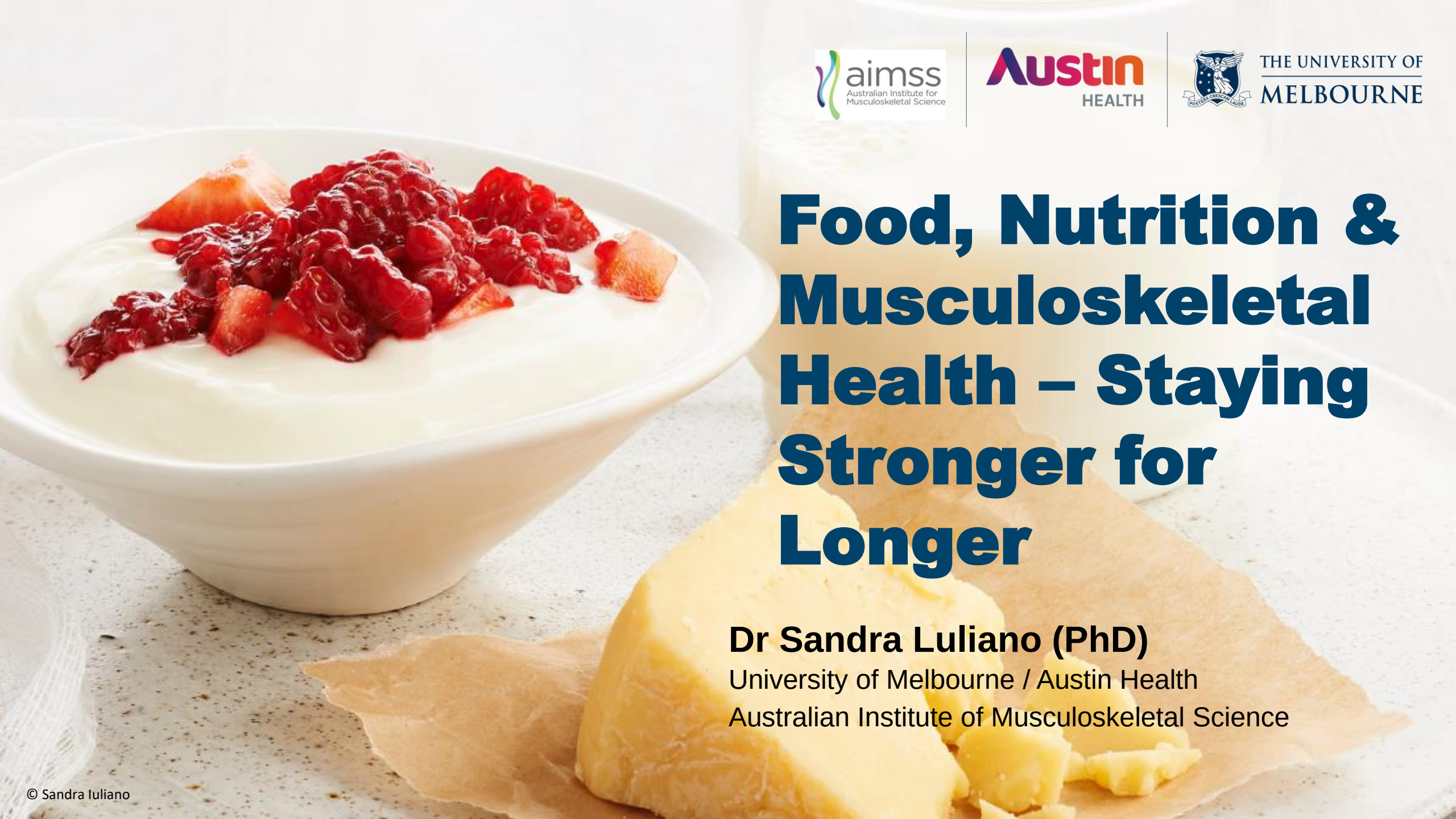


Food, Nutrition & Musculoskeletal Health – Staying Stronger for Longer

Dr Sandra Luliano (PhD)
University of Melbourne / Austin Health
Australian Institute of Musculoskeletal Science

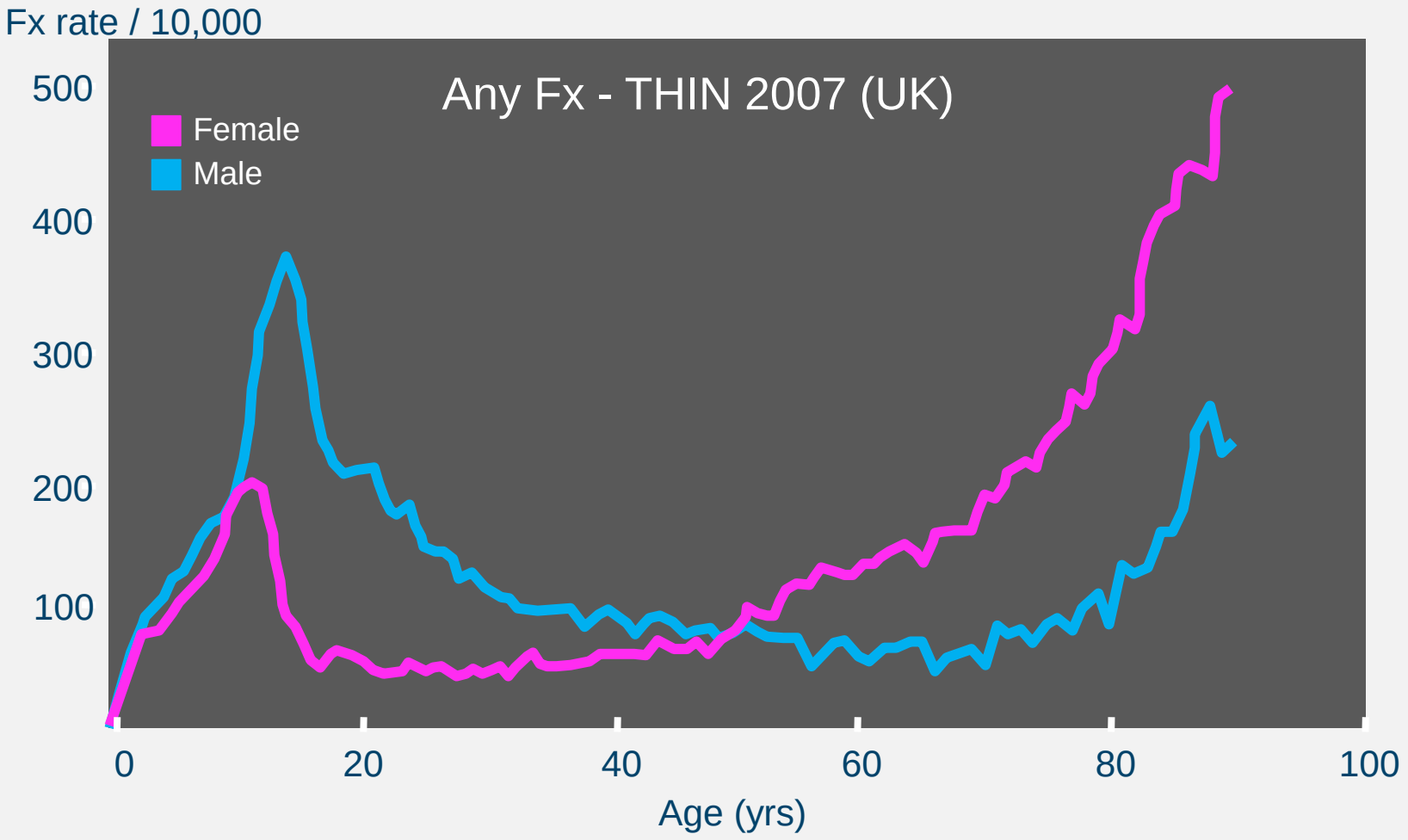
Disclosures

- Abbott: Advisory board / lecture fees
- UK Dairy Council: Expert group-healthy aging
- European Milk Forum: Travel support / lecture fees
- Nestle Health Sciences: Lecture fees
- Israel Milk Board: Lecture fees
- Dairy Australia: Lecture fees

Overview

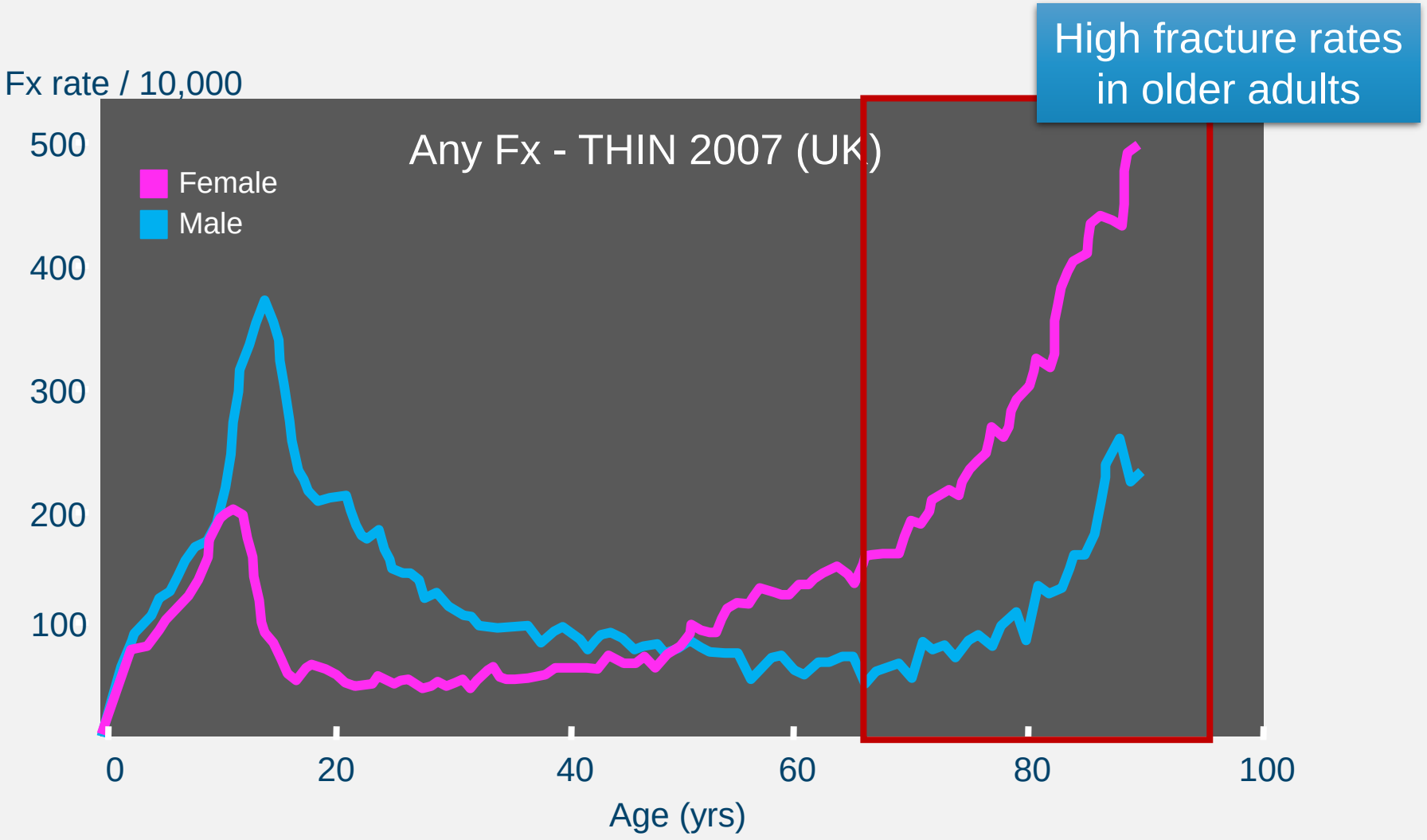
- ✓ Population ageing and fractures
- ✓ Bone over the lifespan: growth, adulthood, older age
- ✓ Calcium and bone
- ✓ Dairy and bone over the lifespan
- ✓ Dairy and muscle in older adults
- ✓ Dairy and falls & fractures in older adults
- ✓ Practical considerations to increase dairy consumption

Fractures over the Lifespan



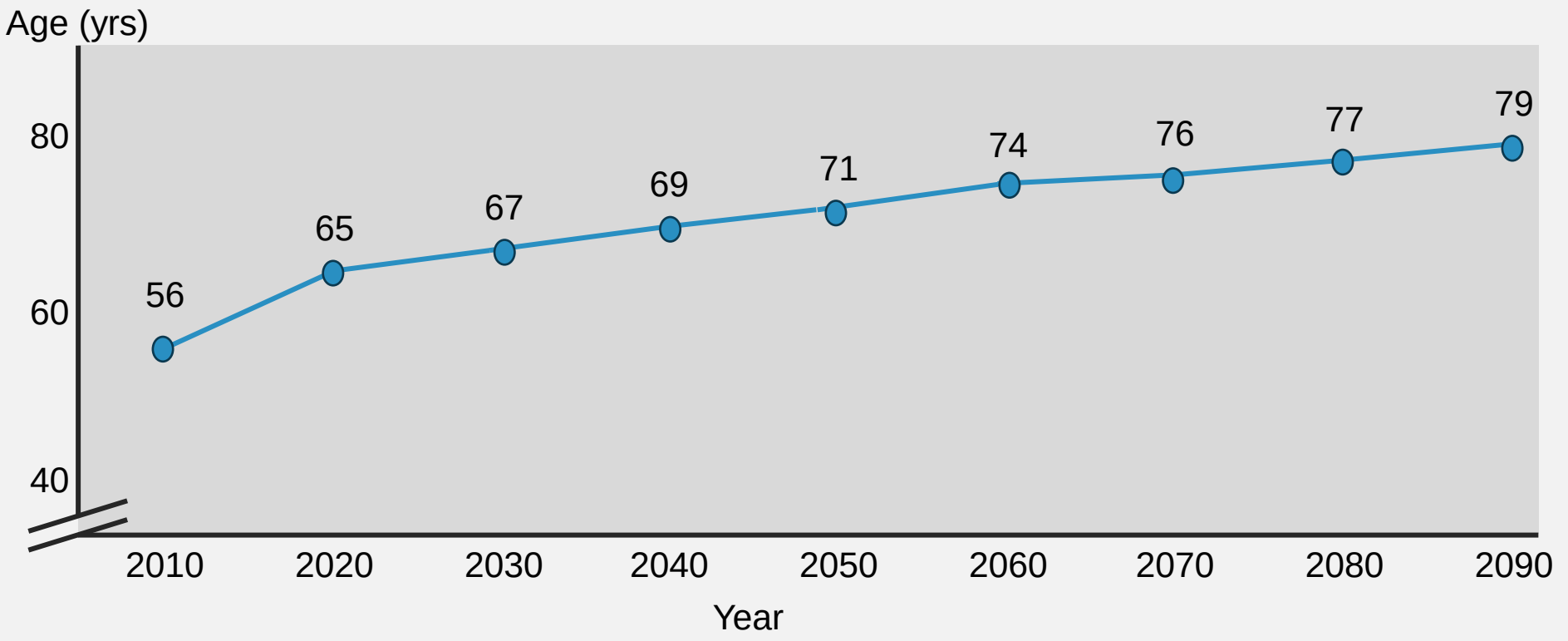
Adapted from Denburg et al. ASBMR-ASM, 2012

