

# 위해평가와 영양

## 정 해 량

(주)영양과미래

- 위해평가 risk assessment
- 전통적 위해평가와 영양 위해평가
- 영양 분야 위해평가 사례
  - 업산 강화정책
  - 임산부의 해산물 소비 권장
- 식품영양정책과 위해평가

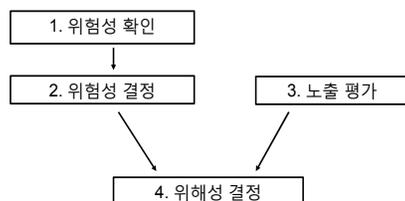
### 위해와 위해평가

- **위해 risk**
  - 식품, 식품첨가물, 기구 또는 용기 포장에 존재하는 위험요소로서 인체의 건강을 해치거나 해칠 우려가 있는 것. 식품위생법 제2조(정의)
- **위해평가 risk assessment**
  - 인체가 식품 등에 존재하는 위해요소에 노출되었을 때 발생할 수 있는 유해영향과 발생확률을 과학적으로 예측하는 일련의 과정으로
- 식품에서 평가대상 위해요소 : 잔류농약, 중금속, 식품첨가물, 잔류 동물용 의약품, 환경오염물질 및 제조, 가공, 조리과정에서 생성되는 물질 등 화학적 요인

위해평가 지침서. 식약처 2011

### 위해평가 과정

- National research council (1983) 소개
- 위험성확인, 위험성결정, 노출평가, 위해도결정 의 4단계



### 1. 위험성 확인 hazard identification

- 독성실험 및 역학연구 등을 활용하여 화학적, 미생물적, 물리적 위해요인의 유해성, 독성 및 그 정도와 영향 등을 파악하고 확인하는 과정
- 주요 내용
  - 물리화학적 성질, 사용용도, 사용량, 사용현황, 제조과정 조사
  - 노출원, 노출기간, 인체영향 여부 및 생물학적 자료 (흡수, 분포, 대사, 배설, 체내 축적성) 조사
  - 독성자료 조사
  - 단기독성, 장기독성, 발암성, 유전독성, 생식독성, 면역독성 등
  - 발암성이 있는 경우 임상 및 동물실험 결과 등을 검토하여 발암성 판단 근거자료를 확보
  - 인체 역학 연구결과, 독성 동태자료 등

## 2. 위험성 결정 hazard characterization

- 위해요소의 노출량과 유해영향 발생과의 관계를 정량적으로 규명하는 단계
- 인체 및 동물 독성자료 등을 토대로, 위해도 결정 시 활용되는 독성값 (NOAEL, BMDL) 및 인체 안전기준을 설정하는 단계

- 인체안전 기준치 (Health based guidance level)
  - **ADI**: 인허가 대상물질 (식품첨가물, 농약, 동물용 의약품 등)로서 의도적으로 사용되는 물질에 적용
    - Acceptable Daily Intake, 1일 섭취 허용량: 인간이 평생 섭취해도 관찰할 수 있는 유해 영향이 나타나지 않는 1인당 1일 최대 허용섭취량 (단위, Mg/kg bw/day)
  - **TDI**: 비의도적으로 노출되어 환경 등을 통해 노출되는 물질에 적용
  - **aRfD**: 축적 독성이 약하며 일시적 노출로 가장 민감한 영향 등을 일으키는 급성 독성 물질 (유기인제 농약, 클렌부테놀 등)

## 3. 노출평가 exposure assessment

- 식품 등을 통하여 사람이 섭취하는 위해 요소의 양 또는 수준을 정량적 및 (또는) 정성적으로 산출하는 과정

## 4. 위해도 결정 risk characterization

- 위험성 확인, 위험성 결정 및 노출평가 결과를 근거로 하여, 평가대상 위해요인이 인체건강에 미치는 유해영향 발생과 위해정도를 정량적 또는 정성적으로 예측하는 과정

$$\text{위해도 산출 (\%)} = \frac{\text{유해물질의 노출량} \left( \frac{\text{mg}}{\text{kg}} \frac{\text{bw}}{\text{day}} \right) \times 100}{\text{인체안전 기준치 (ADI or TDI)} \left( \frac{\text{mg}}{\text{kg}} \frac{\text{bw}}{\text{day}} \right)}$$

