Dairy Foods as a Vehicle for Vitamin D Delivery

Mairead Kiely

Vitamin D Research Group

University College Cork

http://www.ucc.ie/en/vitamind/

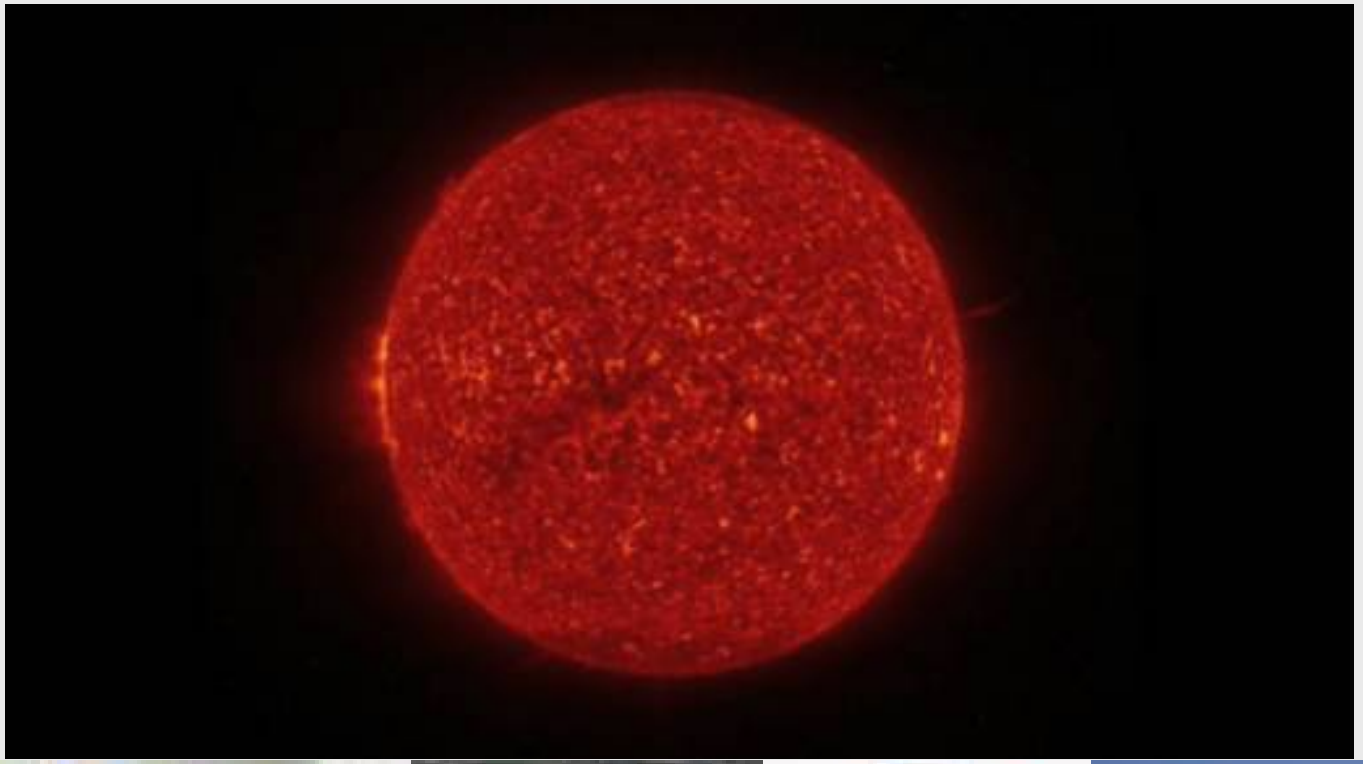
ucc
Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

The vitamin D PROBLEM

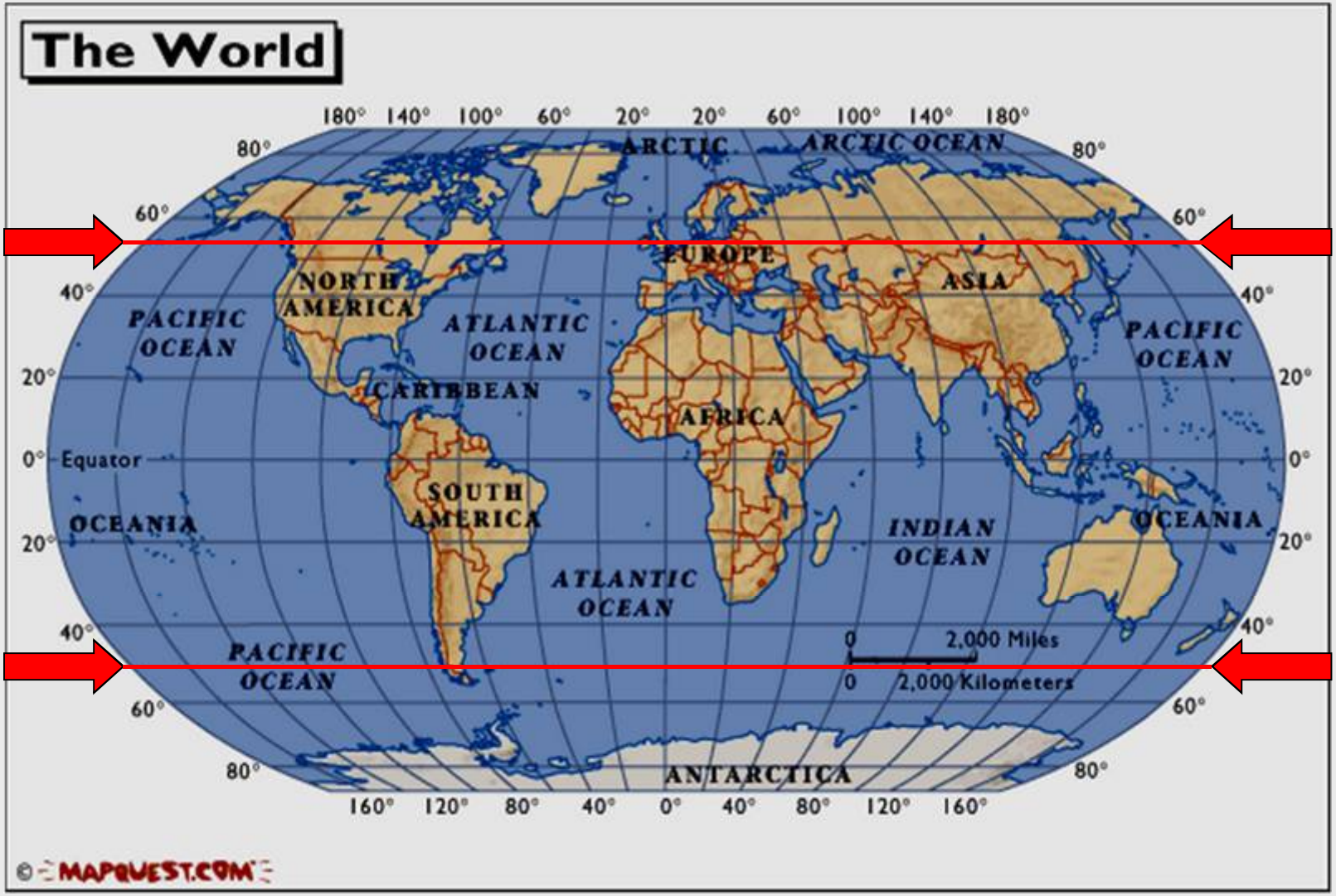
Low vitamin D status is endemic at Northern latitudes, particularly in winter

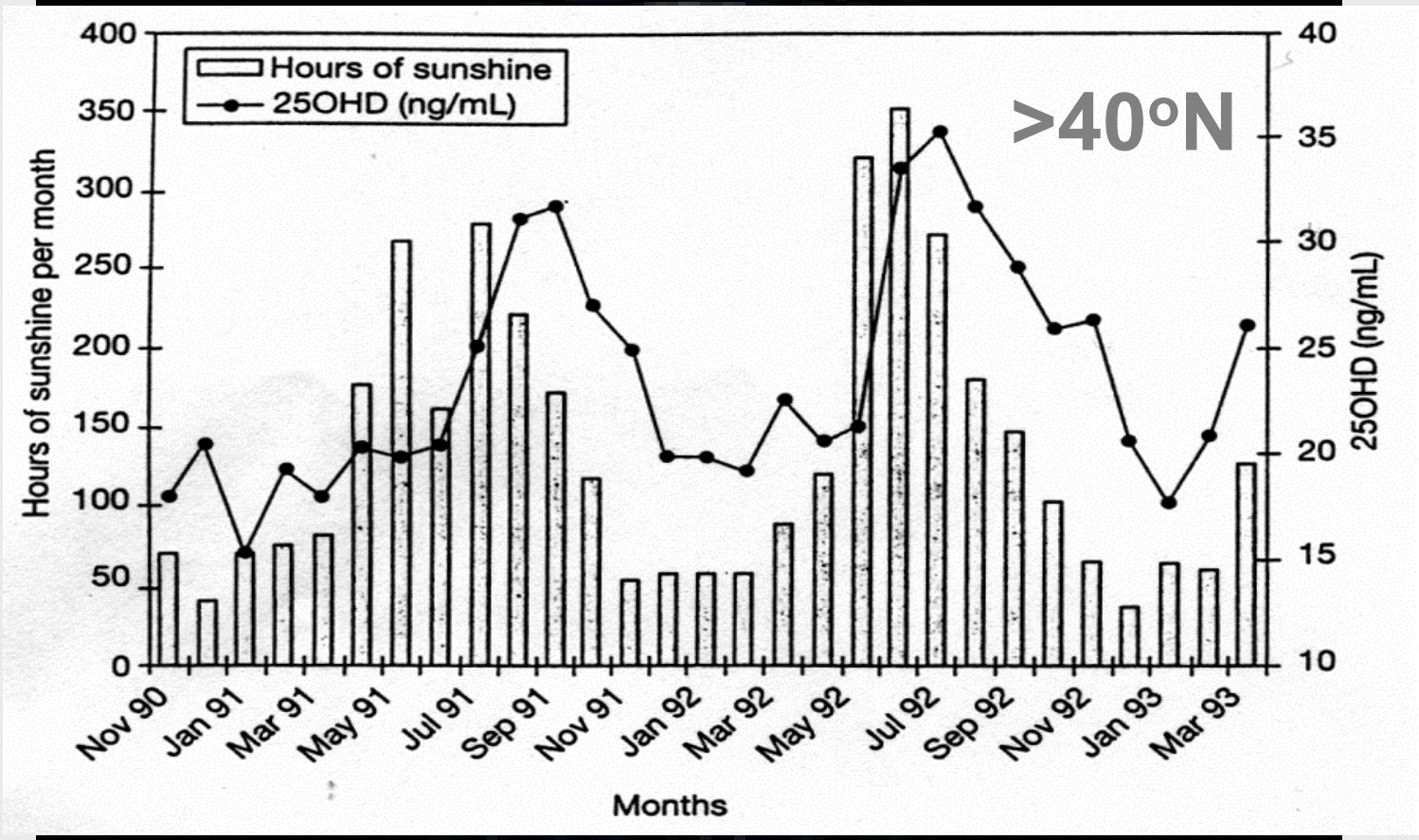
Inadequate sun exposure &
Insufficient dietary supply

Sources of Vitamin D



Typically around 3-5 µg/d

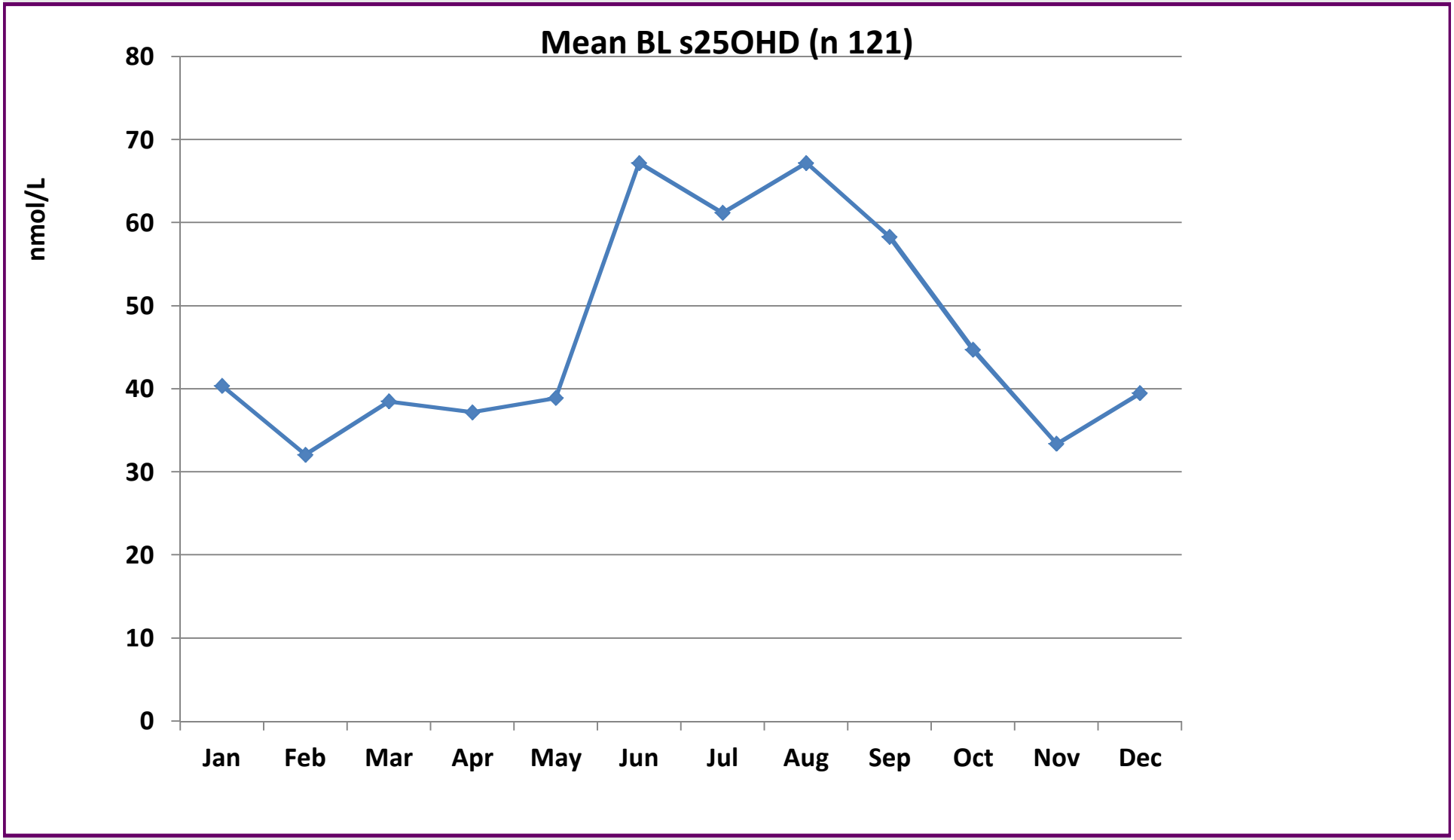

The World
52°N
ARCTIC
ARCTIC OCEAN
EUROPE
ASIA
NORTH AMERICA
PACIFIC OCEAN
ATLANTIC OCEAN
CARIBBEAN
AFRICA
PACIFIC OCEAN
Equator
SOUTH AMERICA
OCEANIA
INDIAN OCEAN
OCEANIA
ATLANTIC OCEAN
PACIFIC OCEAN
0 2,000 Miles
0 2,000 Kilometers
ANTARCTICA
180° 140° 100° 60° 20° 20° 60° 100° 140° 180°
80° 60° 40° 20° 0° 20° 40° 60° 80°
160° 120° 80° 40° 0° 40° 80° 120° 160°
©MAPQUEST.COM


