PROTEIN REQUIREMENTS & ROLE IN MUSCLE PROTEIN SYNTHESIS

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OVERVIEW

• The role of protein in the body

• Regulation of muscle protein synthesis (MPS)

• Protein quality
PROTEINS IN THE BODY
PROTEIN AND THE BODY

- Structure
- Movement
- Immune function
- Transport
- Hormones
- Enzymes
- Cell signaling
PROTEIN REQUIREMENTS

0.8 g/kg/d

Adults > 18 years

Varying sources

National Academy of Medicine (Formerly the Institute of Medicine)
Daily Intake Guidelines for Athletes

TEAM SPORTS
1.2-1.7 G/KG/D

ENDURANCE
1.2-1.4 G/KG/D

STRENGTH
1.6-1.7 G/KG/D

POWER
1.5-1.7 G/KG/D

Why do you think protein intake guidelines are higher for athletes than the RDA?
Amino Acid Structure

AMINO ACID BUILDING BLOCKS

- Amino group
- Acid group

Side group = Functional differences of AA

AMINO ACID
nitrogen-containing organic molecule

AMINO ACIDS BOND TOGETHER

PROTEIN
CLASSES OF AMINO ACIDS

ESSENTIAL
- Histidine
- Isoleucine
- Leucine
- Lysine
- Methionine
- Phenylalanine
- Threonine
- Tryptophan
- Valine

NON-ESSENTIAL
- Arginine
- Asparagine
- Aspartic Acid
- Glutamic Acid

CONDITIONAL
- Arginine
- Cysteine
- Glutamine
- Glycine
- Tyrosine
- Ornithine
- Proline
- Serine
>40% of body mass is skeletal muscle

Collagen is the most abundant protein in the body (25-35%)

There is no protein storage site in the body (unlike glucose or fat)

Consuming protein regularly is important to ensure there are adequate AAs to replenish pools

Urea is the principal vehicle for excreting unused nitrogen
MUSCLE PROTEIN TURNOVER: MPS & MPB IN REGULATING MUSCLE SIZE
Muscle Protein Turnover- the Amino Acid Pools

Dietary Intake $\rightarrow$ Free Amino Acids

- De Novo Synthesis (dispensable)
- Excretion
- Oxidation
- Non-Protein Pathways
- Protein Turnover $\rightarrow$ Tissue Protein

- Degradation $\leftrightarrow$ Synthesis
- Protein Losses $\rightarrow$
  - Skin
  - Hair
  - Feces

Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Institute of Medicine. 2005
MUSCLE PROTEIN SYNTHESIS

AMINO ACIDS

BLOODSTREAM

MUSCLE PROTEIN BREAKDOWN

MUSCLE PROTEIN TURNOVER
MUSCLE PROTEIN TURNOVER

Hypertrophy (growth)  

Atrophy (loss)
There are 2 main drivers to muscle protein synthesis:

- **Protein Ingestion**
- **Muscle Damage/Exercise**
Why do we go into NEGATIVE protein balance?

Periods of **negative protein balance** are typically less than or equal to periods of positive protein balance.

But we can **induce negative protein balance** by:

1. Calorie restricting
2. Bed rest/hospitalization

Adapted from Oikawa SY, Holloway TM, Phillips SM. *Frontiers*. 2019
What are the effects of amino acids and exercise on MPS?

Both amino acids (AA) and resistance exercise (RE) can stimulate MPS. When combined, they act synergistically to increase MPS.


Essential Amino Acids Drive MPS

Increasing total protein intake with non-essential amino acids (NEAA) does not increase MPS.

Leucine as the Primary Driver of MPS

- 6 g Whey
- 6 g Whey + Low-Leu (3.0 g)
- 25 g Whey
- 6 g Whey + High-Leu (5.0 g)

**MUSCLE PROTEIN SYNTHESIS**

**Leucine as the Primary Driver of MPS**


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**FSR (%/h)**

- **FED**
  - Basal
  - 0 - 4.5

- **Exercise - FED**
  - Basal
  - 0 - 4.5

Leucine as the Primary Driver of MPS

What these data show is that with feeding alone and with feeding + exercise, 6 g of whey protein with added leucine resulted in similar stimulation of MPS to 25 g of whey protein alone.

Leucine drives the increase in MPS in the absence of elevated levels of other EAA.
Does protein supplementation impact strength?

MUSCLE PROTEIN SYNTHESIS

Gains from resistance exercise training alone
Gains from resistance exercise training + protein supplementation

Δ 1RM (Kg)

Δ FFM (Kg)

PROTEIN QUALITY: WHAT DOES IT MEAN? HOW DO WE ASSESS IT?
Protein Quality - the PDCAAS

Protein quality is determined by:

- Availability
- Digestibility
- Amount of essential amino acids

FAO and FDA use the Protein Digestibility-Corrected Amino Acid Score:

\[
\text{PDCAAS} \% = \frac{\text{mg of limiting AA in 1 g of the protein}}{\text{mg of the same AA in 1 g of the reference protein}} \times \text{true fecal digestibility (\%)} \times 100
\]

Scores: 0 - 1
Protein Quality - the DIAAS

More recently, the FAO has adopted the Digestible Indispensable Amino Acid Score (DIAAS) as the preferred method to evaluate protein quality.

\[
\text{DIAAS}\% = \frac{\text{mg of digestible indispensible AA in 1 g of the protein}}{\text{mg of the same indispensible AA in 1 g of the reference protein}} \times 100
\]

Scores: 0 +
The change in assessment from the PDCAAS to the DIAAS were several fold:

The PDCAAS does not give **extra credit to the highest quality proteins** since it truncates values at 1.

