Protein and Amino Acids in Sports Nutrition

Advanced Level
Module II

Evaluating Protein Quality
Determining Protein Recommendations for Athletes
Evaluating Protein Quality
Protein Quality

- **Complete protein**
  - Contains all the essential AAs in amounts that meet what is required by humans to prevent deficiency
    - Animal proteins (except gelatin)
    - Dairy proteins
    - Soy protein

- **Incomplete protein**
  - Too low in one or more of the essential AAs to support human growth and maintenance
    - Cannot serve as a sole source of protein in the diet without deficiency developing
    - Limiting AA (LAA) is the essential AA present in the lowest quantity in the food
    - Most plant proteins are incomplete proteins (except soy)

Protein Quality: Complementary Proteins

- Complementary proteins
  - Combinations of incomplete proteins that, when added together, result in a complete protein (eg, beans and rice)
    - Legumes: ↓ methionine, ↑ lysine
    - Grains: ↑ methionine, ↓ lysine
  - Combining a complete protein with an incomplete protein is also considered complementary
    - Exceptions are milk and legumes
      - Although milk has a greater amount of sulfur-containing AAs (ie, methionine and cysteine) per gram compared with legumes, not enough sulfur-containing AAs are present for an ideal AA profile when the 2 foods are consumed together

Complementary proteins

- Combining complementary proteins at each meal for vegetarians is not necessary
  - What matters is the total intake of complementary proteins over the course of a day
  - May be more crucial for individuals wishing to optimize meal-stimulated protein synthesis in muscle
    - Requires full complement of essential AAs as well as relatively high leucine content to maximally stimulate mTOR pathway
Evaluation of Protein Quality

- Two important aspects of evaluating protein quality
  - Amino acid profile (compared to “ideal” pattern)
  - Digestibility of the protein
    - Plant proteins are often contained within cell walls that are resistant to human digestion, limiting digestibility
    - Some legumes have antinutritional factors such as trypsin that also limit digestibility

<table>
<thead>
<tr>
<th>Source</th>
<th>True Digestibility, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg</td>
<td>97</td>
</tr>
<tr>
<td>Milk / cheese</td>
<td>95</td>
</tr>
<tr>
<td>Meat / fish</td>
<td>94</td>
</tr>
<tr>
<td>Soy flour</td>
<td>86</td>
</tr>
<tr>
<td>Whole wheat</td>
<td>85</td>
</tr>
<tr>
<td>Corn, whole</td>
<td>87</td>
</tr>
<tr>
<td>Oatmeal</td>
<td>86</td>
</tr>
<tr>
<td>Beans</td>
<td>78</td>
</tr>
<tr>
<td>American mixed diet</td>
<td>96</td>
</tr>
</tbody>
</table>

Protein Digestibility Corrected Amino Acid Score

- Protein digestibility corrected amino acid score (PDCAAS) is the current “gold” standard by FAO/WHO for assessing protein quality

\[
\text{PDCAAS} (\%) = \frac{\text{mg of limiting AA in 1 g test protein}}{\text{mg of same AA in 1 g of reference or “ideal” protein}}
\]

\[
D_F = \frac{(N_I - N_{FA})}{N_I}
\]

- Complete proteins can often have PDCAAS values of \( \geq 1.00 \)
- Standard practice is to truncate values exceeding 1.00 to simply 1.00

Abbreviations: FAO, Food and agriculture Organization; WHO, world Health Organization.
Schaafsma G. *J Nutr*. 2000;130(7):1865S-1867S.
## Example of PDCAAS Calculation

- Identify the limiting AA (LAA) in a protein source

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Whole Wheat Flour</th>
<th>FNB/IOM Standard</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histidine</td>
<td>22</td>
<td>18</td>
<td>1.22</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>40</td>
<td>25</td>
<td>1.6</td>
</tr>
<tr>
<td>Leucine</td>
<td>63</td>
<td>55</td>
<td>1.15</td>
</tr>
<tr>
<td>Lysine</td>
<td>26</td>
<td>51</td>
<td>0.51 (LAA)</td>
</tr>
<tr>
<td>Met + Cys</td>
<td>35</td>
<td>25</td>
<td>1.4</td>
</tr>
<tr>
<td>Phe + Tyr</td>
<td>81</td>
<td>47</td>
<td>1.72</td>
</tr>
<tr>
<td>Threonine</td>
<td>27</td>
<td>27</td>
<td>1.00</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>11</td>
<td>7</td>
<td>1.57</td>
</tr>
<tr>
<td>Valine</td>
<td>43</td>
<td>32</td>
<td>1.34</td>
</tr>
</tbody>
</table>

FNB, Food and Nutrition Board; IOM, Institute of Medicine.