Fractures over the Lifespan



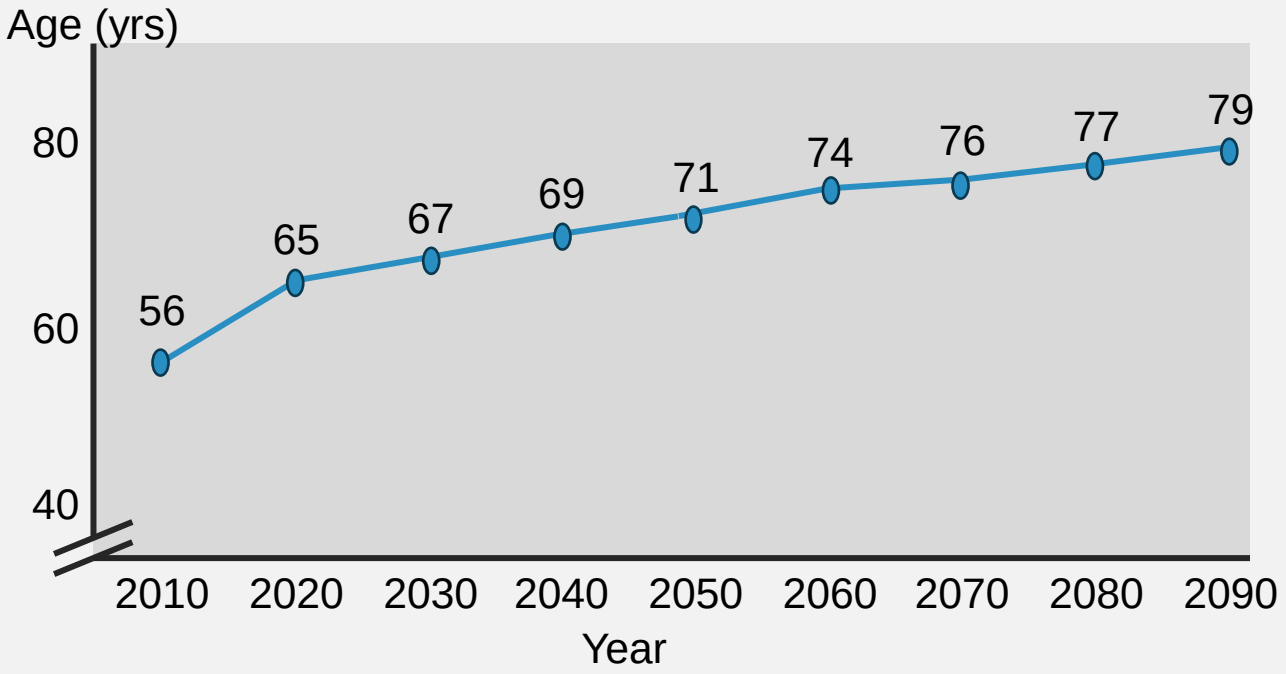
Adapted from Denburg et al. ASBMR-ASM, 2012

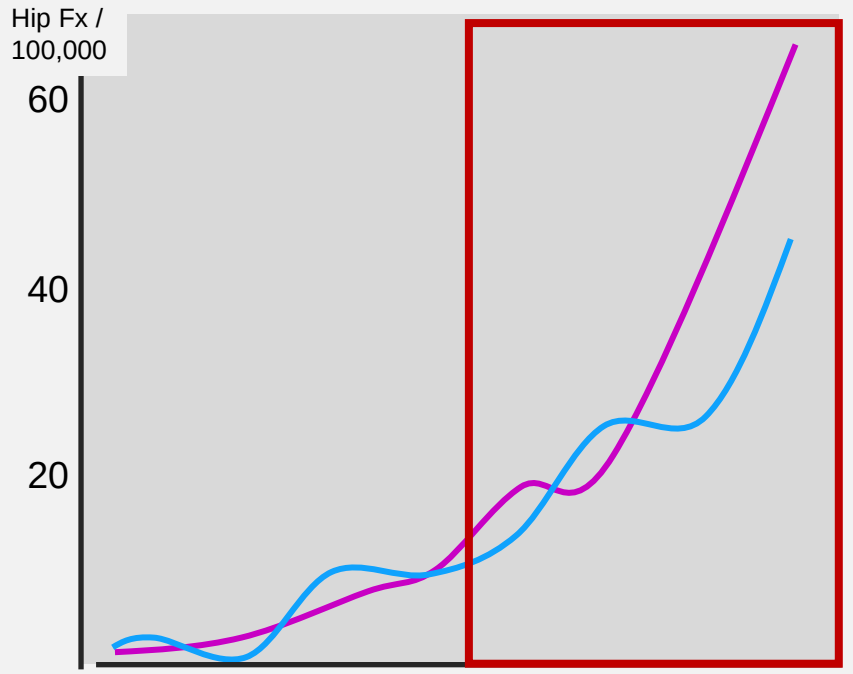
Average Life Expectancy in South Africa



Adapted from theglobalgraph.com

Average Life Expectancy in South Africa & Fractures

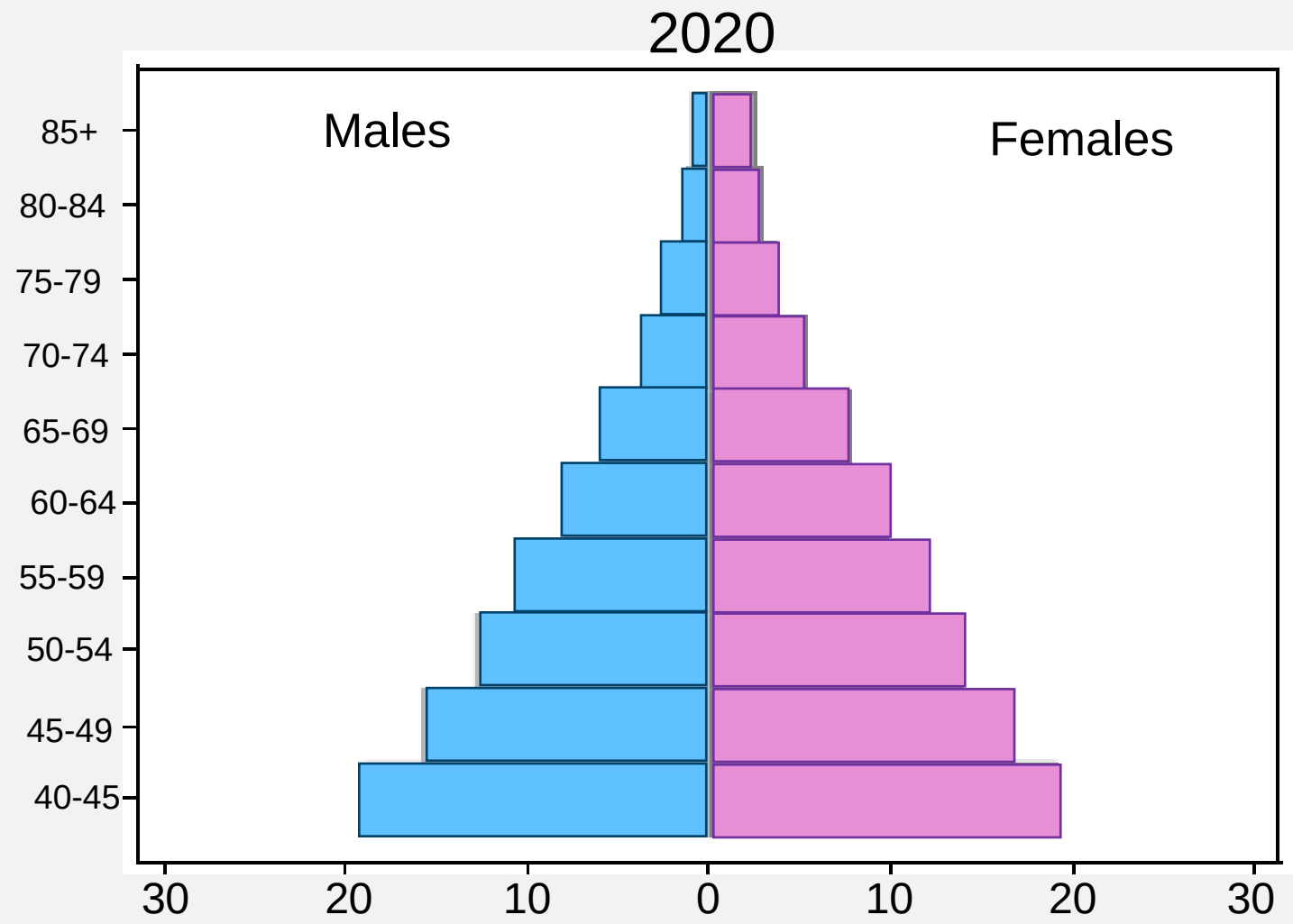




Age Group	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
Female	1.7	2.8	6.8	10.2	19.1	22.8	43.3	66.7
Male	2.8	1.7	10.0	10.0	14.0	25.3	26.7	45.6

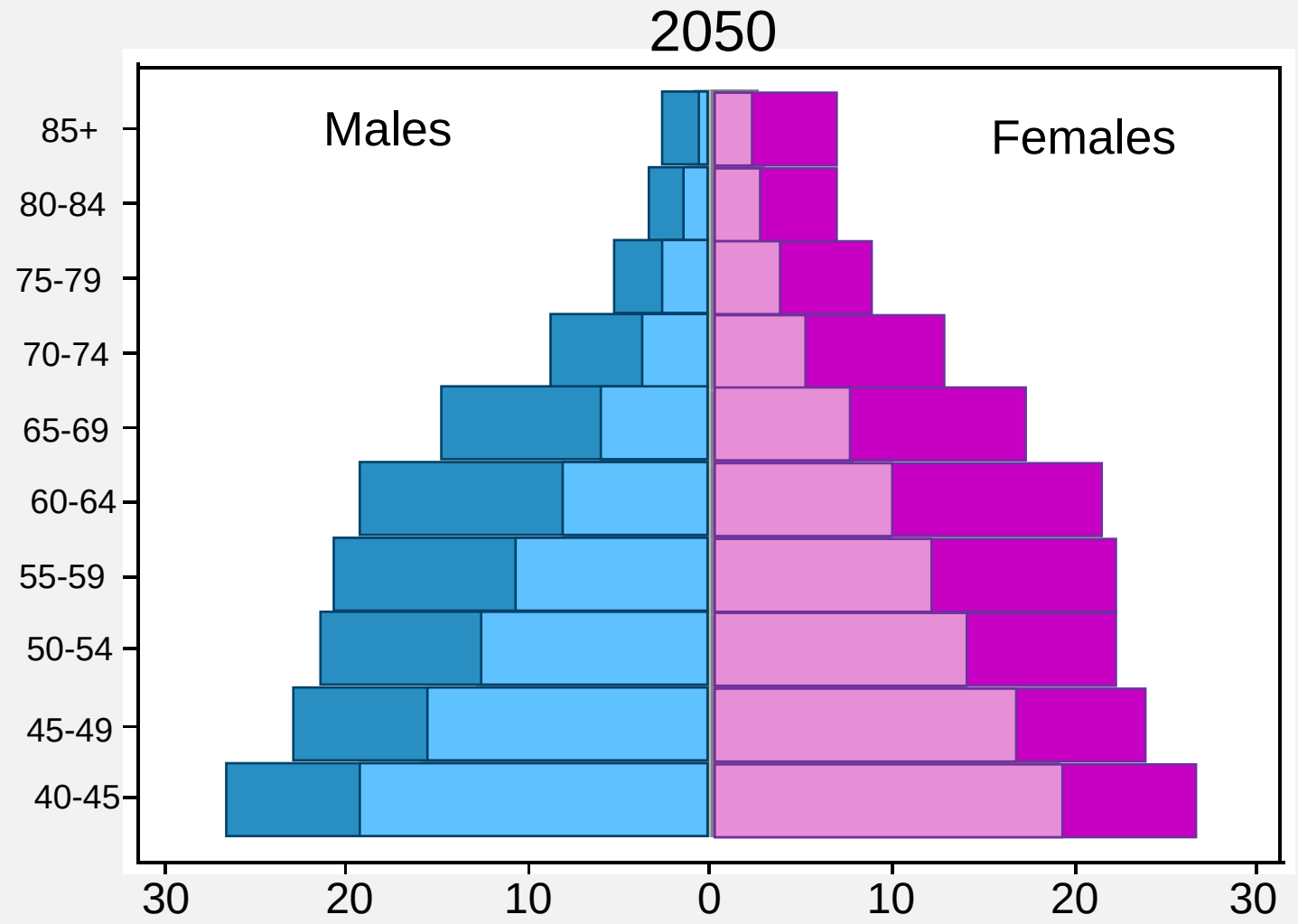
Adapted from theglobalgraph.com; Grundill et al., St Afr Med J, 2021