- 식품첨가물 위해평가는 1일 허용 섭취량 대비 추정 1일 허용섭취량을 비율로 표시

$$\text{첨가물 위해평가 (\%)} = \frac{\text{추정 1일 허용 섭취량} \left( \frac{\text{mg}}{\text{kg}} \frac{\text{bw}}{\text{day}} \right) \times 100}{\text{1일 허용 섭취량} \left( \frac{\text{mg}}{\text{kg}} \frac{\text{bw}}{\text{day}} \right)}$$

## 영양 위해평가

## 전통적 위해평가 방법과 영양 위해평가

- 전통적 위해평가
  - 여러 변수와 가정을 통해 노출과 위해를 계량화
    - 독성물질: 무편의. 소비자에게 위해가 없는 보수적 접근
    - 의약품: 일부 부작용도 채택
- 영양 위해평가
  - 복합적, 위해와 편익의 균형
  - 영양소 부족, 영양소 과잉

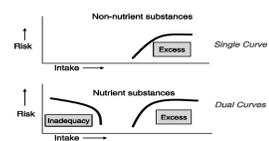
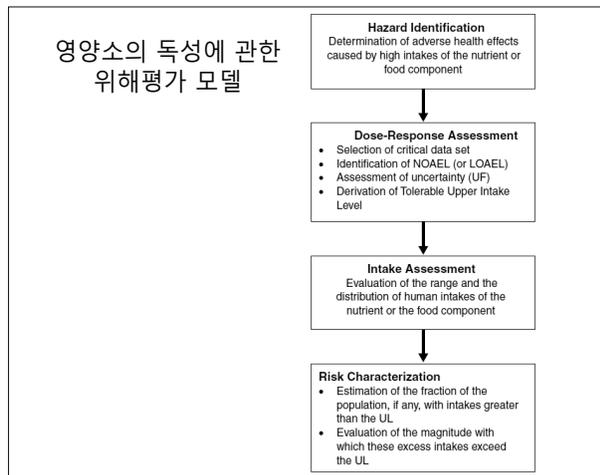


FIGURE 3-2 Comparison of the relationship between intake and risk for non-nutrient and nutrient substances. Non-nutrient suffer from assumptions in that nutrient present dual risk curves (that is, risk curves for both inadequacy and excess).



### 영양소의 위험성 확인

Group A 위해 가능성 매우 낮음	Group B 위해 가능성 낮음	Group C 위해 가능성 높음
비타민 B1 B2 B12 K 비오틴 판테텐산	비타민 D E B6 C 나이아신	비타민 A 엽산 Ca Fe Zn Cu Mn Se

### 노출평가 : 식품첨가물과 영양소

#### How Dietary Exposure Works

**Chemical Y**

Person 1	Exposure
150 ml	= 3 mg/d
Person 2	Exposure
960 ml	= 19 mg/d
40 g	= 6 mg/d
	Σ 25 mg/d

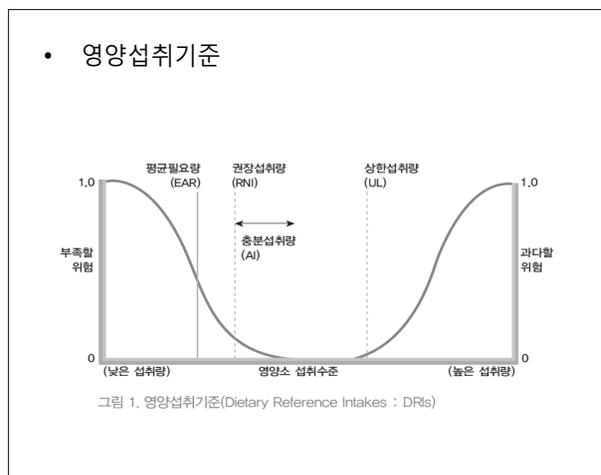
식품내 화학물질 농도 \* 식품 섭취량 = 노출량

#### How Dietary Intake Works

**Nutrient Y**

Person 1	Intake
150 ml	= 3 mg/d
Person 2	Intake
960 ml	= 19 mg/d
40 g	= 6 mg/d
	Σ 25 mg/d

