The Choline Connection
A Healthcare Professional’s Guide
to Choline, Fetal Development,
Maternal Health & More

Developed by the Egg Nutrition Center
• Discuss Function & Benefits of Choline
• Highlight Dietary Sources & Recommended Intake of Choline
• Discuss Current & Emerging Choline Research
• Call to Action
Learning Objectives

• Define the health benefits of choline
• Discuss the role of choline in fetal and early childhood development
• Understand areas of emerging choline research and the interaction between choline and homocysteine
• Identify dietary sources of choline
Choline: An Overview

- Choline is an **essential** nutrient
- **Functions**
  - Strengthens cell membranes
  - Aids in memory development and cognition
  - Needed for proper fetal brain development
  - Maintains normal maternal homocysteine levels
  - Decreases the incidence of neural tube defects
  - Needed to make acetylcholine, a major neurotransmitter
  - Precursor for sphingomyelin, an essential element of cell membranes

**Choline needs increase during pregnancy and again during lactation**
Historical Information

• Choline was discovered in 1862 by Andreas Strecker
• In 1998 the Food and Nutrition Board of the Institute of Medicine evaluated numerous research studies about choline to set Dietary Reference Intakes (DRIs)
• Choline was recognized as an essential nutrient and Adequate Intake (AI) levels were established

Biochemical Structure

Chemical Structure of Choline

- Choline is a natural amine found as free choline and in lipids of cell membranes
- Choline is classified as a water-soluble nutrient and is usually grouped within the vitamin B complex
- There is a relationship between folate and choline metabolism in the liver
Mechanism of Action

- Choline and folate provide methyl groups for the conversion of homocysteine in the synthesis of the amino acid methionine
- When choline is deficient in the diet, folate metabolism is disturbed

When folate is deficient in the diet, choline becomes a limiting nutrient
Why is Choline Essential?

• Choline is a basic cell building block that:
  – is necessary for production of the phospholipids
  – is used to make acetylcholine, a neurotransmitter
  – is used to make lipoproteins, which shuttle nutrients around the body

• Choline is necessary for fetal and infant brain development
  – Maternal choline becomes depleted when fetal demand increases
  – Choline is vital to the proper development of the brain and spinal cord
  – Choline aids in memory development and cognition
  – Choline intake is critical up to the age of four in humans as the brain develops new cells
Why is Choline Essential?

• Choline is necessary for maintaining normal maternal homocysteine levels
  – Choline deficiency results in elevated serum homocysteine

• Choline helps decrease the incidence of neural tube defects
  – Insufficient choline intake during pregnancy is associated with a four-fold increase in the risk of neural tube defects such as spina bifida
  – Higher levels of total blood choline are associated with a 2.5-fold reduction in risk for neural tube birth defects.

Sources:
Zeisel SH. Choline: Needed for normal development of memory. JACN 2000;19 (5): 528S-531S.
Emerging research demonstrates benefits of choline beyond fetal development

- Optimal Memory Function
- Reduced Breast Cancer Risk
- Improved Cardiovascular Health
• Animal model studies have shown that choline availability during embryogenesis and prenatal development is important for long-term memory

• Normal age-associated memory decline in rat offspring is lessened when the dam (mother rat) receives choline supplementation during pregnancy

Choline and Breast Cancer

• Research funded by the National Institutes of Health found that higher levels of choline consumption were associated with a 24% reduction in breast cancer risk.

• Results are consistent with two previous National Institutes of Health funded studies which showed that egg consumption was associated with a reduced risk of breast cancer.

Choline & Cardiovascular Health

• Elevated plasma homocysteine is a known risk factor for cardiovascular disease
  – High dietary choline and betaine consumption are related to lower plasma homocysteine concentrations
  – Betaine is a metabolite of choline and, like choline, it is involved in the methylation of homocysteine to methionine.

• Individuals who consume the highest amounts of choline and betaine have significant decreases in cardiovascular disease biomarkers: plasma concentrations of C-reactive protein, interleukin-6 and tumor necrosis factor-alpha.