Example of PDCAAS Calculation (Cont’d)

- PDCAAS of whole wheat = ratio for lysine (LAA) x digestibility
  - $0.51 \times 0.85 = 0.433$
  - Therefore, whole wheat is an incomplete protein and not suitable as a sole protein source in the diet

- For the percent daily value (% DV) of protein on food labels, the total protein content is first corrected using PDCAAS before a % DV value is listed
  - % DV = amount of nutrient in 1 serving (corrected) / DV for nutrient (50 g for protein in adults)

# PDCAAS of Protein Sources

<table>
<thead>
<tr>
<th>Protein Source</th>
<th>PDCAAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg</td>
<td>1.0</td>
</tr>
<tr>
<td>Milk</td>
<td>1.0</td>
</tr>
<tr>
<td>Beef</td>
<td>0.92</td>
</tr>
<tr>
<td>Soy protein</td>
<td>1.0</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.42</td>
</tr>
<tr>
<td>Whey protein</td>
<td>1.0</td>
</tr>
<tr>
<td>Casein</td>
<td>1.0</td>
</tr>
<tr>
<td>Peanuts</td>
<td>0.52</td>
</tr>
<tr>
<td>Black beans</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Schaafsma G. *J Nutr.* 2000;130(7):1865S-1867S.
Limitations of PDCAAS for Athletes

- Values above 1.0 are truncated
  - FAO/WHO definition is concerned only with meeting maintenance requirements
  - Does not account for protein intake or outcomes beyond maintenance requirements

- Does not account for relative AA differences among proteins with PDCAAS of 1.0
  - For example, soy isolate and whey isolate both have PDCAAS of 1.0, yet soy has 50% the threonine (an essential AA) of whey

- Ileal digestibility may vary among protein sources
  - AAs not absorbed by the distal intestine can subsequently be consumed by bacteria in the colon; therefore, fecal digestibility may not accurately reflect AA uptake from a protein source

FAO, Food and agriculture Organization; WHO, world Health Organization.
Protein Efficiency Ratio for Protein Quality

- Protein efficiency ratio (PER)
  - Assesses weight gain of growing animals on a particular protein source (e.g., rats, chicks)
    - Diet containing about 10% protein is fed for ~10 days
  - PER = weight gain (g)/protein consumed (g)
  - Not suitable as an index for human consumption
    - Human metabolism often varies substantially from animals
Nitrogen Balance for Protein Quality

- Nitrogen intake (from protein) minus nitrogen excretion equals nitrogen balance
  - Nitrogen balance: Nitrogen intake = nitrogen losses
  - Negative nitrogen status: Nitrogen intake < nitrogen losses
  - Positive nitrogen status: Nitrogen intake > nitrogen losses

- Nitrogen balance is a whole body concept
  - Does not give specific information on flux of protein/AA pool within individual tissues/organs

- FAO/WHO has set protein requirements based on nitrogen balance experiments

Nitrogen Balance in Clinical Studies

- Typically, healthy individuals were on 2 diets
  - Diet with protein of interest versus protein-free diet
  - Test diets were above, below, and near predicted protein requirement
  - Nitrogen losses in feces and urine measured
    - Other losses (e.g., skin) often estimated

Calculating Nitrogen Balance

- General nitrogen-status formula

\[ \text{Nitrogen status} = N_I - [(U - U_E) + (F - F_E) + S] \]

- Where
  - \( N_I \) is nitrogen intake
  - \( U \) and \( F \) are urinary and fecal nitrogen losses, respectively
  - \( U_E \) and \( F_E \) are endogenous urinary and fecal nitrogen losses during a nitrogen-free diet
  - \( S \) is nitrogen loss from sloughed skin cells, sweat, bodily secretions

Calculating Nitrogen Balance (Cont’d)

- Clinical nitrogen-status formula

Nitrogen status = \((g \text{ protein intake}/6.25) – (\text{UUN} + 4)\)