Hours of sunshine
25OHD (ng/mL)
>40°N
Hours of sunshine per month
25OHD (ng/mL)
Months
400
350
300
250
200
150
100
50
0
40
35
30
25
20
15
10
Nov 90
Jan 91
Mar 91
May 91
Jul 91
Sep 91
Nov 91
Jan 92
Mar 92
May 92
Jul 92
Sep 92
Nov 92
Jan 93
Mar 93

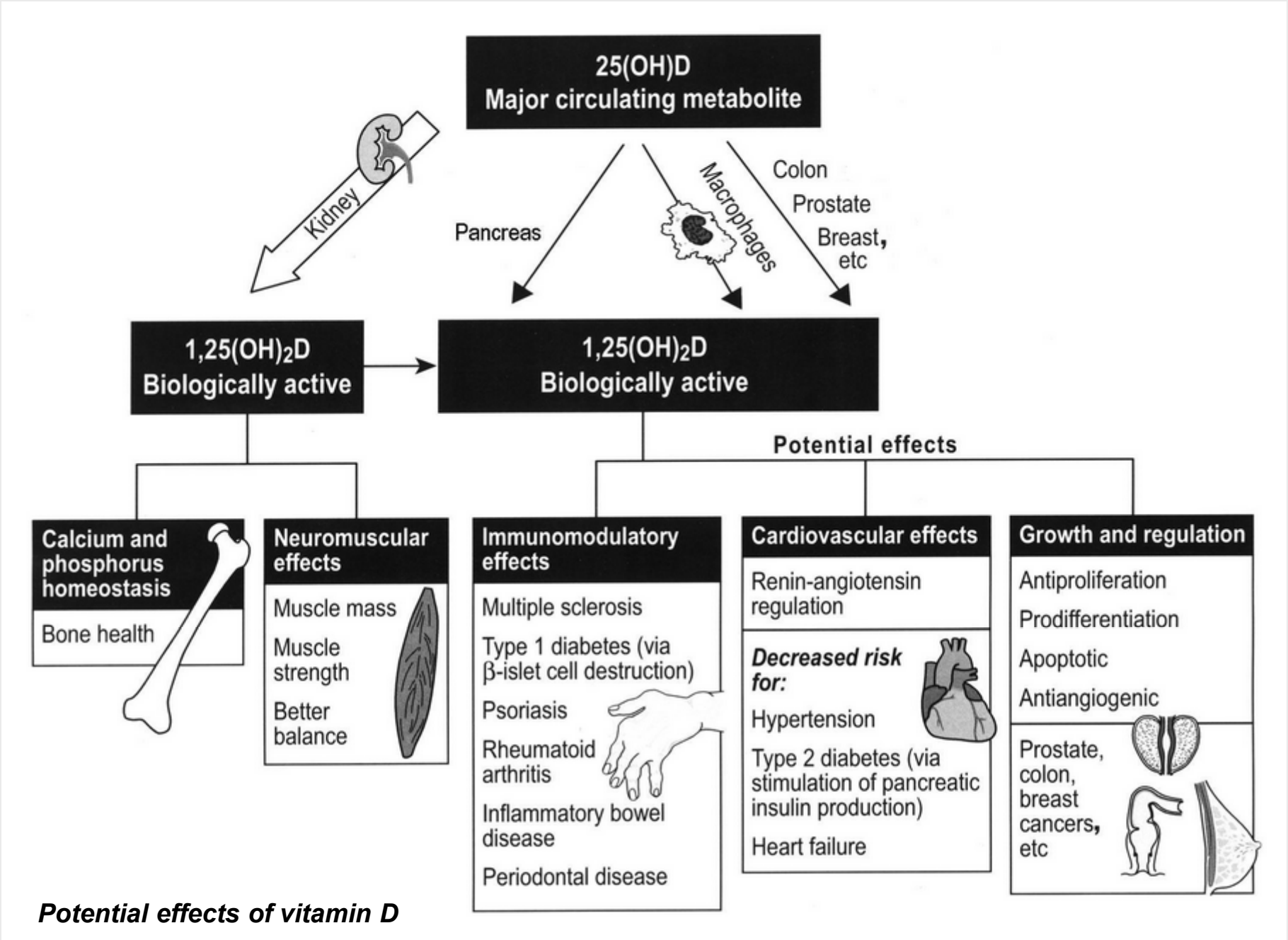
°N

°S

Mean s25OHD in post-partum women according to calendar month




Intake
Status
Naturally occurring
Added/enhanced
Supplemental
Everyone
months
UVB
exposure
Physiological variation
skin colour
age
genotype
body composition ….
Breast milk
6 months
Formula
PREVENT DEFICIENCY
PHYSIOLOGICAL – HEALTH EFFECT?



Potential effects of vitamin D

(Holick, 2006)

Vitamin D Research Group at UCC progress of work

2001

Intakes of vitamin D low in Ireland across the population

Food composition data inadequate

2003-2008

Vitamin D status low in young adults, adolescents, older adults, postmenopausal women, girls, men, pregnant women

2005-2011
Adverse consequences for skeletal, metabolic and cognitive health

Pregnancy, atopic disease, infection?

2008-2012

Dietary requirements higher than previously believed in younger and older adults, girls and breastfeeding women

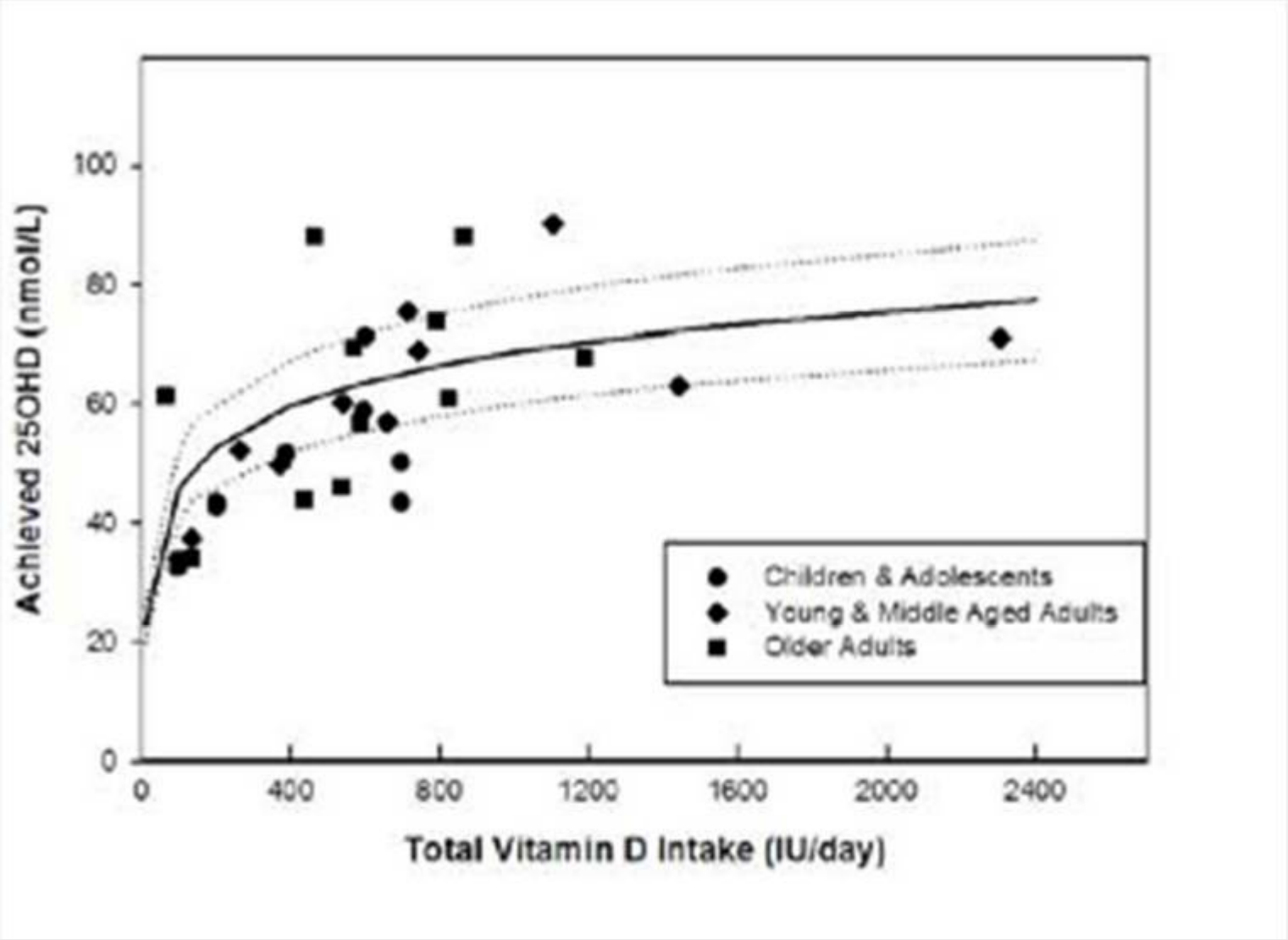
- Nutrition surveillance
  - National nutrition surveys
- Clinical Research
  - CUH/CUMH
- Intervention studies
  - Human Nutrition Research Unit

Dietary Reference Intakes (µg/d) for vitamin D

Age group	EAR	RDA	UL
0-6 mo	-	10‡	25
7-12 mo	-	10‡	37.5
1-3 y	10	15	62.5
4-8 y	10	15	75
9-69 y	10	15	100
70+ y	10	20	100
Pregnancy	10	15	100
Lactation	10	15	100

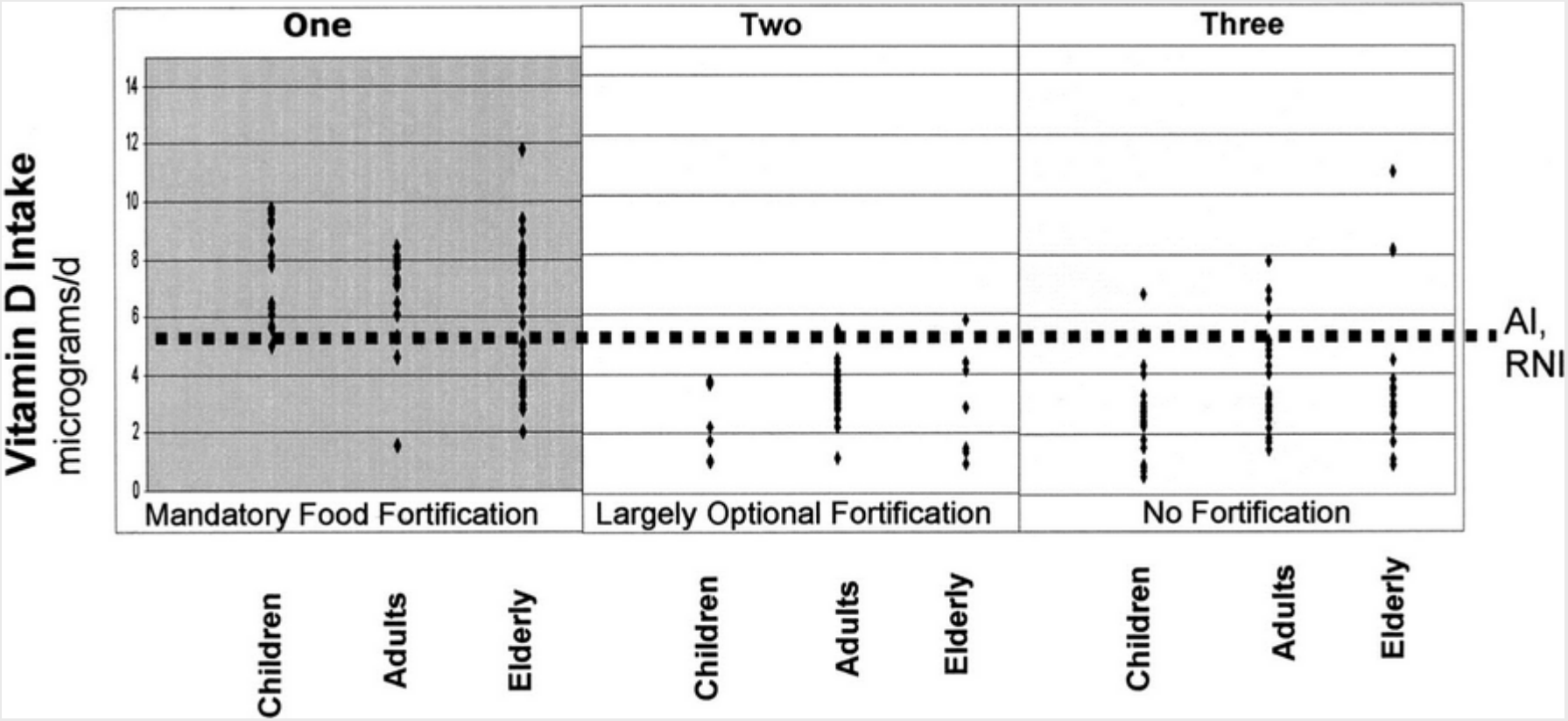
IOM, 2011

Response of serum 25OHD level to total intake of vitamin D in northern latitudes during winter