### Adequate Intake (AI) levels for choline set by the Institute of Medicine:

<table>
<thead>
<tr>
<th>Life Stage</th>
<th>Adequate Intake (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants:</td>
<td></td>
</tr>
<tr>
<td>(0-6 months)</td>
<td>125 milligrams</td>
</tr>
<tr>
<td>(7-12 months)</td>
<td>150 milligrams</td>
</tr>
<tr>
<td>Children:</td>
<td></td>
</tr>
<tr>
<td>(1-3 years)</td>
<td>200 milligrams</td>
</tr>
<tr>
<td>(4-8 years)</td>
<td>250 milligrams</td>
</tr>
<tr>
<td>(9-13 years)</td>
<td>375 milligrams</td>
</tr>
<tr>
<td>Adolescents:</td>
<td></td>
</tr>
<tr>
<td>(14-18 years)</td>
<td>400 milligrams (Female)</td>
</tr>
<tr>
<td></td>
<td>550 milligrams (Male)</td>
</tr>
<tr>
<td>Adults:</td>
<td></td>
</tr>
<tr>
<td>(19 and older)</td>
<td>425 milligrams (Female)</td>
</tr>
<tr>
<td></td>
<td>550 milligrams (Male)</td>
</tr>
<tr>
<td>Pregnant women</td>
<td>450 milligrams</td>
</tr>
<tr>
<td>Breastfeeding women</td>
<td>550 milligrams</td>
</tr>
</tbody>
</table>

Choline: Low Awareness Among Consumers

Three out of four moms are not at all familiar with the benefits of choline

- Research shows that only 1 out of 10 Americans are meeting Adequate Intake (AI) guidelines for choline

- 78 percent of mothers do not know the food sources of choline
Choline: Low Awareness Among Health Professionals

• Health professional awareness of choline is low
  – Familiarity with choline ranks behind other vitamins & minerals
  – Only 6 percent of OB/GYNs are “very likely” to recommend choline to pregnant women
Dietary Sources of Choline

In 2001, the Food and Drug Administration (FDA) allowed a nutrient content claim on labels of foods that meet the following criteria to be termed “good” or “excellent” sources of choline:

**Excellent source of choline**
Must contain at least 110 mg of choline per serving, (20% of the Daily Value for choline based on 550 mg reference).

**Good source of choline**
Must contain at least 55 mg of choline per serving, (10% of the Daily Value for choline based on 550 mg reference).
Sources of Dietary Choline

• An excellent source of choline provides 20 percent or more of the recommended amount of choline per serving
  – Beef liver*, chicken liver* and eggs are excellent sources of choline, providing 20% or more of the Daily Value for choline
  – Other good food sources of choline include lean beef, chicken breast, code, wheat germ and cauliflower.

• Choline-rich foods are the best source of choline
• Most prenatal vitamins and regular multivitamins do not contain choline
• Baby formulas made from soy have less choline than breast milk or bovine-derived formulas

*The March of Dimes recommends that pregnant women minimize their intake of liver due to its excessive vitamin A levels.
Choline & Eggs

- Eggs are an excellent source of choline.
- The choline in eggs is found in the yolk.
- One egg – including the yolk – contains 126 milligrams of choline, or roughly one-quarter of the recommended daily amount.
- Eggs are also a source of high-quality protein – which has been associated with improved birth weight – and other essential nutrients.
- Eggs are nutritious, delicious, convenient and affordable.
• Choline is an **essential** nutrient that is needed by individuals of all ages for optimal health.
Key Takeaway

• Choline is especially important for pregnant and breastfeeding moms for proper fetal brain development
  – For women whose diets are deficient in choline, the risk of having a pregnancy affected by neural tube defects increases four-fold
• Choline is widely unknown and chronically under consumed. It is simple to get the recommended amount of choline in the diet by:
  – Enjoying eggs for breakfast
  – Eating vegetables such as broccoli and cauliflower
  – Enjoying beef as part of a balanced diet
  – Keeping hard-cooked eggs on hand as a simple, nutrient-rich snack
Call to Action

• Stay informed about the latest choline research by regularly visiting the Research Library on www.cholineinfo.org

• Include choline in guidance for pregnant and breastfeeding patients

• Encourage patients to increase choline intake through easy, affordable meals and snacks such as eggs
  – Distribute patient education materials available at www.cholineinfo.org
Thank You!

The Choline Connection