- Where
  - Nitrogen intake is estimated; divide protein intake by 6.25
  - UUN is 24-hour urinary urea nitrogen loss
    - Added to 4, which estimates other nitrogenous urea compounds and non-urea nitrogen losses

- Example

  - Individual with protein intake of 85 g, UUN of 9.9 mg/mL, and 24-hour urine volume of 1,000 mL
    - Nitrogen intake: \(85 \text{ g}/6.25 = 13.6 \text{ g}\)
    - UUN: \(9.9 \text{ mg/mL} \times 1,000 \text{ mL} = 9,900 \text{ mg} \text{ OR } 9.9 \text{ g}\)
    - Nitrogen balance: \(13.6 – (9.9 + 4) = –0.3\)
      - Negative nitrogen balance indicates state of protein loss

Considerations for Nitrogen Balance

- Measurements are difficult and often imprecise

- Urine and fecal collections must fully account for 24-hr period
  - Difficult in practice

- Poor estimates of true nitrogen loss often result in an overestimation of nitrogen retention

- Non-protein energy intake can influence results
  - Carbohydrate and fat are protein-sparing
  - If energy is inadequate, AAs will be used for oxidation (fuel) instead of for synthesis of new proteins, thus nitrogen retention is reduced
Biological Value for Protein Quality

- Biological value (BV) measures how much nitrogen is retained in the body.

- Similar to nitrogen balance concept:
  - 2 diets (one with protein, the other protein-free) that are fed to either humans or animals for 7 to 10 days.
  - Urinary and fecal collections are assessed.

- Calculation:
  \[ BV = \frac{N_I - (U - U_E) - (F - F_E)}{N_I - (F - F_E)} \times 100 \]
  - Where:
    - \(N_I\) is nitrogen intake
    - \(U\) and \(F\) are urinary and fecal nitrogen losses, respectively
    - \(U_E\) and \(F_E\) are endogenous urinary and fecal nitrogen losses during a nitrogen-free diet.

- Maximum biological value = 100 (indicates all nitrogen absorbed is retained).

- Similar limitations for nitrogen balance apply to biological value:
  - Meaningful for whole diets, but not individual components of mixed diets since limiting AAs can differ between sources.
## Biological Value of Selected Foods

<table>
<thead>
<tr>
<th>Protein Source</th>
<th>Biological Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg, whole</td>
<td>93.7</td>
</tr>
<tr>
<td>Milk</td>
<td>84.5</td>
</tr>
<tr>
<td>Fish</td>
<td>76.0</td>
</tr>
<tr>
<td>Beef</td>
<td>74.3</td>
</tr>
<tr>
<td>Soybeans</td>
<td>72.8</td>
</tr>
<tr>
<td>Rice, polished</td>
<td>64.0</td>
</tr>
<tr>
<td>Wheat, whole</td>
<td>64.0</td>
</tr>
<tr>
<td>Corn</td>
<td>60.0</td>
</tr>
<tr>
<td>Beans, dry</td>
<td>58.0</td>
</tr>
</tbody>
</table>

Net Protein Utilization for Protein Quality

- Net protein utilization is similar to nitrogen balance and biological value concepts
  - 2 diets (one with protein, the other protein-free) that are fed to either humans or animals for 7 to 10 days
    - Total carcass nitrogen (TCN) is often measured in animal studies
      - NPU = (TCN on test protein – TCN on protein-free diet) / N intake
    - Urinary and fecal collections are assessed

- Calculation

\[
\text{NPU} = \left( \frac{N_I - (U - U_E) - (F - F_E)}{N_I} \right) \times 100 = \frac{\text{Nitrogen retained}}{\text{Nitrogen intake}} \times 100
\]

- Where
  - \( N_I \) is nitrogen intake
  - \( U \) and \( F \) are urinary and fecal nitrogen losses, respectively
  - \( U_E \) and \( F_E \) are endogenous urinary and fecal nitrogen losses during a nitrogen-free diet

Leucine Content as an Additional Indicator of Protein Quality

- A recent animal study has shown that the leucine content of a meal determines its capacity to maximally stimulate muscle protein synthesis\(^1\)
  - Whey protein (higher leucine) activates protein synthesis more than wheat protein (lower leucine)