Age Distribution & Fracture Burden



Adapted from Hawley et al., Osteoporosis Int, 2022

Age Distribution & Fracture Burden



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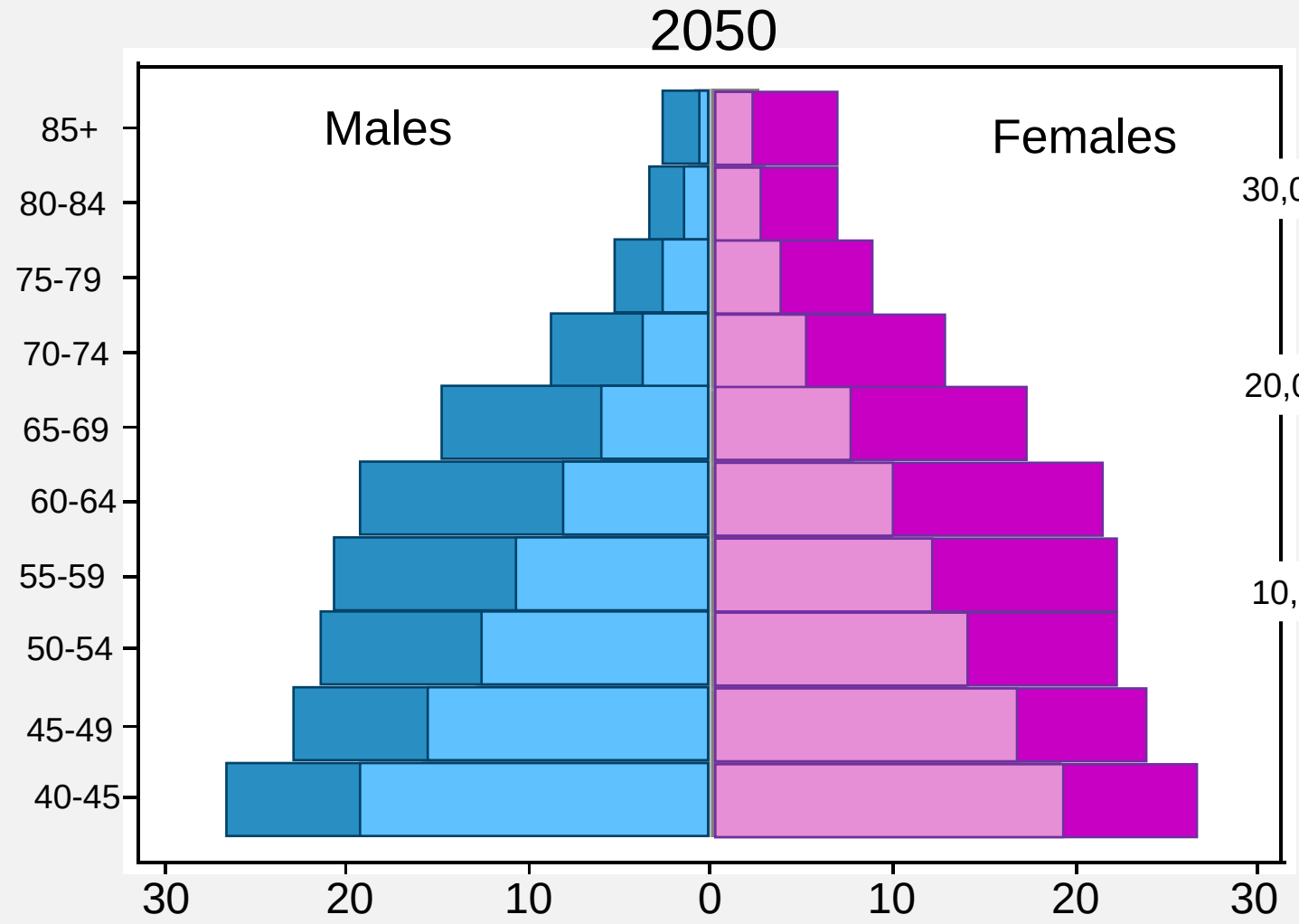
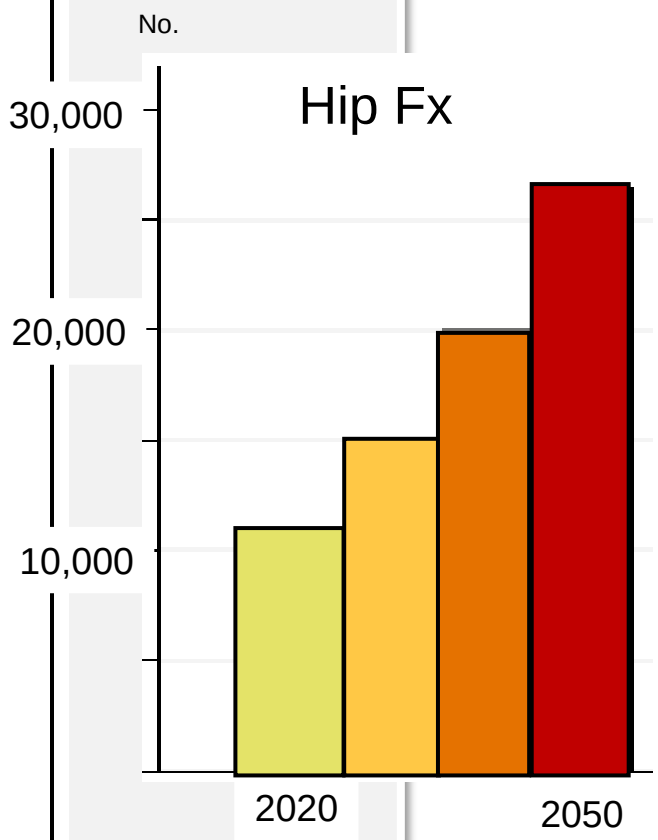
Age Distribution & Fracture Burden

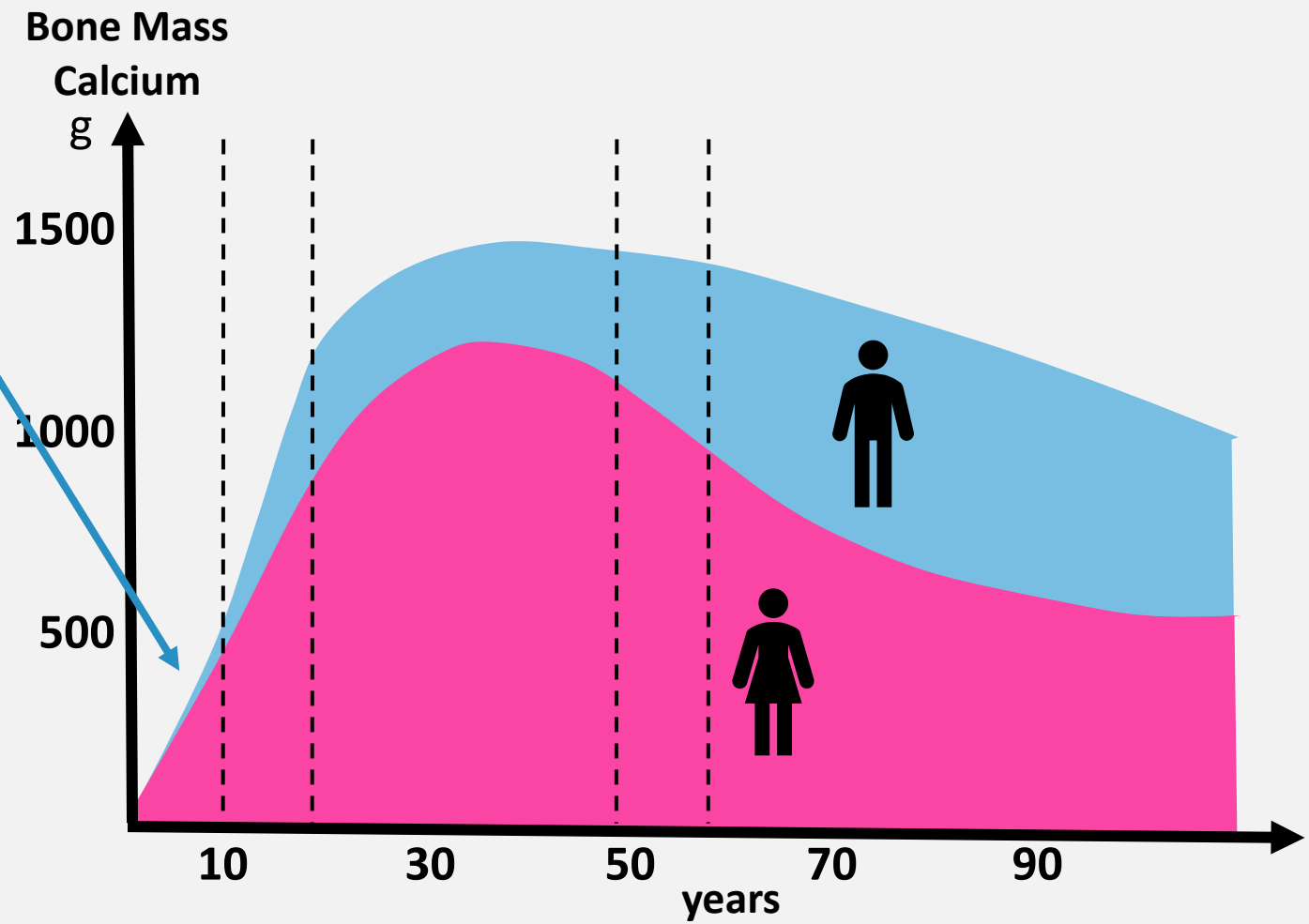




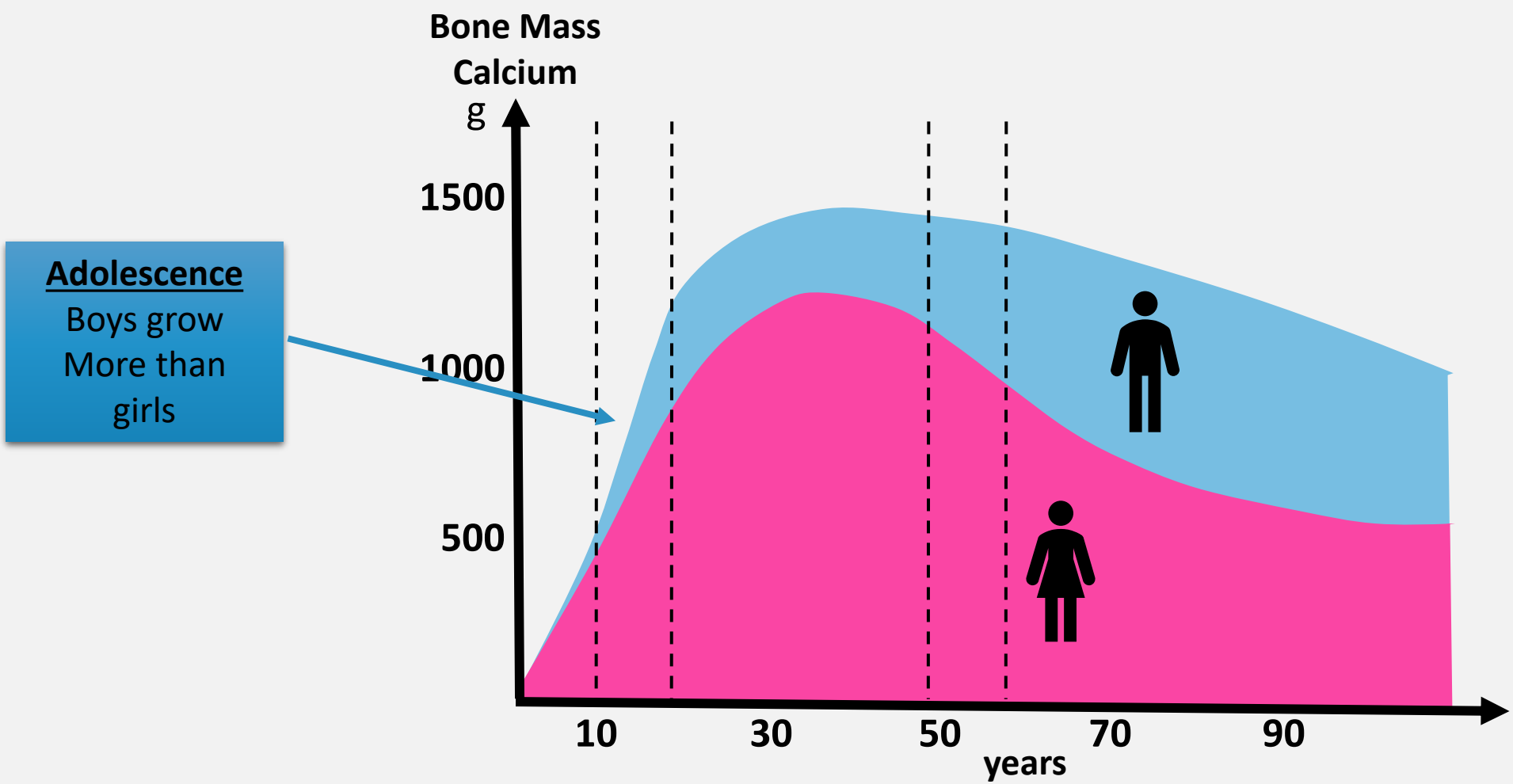
Adapted from Hawley et al., Osteoporosis Int, 2022