IOM, 2010; Fig 5-4

Vitamin D in countries classified by the national food fortification policy



Calvo M S et al. J. Nutr. 2005;135:310-316

Median (IQR) vitamin D intakes from food in the Canadian Community Health Survey (2004)

	Age group	N	Median	IQR
Male	9-18	4536	6.9	4.9, 9.4
	19-50	4650	5.7	4.0, 7.8
	51-70	2730	5.6	3.7, 8.3
	>70	1605	5.3	3.9, 8.0
Female	9-18	4406	5	3.7, 6.8
	19-50	5018	3.5	1.7, 6.0
	51-70	3412	4.5	3.2, 6.6
	>70	2777	4.4	3.2, 6.4

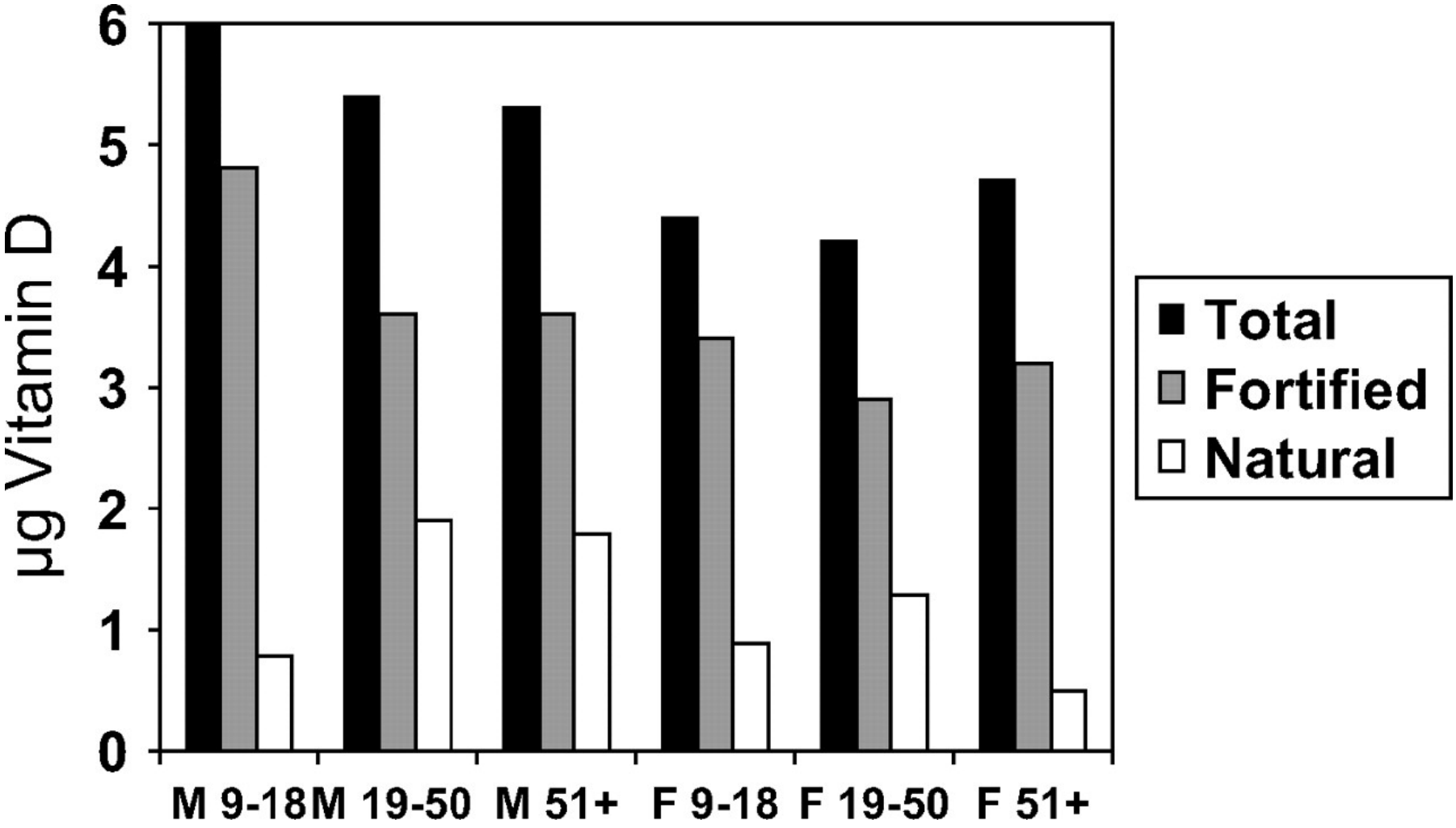
Whitton et al, 2011 BJN; 106, 1899-914

Median (IQR) vitamin D intakes from food in the UK NDNS rolling program (2008-2009)

	Age group	N	Median	IQR
Male	4-10	119	1.8	1.2-2.5
	11-18	114	2	1.3-2.9
	19-64	181	2.8	1.9-3.6
Female	4-10	119	1.9	1.3, 2.4
	11-18	110	1.8	1.3-2.4
	19-64	253	2.3	1.3-3.4

Whitton et al, 2011 BJN; 106, 1899-914

Vitamin D from fortified and natural food sources by sex & age NHANES (1999–2000)



Calvo M S , Whiting S J J. Nutr. 2006;136:1135-1139

Distribution of Vitamin D intake in the US NHANES (2003-6)

µg/d	10	25	50	75	90		<EAR
Natural	0.7	1.0	1.5	2.1	2.9		100
+ fortified	2.3	3.5	5.4	7.9	10.9		87
+supplements	2.5	3.9	6.3	10.5	15.5		73

Fulgoni et al, 2011; J Nutr: 141, 1-8

Vitamin D intakes in 18–64-y-old Irish adults

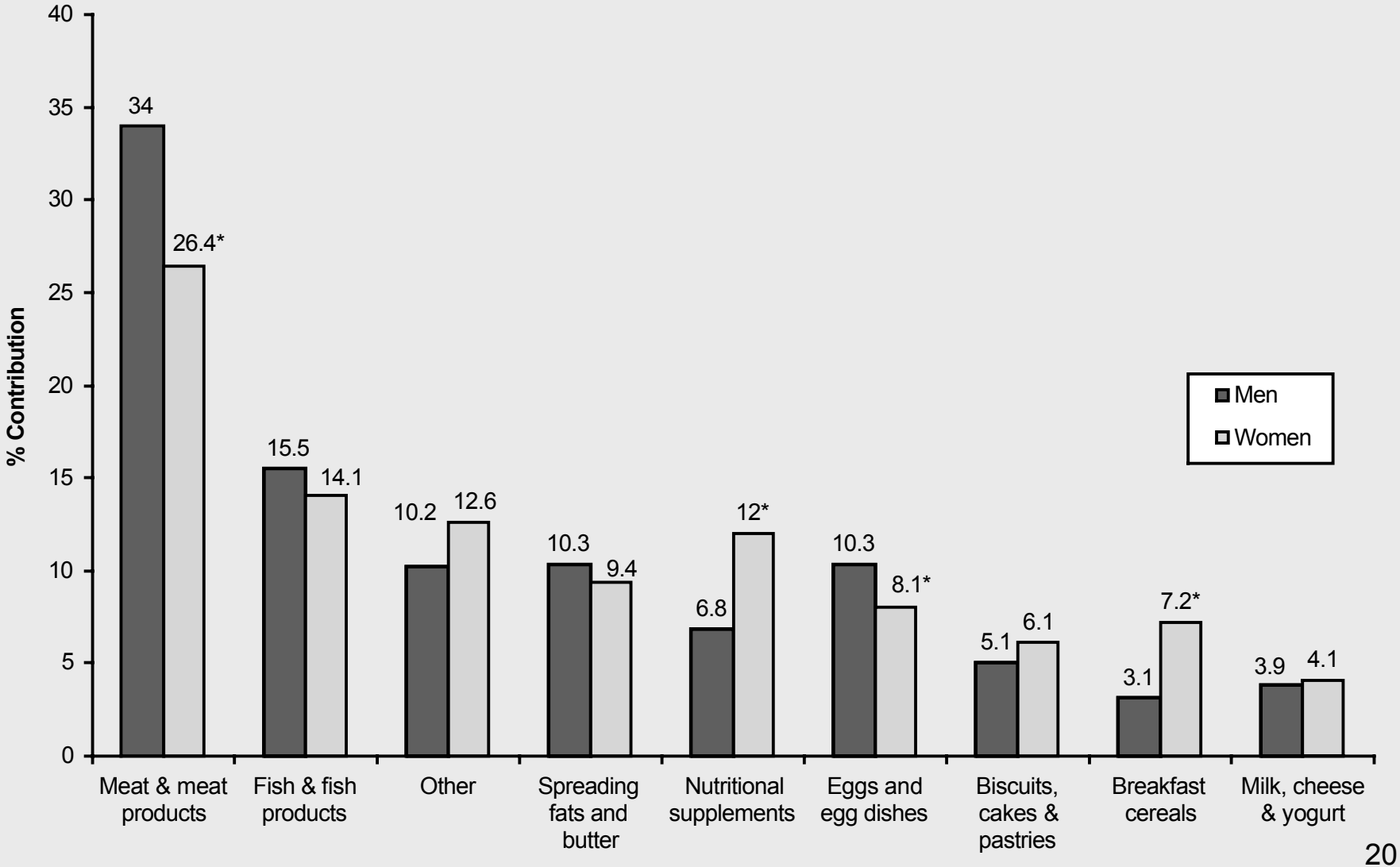
TR Hill, MM O'Brien, KD Cashman, A Flynn and M Kiely*

Conclusion: …… a large number of Irish adults have low vitamin D intakes. This, along with emerging evidence of low vitamin D status in at least some population subgroups, suggests that strategies to increase vitamin D intakes, including fortification of food, should be investigated.

European Journal of Clinical Nutrition

2004; 58, 1509–1517.

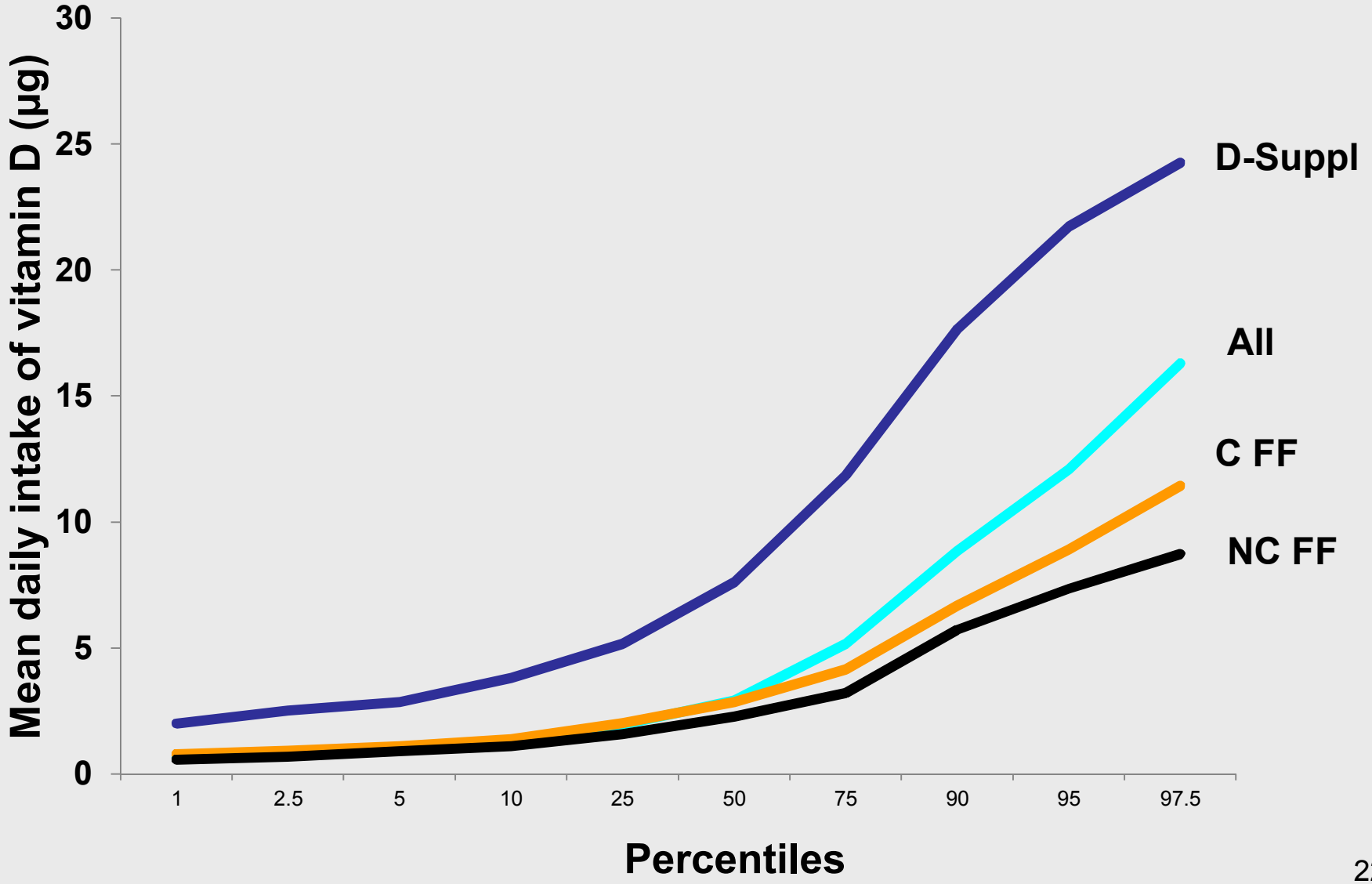
Contributions of foods to vitamin D intake in 2004