- Human studies have shown that leucine-rich protein sources such as whey are better at stimulating muscle growth than sources with less leucine, such as soy\(^2,3\)
  - For example, compared with soy protein, whey promoted more muscle protein synthesis
    - By 18% at rest \((P = .067)\)
    - By 31% following resistance exercise \((P < .05)\)

# Leucine Content of Selected Protein Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Leucine, g/100 g</th>
<th>Total Essential AAs, g/100 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soy protein isolate</td>
<td>8.2</td>
<td>36.0</td>
</tr>
<tr>
<td>Egg protein</td>
<td>8.4</td>
<td>42.3</td>
</tr>
<tr>
<td>Casein</td>
<td>8.9</td>
<td>40.7</td>
</tr>
<tr>
<td>Milk protein isolate</td>
<td>10.3</td>
<td>42.7</td>
</tr>
<tr>
<td>Whey protein isolate</td>
<td>12.2</td>
<td>49.2</td>
</tr>
<tr>
<td>Whey protein hydrolysate</td>
<td>14.2</td>
<td>49.8</td>
</tr>
</tbody>
</table>

Considerations for Protein Sources, Quality, and Turnover

- Casein, whey, and egg are all high-quality proteins capable of supporting muscle growth
- Whey protein supplementation appears to be particularly good at stimulating muscle protein synthesis
  - Leucine content highest (in addition to speed of digestion)
- Casein may reduce muscle protein breakdown (slow digesting, high quality source ideal before bedtime)
- Soy is also high quality according to the standard definition, but may be less ideal due to lower leucine content
- Combination of protein sources are ideal to get wide range of effects

Protein Quality Summary

- **PDCAAS** is the “Gold Standard” for protein quality
  - Accounts for digestibility as well as amount of essential AAs
    - Animal, dairy, and soy are of highest quality by this definition

- Nitrogen balance
  - Used to determine protein requirements to prevent deficiency in humans (RDA)
  - Does not account for different AA compositions among protein sources
  - Potentially flawed due to measurement errors

- PER, BV, and NPU are not as robust in determining true protein quality
  - More often used in agriculture

- Leucine content of a protein source may determine the protein source’s ability to stimulate protein synthesis in muscle

Abbreviations: PDCAAS, protein digestibility corrected amino acid score; PER, protein efficiency ratio; BV, biological value; NPU, net protein utilization; RDA, recommended dietary allowance.
Determining Protein Recommendations for Athletes
Recommended Daily Requirement for Protein

- Current RDA for protein is 0.8 g/kg body weight per day
  - ~65 g/day for a 180 lb (82 kg) individual
  - ~47 g/day for a 130 lb (59 kg) individual
- The RDA was calculated using nitrogen balance studies
  - Defines amount of protein required to maintain nitrogen balance in a healthy adult
    - Consume just enough protein to not be deficient
- Most Americans appear to consume adequate protein by this definition
  - Median protein intake for all adult age and gender groups ranged from 55 to 101 g/day
  - Adequate intake does not necessarily = optimal for health or performance

Protein Requirements

- The current RDA for protein may be too low
  - Nitrogen balance studies often overestimate nitrogen retention
    - Therefore, the nitrogen (protein) requirement may be underestimated
  - Reanalysis of existing nitrogen balance studies suggests that the population requirement is ~1.0 g/kg body weight per day
    - Calculations using a new method (Indicator Amino Acid Oxidation) suggest that the population requirement is ~1.2 g/kg body weight per day
  - These results are not official recommendations, but they suggest that the current guideline may not be perfect and merits continuous reevaluation

Abbreviation: RDA, recommended dietary allowance.
Preventing Protein Deficiency Versus Optimal Outcome

- The RDA for protein is set to prevent protein deficiency (maintenance) in healthy adults

- The RDA for protein does not consider potential benefits that might be obtained from consumption beyond that needed simply to maintain nitrogen balance
  - What is the optimal protein intake for
    - Skeletal muscle function?
    - Bone health?
    - Athletic performance?