Bone Mass Over the Lifespan

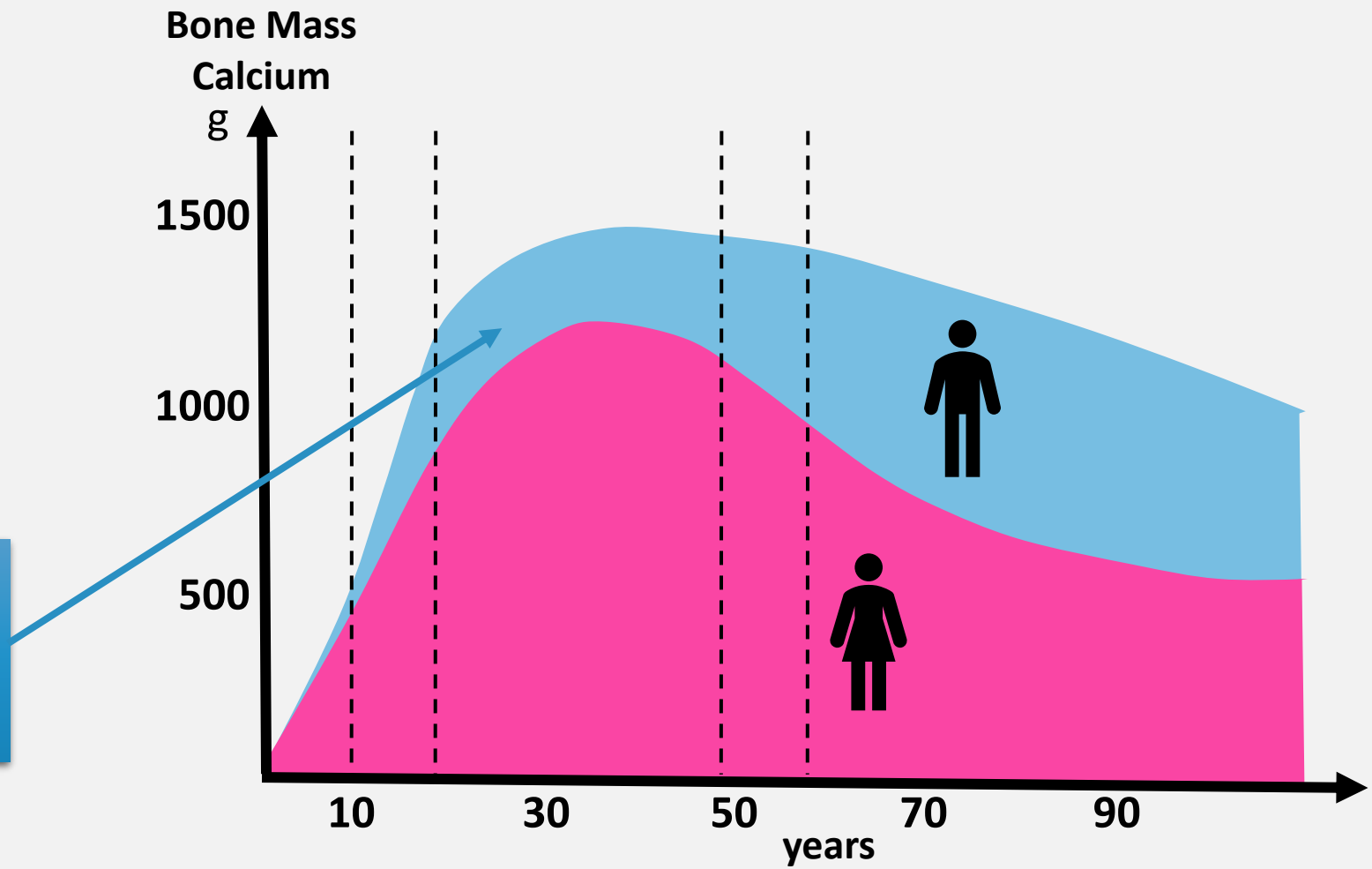
Childhood
Boys & Girls
are similar



Bone Mass Over the Lifespan

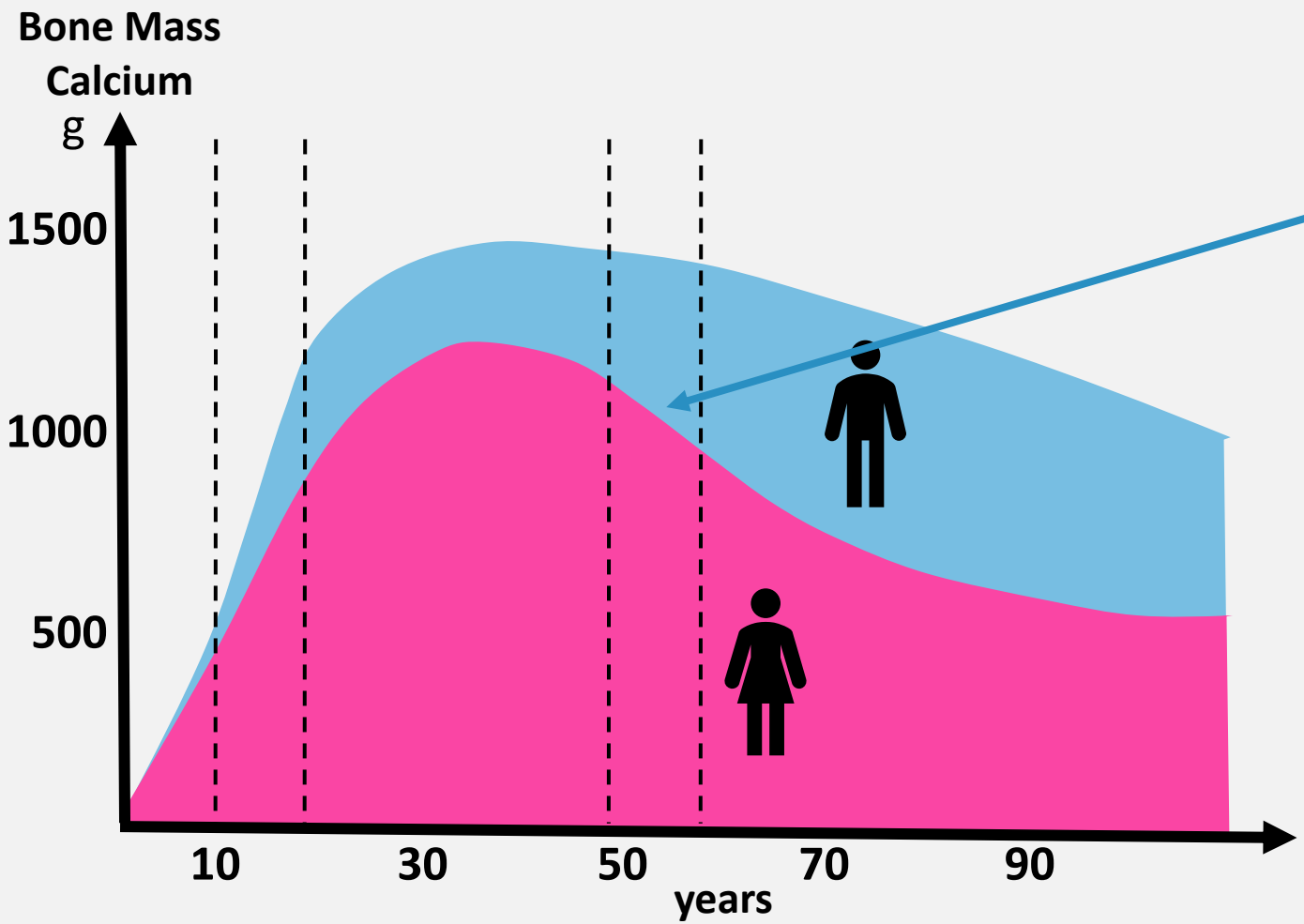


Bone Mass Over the Lifespan

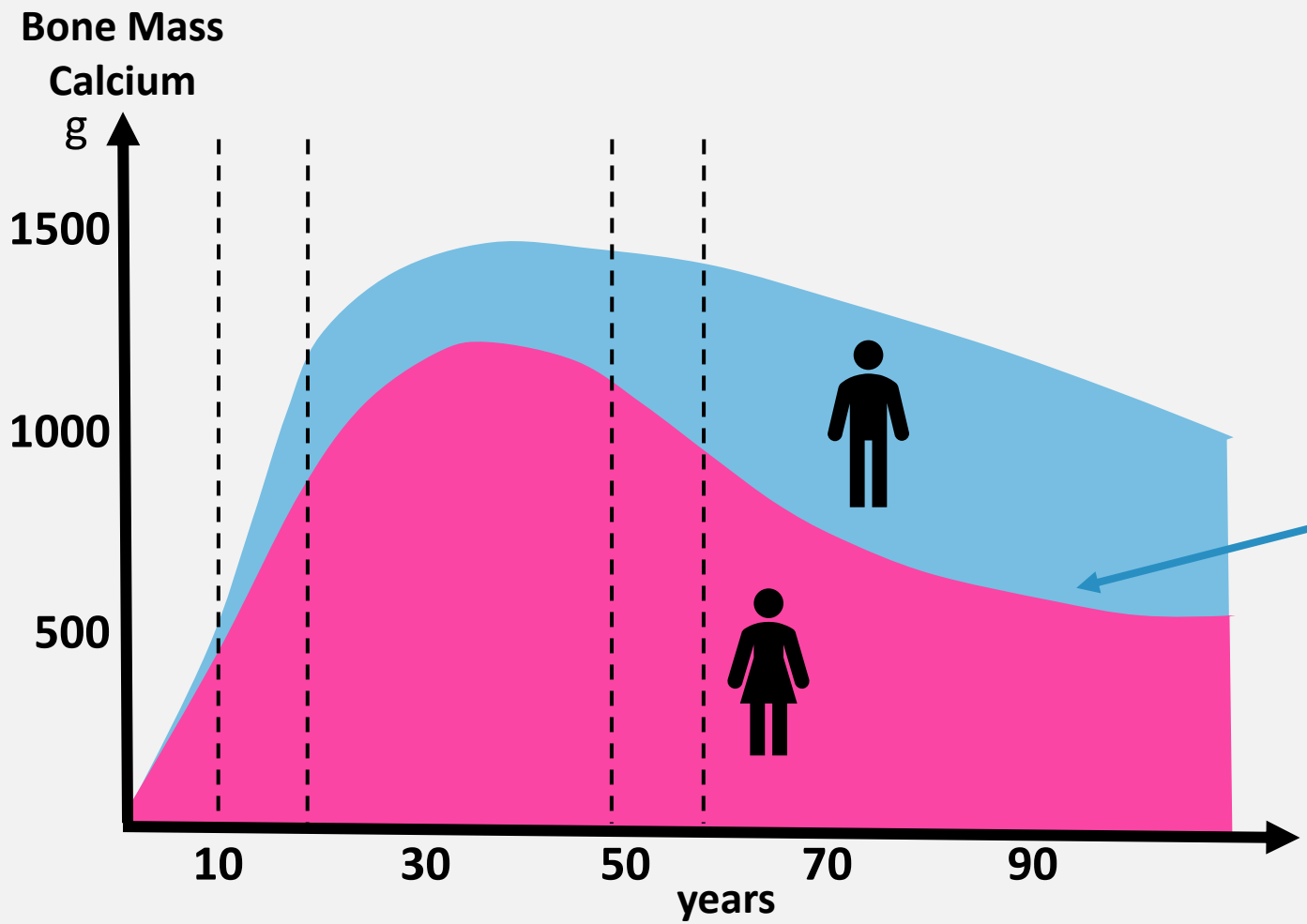


Adulthood
Men have
Larger skeletons
than women

Bone Mass Over the Lifespan

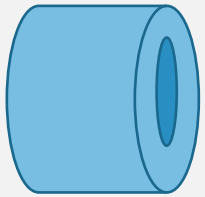


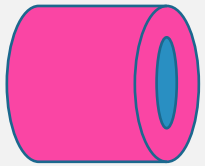
Bone Mass Over the Lifespan



Old age
Bone continues to be lost by men & women

Bone Structure Over the Lifespan

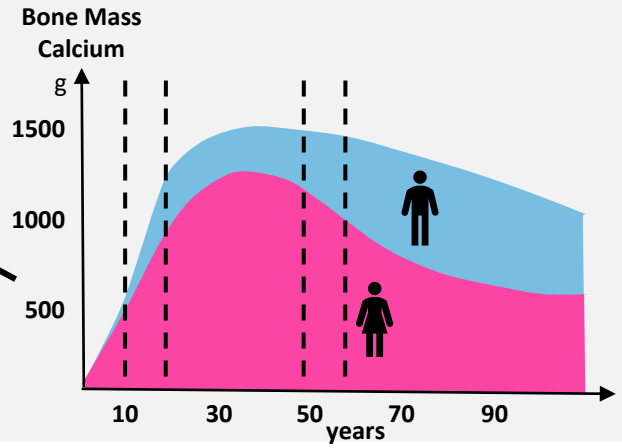




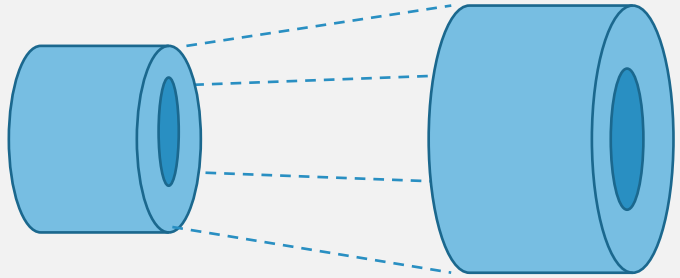
Childhood

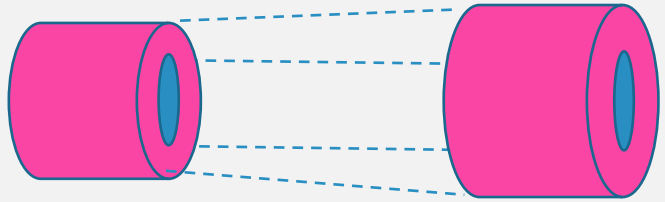
Similar bone size between boys & girls

Wider in boys



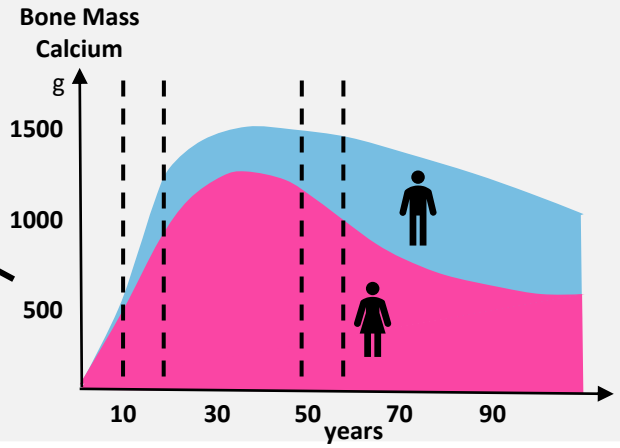
Bone Structure Over the Lifespan



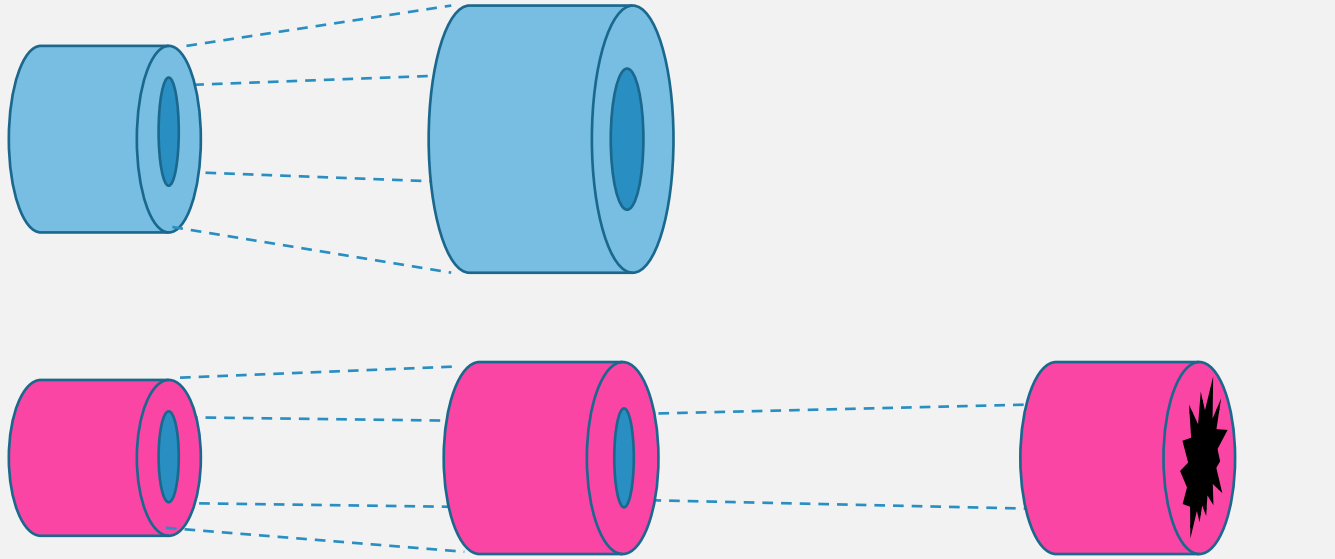


Adolescents