식품내 영양조성 \* 식품 섭취량 = 섭취량



- ### 한국인 영양섭취기준
- 평균필요량(Estimated Average Requirement, EAR)**
    - 대상 집단을 구성하는 사람들의 절반에 해당하는 사람들의 일일 필요량을 충족시키는 값
    - 대상 집단의 필요량 분포치 중앙값
    - 영양소의 부족을 평가하기 위한 최소량의 기준
  - 권장섭취량(Recommended Nutrient Intake, RNI)**
    - 성별, 연령군별로 거의 모든(97~98%) 건강한 인구 집단의 영양소 필요량을 충족시키는 추정치
    - 평균필요량에 표준편차의 2배를 더한 값
    - 평균필요량이 정해진 영양소에 한해서만 권장섭취량이 정해지게 되며, 기존의 영양권장량(RDA)과 동일한 개념
  - 충분섭취량(Adequate Intake, AI)**
    - 영양소 필요량에 대한 정확한 자료 등이 부족하여 권장섭취량을 정할 수 없는 경우 역학조사에서 관찰된 건강한 사람들의 영양소 섭취량의 중앙값으로 결정
  - 상한섭취량(Tolerable Upper Intake Level, UL)**
    - 과잉 섭취로 인한 건강상의 위험이 나타날 수 있는 경우 인체에 건강유해영향이 나타나지 않는 최대영양소섭취수준
    - 개인 차이와 불확실성 등을 충분히 감안하여 설정

### 위해평가의 영양분야 적용 사례

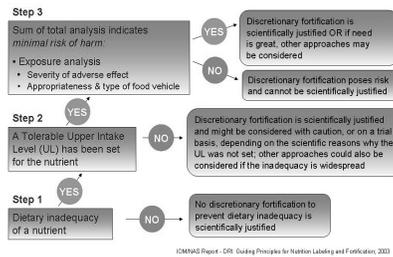
### 업산 강화정책

#### 식품 첨가물 및 영양소 강화의 기본 접근

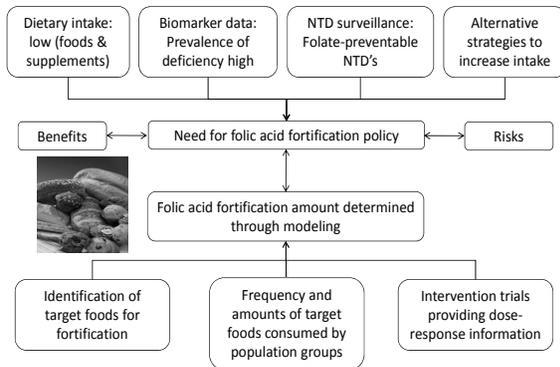
- 해당 화학물질/영양소의 현재 섭취량 산출
- 규정을 변경할 경우 (즉 식품 내 농도를 변경)의 향후 섭취량 추정
- 현재 섭취량과 향후 추정 섭취량을 건강 기준과 비교
  - ADI, UL 등의 초과 비율 (적절한 것으로)
  - EAR 미만 비율 (영양소일 경우)

### 임의 강화 정책

- Decision tree for the discretionary fortification of foods (IOM 2003).

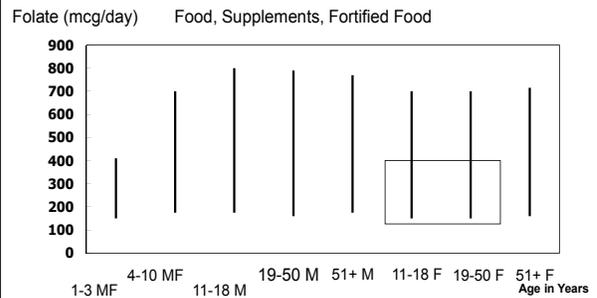


### 업산 강화정책의 도입

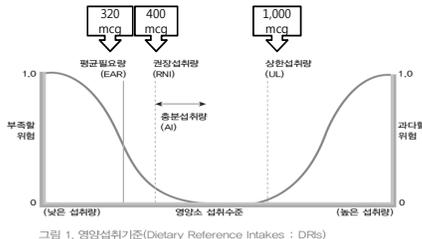


Feinleib M et al. Folate fortification for the prevention of birth defects: case study. Am J Epidemiol 2001

