What You Eat Is How You Feel: nutrition and its impact on immunity and health

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OVERVIEW

- Introduction to the immune system
- Obesity
- Maternal obesity and infant immunity
- Malnutrition
- Caloric restriction
- Microbiome
- Micronutrients
Immune system defends us against many pathogens

- BACTERIA
- VIRUSES
- PARASITES
- CANCER
- FUNGI
Overview of the immune system, part 1

- **Barriers**: skin, mucus, cilia, tears, saliva - repel microbes
- **Phagocytes**: monocytes and neutrophils - ingest microbes to destroy them
- **Dendritic cells**: ingest microbes and display small parts on their surface
- **NK cells**: kill “unhealthy” cells (cancer, viral infection)
- **Plasma proteins**: cytokines, chemokines, complement

[Image: Innate Immunity diagram]

www.ucsf.edu/lm/immunology_module
Overview of the immune system, part 2

> **B cell**: produce antibodies that can neutralize pathogens or flag them for destruction

> **T cells**:
  > **CD4 helper T cells**: important for antibody production and monocyte function
  > **CD8 killer T cells**: eliminate cancer cells and those infected with pathogens
  > Secrete cytokines and chemokines and antimicrobial peptides
Innate and adaptive immunity work together to eliminate pathogens
Immune system is under the influence of many factors

- Progesterone
- Testosterone
- Estrogen
The impact of weight on immunity

Normal weight

Malnutrition
Starvation

Immunodeficiency

Obesity

Inflammation

Gerriets V. A et al., Front. Immunol., 11 August 2014
30% of US population is obese

Leanest State
Colorado

Fattest State
Mississippi

Percentage of Obese Adult Population
(3-year average from 2011-13 CDC Behavioral Risk Factor Surveillance System data)
Obesity results in increased risk of infection

Infections
- Influenza associated hospitalization
- Urinary tract infections
- Periodontitis
- Hospital acquired infections
- Surgical complications

Immune system changes
- Impaired skin barrier
- Decreased frequency of T cells
- Impaired migration of immune cells
- Over-production of inflammatory cytokines
Excessive Inflammation leads to the development of many chronic diseases.
Maternal obesity and neonatal immunity

Risks to the mother
- Pre-eclampsia
- Gestational Diabetes
- Labor and delivery complications

Risks to the child
- Birth defects
- Still birth
- Obesity and diabetes
- Asthma
- Cardiovascular disease

% obese women 20-45 years old

Maternal obesity may compromise immune system of the neonate

Wilson et al., PAI, 2015
Malnutrition and immunity


Undernutrition
- food security
- appetite
- absorption
- utilization
- excretion

Poverty
- living conditions
- pathogen load
- enteropathy

Infections
- access to health care
- social support

Non-immunological factors increasing severity of disease:
- respiratory muscles
- prone to dehydration
- cardiac function

Immunity
- Affected in severe malnutrition
  - Gastric acid production ↓
  - Flow of saliva ↓
  - Secretory IgA (saliva and tears) ↓
  - Gut permeability ↑
  - Inflammatory cells in intestine ↑
  - Microbicidal activity of granulocytes ↓
  - Blood dendritic cells ↓
  - Blood complement factors ↓
  - Delayed type hypersensitivity ↓
  - Proliferative response to PHA ↓
  - Effector T-cells ↓
  - Apoptosis in lymphocytes ↑
  - B-cells in blood ↓
  - IgA in blood ↑
  - Vaccination titre response ↓

Mortality

Thymus size ↓
Th2 cytokines (IL4, IL10) ↑
Th1 Cytokines (IL2, IL12, IFNγ) ↓

Heilskov Rytter et al., PLoS ONE 9(8): e105017.
Alcohol and immunity

- Alcohol use disorder is associated with increased incidence of bacterial and viral infections (pneumonia, HIV and HCV)
  - Disrupted (leaky) barriers
  - Reduced phagocytosis ability
  - Reduced number of T and B cells
  - Reduced migration of immune cells
- Moderate alcohol consumption is associated with decreased incidence of colds
Alcohol has a dose dependent effect on immunity

Messaoudi et al., 2014
Alcohol has a dose dependent effect on immunity

- Changes in gene expression with excessive ethanol consumption:
  - Suppression of protective immune responses
  - Exacerbation of chronic inflammatory lung disease
  - Increased incidence of cancer
  - Increased incidence of cardiovascular disease

- Changes in gene expression with moderate ethanol consumption:
  - Enhancement of immune cell recruitment
  - Reduced incidence of cancer
Micronutrients and immunity

