



The Choline Connection

*A Healthcare Professional's Guide to
Choline, Fetal Development,
Maternal Health & More*



Introduction

Dear Colleague,

As a busy healthcare practitioner, your time is limited. Yet, you always work to stay ahead of the curve with the latest health and nutrition information to help promote the well-being of mothers and their babies. Choline is one such emerging nutrition topic that is gaining substantial attention for its role in improving pregnancy outcomes and maternal health. You're probably aware that choline is an **essential nutrient** vital to fetal brain development. But did you know that adequate dietary choline works closely with folate to lower the risk of neural tube defects, such as spina bifida, by as much as four-fold?

Despite its important role in the body, consumer awareness about choline is low. Likewise, choline consumption is inadequate in several vulnerable groups, including women in their childbearing years. Research shows that **only 1 out of 10 women of childbearing age in the U.S. is meeting Adequate Intake (AI) guidelines for choline. Perhaps that's because 3 out of 4 moms are not at all familiar with the benefits of choline.** In addition, a 2007 survey of healthcare professionals shows that only 6 percent of OB/GYNs are very likely to recommend choline to pregnant women. Closing the choline consumption gap is one important way to help women have better health and healthier pregnancies.

In fact, the inadequate intake of choline among all adults in the U.S. population has tremendous public health implications. That's why we've developed a tool kit to provide you with the resources you, your colleagues and your patients need to learn more about this vital nutrient. Given that many women are particularly interested in good nutrition while they are pregnant and breastfeeding, I encourage you to take advantage of this window of opportunity to help educate your patients about the importance of including choline-rich foods in their diet, using the information and educational tools provided for you.

We hope you find this tool kit a valuable resource for promoting healthier pregnancies and fostering maternal health among your patients. Continuing education credit may be available from your healthcare professional organization for your review of these materials. For more information about choline and continuing education, please visit www.cholineinfo.org.

Sincerely,



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How to Use The Choline Connection Tool Kit

The Choline Connection tool kit focuses on the most recent choline research and how to incorporate choline education into your day-to-day discussion with patients, clients and colleagues. This tool kit also provides the background and tools to conduct in-service training with your colleagues and team members to spread knowledge about choline.

Components of The Choline Connection Tool Kit

This presentation is a summary of the information covered in the Healthcare Professional's Guide. The guide serves as one part of a tool kit which also includes:

- **The Choline Connection slide presentation** – This presentation is a summary of the information covered in the Healthcare Professional's Guide. The presentation serves as a quick reference guide to the materials and provides an easy way for you to educate your colleagues. The presentation includes accompanying continuing education questions. Please see cholineinfo.org for more information about continuing education.
- **Reproducible Patient Handouts** – Developed to provide your clients/patients with tailored information on healthy eating during pregnancy.
 - **Eating Right During Pregnancy** handout – Choline information developed with a range of reading levels in mind. Available in Spanish and English.
 - **Eggs: A Good Choice for Moms-to-Be** handout
 - **I'm An Incredible Kid!** coloring page – A fun activity for kids to help encourage early development of healthy eating behaviors.

Please see www.cholineinfo.org for more information.

Message In A Minute

Eating certain foods while pregnant has been shown to improve the health and development of your baby. Some nutrients such as choline, protein, iron, folate and zinc are very important for the baby to form correctly. Evidence suggests that by eating choline-rich foods such as eggs, lean beef, cauliflower and peanuts during pregnancy and breastfeeding, you may help your baby develop and sustain memory function throughout life.

Choline: The Unknown Essential Nutrient

The History of Choline

Choline was discovered by Andreas Strecker in 1862, but it was not until 1998 that it was recognized as an essential nutrient. In 1998, an Adequate Intake (AI) was established for choline by the Food and Nutrition Board of the Institute of Medicine.¹ Eating foods naturally rich in choline, such as beef liver*, chicken liver* and eggs, is the best way to get the recommended amount of choline. Other good food sources of choline include lean beef, chicken breast, cod, wheat germ and cauliflower.