- 균형
  - 모든 소비자에 안전한 섭취
  - 표적 소비자의 섭취 증가

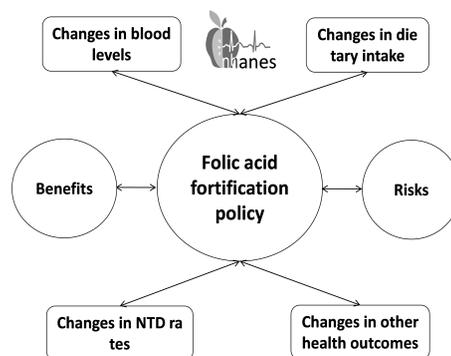


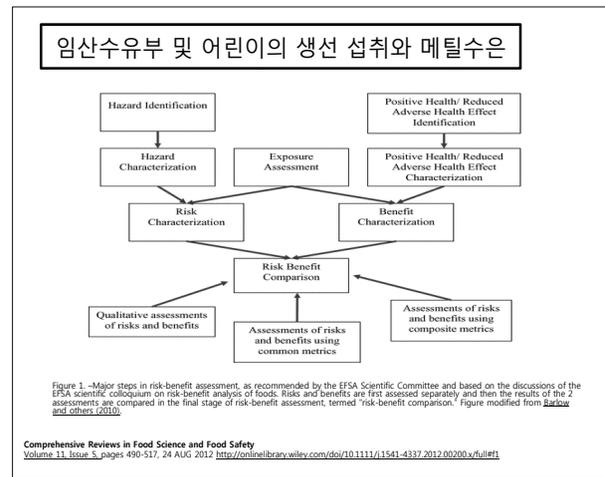
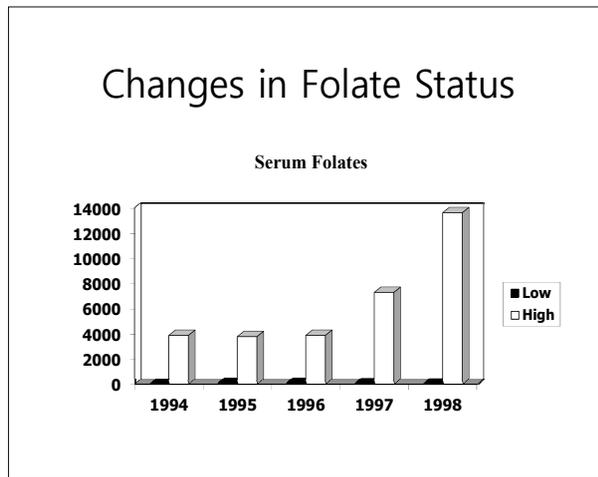
### 업산 강화 기준 결정



- "enriched" 시리얼 곡류제품에 업산강화 의무화
- 아침식사용 시리얼에 100% 영양소 기준치 (400 µg/serving)까지 강화 허용
- 식사보충제는 강화 수준 제한 없음
- 1996년 시행

### 업산 강화정책의 영향 모니터링





### Identification and characterization of the health effects of seafood

- Positive or reduced adverse health effects of seafood

Table 1—Health guidance values for beneficial compounds worldwide.

Compound	Guidance term	Guidance value	Target population	Organization/reference
DHA + EPA	RI	500 mg/d	1a	ISSFAL 2004
	RDI	250 mg/d	1c	FAO/WHO 2008
	RDI	300 mg/d*	4a	FAO/WHO 2008
	RI	1000 mg/d*	5	AHA/Kris-Etherton and others 2003
EPA + DHA	—	800 mg	1b	NATO (Simopoulos 1989)
	—	EPA + DHA	—	—
DHA + EPA/seafood	RI	Two, 113-g servings of seafood per week, equivalent to about 250 mg/d	1b	DCAG 2010
Omega-3 fatty acids from fish	AI	450 mg/d	All	HCN (Netherlands 2006)
	RDA	500 mg/d	1b4b	AFSA (AFFSA 2010)
Long-chain omega-3 fatty acids	RDA	250 mg DHA and 500 mg EPA + DHA	—	—
Fish	—	Two servings of fish per week, especially fatty fish	1b	AHA (Kris-Etherton and others 2003)
PUFA	—	500 mg/d long chain PUFA	1b	ADA (Kris-Etherton 2007)
ALA; 10% EPA + DHA	—	1.6 g/d approximately 10% EPA + DHA; 1.1 g/d approximately 10% EPA + DHA	23	ICM 2005a
n-3 PUFAs	—	1% to 2% of energy/d	1b	WHO (WHO/FAO 2002)
DHA	—	200 mg DHA	4c	WAPM (Kolezic and others 2007)