Greater increase in boys than girls

Childhood
Similar bone size between boys & girls



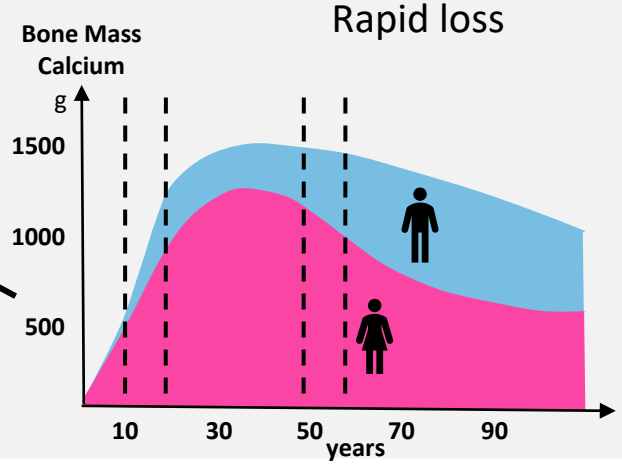
Bone Structure Over the Lifespan



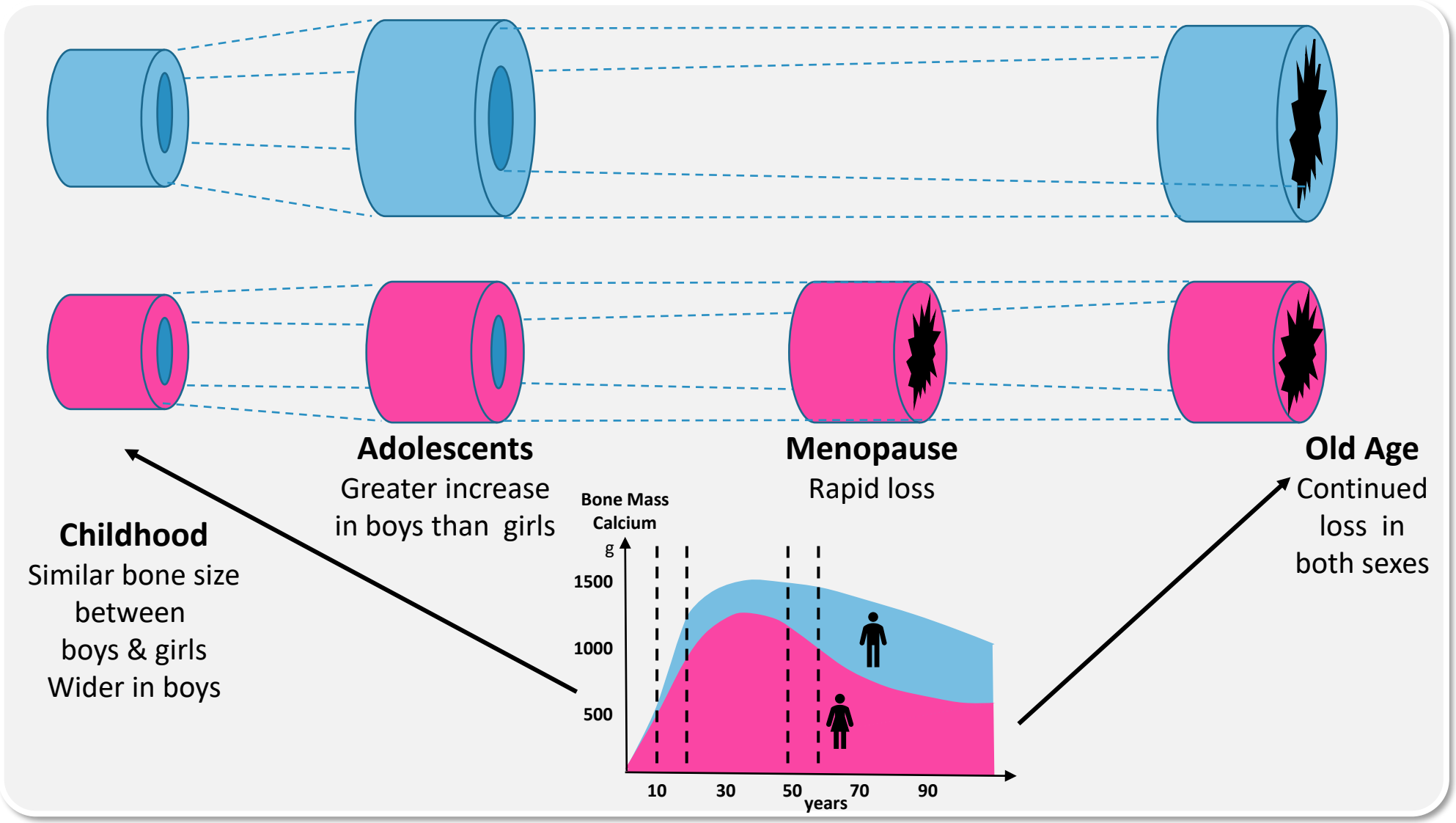
Childhood
Similar bone size between boys & girls
Wider in boys

Adolescents
Greater increase in boys than girls

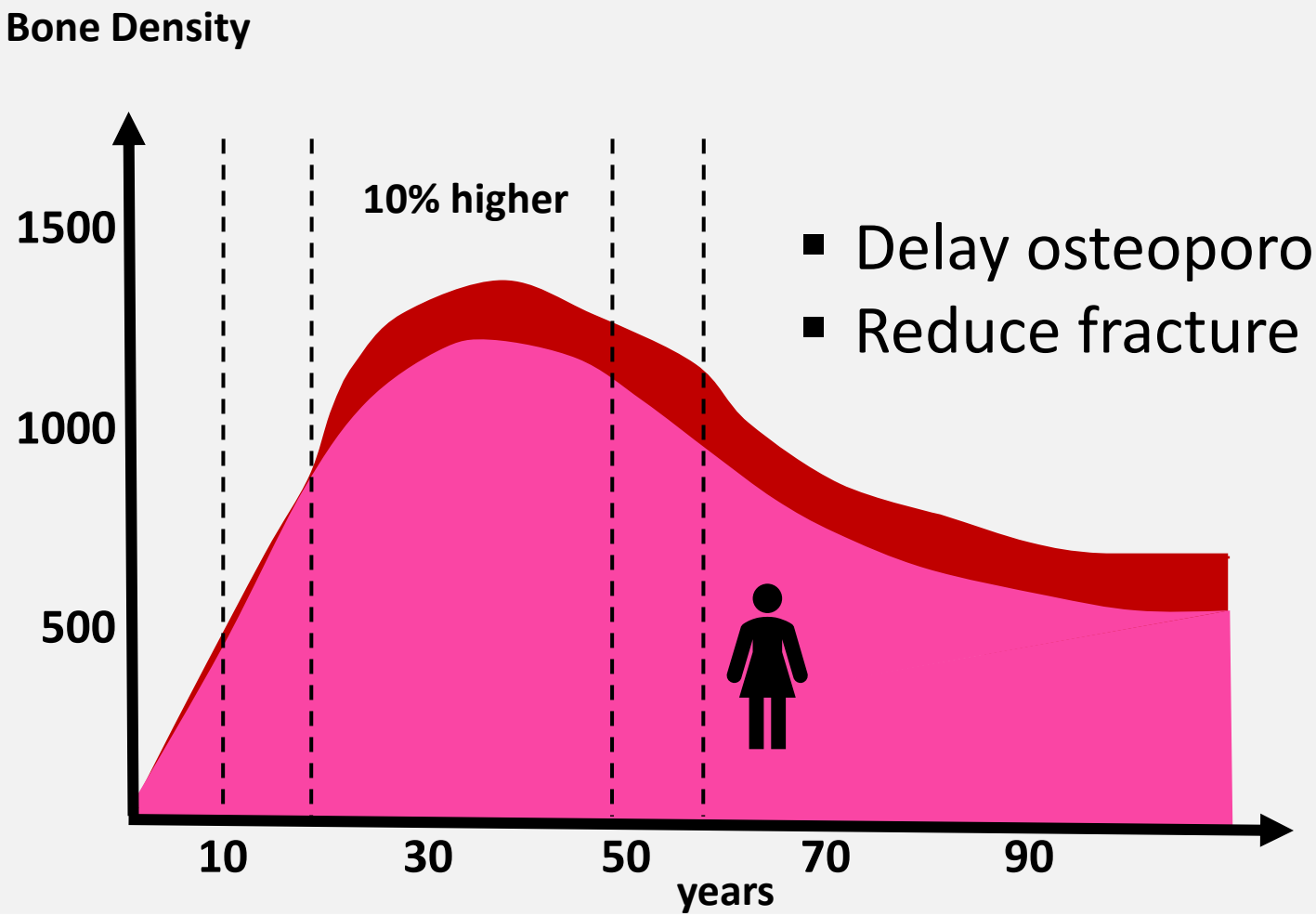
Menopause
Rapid loss



Bone Structure Over the Lifespan



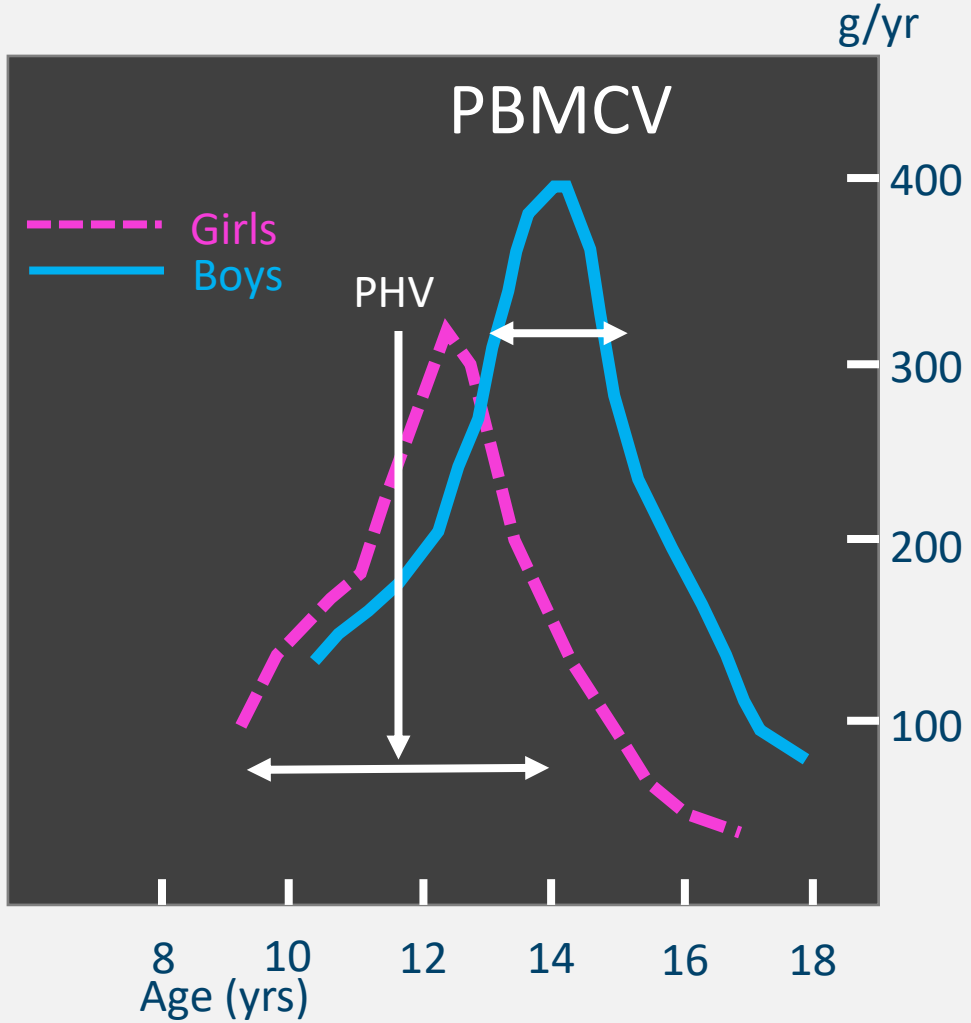
Peak Bone Mass & Fracture Risk



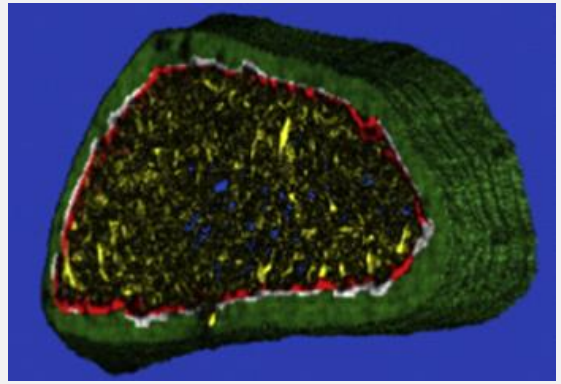
- Delay osteoporosis by 13 years
- Reduce fracture risk by 50%

Bone Mineral Content Accrual During Puberty (PBMCV)

4 years around PHV
27% of femoral neck bone mineral accretion
Similar amount to that lost in adult life

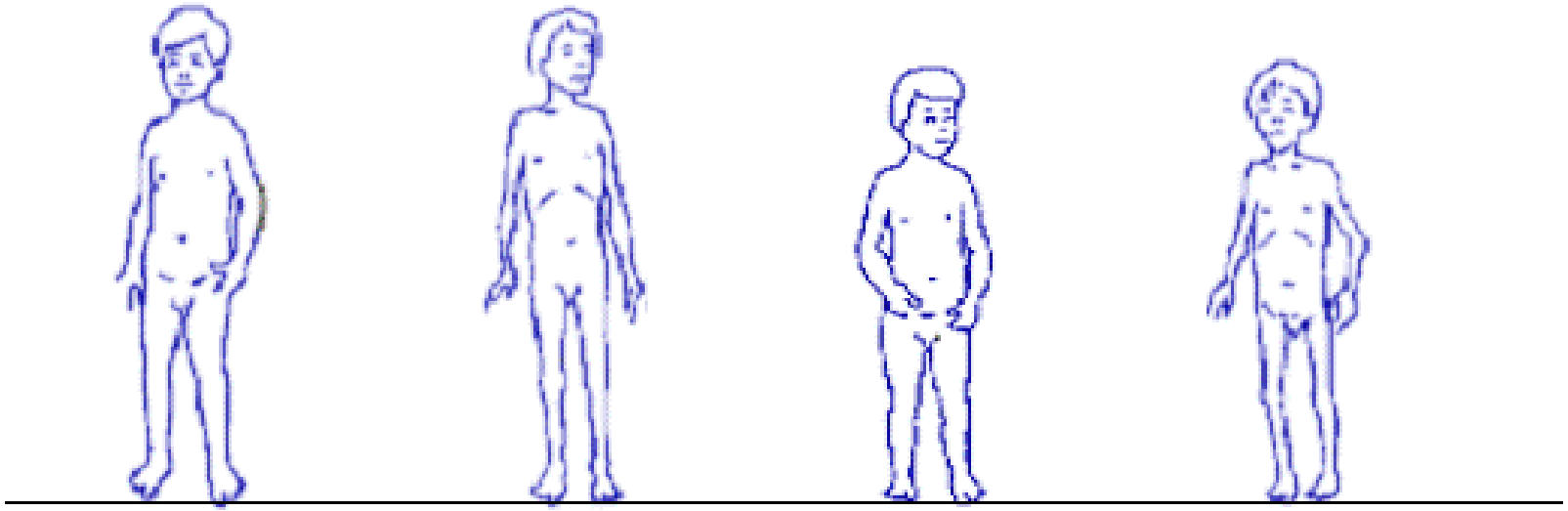


2 years around PBMCV
26% of adult calcium is accrued in bone.