- Immune cells are metabolically very active and thus are influenced by micronutrients such as vitamins and minerals.
- They primarily serve as:
  - Cofactors of enzymes involved in cell division, and signal transduction
  - Cofactors of transcription factors
  - Anti-oxidants, needed because immune cells have a high burden of reactive oxygen species
  - Epigenetic factors
Vitamins and immunity

- **Vitamin A**: essential for host defense especially at mucosal surfaces (gut, skin, lung and eye)
- **Vitamin C**: anti-oxidant important for phagocytic activity of neutrophils and monocytes; enhances T cell responses
- **Vitamin D**: stimulates production of anti-microbial peptides by keratinocytes and differentiation of monocytes
- **Vitamin E**: lipid soluble anti-oxidant, essential for well functioning of T cells, anti-inflammatory properties
Trace elements and immunity

- **Zinc**: development of lymphocytes, especially T cells; anti-oxidant; essential factor for T cell proliferation and cytokine synthesis;
- **Copper**: neutrophil production; T cell proliferation; anti-oxidant; skin
- **Iron**: phagocytosis and intracellular bacteria killing, T cell proliferation and cytokine responses
- **Selenium**: anti-viral immunity by boosting lymphocyte function; powerful anti-oxidant
**zinc**
- Oysters
- Chicken
- Cheddar Cheese
- Cashews
- Watermelon Seed
- Almonds
- Milk
- Red Meat
- Yoghurt
- Pumpkin Seed
- Salmon
- Cacao/Cocoa
- Dark Choc

**selenium**
- Nutrient-rich foods

**iron**
- Legumes
- Spinach
- Broccoli
- Green vegetables
- Seafood
- Red meat

**copper**
- Nuts
- Seeds
- Mushrooms
- Raisins
- Beans
We coexist with a large number of microbes

<table>
<thead>
<tr>
<th>Body Part</th>
<th>Density</th>
<th>Frequency of Occurrence in Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>esophagus</td>
<td>lactobacilli</td>
<td></td>
</tr>
<tr>
<td>stomach</td>
<td>lactobacilli, streptococci</td>
<td></td>
</tr>
<tr>
<td>small bowel</td>
<td>duodenum, jejunum, ileum</td>
<td>Enterobacteria, Bacteroides spp.</td>
</tr>
<tr>
<td>large bowel</td>
<td>Bacteroides spp., Fusobacterium spp., Strep. faecalis, Escherichia coli</td>
<td>Enterobacteria, Klebsiella spp., subbacteria, bifidobacteria</td>
</tr>
<tr>
<td>fecal material</td>
<td>Bacteroides spp., bifidobacteria, subbacteria</td>
<td>Coliforms, Strep. faecalis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Density</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>very low (10^2-10^5/g)</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>low (10^2-10^5/g)</td>
<td>10-25%</td>
</tr>
<tr>
<td>medium (10^5-10^10/g)</td>
<td>25-75%</td>
</tr>
<tr>
<td>high (&gt;10^10/g)</td>
<td>100%</td>
</tr>
</tbody>
</table>
Functions of the microbiome

- **Protective:**
  - Control of epithelial cells proliferation
  - Induction of tight junctions
  - Induction of IgA
  - Production of antimicrobial peptides
  - Barrier against pathogenic bacteria
  - Education of the immune system

- **Metabolic:**
  - Synthesis of vitamins
  - Fermentation of non-digestible substances
  - Metabolism of dietary carcinogens
  - Energy salvage
Our microbiome is controlled by many factors

- Smaller family size
- Delayed infections
- Antibiotics/vaccinations
- Hygiene and water quality
- Lifestyle (early life)
- Microbiota
- Metabolic signalling
- Immune priming and inflammatory signalling
- Diet and nutrition
- Cooking and refrigeration
- Urban life
And in turn our microbiome influences many aspects of our health
Probiotics and immunity

- **Probiotics**: live bacteria and yeast that can confer health benefits
- **Prebiotics**: non-digestible carbohydrates that provide nutrients for probiotics
- Fermented milk products (e.g. yogurt) contain both live bacteria and the food they need
- **Probiotics**:  
  - Are effective in treating diarrhea, especially after antibiotic treatment  
  - Can help reduce severity of IBD and IBS
Summary

- Adequate nutrition is critical for maintaining a well functioning immune system
  - Nutrient excess and deficiency can both harm the immune system
  - Nutrient excess during pregnancy can affect the immune system of the fetus
  - Alcohol excess harms the immune system
  - Micronutrients are also important for immunity
  - A healthy microbiome is essential for a well functioning immune system
Resources