\*of which at least 200 mg/d should be DHA.  
1. (a) healthy adults; (b) general adult population; (c) adult males and nonpregnant/nonlactating adult females; (d) adult males.  
2. Adult males.  
3. Adult women.  
4. (a) Adult pregnant and lactating females; (b) pregnant women; (c) pregnant and lactating women.  
5. Patients with cardiovascular disease.  
6. See Appendix 3 for abbreviations/acronyms.

- Hazards and negative health effects of seafood

Table 2—Health guidance values for contaminants worldwide.

Compound	Guidance term	Guidance value	Target population	Organization/reference
Mercury	RfD	0.1 µg/kg bw/d	1c	EPA 2001; Rice and others 2003
	PTDI	0.2 µg/kg bw/d (0.47 µg/kg bw/d)	3; 1b	HC (Dabeka and others 2004)
	PTWI	0.3 µg/kg bw/d*	1c	FAO/WHO (JECFA 2003)
	MRL	0.3 µg/kg bw/d	1d	ASTDR 1999
Hg in seafood	GL	0.23 µg/kg bw/d (0.47 µg/kg bw/d)	2; 4a	SACN/COT 2004
	ML	0.5 ppm; 1.0 ppm for sea food	1	HC (2007)
Cadmium	EU ML	0.5 ppm*	1	EC (2006)
	AL	1.0 ppm	1	FDA (2011)
Lead	PTWI	0.83 µg/kg of body wt/d*	—	JECFA 2010
	PTWI	3.6 µg/kg of body wt/d*	—	JECFA 2010
Hexachlorobenzene	TDI	0.1 µg/kg bw/d (0.10 µg/kg bw/d)	5; 6	IPCS 1997
	PTM <sup>b</sup>	2.33 pg TEQ/kg body wt/d*	—	JECFA 2001
Dioxins and d PCBs	PTWI	2 pg TEQ/kg body wt/d*	4b	SCF 2001a; SCF 2001b
	GL	2 pg TEQ/kg bw/d; 8 pg TEQ/kg bw/d	4b; 4a	SACN/COT 2004
Dioxins (PCDD/F)	EU ML	4 pg TEQ <sup>c</sup>	1	EC 2006
	TDI	1 pg TEQ/kg bw/d	1	FAO/WHO (JECFA 2003)
Dioxins and d PCBs <sup>d</sup>	EU ML	8 pg TEQ <sup>c</sup>	1	EC 2006
	TDI	0.3 µg/kg bw/d	1	HC (Health Canada 2007)
PCBs	REF <sup>e</sup>	0.02 µg/kg bw/d	1c	EPA 1999
	CO MRL <sup>f</sup>	0.02 µg/kg bw/d	1	AISDR 2009
PCBs <sup>g</sup>	TDI	0.02 µg/kg bw/d (0.01 for PCBs)	4c	AFSA 2007
	TL <sup>h</sup>	2.0 ppm	1	FDA/ EPA (FDA 2011)

\*Originally expressed on a weekly or monthly basis. <sup>a</sup>Reference TDI was based on 30-d wet. <sup>b</sup>Only in regards to dioxin 1016, 1248, and 1254. <sup>c</sup>PCDDs, orange coum, maleic, fish and trans trans, thak, and methyl. <sup>d</sup>For protection of infants. <sup>e</sup>Reference to 2010 to use the WHO established. <sup>f</sup>The grain source, meat of fish and bakery products, including wet to fish. <sup>g</sup>all (B) general population; (c) all (B) special groups in need; (d) all potentially exposed populations. <sup>h</sup>Original source and present use are not known or present with a trace.  
1. Children and women of childbearing age.  
2. For protection against reproductive adverse effects (that is, increased cancer risk); (b) for protection of developing male reproductive system; (c) for protection of developmental effects.  
3. For reproductive effects.  
4. For reproductive effects.  
5. See Appendix 3 for abbreviations/acronyms.