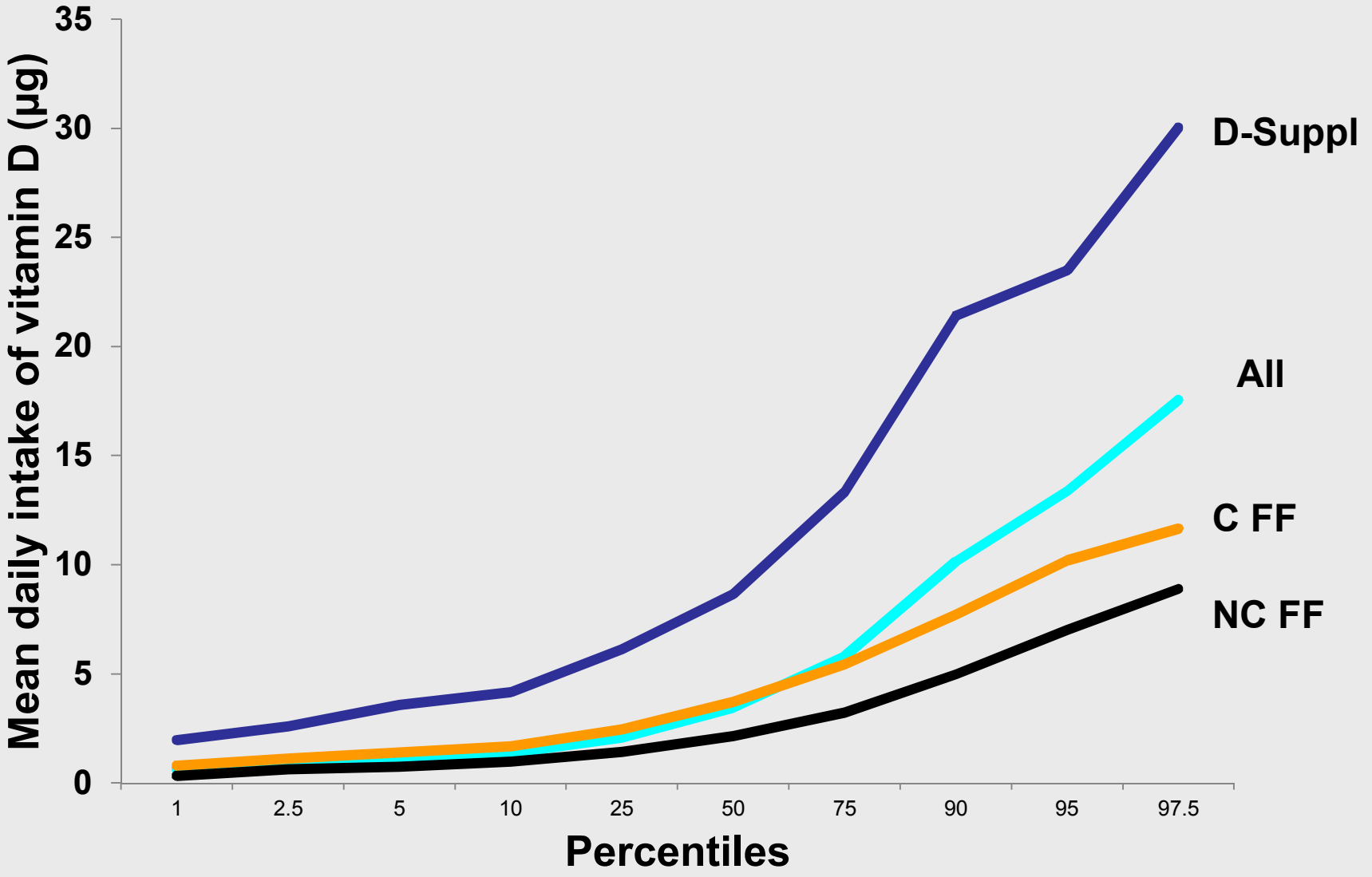
- **Sources of Vitamin D**

- **Food**
- **Fortification**
- **Nutritional supplements**

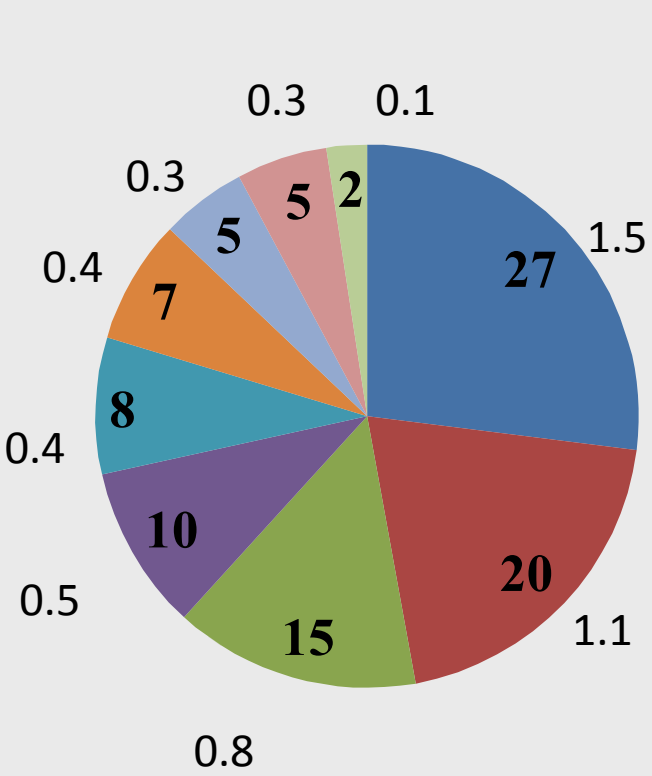
18-64 y, 2000


Mean daily intake of vitamin D (µg)
30
25
20
15
10
5
0
1
2.5
5
10
25
50
75
90
95
97.5
Percentiles
D-Suppl
All
C FF
NC FF

18-64 y, 2010


Mean daily intake of vitamin D (µg)
35
30
25
20
15
10
5
0
1
2.5
5
10
25
50
75
90
95
97.5
Percentiles
D-Suppl
All
C FF
NC FF

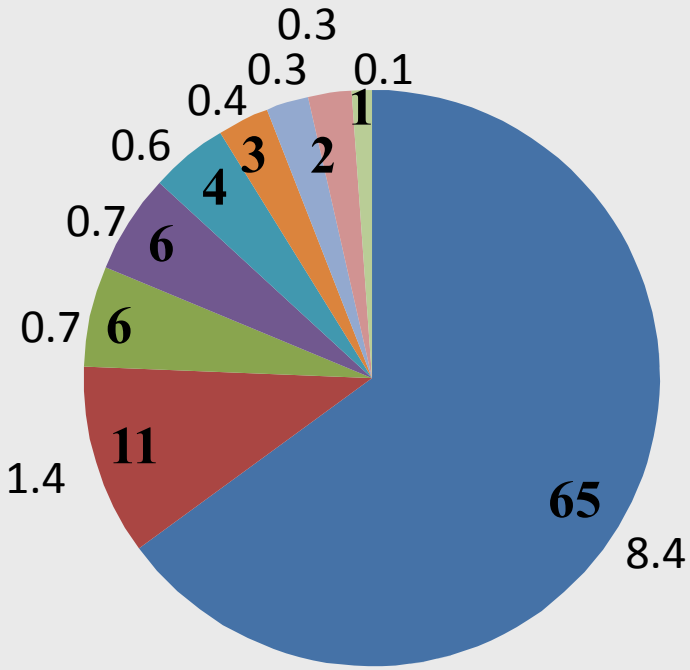
% (on the chart) and contribution (µg/d) of foods to vitamin D intake in Irish adults



Total population

5.4 µg/d

88% <EAR

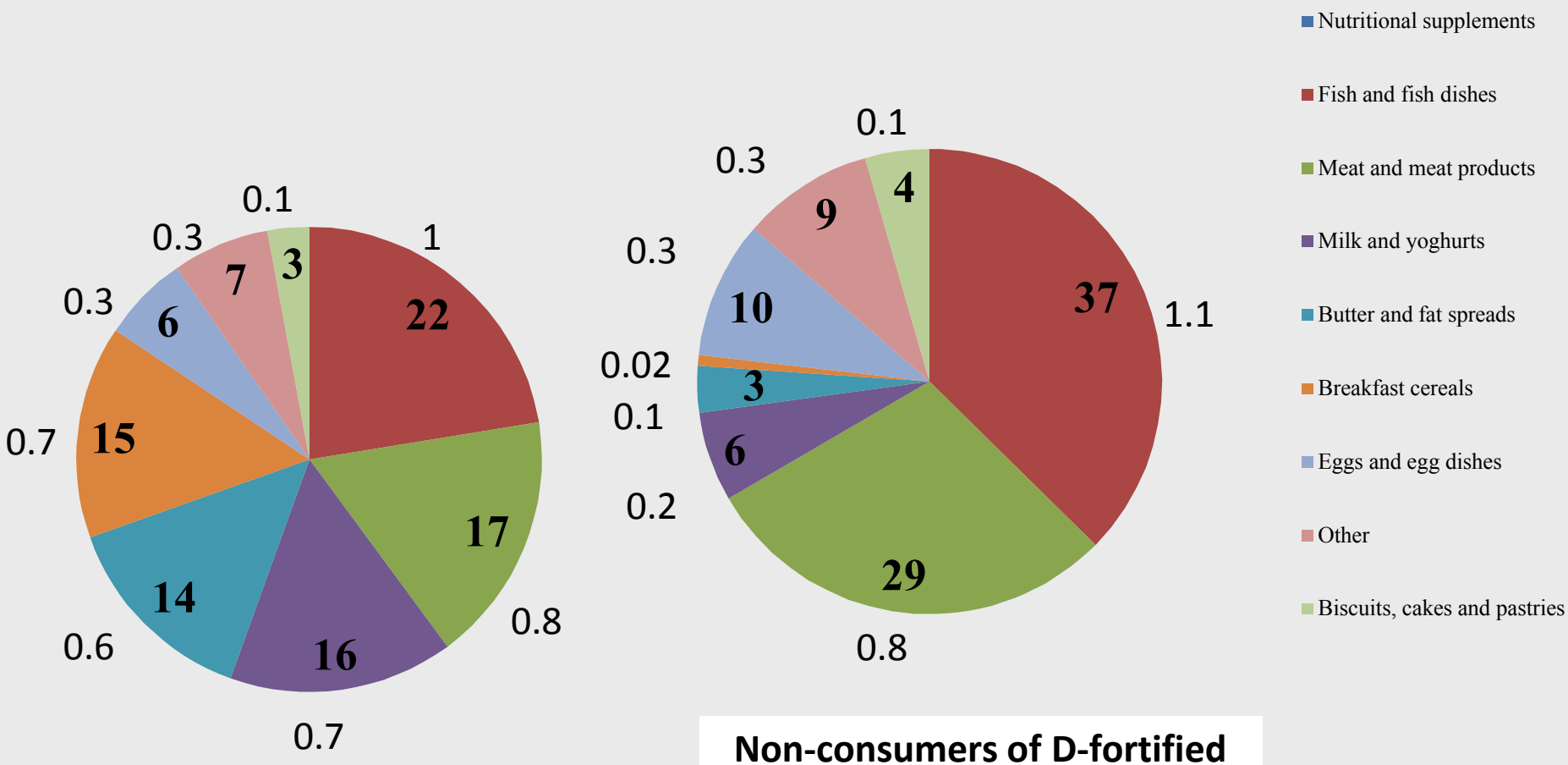


Supplement users

13.0 µg/d

52% <EAR

% (on the chart) and contribution (µg/d) of foods to vitamin D intake in non-supplement users