Iuliano-Burns et al. AJHB 2001, Bailey Int J Sports Med, 1997, Bailey et al. JBMR, 2000

Effect of Protein-Energy Malnutrition on Growth



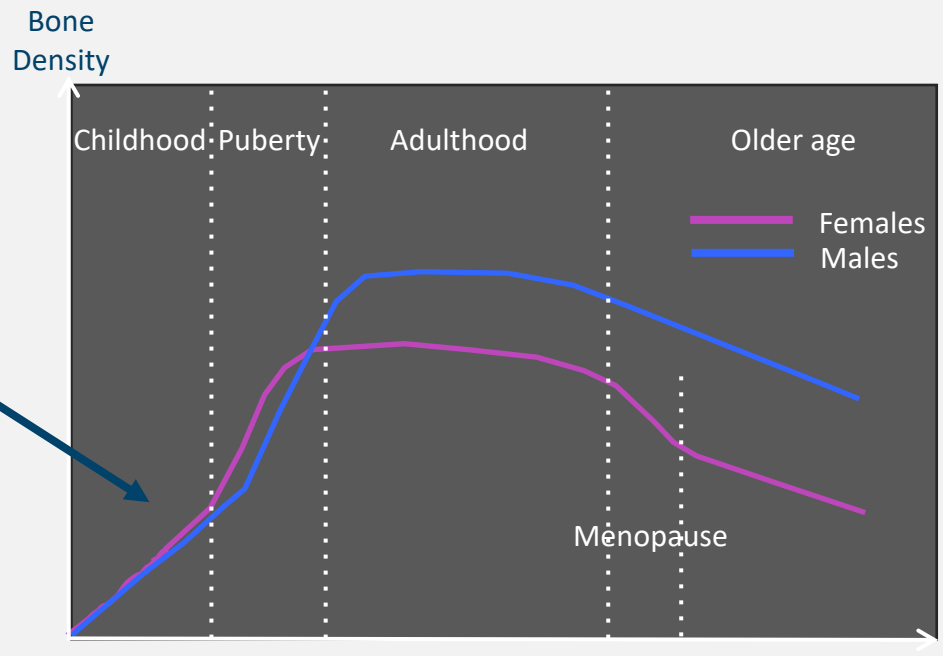
Normal	**Wasted**	**Stunted**	**Wasted & Stunted**
Normal weight & height	Thinner than normal	Shorter than normal	Thinner & Shorter than normal

- Wasting: acute malnutrition
- Stunting: chronic malnutrition

Adapted from London School of Hygiene and Tropical Medicine 2009

Skeletal Effects of a Dairy-Free Diet

Case-Control
n=53 Infants
Macrobiotic diet
(no dairy)
55%: symptoms of rickets
Dagnelie et al. AJCN 1990



Skeletal Effects of a Dairy-Free Diet

Case-Control
n=81 Fx Children
Milk-free diet
Female: OR 4.6 (1.4, 15.5)
Konstantynowicz et al. OI 2007

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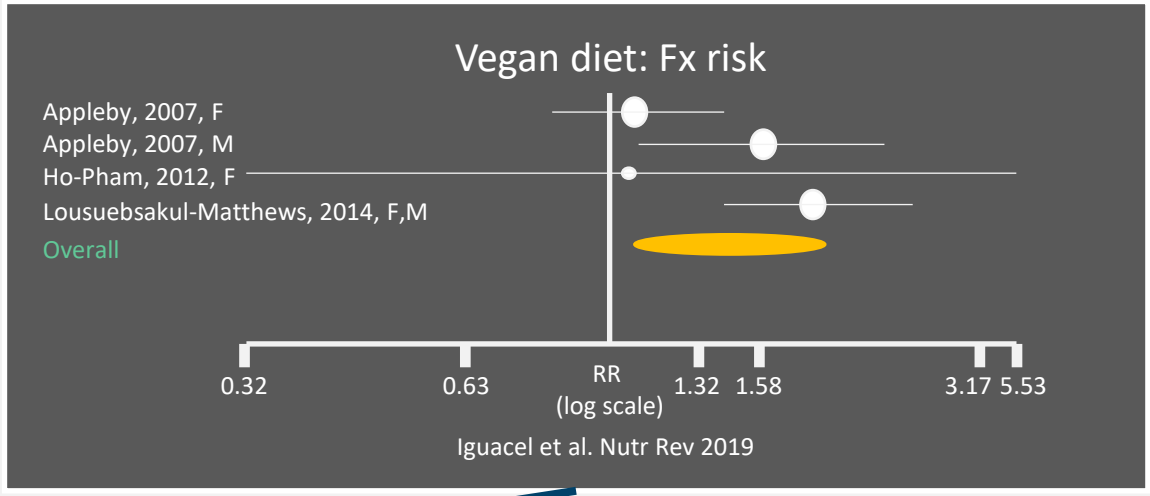
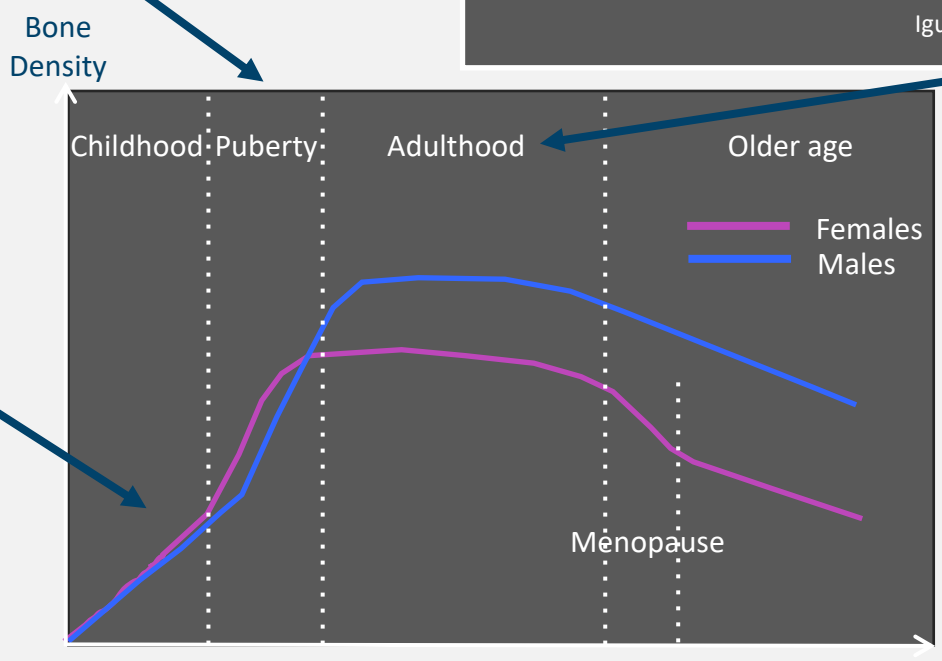
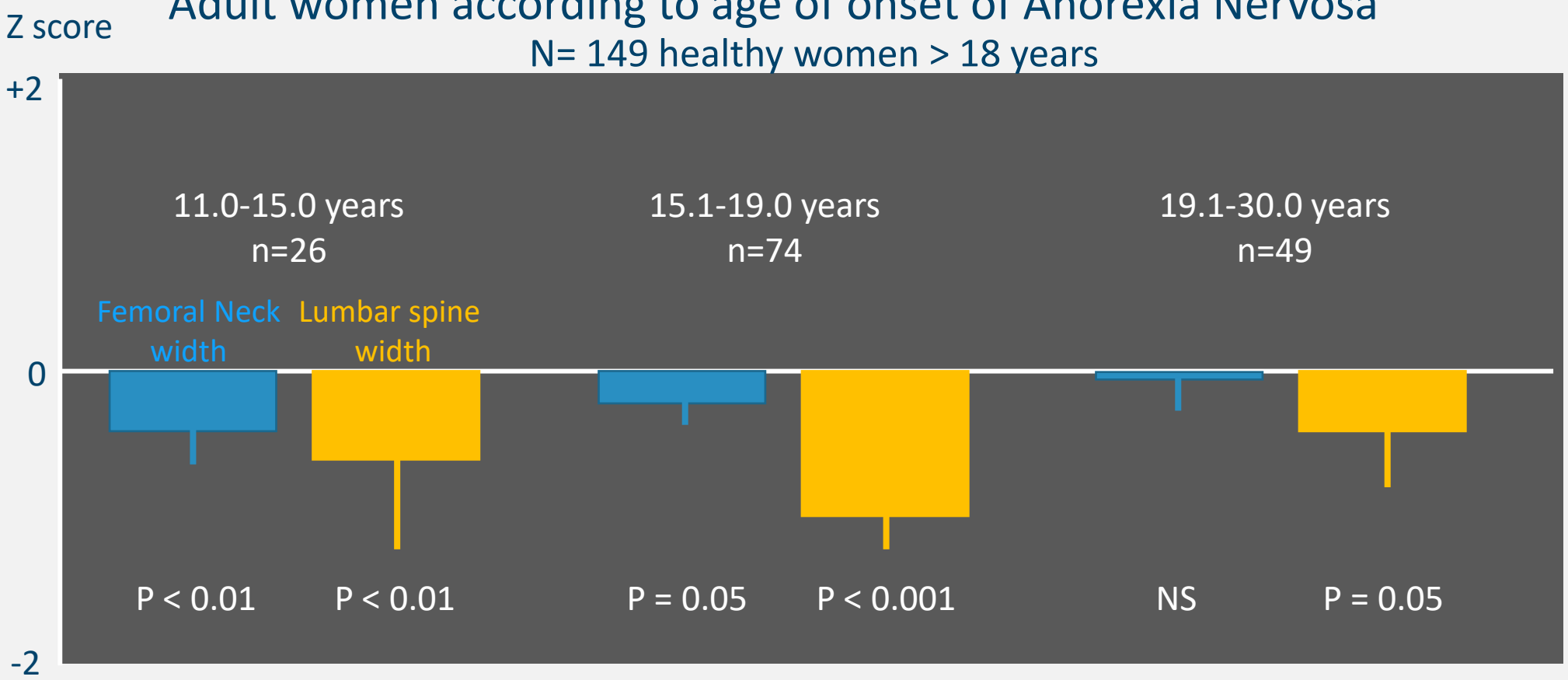