### Qualitative risk-benefit assessments

- Seafood 관련한 많은 건강 종합점을 고려한 통합적 평가를 위해 몇 가지 대규모 질적 평가 수행
  - 2005. National Oceanic and Atmospheric Administration, Institute of Medicine.
  - 2006. Harvard School of Public Health and Harvard Medical School
  - 2010. FAO/WHO. 코덱스 위원회의 과학 자문 요청에 따라 전문가 협의 개최
  - 2010. Dietary Guidelines Advisory Committee

Comprehensive Reviews in Food Science and Food Safety  
Volume 11, Issue 5, pages 490-517, September 2012

### Quantitative risk-benefit assessments

- Assessments based on common metrics
  - 단일 성과. 예. 사망률, 이환율, 건강 관련 기준값의 초과/부족 등
- Assessments based on composite metrics
  - Studies using QALYs
  - Health-based monetary impacts

**FOODS AND NUTRIENTS TO INCREASE**

Individuals should meet the following recommendations as part of a healthy eating pattern while staying within their calorie needs.

- Increase vegetable and fruit intake.
- Choose a variety of vegetables, especially dark green and red and orange vegetables and beans and peas.
- Consume at least half of all grains as whole grains. Increase whole grain intake by replacing refined grains with whole grains.
- Increase intake of fat-free or lowfat milk and milk products, such as milk, yogurt, cheese, or fortified soy beverages.<sup>4</sup>
- Choose a variety of protein foods, which include seafood, lean meat and poultry, eggs, beans and peas, soy products, and unsalted nuts and seeds.
- Increase the amount and variety of seafood consumed by choosing seafood in place of some meat and poultry.
- Choose protein foods that are higher in solid fats with choices that are lower in solid fats and calories and/or are sources of oils.
- Use oils to replace solid fats where possible.
- Choose foods that provide more potassium, dietary fiber, calcium, and vitamin D, which are nutrients of concern in Americans' diets. These foods include vegetables, fruits, whole grains, and milk and milk products.

**Recommendations for specific population groups**

*Women capable of becoming pregnant<sup>5</sup>*

- Choose foods that supply heme iron, which is more readily absorbed by the body, additional iron sources, and enhancers of iron absorption such as vitamin C-rich foods.
- Consume 400 micrograms (mcg) per day of synthetic folic acid (from fortified foods and/or supplements) in addition to food forms of folate from a varied diet.<sup>6</sup>

*Women who are pregnant or breastfeeding<sup>7</sup>*

- Consume 8 to 12 ounces of seafood per week from a variety of seafood types.
- Due to their high methyl mercury content, limit white (albacore) tuna to 6 ounces per week and do not eat the following four types of fish: tilefish, shark, swordfish, and king mackerel.
- If pregnant, take an iron supplement, as recommended by an obstetrician or other health care provider.

*Individuals ages 50 years and older*

- Consume foods fortified with vitamin B<sub>12</sub>, such as fortified cereals, or dietary supplements.

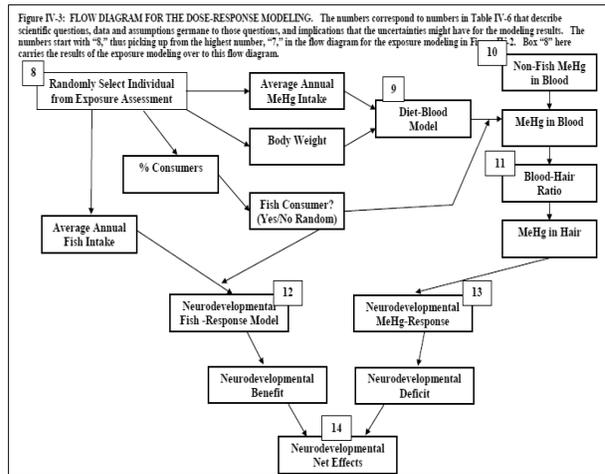
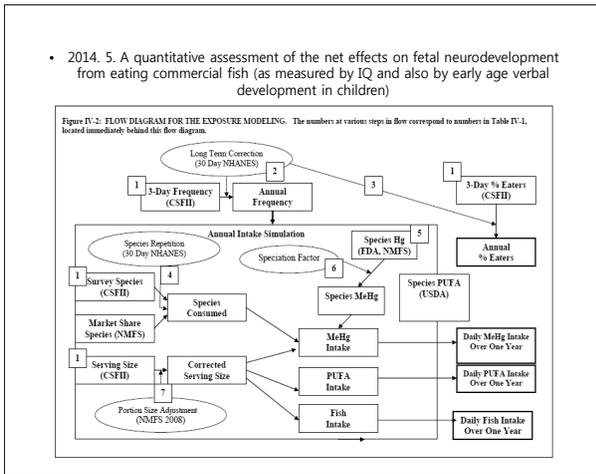
**TABLE A2.1. Key Consumer Behaviors and Potential Strategies for Professionals (Continued)**