D-fortified food consumers

4.5 µg/d

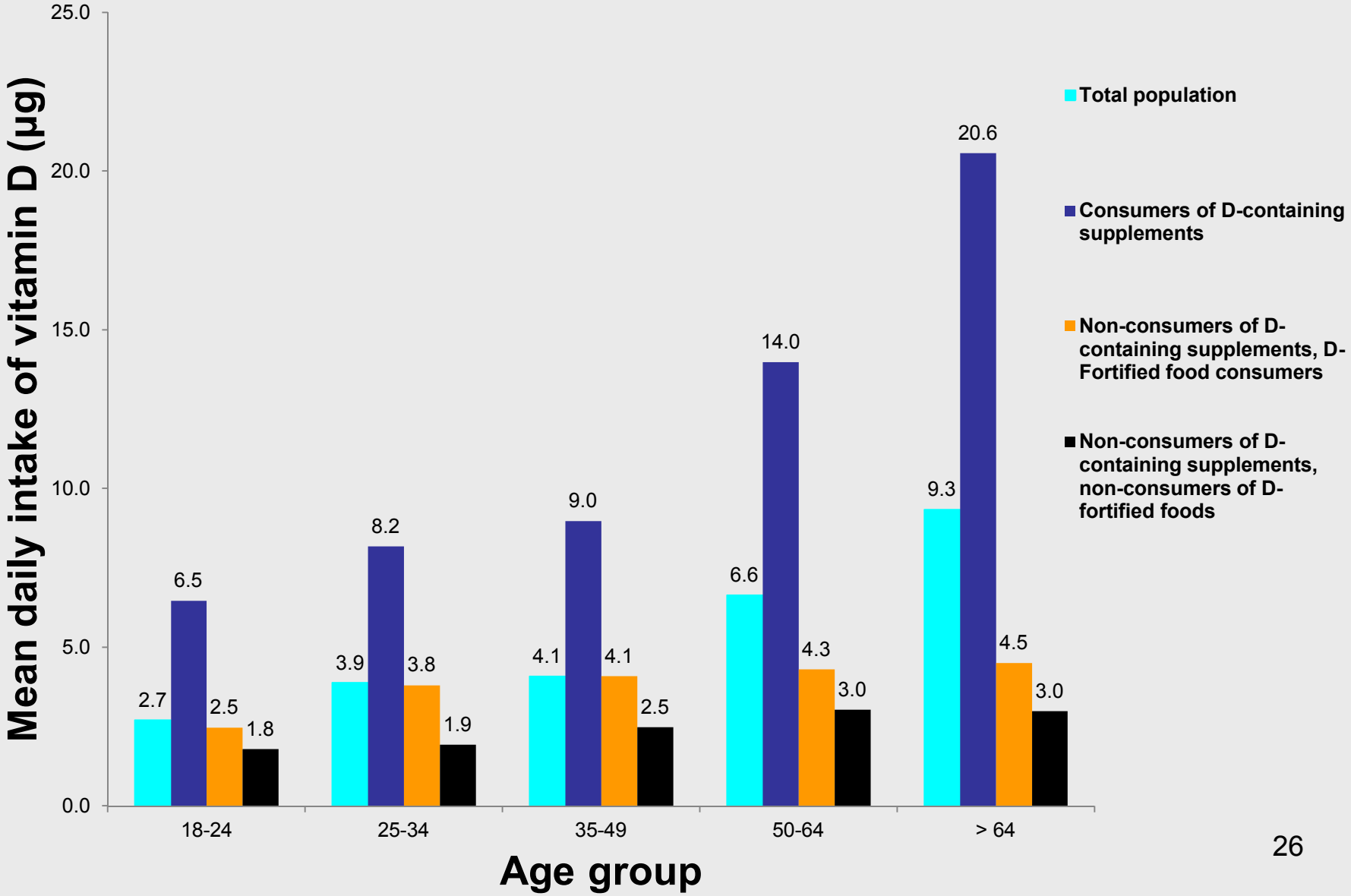
95% <EAR

Non-consumers of D-fortified foods

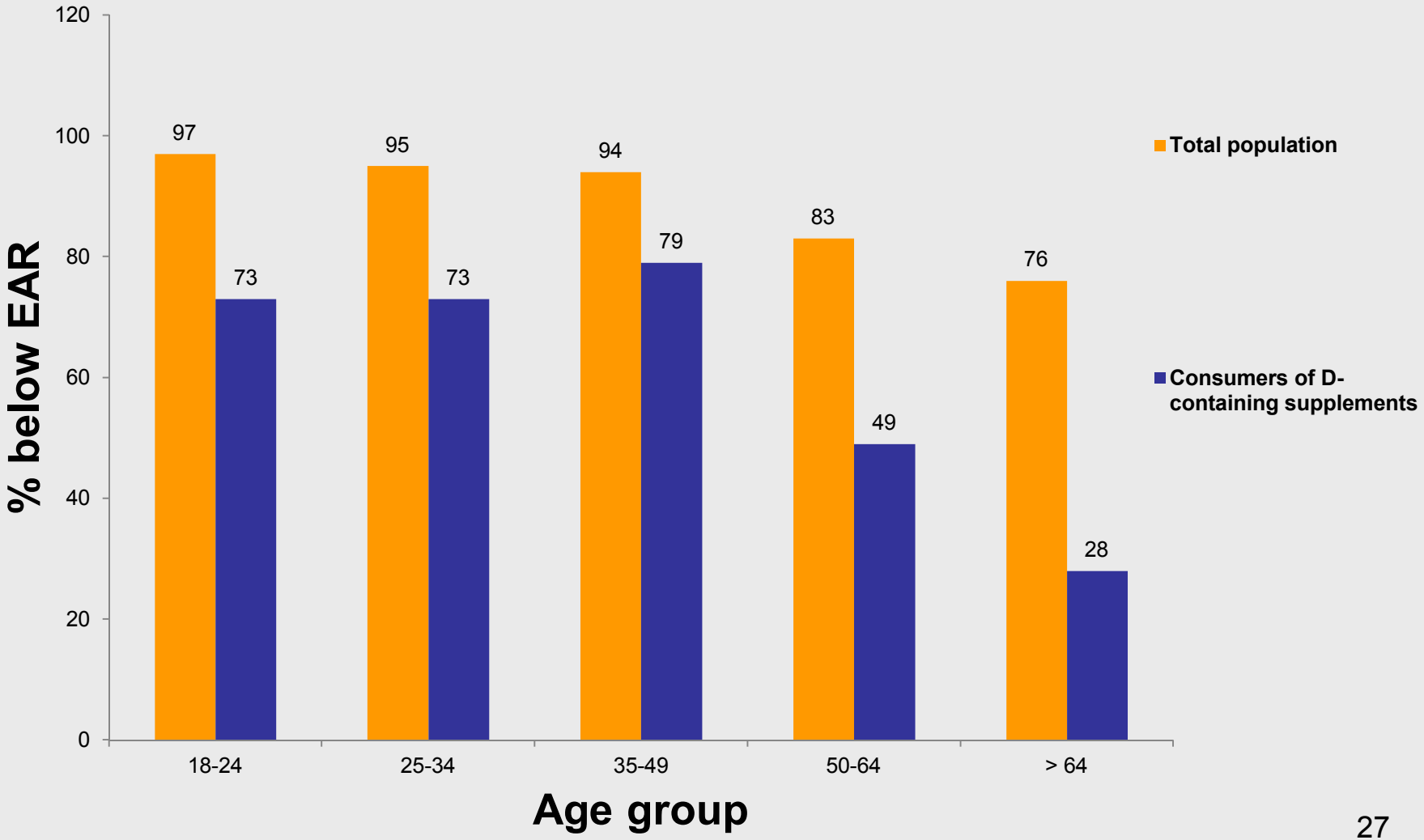
2.9 µg/d

98% <EAR

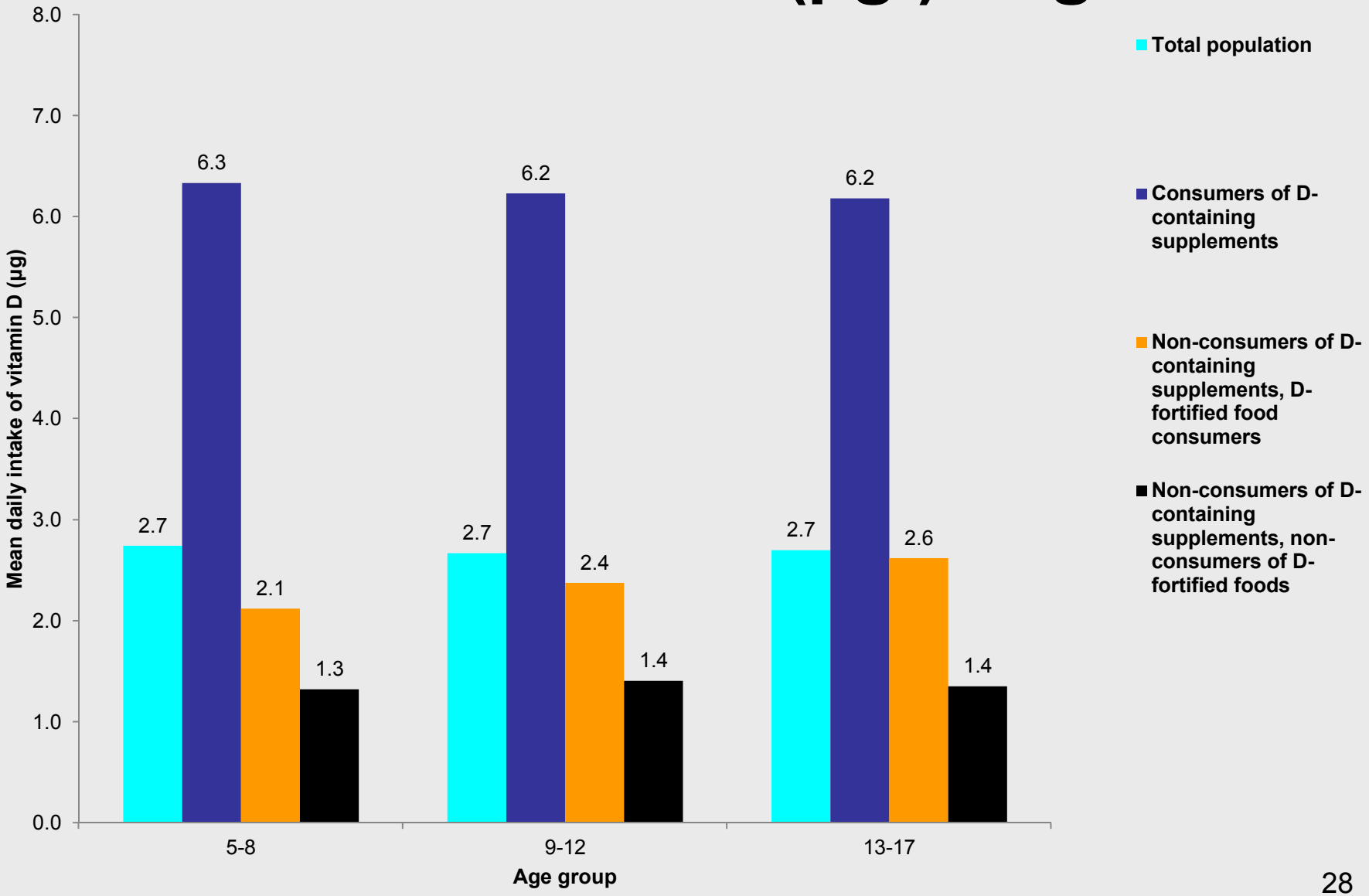
Vitamin D intake (µg/) in women



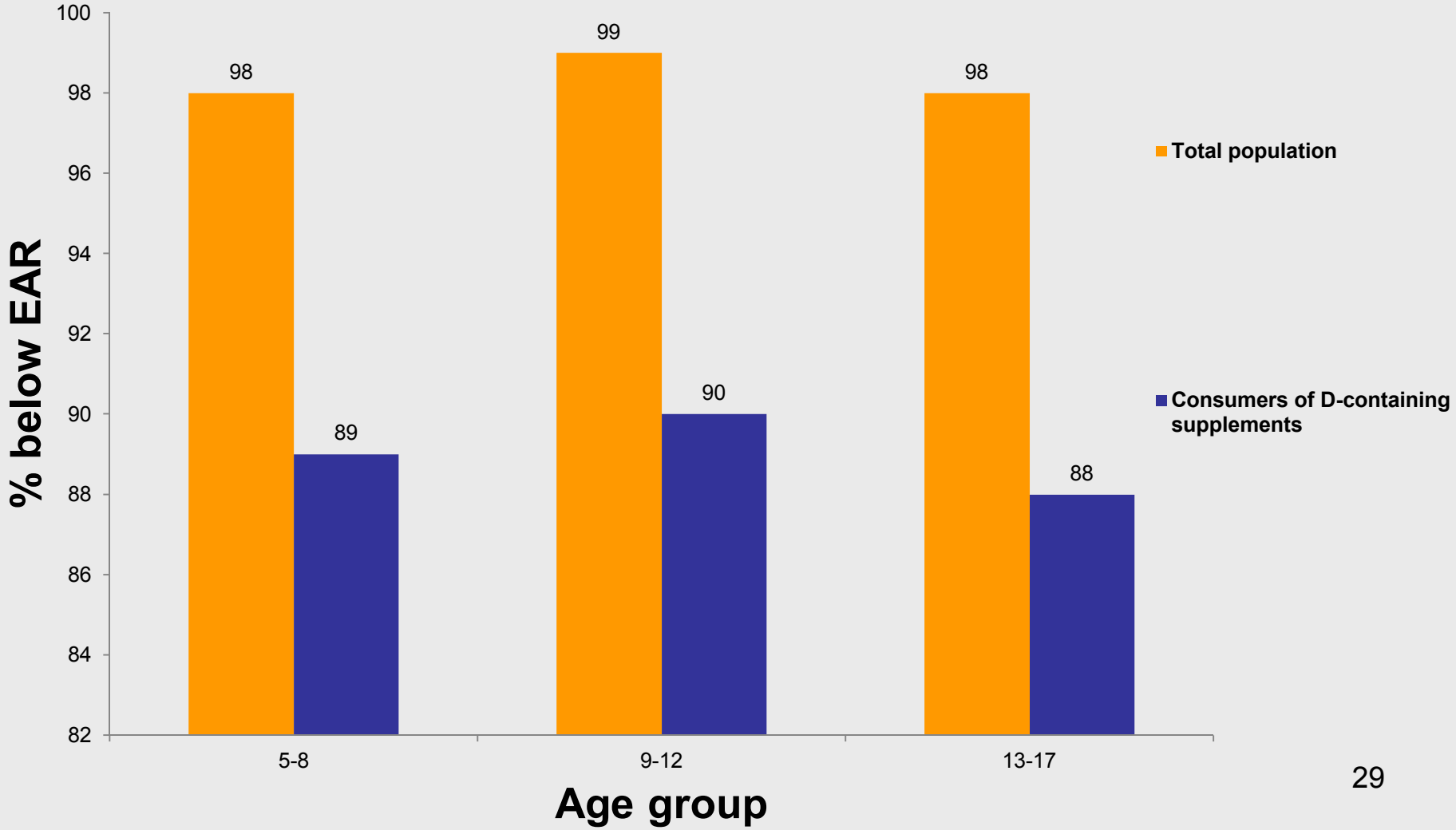
% women < EAR


120
100
80
60
40
20
0
% below EAR
97
73
95
73
94
79
83
49
76
28
18-24
25-34
35-49
50-64
> 64
Age group
Total population
Consumers of D-containing supplements

Vitamin D intake (µg/) in girls



% girls < EAR


100
98
96
94
92
90
88
86
84
82
% below EAR
98
89
99
90
98
88
5-8
9-12
13-17
Age group
Total population
Consumers of D-containing supplements

Vitamin D supplements?

- Vitamin D content of most supplements usually low relative to requirement

- Low-variable rate of uptake
  - NHANES 1999-2002
  - 33% 1-3 y
  - 36% 4-8 y
  - 23% 9-13 y
  - 16% adolescents
  - ~ 25% adults (Yetley, 2008)

Evidence from randomised controlled trials of fortified foods

Food Fortification

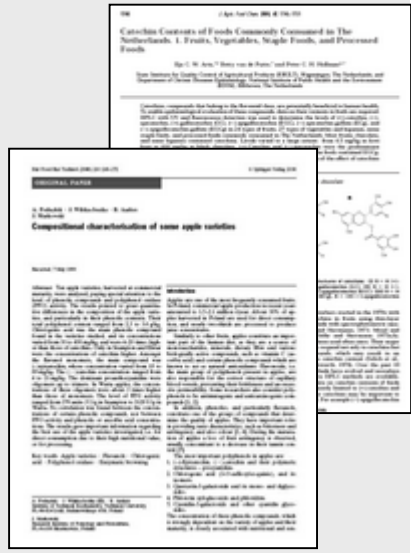
- Evidence for efficacy?

