differences in:
  – Diet
  – Metabolism
  – Genetics?
Micronutrients in disease

• Requirements likely to be increased due to (Shenkin, 2000):
  – Inadequate (or imbalanced) intake
  – ↑ metabolic rate and ↑ number of biochemical reactions
  – Adverse effects of treatment
  – ↑ oxidative stress
  – Losses from fistulae, burns, diarrhoea, dialysis

• Symptoms of micronutrient deficiency non-specific and insidious e.g. muscle weakness, anorexia, depression

• Sub-optimal levels may impair function before signs of deficiency become evident

∴ Micronutrient deficiencies may go undiagnosed in the presence of illness or injury
Micronutrient requirements

- Considerations in illness and injury
  - Aims of treatment
  - Feeding route
  - Metabolic state
  - Length of feeding
  - Likely deficiencies
  - Monitoring

- Evidence from RCTs?
Recommendations

• Recommendations are made for specific nutrients based on route of administration (ASPen, 2002)

• Provision of adequate electrolytes, minerals, micronutrients (allowing for any pre-existing deficits, excessive losses or increased demands) and fibre if appropriate (nicE, 2006)

• Recommendations are made for specific nutrients based on route of administration (PENG, 2011)
Brain, liver, kidney, heart, and lung
Skeletal muscle
Internal organs
Fat + other tissues
Skeletal muscle
Brain, liver, kidney, heart, and lung
Fat mass increases
45kg (BMI 14 kg/m²)
70kg (BMI 22 kg/m²)
100kg (BMI 31 kg/m²)
Internal organs
Fat + other tissues
Skeletal muscle
Obesity

- Metabolic response to injury has not been specifically investigated in obese individuals although the effects are thought to be similar to those observed in non-obese.

- Although obese patients have large fat and lean body mass stores, they are likely to develop malnutrition in response to metabolic stress, particularly if their nutritional status was poor before injury or illness.

- The determination of energy requirements is particularly problematic in obese patients (Horgan & Stubbs, 2003; Frankenfield et al., 2005). Some have recommended indirect calorimetry (ASPEN, 2002).

- PENG recommendations remain unchanged.
Which to use?

• Actual body weight (ABW)

• Ideal body weight (IBW)

• Adjusted body weight e.g. 25 % (ABW x 0.25 + IBW)

• Remains contentious as there is little evidence to support any particular method (Ireton-Jones, 2005; Krenitsky, 2005)
Re-feeding syndrome

• Key to successful management is prevention

• Early identification of at risk individuals

• Monitoring during re-feeding

• Appropriate feeding regimen
  – cautious re-introduction of energy
  – correction of biochemical abnormalities

• Lack of randomized controlled trials re correction of electrolyte abnormalities before or during introduction of energy and protein
  (Khan et al., 2011)
Very low requirements

• Small proportion of patients on long term ANS may have much lower energy requirements than predicted (BANS, 2009; Hubbard et al., 2010)

• Predominantly immobile patients with neuro-developmental disabilities or severe damage to the CNS receiving long term tube feeding in institutionalized settings (Bandini et al., 1995; Dickerson et al., 2002; Dickerson et al., 2003; Leone et al., 2010)

• REE measurements for each study population were in the range of 800 – 950 kcal/day, however when expressed as kcal/kg body weight, results for individuals were very variable, from as low as 12.6 kcal/kg/d up to 34 kcal/kg/d

• Do low requirements for energy indicate low requirements for other nutrients?
Implications for clinical practice

• The evidence-base for all prediction methods currently in use is poor

• The determination of nutritional requirements therefore requires a significant element of clinical judgment

• Irrespective of the method used, requirement calculations should be interpreted with care and used as a starting point only

• Establish realistic goals of treatment at the outset and review regularly
Implications for clinical practice

- Assess metabolic state at baseline and regularly throughout treatment.

- Recognise recovery:
  - Oedema resolving
  - Hyperglycaemia resolving and ↓ insulin requirements
  - ↓ CRP, ↑ pre-albumin
  - Patient mobilising and appetite returning

- Consider physical activity level and DIT.

- Practitioners should regularly review the patient and reassess requirements to take account of any significant changes in clinical condition, nutritional status, activity level and goals of treatment.

- N.B. 500, 1000 and 1500ml ready-to-hang bags.
Implications for research

• The nutritional requirements for a number of clinical conditions have yet to be established

• The requirements for a number of nutrients in illness and injury have yet to be established
  – How do different levels of feeding affect patient-centred outcomes in ITU (and other healthcare settings)?
  – What are the effects of chronic inflammation and cachexia on TEE in community patients on long-term nutrition support e.g. COPD and cancer?

• Practitioners should regularly critically review the literature on nutritional requirements in their specialist area
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