Topic Area	Key Consumer Behaviors	Potential Strategies
<b>PROTEIN FOODS</b>	Choose a variety of foods from the protein foods group.	Eat a variety of foods from the protein foods group each week. This group includes seafood, beans and peas, and nuts, as well as lean meats, poultry, and eggs.
	Increase the amount and variety of seafood consumed by choosing seafood in place of some meat and poultry.	Eat seafood in place of meat or poultry twice a week. Select some seafood that is higher in oils and lower in mercury, such as salmon, trout, and herring.  Select lean meats and poultry. Choose meat cuts that are low in fat and ground beef that is extra lean (at least 90% lean). Trim or drain fat from meat and remove poultry skin before cooking or eating.  Try grilling, broiling, poaching, or roasting. These cooking methods do not add extra fat.  Drain fat from ground meats after cooking. Avoid breading on meat and poultry, which adds calories.

**APPENDIX 11. ESTIMATED EPA AND OHA AND MERCURY CONTENT IN 4 OUNCES OF SELECTED SEAFOOD VARIETIES**

Common Seafood Varieties	EPA-DBP <sup>1</sup> mg/kg wet wt	Mercury <sup>2</sup> mg/kg wet wt
Salmon <sup>1</sup> : Atlantic <sup>2</sup> , Chinook <sup>2</sup> , Coho <sup>2</sup>	2,300-2,600	0-10
Albacore <sup>1</sup> : "Longfin" <sup>2</sup> , Tail and Shell <sup>2</sup>	1,300-1,600	0-13
Mackerel: Atlantic and Pacific (not King)	1,300-2,300	0-13
Tuna: Bluefin <sup>1</sup> and Albacore <sup>1</sup>	1,700	54-58
Sardines <sup>1</sup> : Atlantic <sup>2</sup> and Pacific <sup>2</sup>	1,000-1,600	2
Oysters: Pacific <sup>2</sup>	1,550	2
Tuna: Freshwater	1,000-1,000	11
Tuna: White (Albacore) canned	1,000	40
Mussels <sup>1</sup> : Blue <sup>2</sup>	900	NA
Salmon <sup>1</sup> : Pink <sup>2</sup> and Sockeye <sup>2</sup>	700-900	2
Squid	750	11
Crab	600	6
Pollock <sup>1</sup> : Atlantic <sup>2</sup> and Walleye <sup>2</sup>	200-550	9
Cod <sup>1</sup> : Blue <sup>2</sup> , King <sup>2</sup> , "Snow" <sup>2</sup> , Queen <sup>2</sup> , and Norwegian <sup>2</sup>	150-300	31-49
Tuna: Skipjack and Yellowfin	150-300	0
Clam <sup>1</sup>	100-300	0
Tuna: Light canned	150-300	13
Catfish	100-250	7
Crab <sup>1</sup> : Atlantic <sup>2</sup> and Pacific <sup>2</sup>	200	14
Scallops (1/2 Bay and Sea <sup>2</sup> )	200	2-5
Haddock <sup>1</sup> and Hake <sup>1</sup>	200	47
Unfished <sup>1</sup> : Northern <sup>2</sup> American <sup>2</sup>	200	5
Coyfish <sup>1</sup>	200	2
Tilapia	150	5
Shrimp	700	0
<b>Seafood varieties that should not be consumed by women who are pregnant or breastfeeding<sup>3</sup></b>		
Shark	1,250	81
Tilefish <sup>1</sup> : Gulf of Mexico <sup>2</sup>	1,000	279
Swordfish	1,000	147
Mackerel: King	450	133