Abbreviation: RDA, recommended dietary allowance.
Protein Intake Recommendations for Athletes

- American College of Sports Medicine (ACSM)/American Dietetic Association (ADA)
  - Endurance athletes, 1.2 to 1.4 g/kg per day
    - Based on nitrogen balance studies
      - Increased protein oxidation during endurance exercise
  - Strength athletes, 1.2 to 1.7 g/kg per day
    - Essential AAs are needed to support muscle growth, particularly during early phase of training when most significant gains in muscle occur and protein utilization is less efficient
  - Despite increased recommendations, ACSM does not state that protein supplementation has a positive impact on athletic performance

Nitrogen Balance and Athletes (1 of 3)

- The RDA for protein (0.8 g/kg) is probably insufficient for maintaining nitrogen balance in either strength or endurance athletes
  - 0.97 to 1.37 g/kg per day for endurance athletes
  - 0.82 to 1.43 g/kg per day for strength athletes (experienced, novice)
- Endurance athletes may require more protein than strength athletes to maintain nitrogen balance
  - Higher energy requirements dictate greater protein needs
  - Contracting skeletal muscles oxidize BCAAs for energy production
  - Adequate caloric intake to match physical demands is key in order to spare AAs for muscle protein synthesis

Abbreviations: RDA, recommended dietary allowance; BCAA, branched-chain amino acids.

Nitrogen Balance and Athletes (2 of 3)

- Experienced weight lifters require less protein intake per kg of lean body mass than that of novices
- Less potential expansion of muscle mass to be added in experienced weight lifters
  - In the first month of training, 1.4 g protein/kg versus 2.4 g protein/kg for novices
    - Calculated 1.43 g/kg per day for nitrogen balance
  - Nitrogen balance no longer had significant relationship with protein intake above 2.0 g protein/kg
  - Increased AA oxidation generally seen above 2.0 g/kg
    - Generally indicates no further metabolic benefit, at which point additional protein is used purely as a substrate for energy production/storage
  - No apparent effect of >2.0 g protein/kg on strength

Nitrogen Balance and Athletes (3 of 3)

- Additional protein intake can account for individual variability (1-2 standard deviations) and for promoting positive nitrogen status rather than nitrogen balance
  - 1.5 to 1.8 g/kg for strength athletes
    - This range should be adequate for endurance athletes as well
  - ~2.0 g/kg appears to be upper limit before protein intake has no additional benefit
  - Energy intake is an important influence (male vs female)
    - Requirement may go beyond 2.0 g/kg if energy intake is inadequate

Vegetarian Diets

- Most vegetarian athletes meet the RDA for protein intake (0.8 g/kg per day)
  - Like non-vegetarian athletes, the protein requirement for supporting muscle growth and function is probably higher than the RDA

- Protein quality of non-animal/dairy sources is reduced
  - Vegetable/legume proteins may be limited in the essential AAs lysine, threonine, tryptophan, or methionine
  - Vegetable/legume proteins are more poorly digested

- ACSM/ADA recommends 1.3 to 1.8 g/kg of protein per day for vegetarian athletes
  - Vegetarian protein needs are likely higher than omnivore protein needs at all activity levels

Abbreviations: RDA, recommended dietary allowance; ACSM, American College of Sports Medicine; ADA, American Dietetic Association.
How Much Protein Are Athletes Eating?

- Many athletes may already meet or exceed protein recommendations.
- Strength athletes in particular may believe that much larger protein intakes are necessary for increasing muscle mass.
  - Intakes at 4 to 6 g/kg range are not uncommon.
  - It is possible that this much protein intake could adversely affect the nutrient quality of the overall diet.

Protein intake of 0.8 to 2 g/kg per day is safe in healthy individuals.
Protein intake above 2 g/kg per day is not recommended due to lack of benefit and potential for adverse health effects.

Potential Downside to “High Protein” Diets (1 of 2)

- **Hydration status**
  - Eating protein beyond requirements can result in
    - Increased protein use for energy
    - Increased fat storage
  - The body must excrete the nitrogen from protein in urine (as urea)
  - Increased urinary output increases the likelihood of dehydration

- **Diets very high in protein may lack appropriate amounts of carbohydrate, fiber, and some vitamins/minerals**
  - Could impair exercise performance
  - Could increase long-term risk of diseases such as colon cancer
    - Possibly due to lack of fiber or increased intake of red meat

- **Excessively fatty protein sources could increase risk of cardiovascular disease**
  - Make sure protein sources chosen are mostly lean
    - For example, salmon is more desirable than a rib-eye steak

Potential Downside to “High Protein” Diets (2 of 2)