- O'Donnell et al. (2008)
  - Systematic review
  - No reporting of prevention of deficiency
  - Subsequent studies published

Aim

Systematic review to evaluate whether fortification can improve vitamin D status by increasing 25(OH)D in excess of cut-off levels for deficient or desirable status

Literature search



- Randomised controlled trials
  - Free-living adults
  - Foods fortified with vitamin D_2 or D_3
  - Circulating 25(OH)D concentrations
- Databases
  - Medline OVID 1950 to June 2010; PubMed; CINAHL; Embase; Cochrane Central Register of Controlled Trials
- Number of relevant studies = 18

Description of trials (n=18)

- Characteristics
  - Latitude > 40˚ ; < 40˚
  - Range of durations (3 weeks – 2 years)
  - Range of seasons (winter, spring, unknown)
  - Range of ages (all adults; over 50)
  - Range of baseline 25(OH)D levels

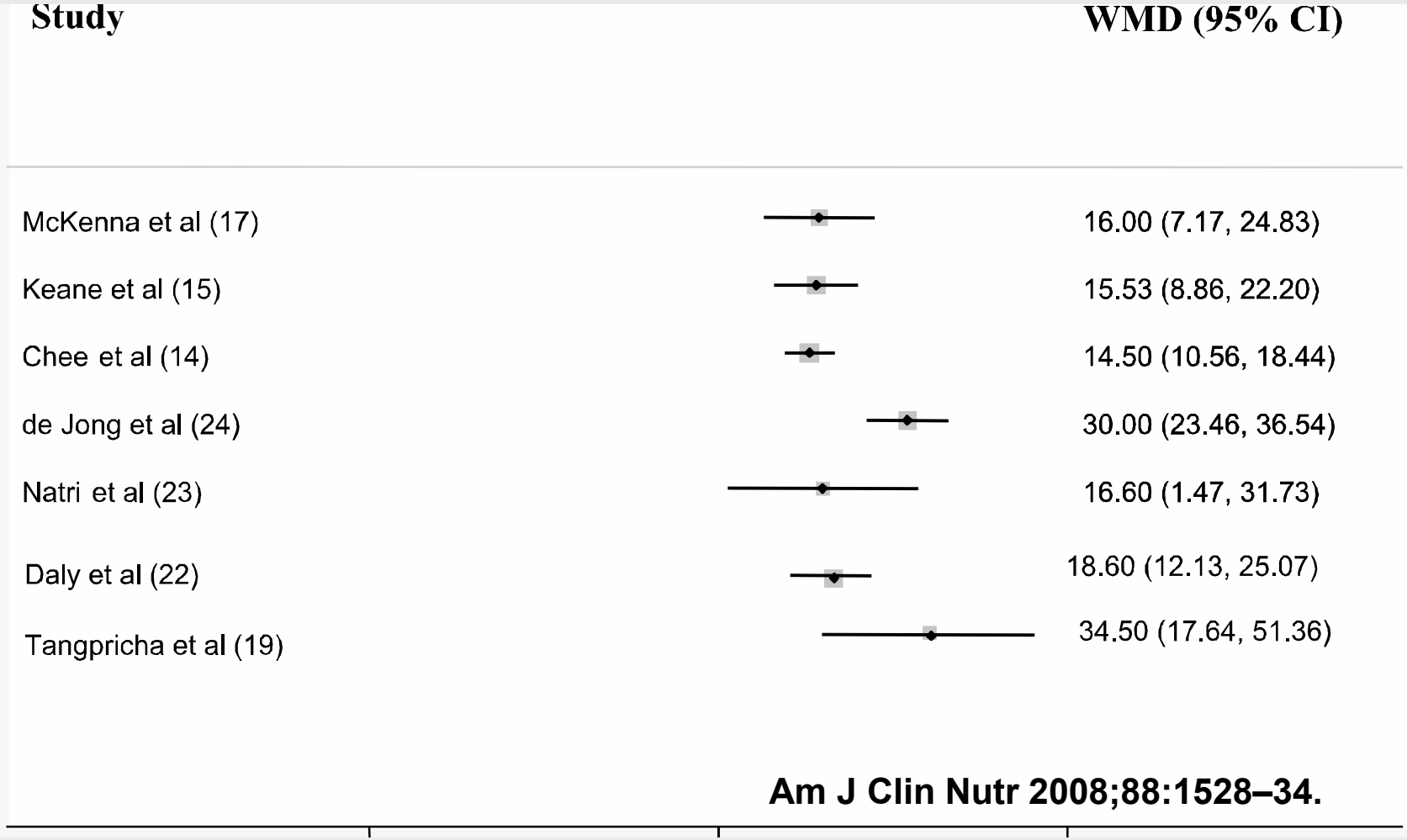
- Interventions

  - Dose 120 – 1000 IU
    - Dairy product (n=13)
    - Orange juice (n=3)
    - Bread (n=2)
  - Placebo product (n=13); usual diet (n=5)
  - Range of vit D assays (RIA, HPLC, CPBA)

- Quality
  - Sunlight exposure
    - Reported in 5 trials
  - Dietary intake of vitamin D
    - Reported in 5 trials
  - Independent dose check
    - Reported in 10 trials
  - Compliance
    - Reported in 12 trials

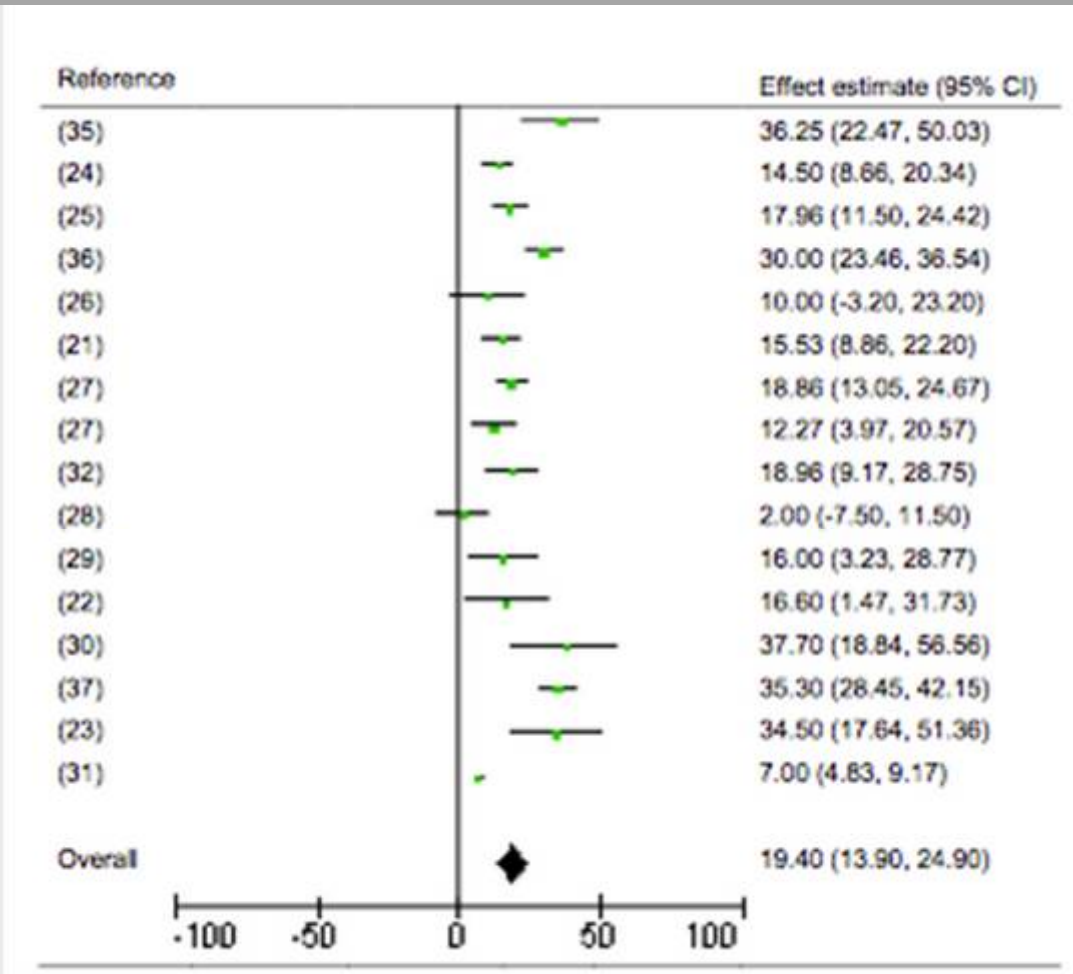
Efficacy of food fortification on serum 25-hydroxyvitamin D concentrations: systematic review[1–4]

Siobhan O'Donnell, Ann Cranney, Tanya Horsley, Hope A Weiler, Stephanie A Atkinson, David A Hanley, Daylily S Ooi, Leanne Ward, Nick Barrowman, Manchun Fang, Margaret Sampson, Alexander Tsertsvadze, and Fatemeh Yazdi



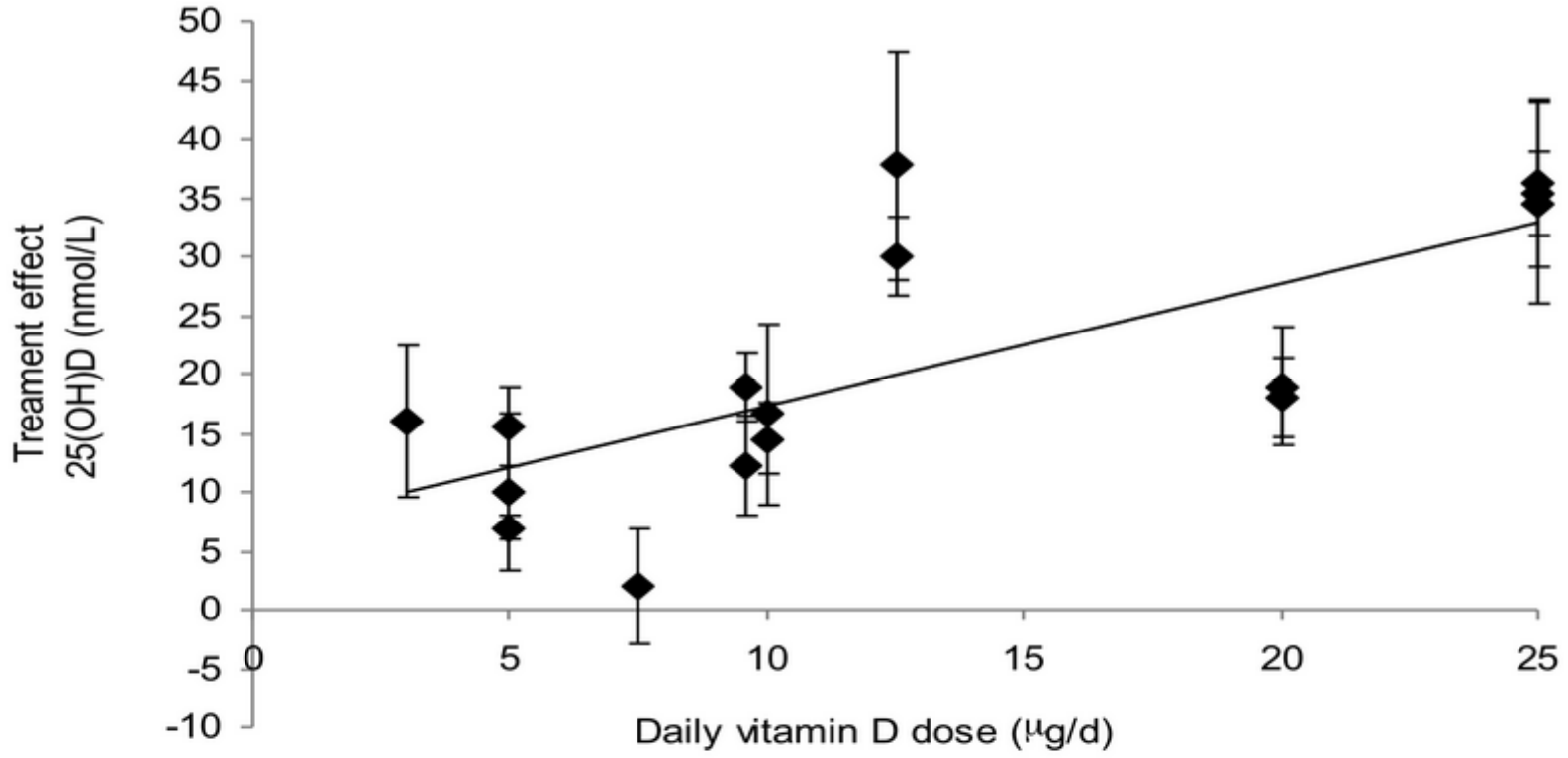
An updated systematic review and meta-analysis of the efficacy of vitamin D food fortificaton. Black LJ, Seamans KM, Cashman KD, Kiely M. J Nutr. 2012 Jun;142(6):1102-8.

Change in circulating 25(OH)D associated with food fortification with vitamin D



Weighted mean difference in absolute change estimated; mean dose of ~11 µg/d increased s25(OH)D by 19.4 nmol/L (95% CI = 13.90, 24.90)

Dose-response of 25(OH)D to additional vitamin D at doses between 3 - 25 µg/d delivered in fortified foods in 16 randomized controlled studies.