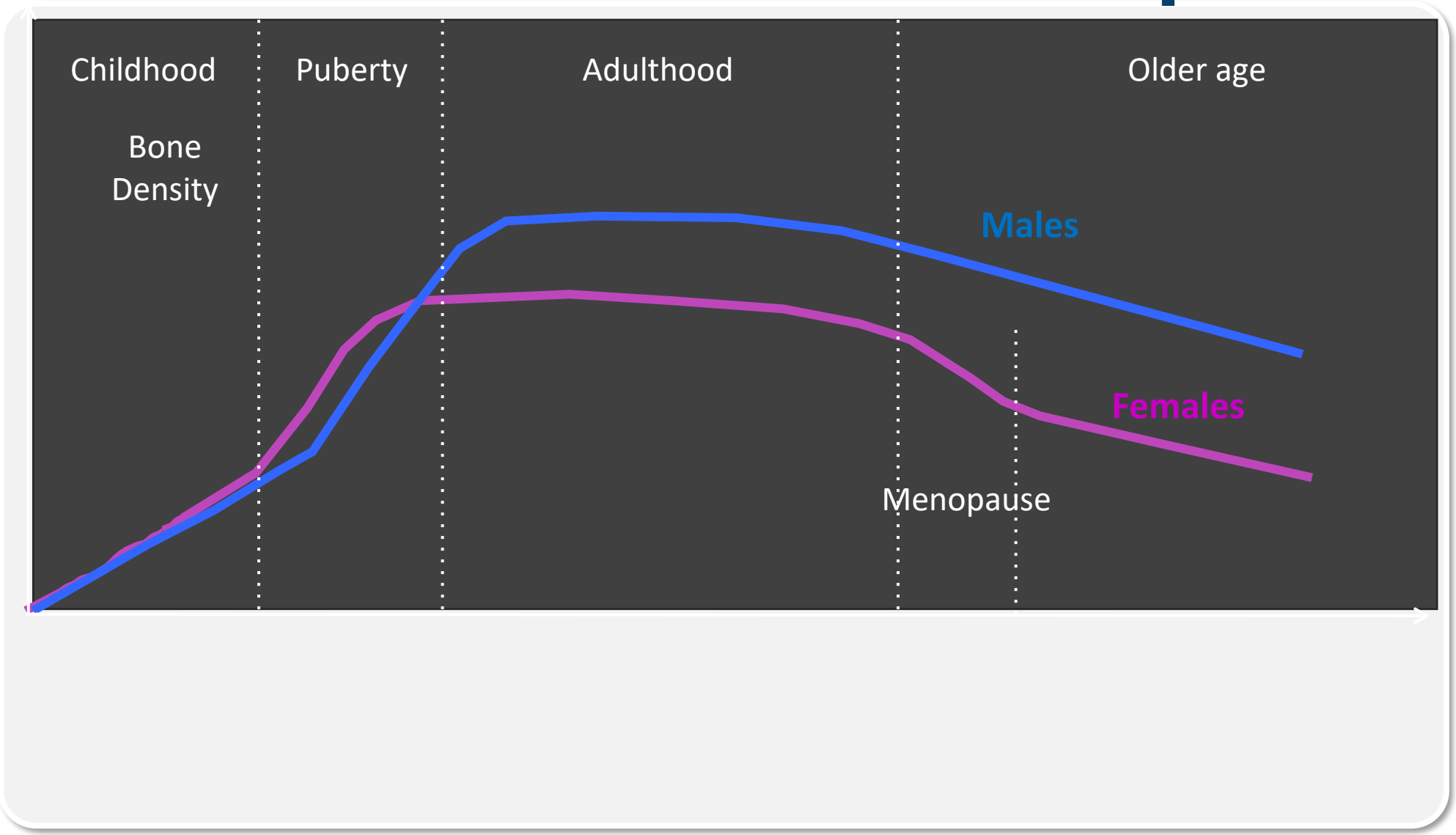


Effect of Timing of Energy Restriction on Bone



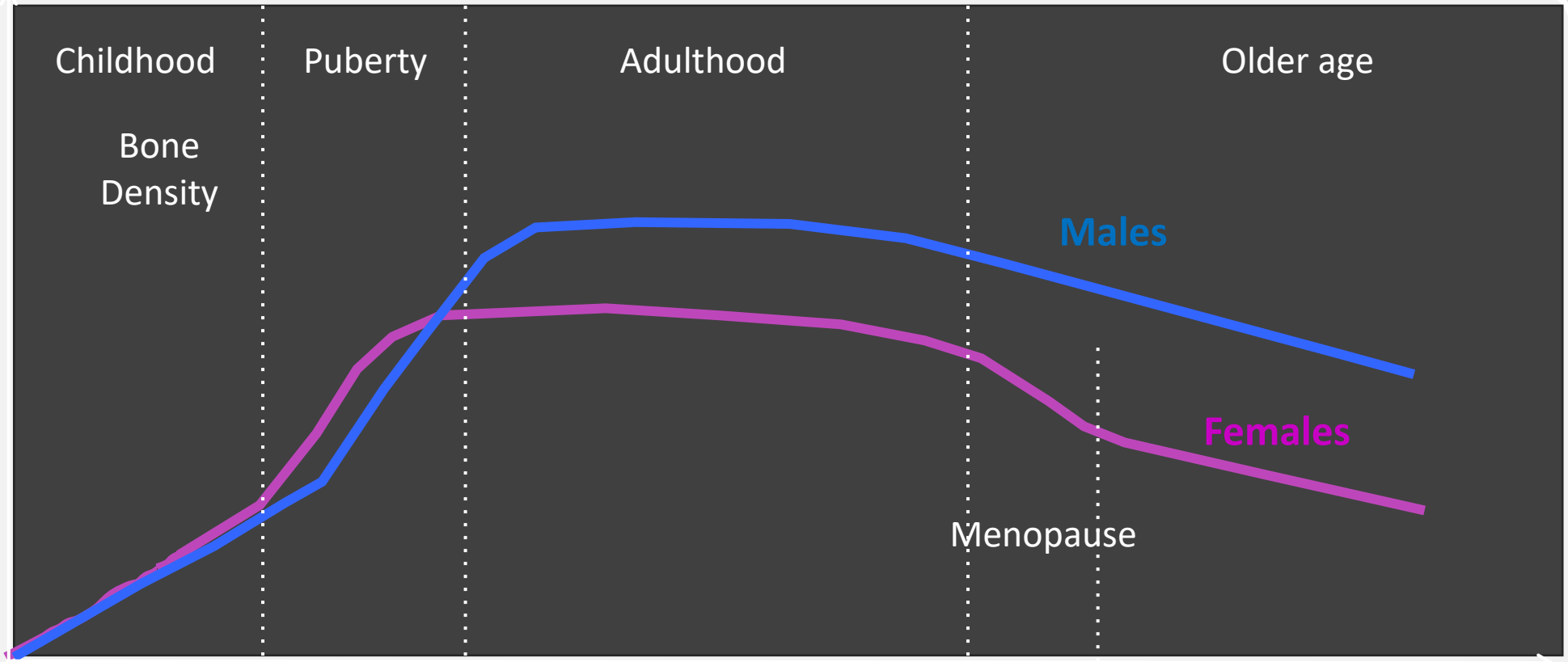
Seeman et al. JBMR 2000

Calcium Intake Over the Lifespan



Kolahdooz et al. PLoS 2103; Kruger et al., Nutr Res, 2011; Wright et al., Nutrients, 2019; Charlton et al., Nutr, 2005; Charlton et al., Euro J Clin Nutr, 2005; MacKeown et al., Public Health Ntr, 2005; Charlton et al., Asia Pacific J Clin Nutr, 2001

Calcium Intake Over the Lifespan

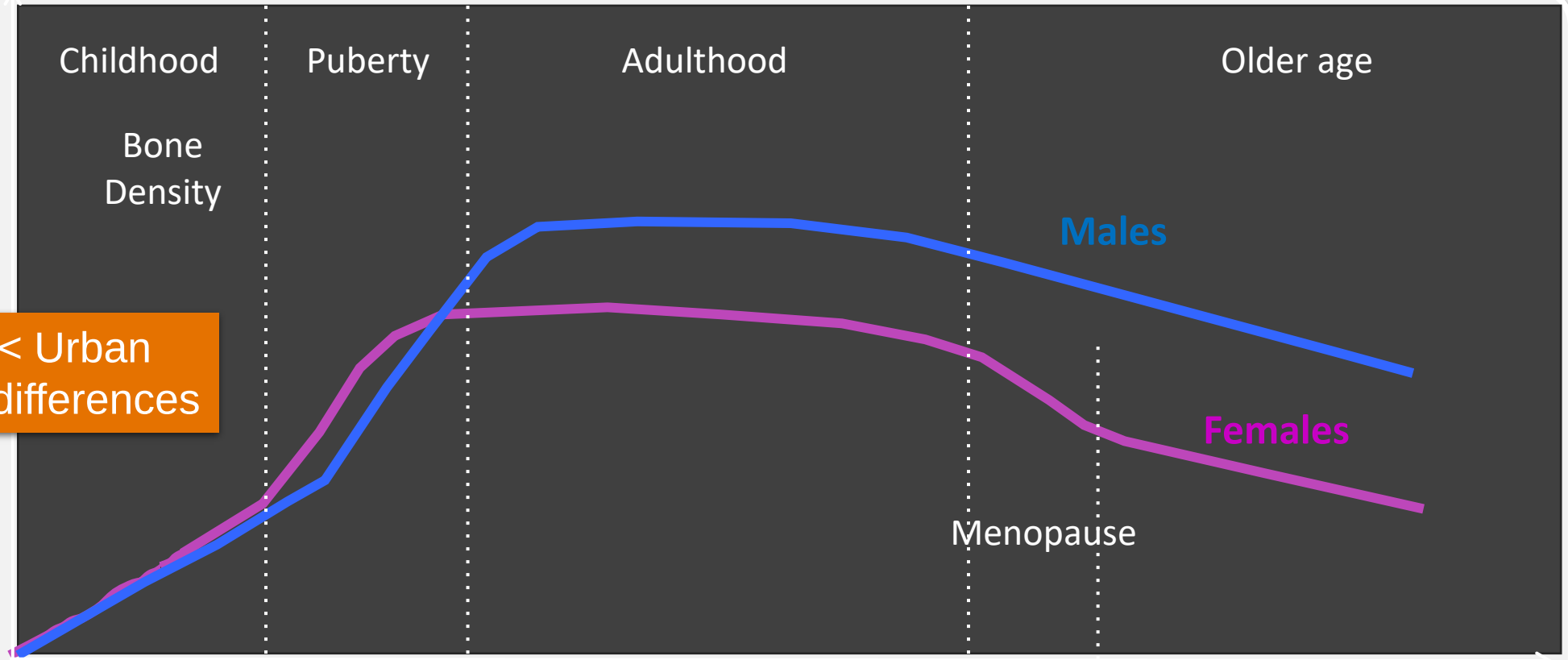


Age	7-10	11-18	20-34	35-49	50-55	56-74	75+	80+
Male	497	642	329	329	299	424	424	424
Female	497	642	245	245	265	424	424	424

Kolahdooz et al. PLoS 2103; Kruger et al., Nutr Res, 2011; Wright et al., Nutrients, 2019; Charlton et al., Nutr, 2005; Charlton et al., Euro J Clin Nutr, 2005; MacKeown et al., Public Health Ntr, 2005; Charlton et al., Asia Pacific J Clin Nutr, 2001

Calcium Intake Over the Lifespan

- Rural < Urban
- Ethic differences



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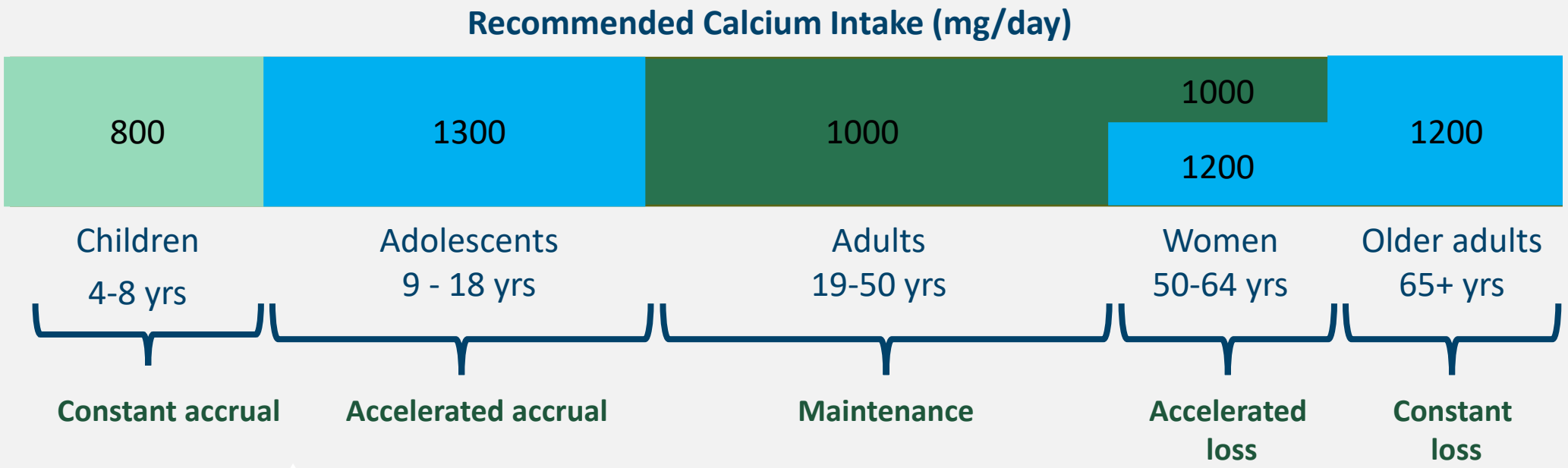
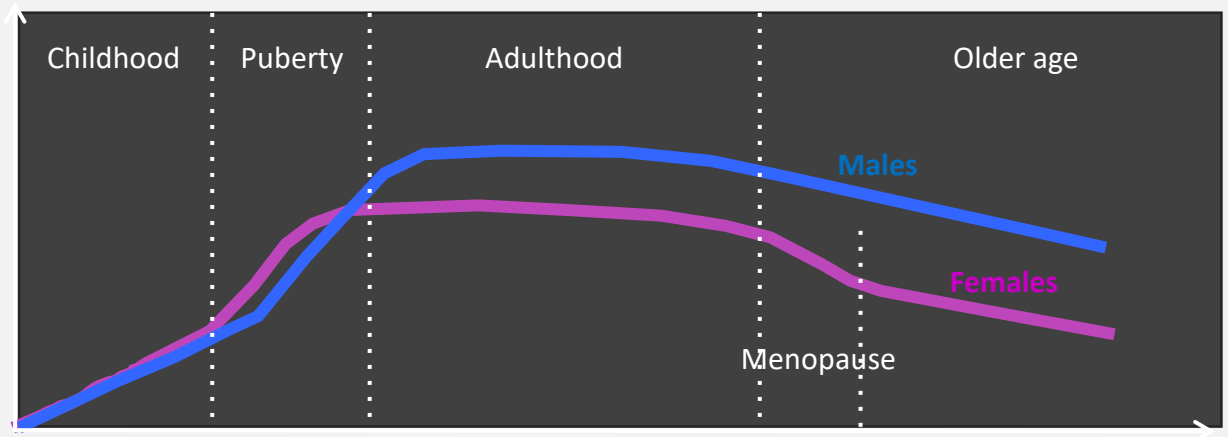
Bone Mineral Content Accrual & Recommended Calcium Intake

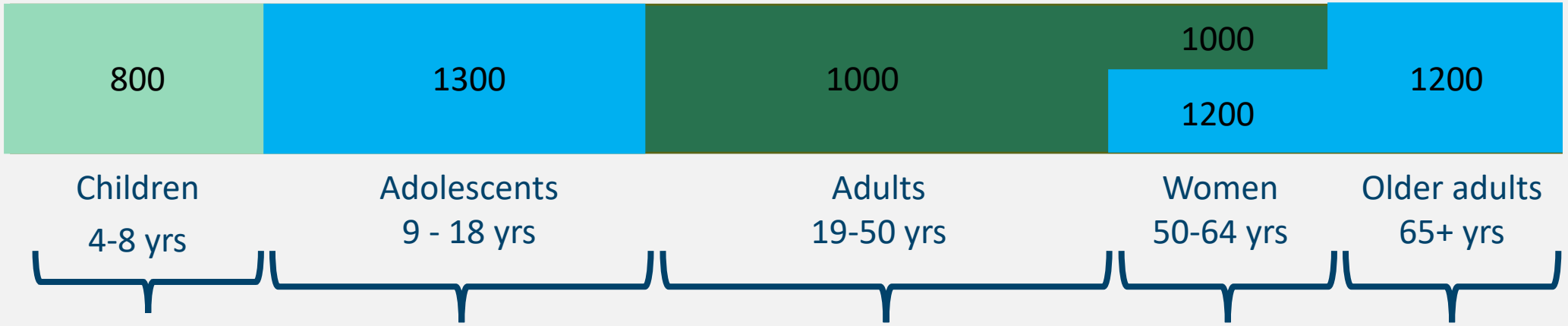




Have milk, maas or yoghurt every day

Bone Mineral Content Accrual & Recommended Calcium Intake

Recommended Calcium Intake (mg/day)



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Calcium Requirement & Intake Over the Lifespan

Calcium Intake (mg/d)

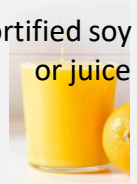
Age	7-10	11-18	20-34	35-49	50-55	56-74	75+	80+
Male	497	642	329	329	299	424	424	424
Female	497	642	245	245	265	424	424	424

Calcium Requirement (mg/d)

Age	4-8	9-18	19 - 50	51-70	70+
Male	800	1300	1000	1000	1200
Female	800	1300	1000	1200	1200

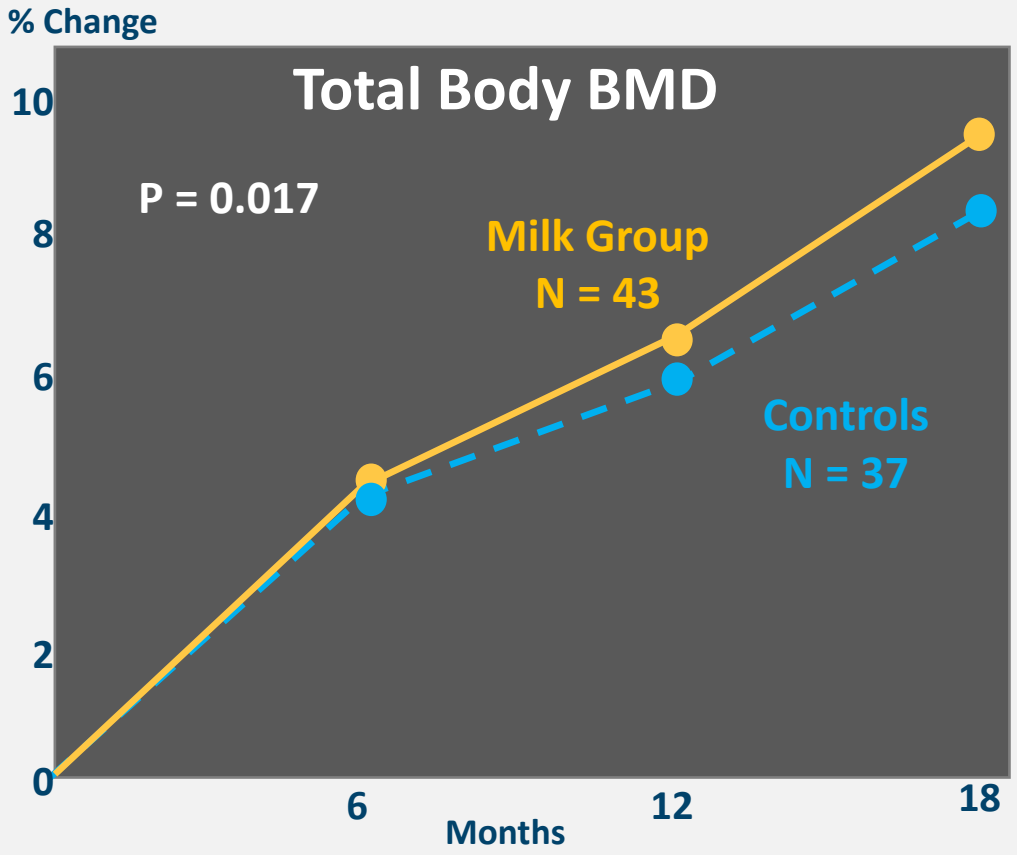
Recommended dairy intake (servings/d)