- Kidney disease
  - No good evidence of damage in individuals with healthy kidneys
  - Protein-rich diets are high in phosphorus, which can be detrimental to individuals with kidney disease
    - Primarily a concern with elderly or sick individuals, as opposed to healthy athletes

- Bone health
  - Higher protein diets may increase calcium loss in urine
    - However, gut absorption of calcium is likely improved, so there may be no net difference
  - Elevated protein diets appear to have either no or a slightly beneficial effect on skeletal health

Summary of Protein Recommendations

- Daily Recommended Intake is 0.8 g/kg per day (2002)
  - No recommendation for increase in athletes

- American College of Sports Medicine
  - Endurance: 1.2 to 1.4 g/kg per day
  - Strength athletes: 1.2 to 1.7 g/kg per day

- Vegetarians may have higher dietary supplementation protein needs than omnivores

- Protein intakes up to 2.0 g/kg per day are generally safe in healthy adults and may be beneficial
  - Many athletes may already unconsciously eat this amount of protein

- Few convincing data show that > 2 g/kg per day is helpful
  - May actually increase risk of adverse events

- A particular protein intake goal is difficult to establish
  - Influenced by energy intake and factors such as adaptation and desire to increase lean body mass versus maintenance
### Amino Acid Intake Recommendations

- Omnivorous diets are likely to meet AA requirements as long as protein requirements are met.
- Vegetarians should be cognizant of complementary protein sources throughout the day to prevent deficiency of particular AAs.

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>RDA (mg/kg/day)$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histidine</td>
<td>18</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>23</td>
</tr>
<tr>
<td>Leucine</td>
<td>49</td>
</tr>
<tr>
<td>Lysine</td>
<td>48</td>
</tr>
<tr>
<td>Methionine + cysteine</td>
<td>23</td>
</tr>
<tr>
<td>Phenylalanine + tyrosine</td>
<td>48</td>
</tr>
<tr>
<td>Threonine</td>
<td>28</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>8</td>
</tr>
<tr>
<td>Valine</td>
<td>32</td>
</tr>
</tbody>
</table>

Abbreviations: RDA, recommended dietary allowance.

$^a$ Based on maintenance protein requirement and determined by multiplying total protein maintenance needs in adults by amino acid content of whole body protein.
Potential Risks of AA Supplementation (1 of 2)

- Taking large doses of a single AA can affect the absorption of other AAs
  - Certain AAs may utilize the same system for transport/absorption
    - High levels of one AA can inhibit the absorption of other AAs dependent on the same system
  - In chicks, excessive doses of lysine caused increased plasma lysine levels while plasma arginine levels decreased (and vice versa)
  - Branched-chain AAs leucine, isoleucine, and valine are often ingested in a naturally occurring 2:1:1 ratio to ensure that none of the 3 are depleted by the others

- Large single doses of AAs may be poorly absorbed and lead to diarrhea

Potential Risks of AA Supplementation (2 of 2)

- Free AAs in food products often create bitter flavors
  - AA pills don’t have this issue, but dose of AA in pills is often small

- In 1989, there were many cases of a painful and sometimes fatal disease (eosinophilia myalgia syndrome) linked to tryptophan supplements
  - Likely due to contamination
    - Always good to know source and quality of nutritional supplements

Ney KH. Bitterness of Peptides: Amino Acid Composition and Chain Length in Food Taste Chemistry. Washington, DC; American Chemical Society; 1979. p 149-173.
Sports Nutrition Claims for AAs and Derivatives (1 of 4)

The scientific basis for the support of these claims can be found in the ergogenic aids modules on the EAS Academy website.

- Arginine and citrulline (precursor of arginine)
  - Increased nitric oxide for improved blood flow to muscle
  - Improved clearance of ammonia via urea cycle
  - Improved exercise performance
  - Citrulline decreases muscle soreness

- Arginine, ornithine, lysine
  - Stimulation of growth hormone release

Cynober L. *J Nutr*. 2007;137:1646S-1649S.
Sports Nutrition Claims for AAs and Derivatives (2 of 4)

- **Beta-alanine**
  - Forms the dipeptide carnosine when bonded to histidine
    - Buffers muscle pH to improve endurance
  - Not actually incorporated into structural body proteins like alanine

- **Creatine**
  - Increased anaerobic performance
  - Increased strength and muscle mass