Mean s25(OH)D = 1.198 (vitamin D intake) + 2.711; adj *R*2 = 0.674, *P* < 0.001

Modelling – Irish data

Current fortification

- Voluntary fortification of foods, incl some RTEBC, fat spreads and milk

Scenario A

- Reduced fat milk, yoghurt, fat spreads, orange juice and RTEBC

Scenario B

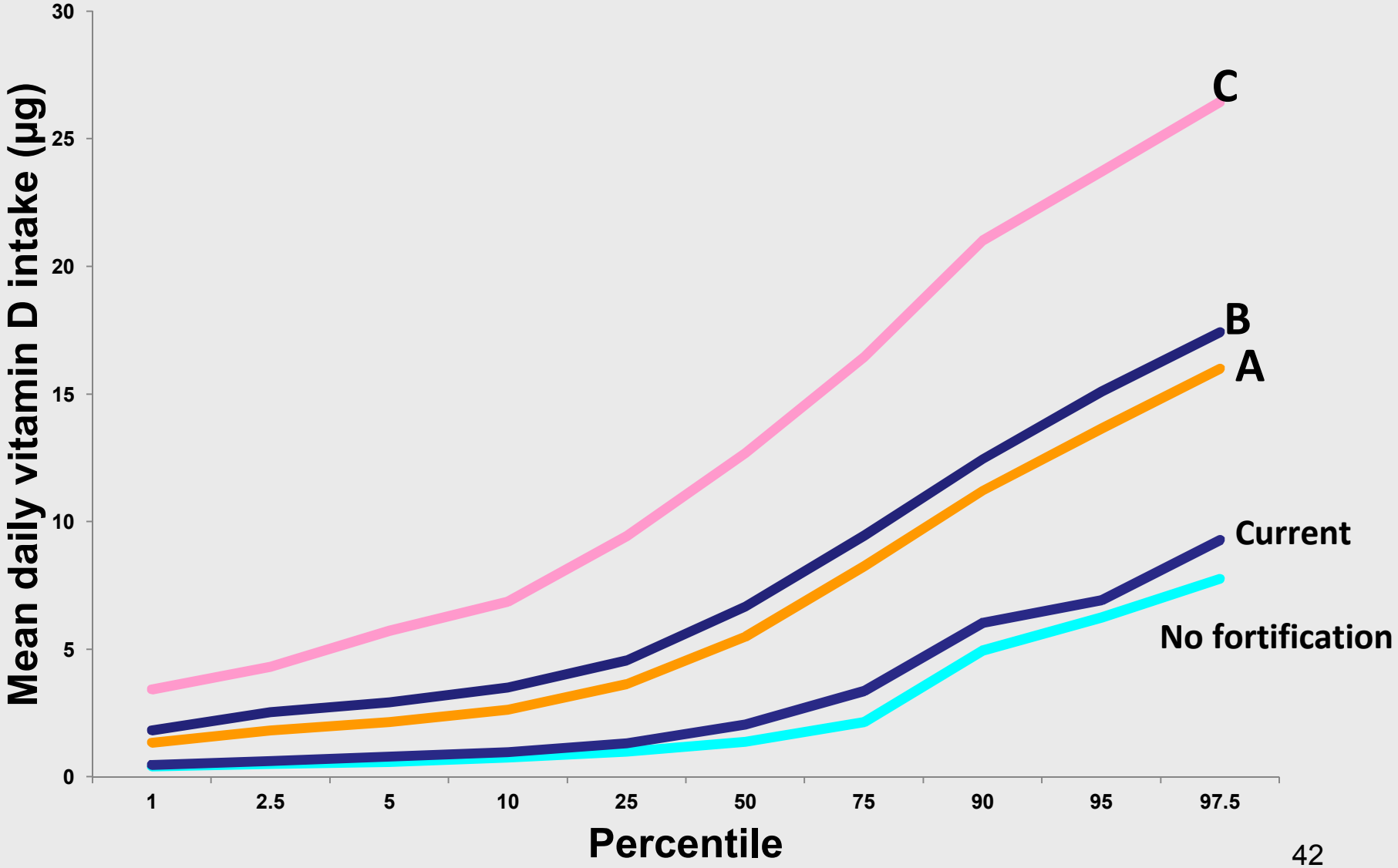
- Reduced fat milk, milk alternatives, yoghurt and alternatives, fat spreads, orange juice, RTEBC and packaged sliced bread

Scenario C

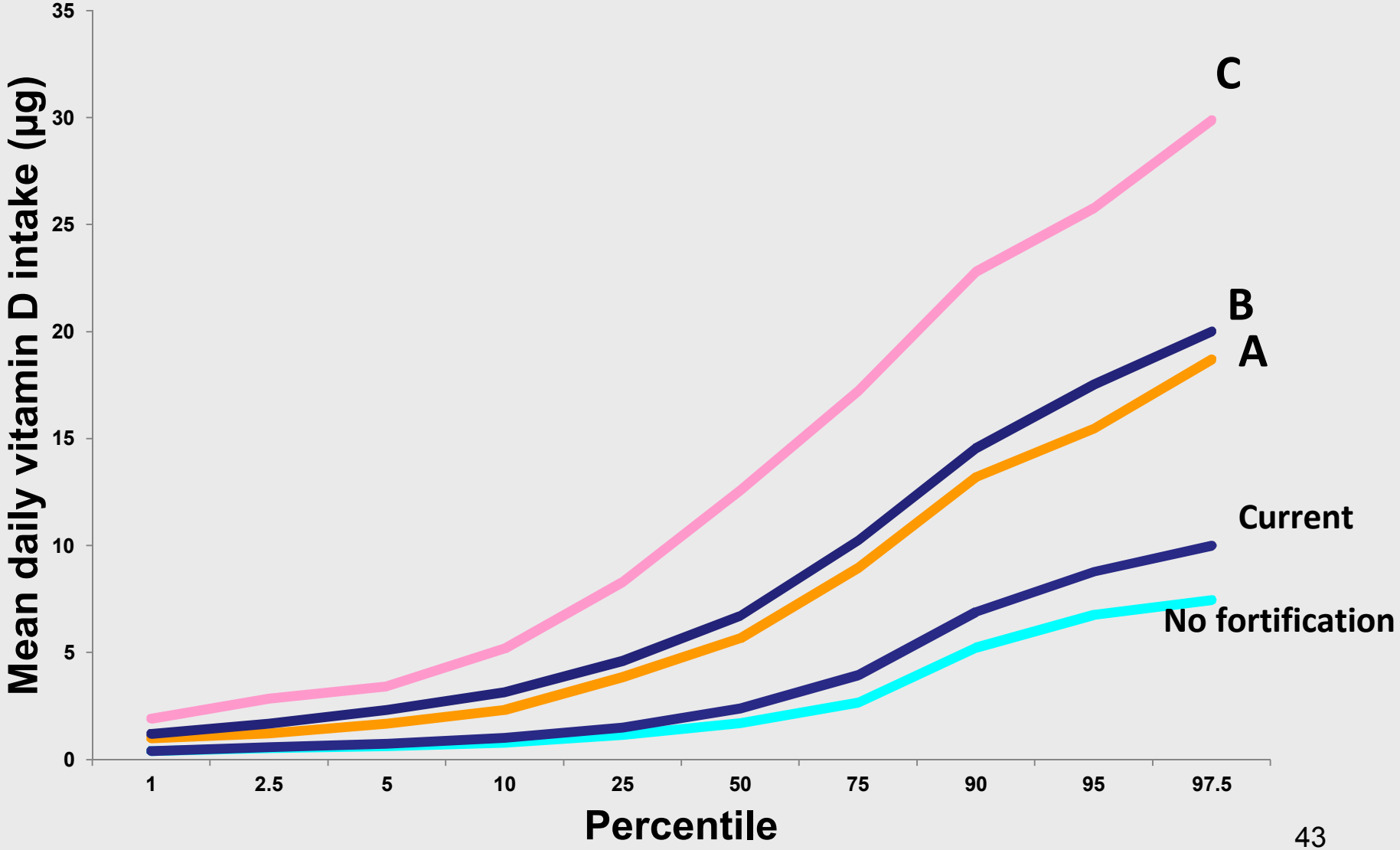
- All dairy, fat spreads, all fruit juice and fruit drinks, RTEBC and all breads and rolls

* Levels: milk and alternatives (2 µg/100 g), yoghurt and alternatives (2 µg/100 g), cream (2 µg/100 g), cheese (2 µg/100 g), fat spreads (8 µg/100 g), fruit juice and drinks (2 µg/100 g), RTEBC (5 µg/100 g), breads and rolls (2 µg/100 g)