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

Population		Adequate Intake (AI) of Choline
Infants:	(0-6 months)	125 milligrams
	(7-12 months)	150 milligrams
Children:	(1-3 years)	200 milligrams
	(4-8 years)	250 milligrams
	(9-13 years)	375 milligrams
Adolescents:	(14-18 years)	400 milligrams (Females)
		550 milligrams (Males)
Adults:	(19 and older)	425 milligrams (Females)
		550 milligrams (Males)
Pregnant Women:	(19 and older)	450 milligrams
Breastfeeding Women:	(19 and older)	550 milligrams

Background

The majority of the body's choline is found in fat molecules known as phospholipids, the most common of which is lecithin, which are structural components of all human cell membranes.¹¹ Notably, adequate maternal choline intake is vital to a healthy pregnancy. Maternal choline intake is critical not only for proper fetal brain development, but also for maintaining normal maternal homocysteine levels. Elevated maternal homocysteine has been associated with an increased incidence of birth defects, such as the neural tube defects spina bifida and anencephaly. Other pregnancy difficulties include spontaneous abortions, placental abruptions and low birth weight babies. In the general population, elevated homocysteine levels have been associated with an increased risk of cardiovascular disease. Choline also serves to strengthen cell membranes and aids in memory development and cognition. There is a high rate of choline transfer from mother to fetus during pregnancy, elevating the demand on maternal choline status. In addition, the need for choline does not diminish when breastfeeding. Breast milk is rich in choline and a breastfeeding mother's need for choline is higher than during pregnancy."

Choline By the Numbers: The Choline Knowledge Gap

- Consumer research has shown that almost **3 out of 4 moms** (74 percent) are not at all familiar with the benefits of choline.
- Consumer research also shows that **78 percent of moms** cannot identify food sources of choline.
- Knowledge and awareness about choline among health professionals is low. A survey of dietitians and doctors found that familiarity with choline was ranked below that of many other vitamins and minerals. Only **10 percent** of the practitioners surveyed indicated they were moderately familiar with choline.
- The survey also found that the likelihood of health professionals to recommend choline to clients/patients was low. Only **6 percent** of OB/GYNs were "very likely" to recommend choline to pregnant women.

How Choline Works

Choline is used to form phosphatidylcholine, a major part of all cell membranes in the body. There is also a relationship between folate and choline metabolism in the liver. Both nutrients provide methyl groups for the conversion of homocysteine in the synthesis of the amino acid methionine. Several animal and human studies have shown that folate metabolism is disturbed during experimental choline deficiency and that choline becomes a limiting nutrient during folate deficiency.ⁱⁱⁱ In addition to inadequate intake, several common factors can cause folate deficiency including:

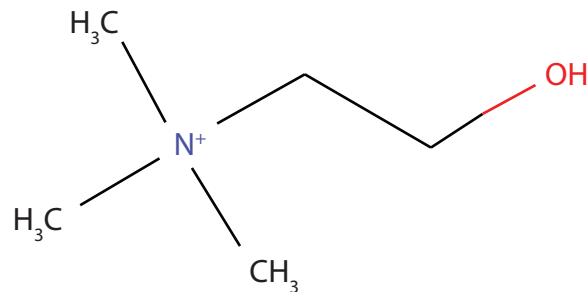


Figure 1: Chemical Structure of Choline

- **Impaired absorption:** Certain diseases, such as celiac disease, other malabsorption syndromes and congenital disorders can impair the absorption of folate. Additionally, drugs such as phenytoin, primidone and barbiturates (all used to treat various types of convulsions and seizures) can contribute to folate malabsorption.
- **Inadequate utilization:** Congenital or acquired enzyme deficiencies can interfere with the utilization of folate, as can “folate antagonist” drugs such as methotrexate (commonly used to treat arthritis and other rheumatic conditions), triamterene (a potassium-sparing diuretic used to treat edema) and trimethoprim (and antibiotic often used to treat urinary tract infections and pneumonia).
- **Increased demand or excretion:** Lifecycle events, such as pregnancy, lactation or infancy can increase the demand for folate, while renal dialysis can increase the excretion rate of folate.
- **Alcohol intake:** Interferes with folate intake, absorption, metabolism, renal excretion and enterohepatic reabsorption.

The Choline Consumption Gap

Researchers at Iowa State University reported in 2008 that choline intakes for older children, men, women and pregnant women are far below the Adequate Intake (AI) levels. Only 10 percent or less of these groups are eating close to the recommended amounts of choline.^{iv} Data from the 1999-2004 National Health and Nutrition Examination Survey (NHANES) found that choline intakes were lower in blacks than whites of all gender-age groups. This consistently low level of choline intake indicates a need for more public education regarding the necessity of choline intake, especially for the most vulnerable members of the U.S. population, including women, seniors and minorities.^v

The Facts About Choline: What the Science Says

When it comes to choline, the facts are clear; Americans are not meeting the recommended AI for choline. Although choline is well recognized as a vital nutrient for fetal brain development and memory function, scientists are just beginning to understand the vital role that choline plays in cardiovascular health. The body of choline research includes exciting work in the areas of fetal brain development, memory function, breast cancer prevention and cardiovascular health. Read on to learn more about the latest scientific discoveries.