- **Glutamine and its precursor alpha-ketoglutarate (AKG)**
  - Boost immune function
  - Fuel for intestinal cells
  - Transport of nitrogen groups in plasma
  - Possible anabolic effects

Leucine/Branched-Chain AAs (BCAAs)

- Leucine stimulates muscle protein synthesis
- BCAAs can serve as an energy source during activity
- Prevention of fatigue
- Reducing muscle soreness
- BCAAs are popular as a supplement among athletes
- BCAA doses of ~2 to 60 g/day have been used in research studies
- Doses of ≥ 30 g/day are impractically high compared to amounts found in typical commercial supplements
  - 1 tablet typically contains 100 mg leucine, 100 mg valine, and 50 mg isoleucine

Sports Nutrition Claims for AAs and Derivatives (4 of 4)

- **Leucine breakdown products**
  - Beta-hydroxy-beta-methylbutyrate (HMB) and alpha-ketoisocaproate (alpha-KIC)
    - Decreased muscle protein breakdown
    - Increased muscle mass and strength

- **Taurine**
  - Antioxidant effects
  - Improved heart functions
  - Insulin actions

Example: Quantity of Amino Acids in Food

- 1 cup of low fat cottage cheese (2%) has 31 g protein
  - This translates to 31,000 mg of amino acids
  - The branched-chain amino acid content of the cottage cheese (leucine + isoleucine + valine) is 6,942 mg (6.9 g)

- Whole protein sources are best (may be less expensive)

Is Protein Used for Energy in Athletes?

In general, the body prefers to spare its endogenous protein stores (skeletal muscle, etc) from oxidation for energy production

– Only in conditions of starvation, extreme energy requirements (eg, ultramarathons), or wasting conditions such as cancer will the body break down muscle for energy

Consider fight or flight response

– Difficult to avoid danger (eg, run from a bear) or obtain food (eg, catch a fish) if muscle protein is sacrificed as fuel for energy

However, exogenous (dietary) protein is commonly used as fuel under certain conditions (eg, during endurance exercise, which can deplete carbohydrate stores in muscle)

Is Protein Used for Energy in Athletes? (Cont’d)

6 AAs are metabolized in resting muscle (leucine, isoleucine, valine, asparagine, glutamate, and aspartate)

- Leucine and isoleucine can be converted to acetyl CoA, which can yield energy for muscle through the TCA cycle
- Carbon skeletons from the other AAs can enter the TCA cycle and have various outcomes
  - Energy production by running through TCA cycle
  - From pyruvate, muscle can generate alanine, which is released into the circulation and can be taken up by liver
    - Liver can utilize alanine to make glucose (via gluconeogenesis), which can be released back into the circulation or stored as liver glycogen
  - Alternatively, muscle can generate glutamine, which is released into the circulation and can be taken up by the small intestine and other rapidly dividing tissues for energy

Abbreviation: TCA, tricarboxylic acid cycle.

Timing of Ingestion and Macronutrient Content of Meals

- There is increasing agreement that immediate post-exercise ingestion of protein and/or carbohydrate has beneficial effects on
  - Muscle glycogen replenishment (particularly carbohydrate, protein may provide additional benefit)
  - Muscle protein synthesis (particularly protein, carbohydrate may have permissive effect due to insulin release)

- A combination of both protein and carbohydrate seems to work better than either carbohydrate or protein alone
  - Proportions of carbohydrate/protein vary based on individual needs
    - Endurance athletes prioritize carbohydrate intake for glycogen replenishment
    - Bodybuilders prioritize protein intake for muscle growth

Protein and Glycogen Replenishment

- Rapid post-exercise consumption of carbohydrate and protein in a 3:1 or 2:1 ratio appears to replenish muscle glycogen to a greater extent than carbohydrate alone
  - Unclear if this effect enables better performance in a subsequent bout of exercise within ~6 hours

- Protein supplementation may exert a stronger replenishment effect when lower post-exercise carbohydrate is provided (<1.0 g/kg/hr)
  - A lesser effect may occur when adequate carbohydrate is provided (>1.2 g/kg/hr)

Preoccupation with protein intake may be at expense of adequate carbohydrate consumption, resulting in poor glycogen recovery and potential for subsequent performance decrements

Putting a Meal Plan Together

- Example: 70-kg athlete requiring 4,000 kcal/day exercising 120 min/day, 4 to 6 times/week