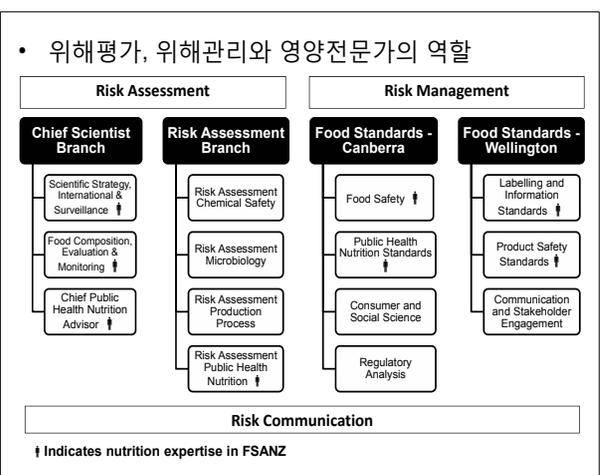
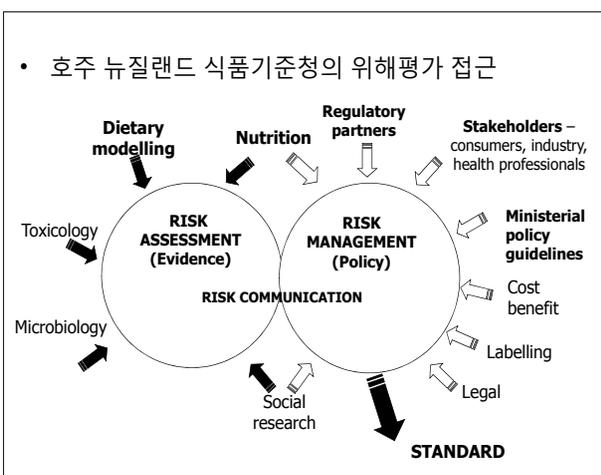
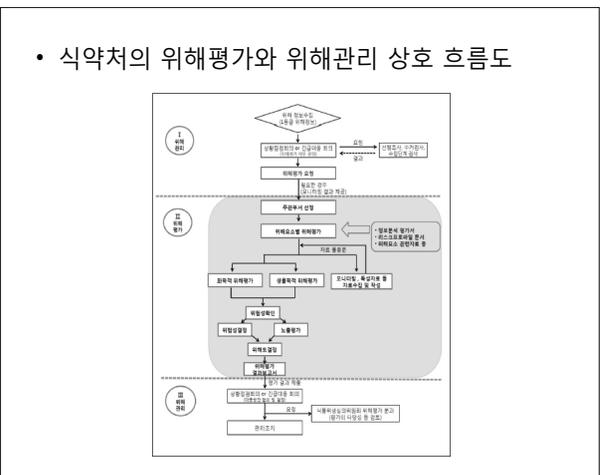
- 2014. 3. FDA/EPA. "Fish: What you need to know about mercury in fish and shellfish" 개정안 발표
  - Risk benefit message
    - 가임기 여성, 임신수유부, young children
      - 단백질 제공, 포화지방 낮고, 여러 미량영양소 풍부. 오메가 3계 지방산 제공
      - 수은을 메틸수은 형태로 함유. 메틸수은은 중양성경계에 영향, 태아의 뇌 발달 저해.
  - 여성 (가임기 여성, 임신수유부) 및 어린이를 위한 3가지 안전 요령
    - Do not eat shark, swordfish, king mackerel, tilefish
    - Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury
    - Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers, and coastal areas



# 식품영양정책과 영양 위해평가



- ### 식품분야 위해평가 관련 규정
- 식품안전기본법
    - 제20조(위해성평가)
  - 식품위생법
    - 제15조(위해평가)
      - 위해평가방법 및 절차 등에 관한 지침
      - 식품에서 평가대상 **위해요소** : 잔류농약, 중금속, 식품첨가물, 잔류 동물용 의약품, 환경오염물질 및 제조, 가공, 조리과정에서 생성되는 물질 등 화학적 요인



### 영양분야 위해의 범위

- the adequacy–toxicity continuum as it relates to the direct effects of essential nutrients;
- 식중독, 알러지 포함
- the broad areas of the **effects of diet on health** as they relate to the prevention and management of chronic diseases.



hrchung@nutrikorea.com