Fetal Brain Development

Choline is a nutrient of vital concern for pregnant and lactating women. Maternal plasma choline can become depleted as fetal demand for choline increases during pregnancy and lactation. The placenta and amniotic fluid store large amounts of choline; plasma choline concentrations can reach up to seven times higher in the fetal blood supply than that of the mother's, indicating the high need for choline in the developing fetus. Identifying choline-rich foods is especially important for women who breastfeed. Breast milk is rich in choline because infant needs are high. Soy- and casein-derived infant formulas generally contain less choline than human milk unless choline is added during processing.^{vi}

Choline is known to be critical during fetal development. Choline influences:

- Stem cell proliferation and apoptosis
- Risk for neural tube defects
- Brain and spinal cord structure and function
- Lifelong memory function

An indication of the importance of adequate dietary choline intake was demonstrated in a case-controlled study that found insufficient maternal intakes of choline during pregnancy were associated with a four-fold increase in the risk of having a pregnancy affected by a neural tube defect. Higher choline intake was associated with a reduced risk of neural tube defects independent of folate intake.^{vii} A separate study found that higher levels of total blood choline were associated with a 2.5-fold reduction in risk for neural tube birth defects (NTDs).^{viii}

What you need to know: Choline has been shown to play an important role in fetal/infant brain development and has been shown to reduce the risk of birth defects, including neural tube defects.

Memory Function

Studies in animal models have shown that choline availability during embryogenesis and perinatal development may be especially important for memory development. Researchers identified two sensitive periods during which treatment with choline produced lifelong memory enhancement in rats, specifically during embryonic days 12 to 17 (rats give birth on day 21) and during postnatal days 16 to 30. Choline supplementation during these sensitive periods resulted in major improvements in memory performance during a maze trial. These improvements persisted into old age and the rats that received more choline during the perinatal period were identifiable later in life via performance in maze trials. Researchers in this study also demonstrated that the normal age-associated memory decline seems to be delayed in rats that receive choline supplementation during the perinatal period.^{ix}

What you need to know: Emerging research indicates that choline intake during the perinatal period not only aids in memory development, but may also delay normal age-associated memory decline later in life.



Choline: The Unknown Essential Nutrient

Breast Cancer Prevention

A study funded by a grant from the National Institutes of Health (NIH) concluded that dietary choline is associated with a 24 percent reduced risk of breast cancer. The case-controlled study examined the diets of 3,000 women who took part in the Long Island Breast Cancer Study Project and found that the risk of developing breast cancer was 24 percent lower among women with the highest intake of choline compared to women with the lowest intake. Women with the highest intake of choline consumed a daily average of 455 mg of choline or more and the women with the lowest intake of choline consumed an average of 196 mg of choline or less per day. This study adds to the body of evidence supporting a link between choline consumption and reduced breast cancer risk.^x Two previously published studies – also supported by NIH grants – reported similar conclusions.^{xi,xii}

What you need to know: Research shows that women who consume higher amounts of dietary choline are at a lower risk of developing breast cancer than those who consume the least amount of choline.

Cardiovascular Health

Researchers studying the Mediterranean diet found that higher intakes of dietary choline and betaine were associated with a reduction in chronic inflammation. Betaine is a metabolite of choline and, like choline, it is involved in the methylation of homocysteine to methionine by providing a methyl donor. Chronic inflammation is recognized as a key player in the etiology of cardiovascular disease. The researchers found that individuals consuming the highest amounts of choline and betaine had significantly lower plasma C-reactive protein, interleukin-6 and tumor necrosis factor-alpha concentrations. These biomarkers are all tools used to assess cardiovascular disease risk.^{xiii} In addition to being a nutrient of concern for women in their childbearing years, choline intake may also be problematic in the general adult population. An analysis of data from the Framingham Offspring Study showed higher intakes of dietary choline and betaine, an oxidative end product of choline, were related to lower homocysteine concentrations independent of other factors including folate and other B vitamins. Elevated plasma homocysteine concentrations are a known risk factor for cardiovascular disease, bone loss, dementia and Alzheimer's disease.^{xiv}

What you need to know: Choline has been shown to play an important role in reducing homocysteine, an amino acid in the blood that may be associated with an increased risk in chronic inflammation which is associated with heart disease risk.