The PDCAAS method **overestimates protein quality** of products containing antinutritional factors.

The PDCAAS method does not adequately take into account the bioavailability of amino acids.

The PDCAAS method overestimates the quality of poorly digestible proteins supplemented with limiting amino acids, and of proteins co-limiting in more than one amino acid.

Bacterial degradation occurs with fecal digestibility **enhances protein quality scores.**
### Examples of Proteins Scored by the PDCAAS vs. DIAAS

<table>
<thead>
<tr>
<th>Food</th>
<th>PDCAAS</th>
<th>DIAAS</th>
<th>Limiting AA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk protein concentrate</td>
<td>1.00</td>
<td>1.18</td>
<td>Met + Cys</td>
</tr>
<tr>
<td>Whey protein Isolate</td>
<td>1.00</td>
<td>1.09</td>
<td>Val</td>
</tr>
<tr>
<td>Soy protein Isolate</td>
<td>0.98</td>
<td>0.90</td>
<td>Met + Cys</td>
</tr>
<tr>
<td>Pea protein concentrate</td>
<td>0.89</td>
<td>0.82</td>
<td>Met + Cys</td>
</tr>
<tr>
<td>Rice protein concentrate</td>
<td>0.42</td>
<td>0.37</td>
<td>Lys</td>
</tr>
<tr>
<td>Whole Milk</td>
<td>1.00</td>
<td>1.14</td>
<td>Met + Cys</td>
</tr>
<tr>
<td>Chicken breast</td>
<td>1.00</td>
<td>1.08</td>
<td>Trp</td>
</tr>
<tr>
<td>Egg (hard boiled)</td>
<td>1.00</td>
<td>1.13</td>
<td>His</td>
</tr>
<tr>
<td>Cooked Peas</td>
<td>0.60</td>
<td>0.58</td>
<td>Met + Cys</td>
</tr>
<tr>
<td>Cooked Rice</td>
<td>0.62</td>
<td>0.59</td>
<td>Lys</td>
</tr>
<tr>
<td>Corn-based cereal</td>
<td>0.08</td>
<td>0.01</td>
<td>Lys</td>
</tr>
<tr>
<td>Hydrolyzed collagen</td>
<td>0.00</td>
<td>0.00</td>
<td>Trp</td>
</tr>
</tbody>
</table>

Table adapted from Phillips SM. *Frontiers.* 2017
Gram per gram is like comparing apples and oranges:

- 25 g whey protein isolate
  - 3.6 g leucine
- 25 g collagen peptides
  - 0.8 g leucine
- 25 g soy protein isolate
  - 2.0 g leucine

To achieve the same amount of leucine:

- 113 g of collagen peptides
  - (4.5 x more)
- 45 g of soy protein isolate
  - (1.8 x more)
### Limiting amino acids in Plant Foods

<table>
<thead>
<tr>
<th>Food</th>
<th>Limiting AA</th>
<th>Plant source of the AA</th>
<th>Combination in which the proteins compliment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legumes (beans)</td>
<td>Met</td>
<td>Grains, nuts, seeds</td>
<td>Red beans and rice</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Met</td>
<td>Grains, nuts, seeds</td>
<td>Green beans and almonds</td>
</tr>
<tr>
<td>Grains</td>
<td>Lys, Thre, Trp</td>
<td>Legumes</td>
<td>Rice and red beans; lentils and rice; corn and beans</td>
</tr>
<tr>
<td>Nuts and Seeds</td>
<td>Lys</td>
<td>Legumes</td>
<td>Soybeans and sesame; peanuts, rice, and black-eyed peas</td>
</tr>
</tbody>
</table>
Often complete proteins (collagen is the exception).

Contain high amounts of leucine.

Options for low fat selections.

Can achieve amino acid goals with complimentary proteins.

Often contain low levels of leucine.

Flexible for vegetarian/vegan diets.

Good idea to compare supplemental protein based on grams of EAA rather than absolute grams of total protein (similar to our apples and oranges slide).
There are 3 branched chain amino acids (BCAA’s):

- Leucine
- Isoleucine
- Valine

**BCAA’s Don’t Enhance Muscle Growth**

- 18 men
- 8 weeks

**Graph:**

- **X-axis:** Pre, Post
- **Y-axis:** FFM (kg)
- **Data:**
  - BCAA
  - PLA

HMB is a metabolite derived from **leucine:**

- HMB is formed naturally when the body breaks down leucine.
- Suggested to boost muscle mass during resistance exercise.
  - Concurrently with losses in fat mass.
- Has been purported to reduce MPB.
- Comes in both a free acid (HMB-FA) and calcium form (HMB-Ca).

**Meta analysis**

- 302 male participants
- 18-45 years
- Training 2-5 days/week
- 4-12 weeks training

Mean difference between HMB and placebo = was 0.29 kg
No difference between groups in fat mass changes

Food Matrix:

- Describes the overall physical form of food.
- Includes how food components are structured and interact.
- Processing and heat treatment also impact the food matrix to modulate digestibility.

Consuming salmon and its AA make up + fish oil = similar MPS response!
Protein as a Fuel Source During Exercise

- Occurs VERY infrequently, only when glucose or fatty acids are limited.
- Body breaks down tissue proteins to use the amino acids for glucose.
- Results in **muscle wasting**.
- Can happen during prolonged exercise when carbohydrates are not supplied throughout the exercise period.
Athletes require more daily protein than the RDA.

Muscle protein turnover is the balance between breakdown and synthesis.

The 2 main drivers of MPS are protein and exercise.

Leucine is the essential amino acid that drives MPS.

All proteins are not created equal.

Protein is not a primary source of fuel during exercise.