- Macronutrient Target Recommendations
  - Grams/kg body weight/day
    - Carbohydrate: 7-10 g/kg (490-700 g/day)
    - Protein: 1.5-2.0 g/kg (105-140 g/day)
    - Fat: Typically use percentage of energy
  - Percentage of energy
    - Carbohydrate: 55-65% of energy (550-650 g/day)
    - Protein: 10-15% of energy (100-150 g/day)
    - Fat: 20-30% of energy (88-133 g/day)

- Target recommendations for this athlete
  - Carbohydrate: 600 g/day (60% of energy)
  - Protein: 130 g/day (13% of energy)
  - Fat: 120 g/day (27% of energy)
# A Potential Distribution of Macronutrients Over the Course of 6 Meals/Day

<table>
<thead>
<tr>
<th>Meal</th>
<th>Time</th>
<th>Carbohydrate, g</th>
<th>Protein, g</th>
<th>Fat, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast</td>
<td>7:00 AM</td>
<td>90</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Mid-morning snack</td>
<td>10:00 AM</td>
<td>25</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Lunch</td>
<td>Noon</td>
<td>75</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Pre-exercise meal</td>
<td>1:30 - 2:00 PM</td>
<td>90</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>During exercise</td>
<td>3:00 - 5:00 PM</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Post-exercise meal</td>
<td>5:00 PM</td>
<td>75</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>Dinner</td>
<td>6:30 PM</td>
<td>120</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>Evening snack</td>
<td>9:00 PM</td>
<td>25</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td></td>
<td><strong>600</strong></td>
<td><strong>130</strong></td>
<td><strong>120</strong></td>
</tr>
</tbody>
</table>
# Protein Content of Various Foods

<table>
<thead>
<tr>
<th>Serving Description</th>
<th>Protein Content, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 egg, 2 egg whites, or ¼ cup egg substitute</td>
<td>6-7</td>
</tr>
<tr>
<td>1 cup of milk</td>
<td>8-10</td>
</tr>
<tr>
<td>¼ cup cottage cheese</td>
<td>7</td>
</tr>
<tr>
<td>1 cup of yogurt</td>
<td>8</td>
</tr>
<tr>
<td>1 oz. of chicken, fish, pork, or beef(^a)</td>
<td>7</td>
</tr>
<tr>
<td>1 oz. of cheese (except cream cheese)</td>
<td>7</td>
</tr>
<tr>
<td>1 slice of bread or ½ bagel</td>
<td>3</td>
</tr>
<tr>
<td>1 cup of cereal</td>
<td>3-6</td>
</tr>
<tr>
<td>2 Tablespoons peanut butter</td>
<td>7</td>
</tr>
<tr>
<td>1/2 to 2/3 cup of dried beans or lentils</td>
<td>8</td>
</tr>
<tr>
<td>1 cup miso</td>
<td>8</td>
</tr>
<tr>
<td>4 oz. raw, firm tofu</td>
<td>9</td>
</tr>
<tr>
<td>½ cup peas or corn</td>
<td>3</td>
</tr>
<tr>
<td>½ cup of non-starchy vegetables</td>
<td>2</td>
</tr>
<tr>
<td>8 oz. soy milk</td>
<td>5-6</td>
</tr>
<tr>
<td>Protein drinks and powders/serving</td>
<td>10-45</td>
</tr>
</tbody>
</table>

\(^a\)3-ounce portion (21 g protein) is the size of the deck of cards.

Summary

- Adequate protein intake is critical for athletic performance and good health.

- For most athletes, protein intakes of 1.5 to 1.8 g/kg/day (0.68-0.81 g/lb/day) will meet protein requirements.

- High quality protein sources (e.g., dairy products, meats, fish, chicken, soy, eggs) should be included in the diet.

- Eating a combination of carbohydrate and protein soon after exercise can help with muscle recovery and building.
Summary (Cont’d)

- Research is emerging on potential benefits of certain amino acids or amino acid metabolites for athletes
  - First rule is to get appropriate amount of high quality protein from diet

- There are several disadvantages of excessive protein intake (ie, well above 2 g/kg/day)
  - In general, no additional benefit for strength or muscle building
  - Increased water loss from the body due to disposal of excess nitrogen in urine, which may lead to dehydration
  - May replace carbohydrates and other vital nutrients for athletic performance and good health