General Health

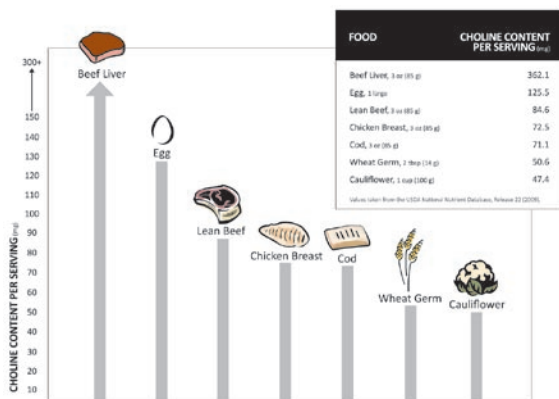
In a study to evaluate the dietary requirements for choline in healthy men and women, researchers found that, when deprived of dietary choline, 77 percent of men and 80 percent of postmenopausal women were found to develop fatty liver or muscle damage, and 44 percent of premenopausal women developed organ dysfunction. During the study all participants were fed a conventional diet containing 550 mg choline for ten days. On the eleventh day, the subjects were fed a choline-depleted diet containing <50 mg choline. When deprived of choline, premenopausal women were less likely to develop organ dysfunction than were men and postmenopausal women. This indicates variability in susceptibility to choline deficiency which may be related to estrogen status.^{xv}

What you need to know: A daily intake of choline at the current AI was not sufficient to prevent conditions such as fatty liver, muscle damage and, in some cases, organ dysfunction. This is important to note as the Institute of Medicine refines estimates for the DRIs for choline.

Closing the Choline Consumption Gap

Closing the Choline Consumption Gap

The best way to meet Adequate Intake levels for choline is to include choline-rich foods in the diet. Most prenatal vitamins and regular multivitamins provide far less than the Adequate Intake for choline. Beef liver*, chicken liver* and eggs are all excellent sources of choline which means that one serving provides 20 percent or more of the recommended amount of choline. Other good food sources of choline include lean beef, chicken breast, cod, wheat germ and cauliflower. The Food Sources of Choline chart (Figure 2) and the table below illustrates the choline content of a variety of foods.



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).

Figure 2: Food Sources of Choline

Excellent Sources	Good Sources	Other Sources
Must contain at least 110 mg of choline per serving (20% of the Daily Value)	Must contain at least 55 mg of choline per serving (10% of the Daily Value)	
Beef Liver, * 3 oz.	Lean Beef	Milk, Skim
Chicken Liver* 3 oz.	Chicken Breast	Soybeans
Egg, 1 Large	Atlantic Cod	Peanuts
	Shrimp	Peanut Butter
	Salmon	
	Wheat germ	
	Cauliflower	

Table 2: Food Sources of Choline

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

Eggs are an excellent source of choline. One egg – including the yolk – contains about 125 milligrams of choline, or roughly one-quarter of the recommended daily amount for breastfeeding and pregnant women. Eggs are also a source of high-quality protein, which, as part of a balanced diet that provides adequate calories, is associated with a healthy birth weight. Eggs are an affordable source of high-quality protein; are easy to prepare, convenient and widely accepted. There are many ways to incorporate eggs into breakfast, lunch, dinner meals and at snack times. The reproducible patient education handouts included with this tool kit are excellent for teaching patients and clients how to easily incorporate the choline they require into a balanced diet that fits their needs. For additional patient education and for choline-rich meal and snack ideas, please visit www.cholineinfo.org.

Cholesterol Myth

Many Americans have shied away from eggs--despite their great taste, good value, convenience and nutrition--for fear of dietary cholesterol. However, more than 30 years of research has shown that most healthy adults can eat eggs on a regular basis without significantly influencing their risk of heart disease or stroke.^{xvi}



A Choline Call to Action

You are now equipped with valuable information about the health benefits of choline. There is an urgent need to share this information with your professional colleagues and patients in order to help them make the choline connection. There are a number of ways that you can help teach others about choline and begin to close the choline consumption gap:

Educate Patients and Consumers:

- Distribute the patient education materials during consultations to educate about choline-rich foods
- Organize a small group session for new moms or moms-to-be to discuss nutrition
- Coordinate a cooking class and highlight recipes which use choline-rich foods
- Host a link to www.cholineinfo.org on your company's patient education Web site
- Coordinate a booth at a community health fair to discuss maternal health and include the consumer education materials in this tool kit

Educate Your Colleagues:

- Host an educational session at your workplace or at a health professional meeting and use The Choline Connection slide presentation to teach your colleagues
- Share this tool kit with your professional mentor or mentee
- Host a link to www.cholineinfo.org on your company's employee Web site for continuing education
- Bring a choline-rich dish to your next office pot-luck and distribute the recipe and choline tips

More Information for You:

- Read what the experts have to say by visiting the Expert Q&A section of www.cholineinfo.org
- Stay informed about the latest choline research by regularly visiting the Research Library on www.cholineinfo.org
- Sign up for regular newsletters and mailings from the Egg Nutrition Center by visiting www.enc-online.org



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Notes

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