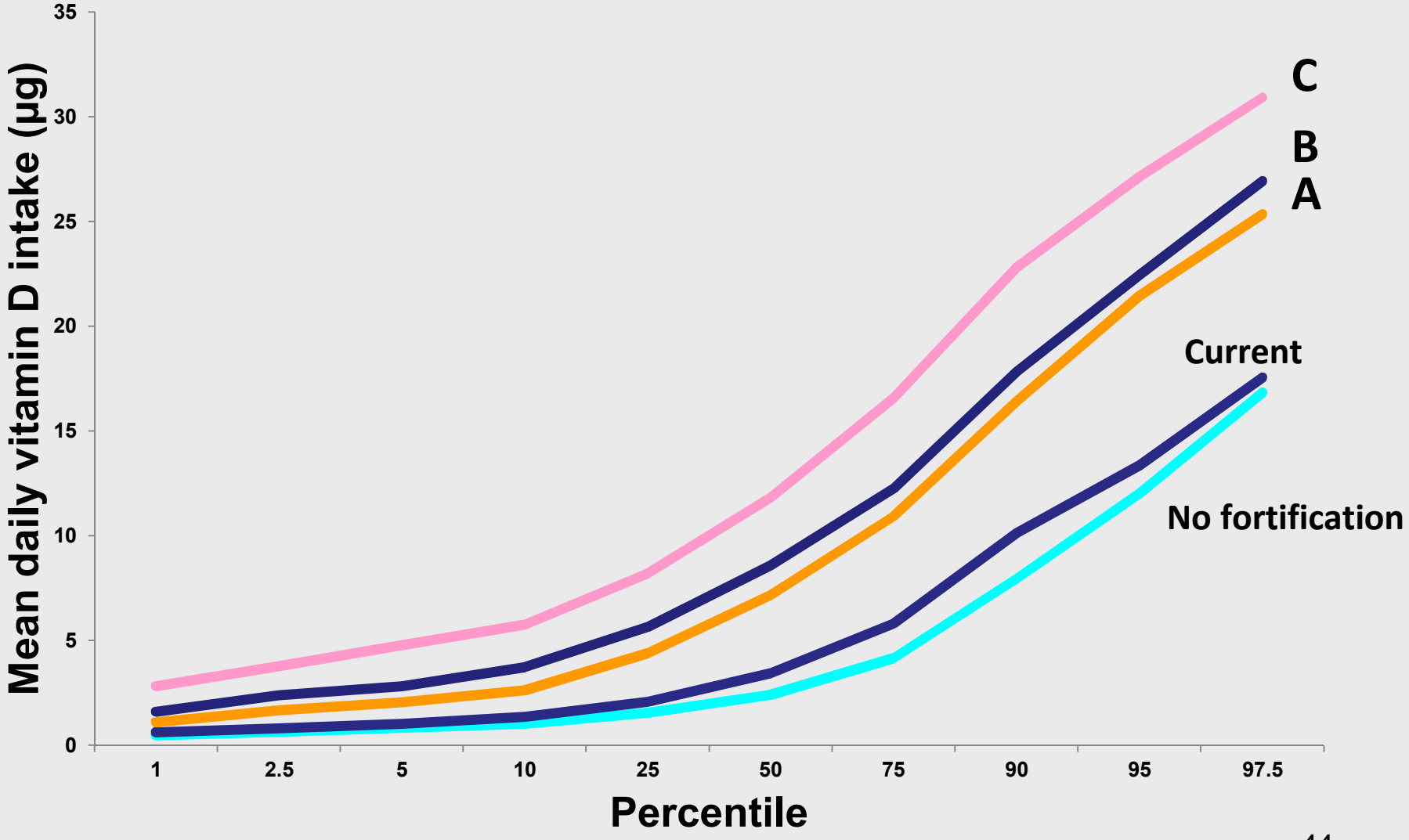
5-12 year olds



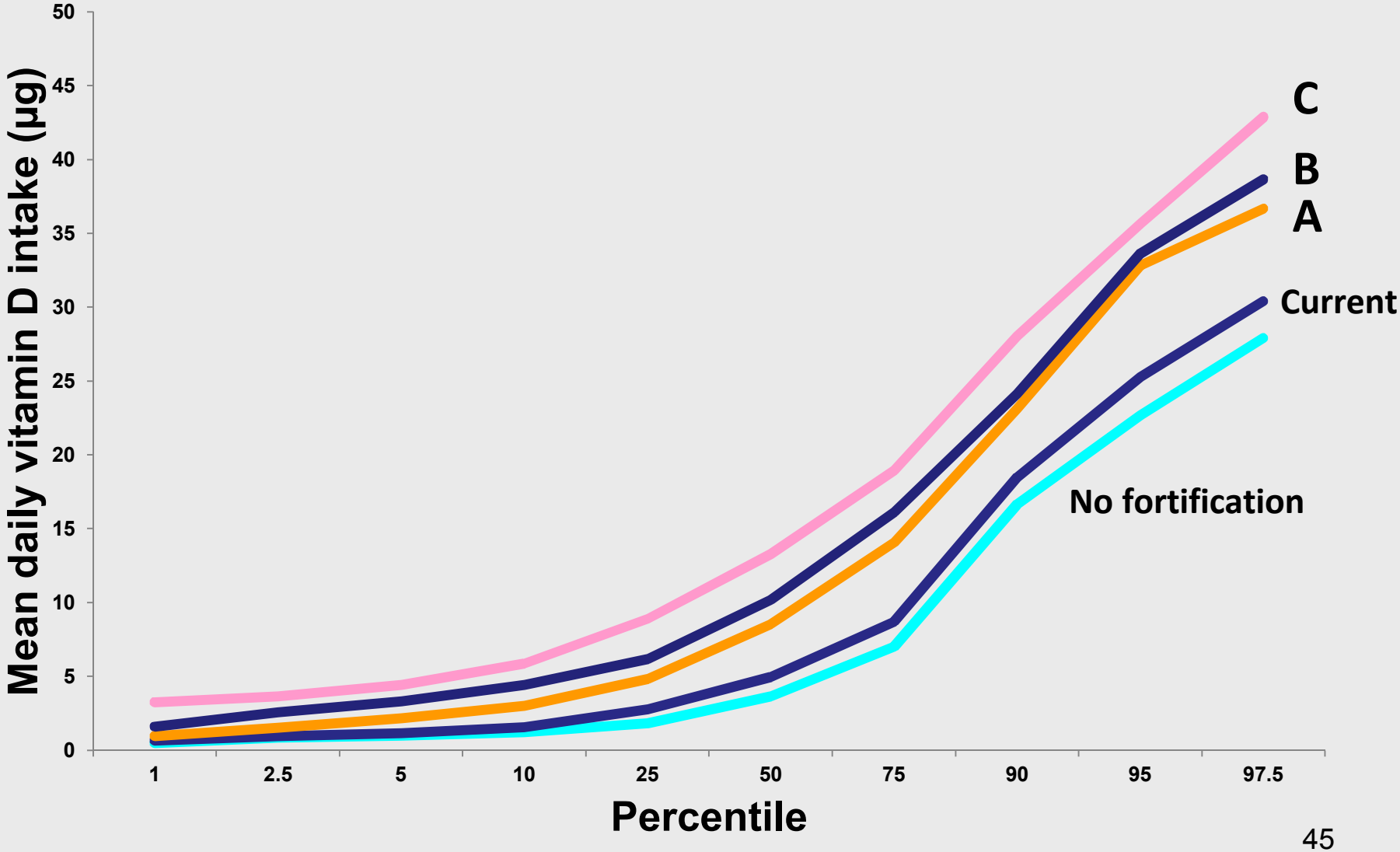
13-17 year olds



18-64 year olds

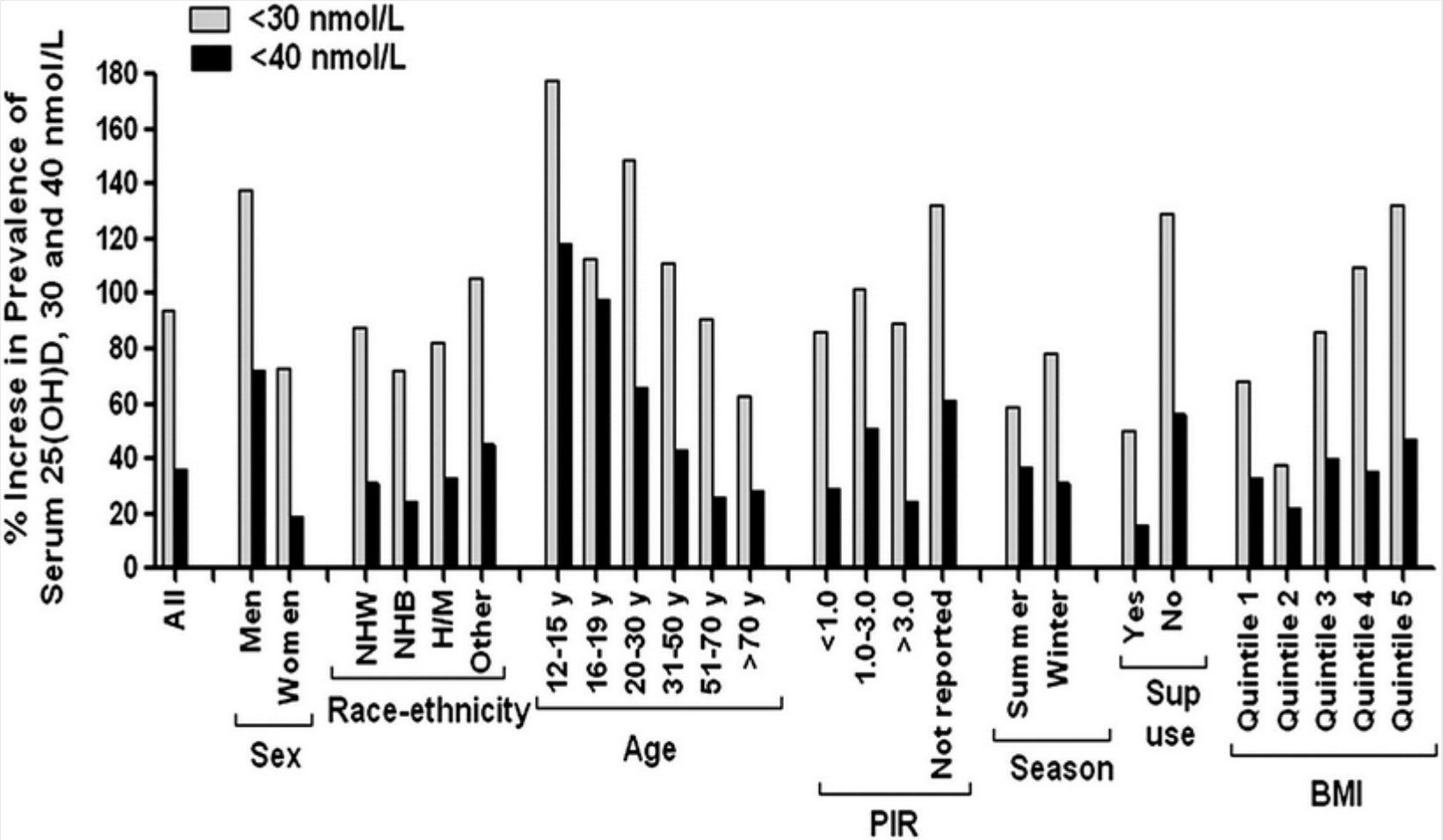


> 64 year olds


Mean daily vitamin D intake (µg)
50
45
40
35
30
25
20
15
10
5
0
1
2.5
5
10
25
50
75
90
95
97.5
Percentile
C
B
A
Current
No fortification

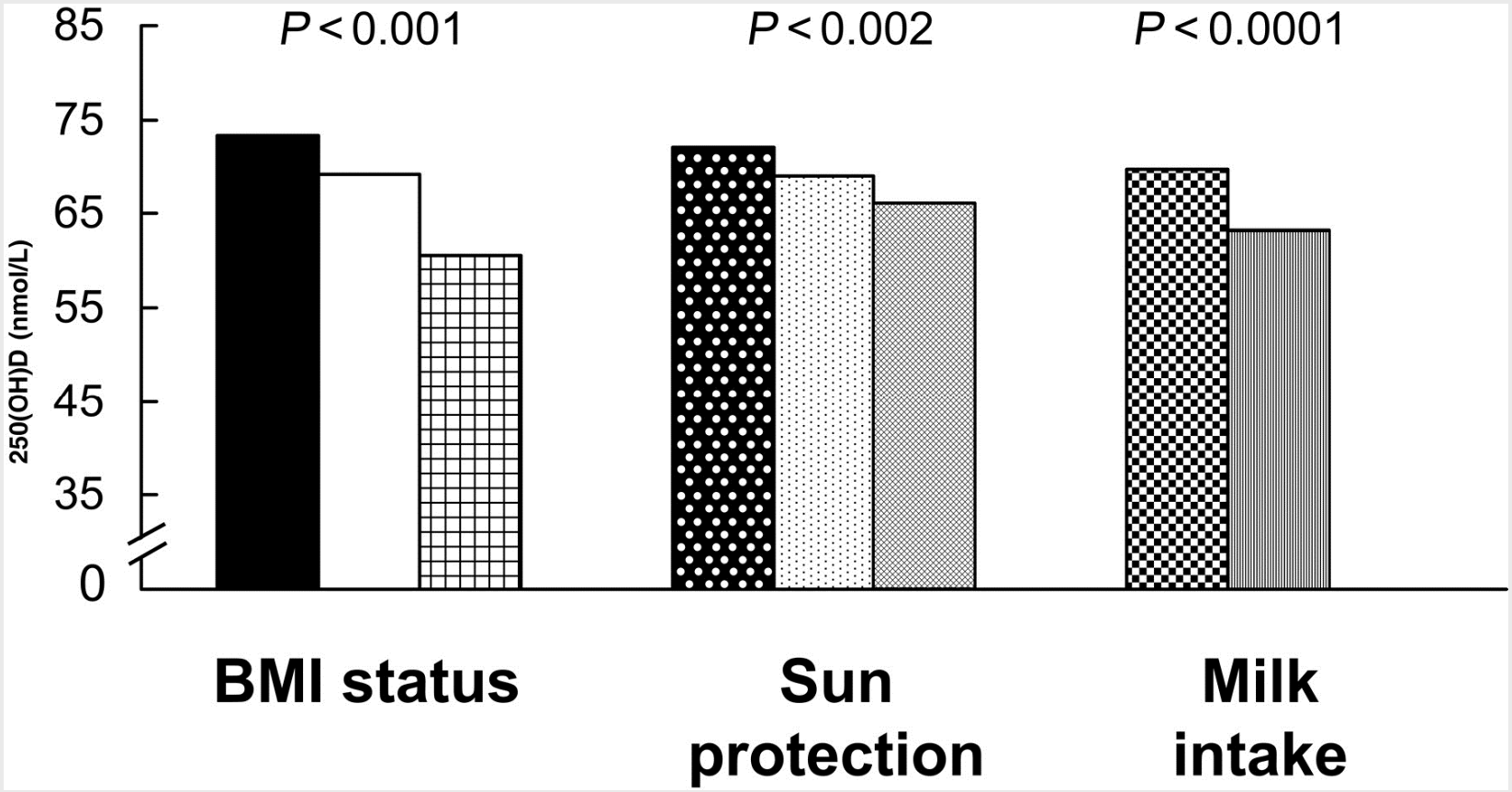
Additional factors to consider

% increase in the prevalence s25(OH)D <30 nmol/L and <40 nmol/Lfrom NHANES 1988–1994 to NHANES 2001–2006 by various factors



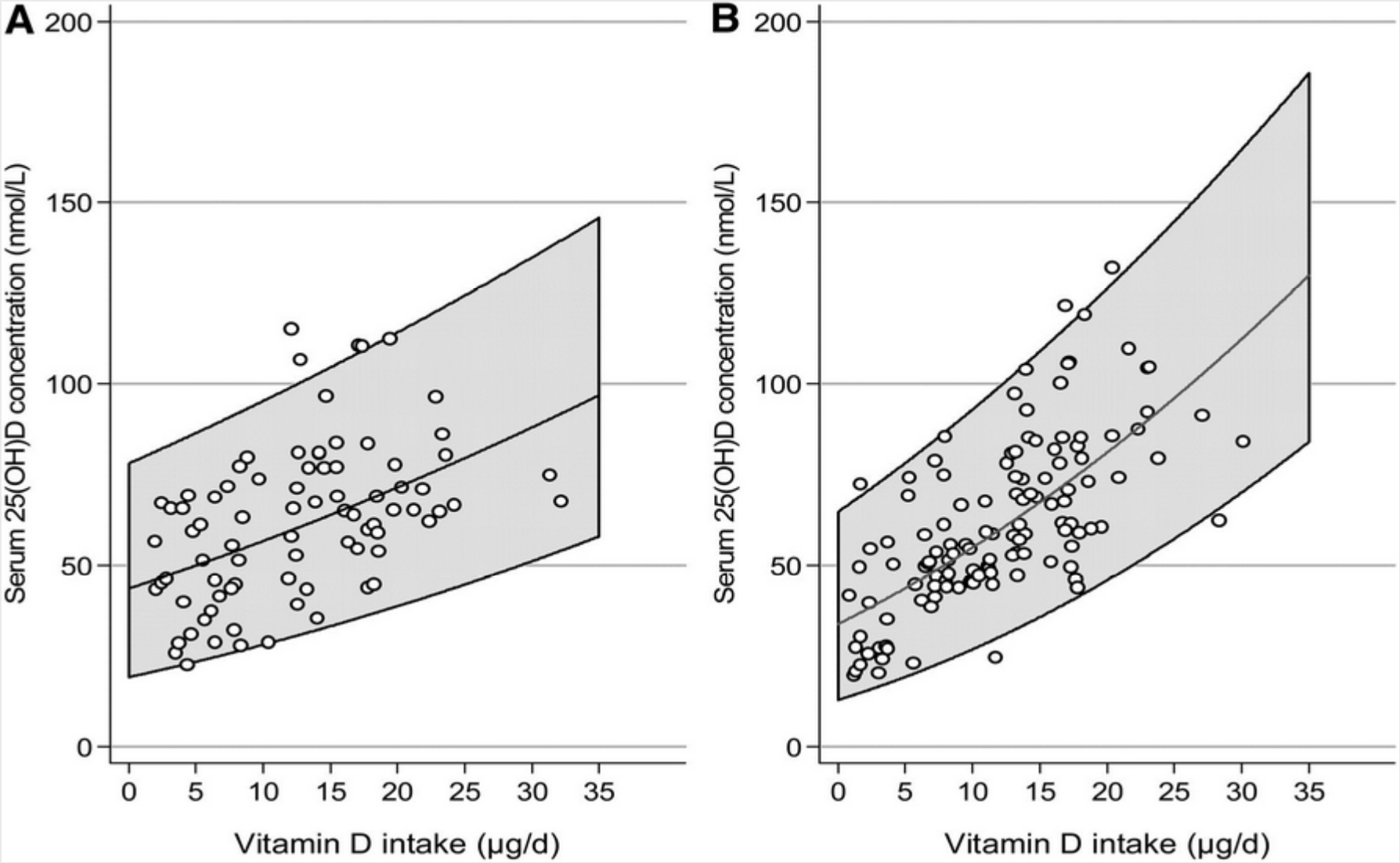
Ganji V et al. J. Nutr. 2012;142:498-507

The American Journal of Clinical Nutrition



Looker A C et al. Am J Clin Nutr 2008;88:1519-1527

S25(OH)D concentrations (in late winter, 2008) and vitamin D intake in healthy men (A; n = 82) and women (B; n = 122) aged ≥64 y living at northerly latitudes (51 and 55° N).



Cashman K D et al. Am J Clin Nutr 2009;89:1366-1374

Slope = 1.97nmol/L/µg (m 1.39; w 2.42)

Influence of sun exposure preference on requirement (20-40y)

25(OH)D cut-offs nmol/L

Sun exposure	>25	>50
Often	7	26
Sometimes	9	28
Avoid	12	31

Influence of sun exposure on requirement (>64 y)

	25(OH)D cut-offs nmol/L	
Sun exposure	**>25**	**>50**
≥15min	8	24
<15min	11	28

Dietary strategies to maintain adequacy of circulating 25-Hydroxyvitamin D concentrations

MAIREAD KIELY & LUCINDA J. BLACK

Vitamin D Research Group, School of Food and Nutritional Sciences, University College Cork, Ireland

The current dietary supply of vitamin D makes it unfeasible for most adults to meet the average requirement of 10 µg/d.

While supplements are an effective method for individuals to increase their intake, food fortification represents the best opportunity to increase the vitamin D supply to the population.

Dietary strategies to maintain adequacy of circulating 25-Hydroxyvitamin D concentrations

MAIREAD KIELY & LUCINDA J. BLACK

Vitamin D Research Group, School of Food and Nutritional Sciences, University College Cork, Ireland

Well-designed sustainable fortification strategies, which use a range of foods to accommodate diversity, have potential to increase vitamin D intakes across the population distribution and minimize the prevalence of low 25(OH)D concentrations.