2-3 | 2



Dairy Supplementation During Growth

- Milk supplement
- Calcium ~ 750mg/d
- Girls only
- Matched for maturity
- Minimal drop-outs
- Consistent compliance



Cardogan et al. 1997 BMJ

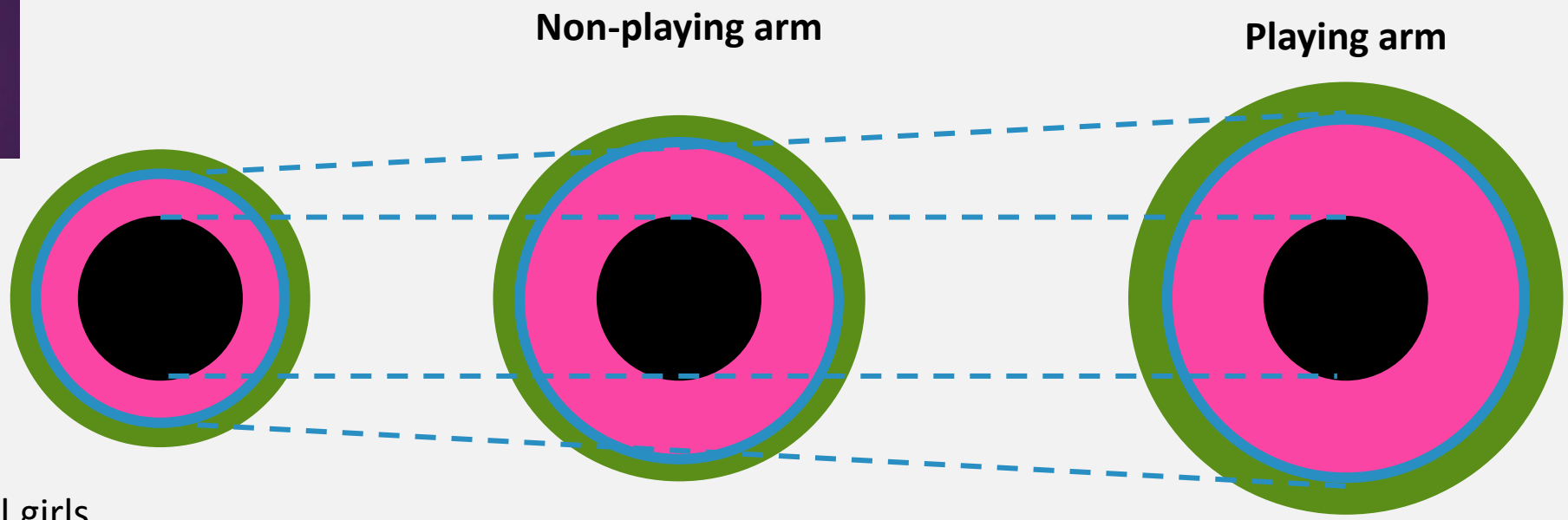
Studying the side-to-side Differences in Bone

Controls for:

- ✓ Age
- ✓ Maturity
- ✓ Genetics
- ✓ Environment
- ✓ Diet

Apttour.com

Response to mechanical loading before maturity



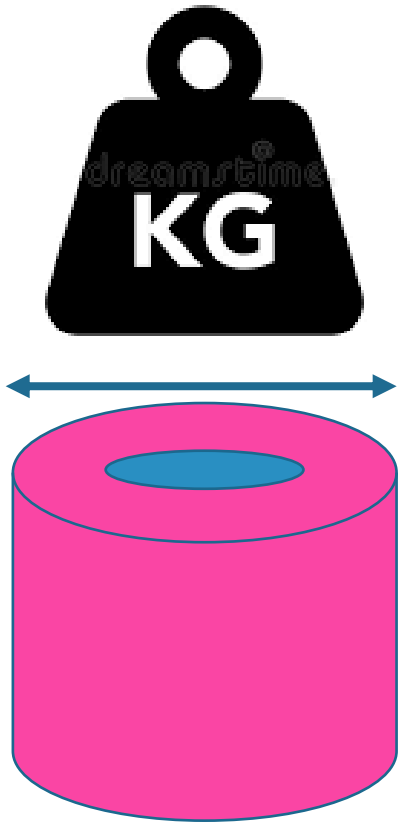
- 13 pre/peri-pubertal girls
- Compare playing arm to non-playing arm
- Increase due to growth (Non-playing arm)
- Greater increase in playing arm due to mechanical loading ($p < 0.01$)

Non-playing arm	Playing arm
Cortical area 10% ↑	Cortical area 13% ↑
Medullary area NS	Medullary area NS
Muscle area 8% ↑	Muscle area 13% ↑
Total area 8% ↑	Total area 13% ↑

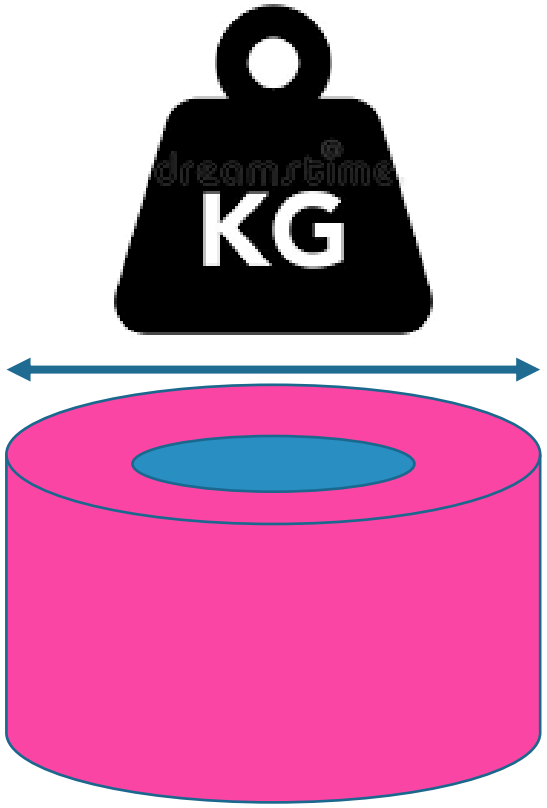
Ducher et al., JBMR, 2011

Which Bone is Stronger and Why?

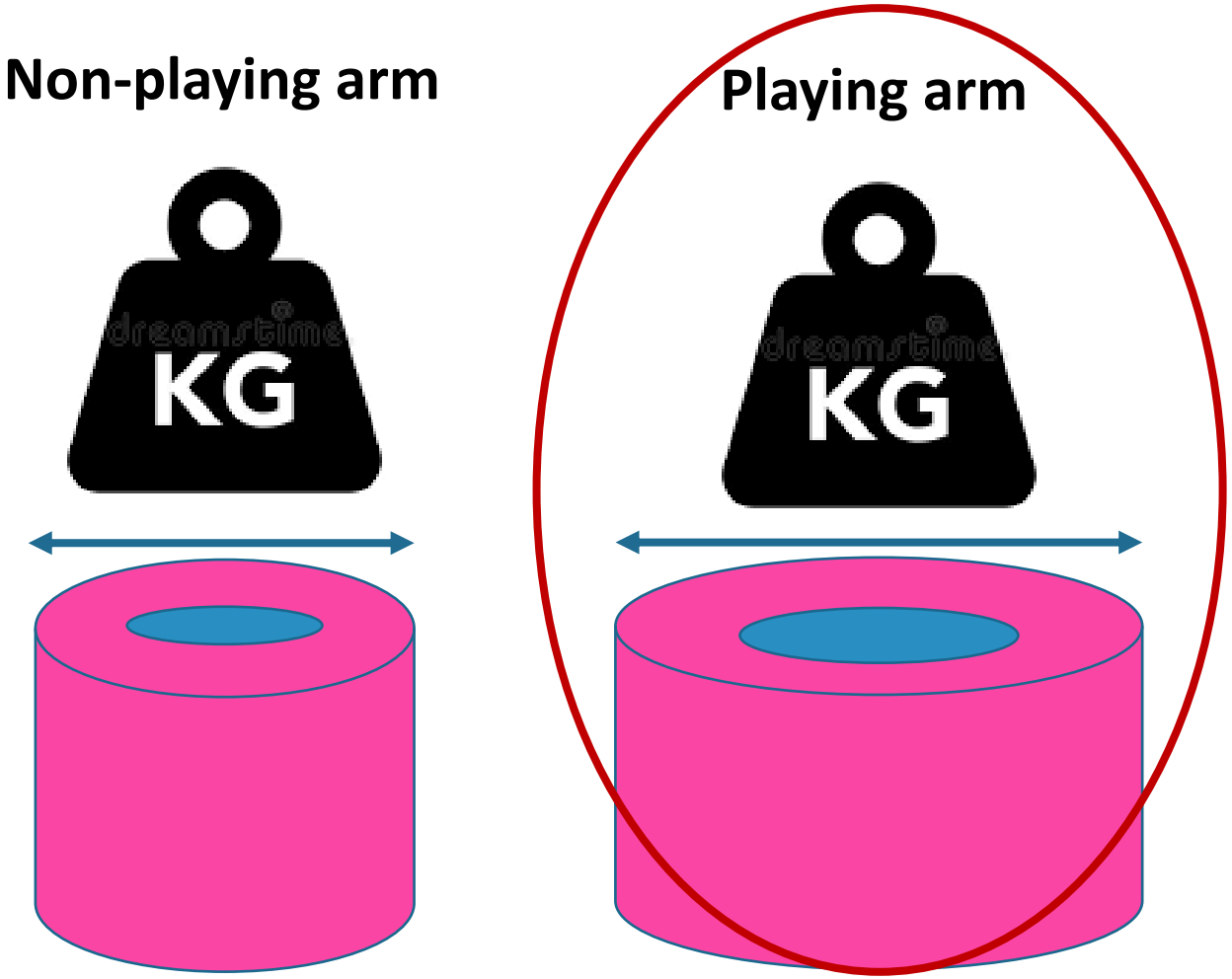
Non-playing arm



Playing arm



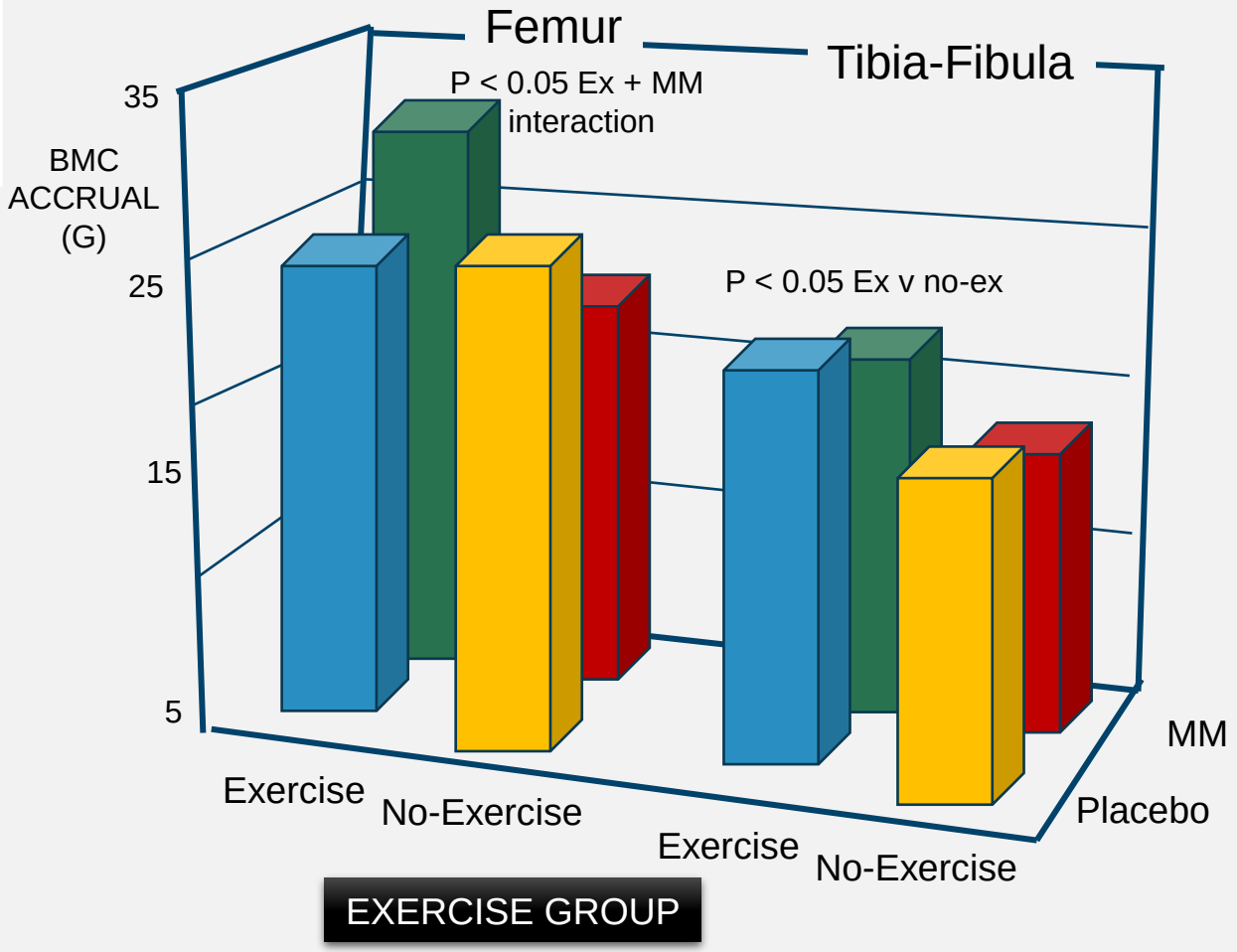
Which Bone is Stronger and Why?



Force spread over a
Larger surface area

School-based Exercise & Milk Mineral Program for Bone

9 yo girls
10 months
20 min: 3 x week



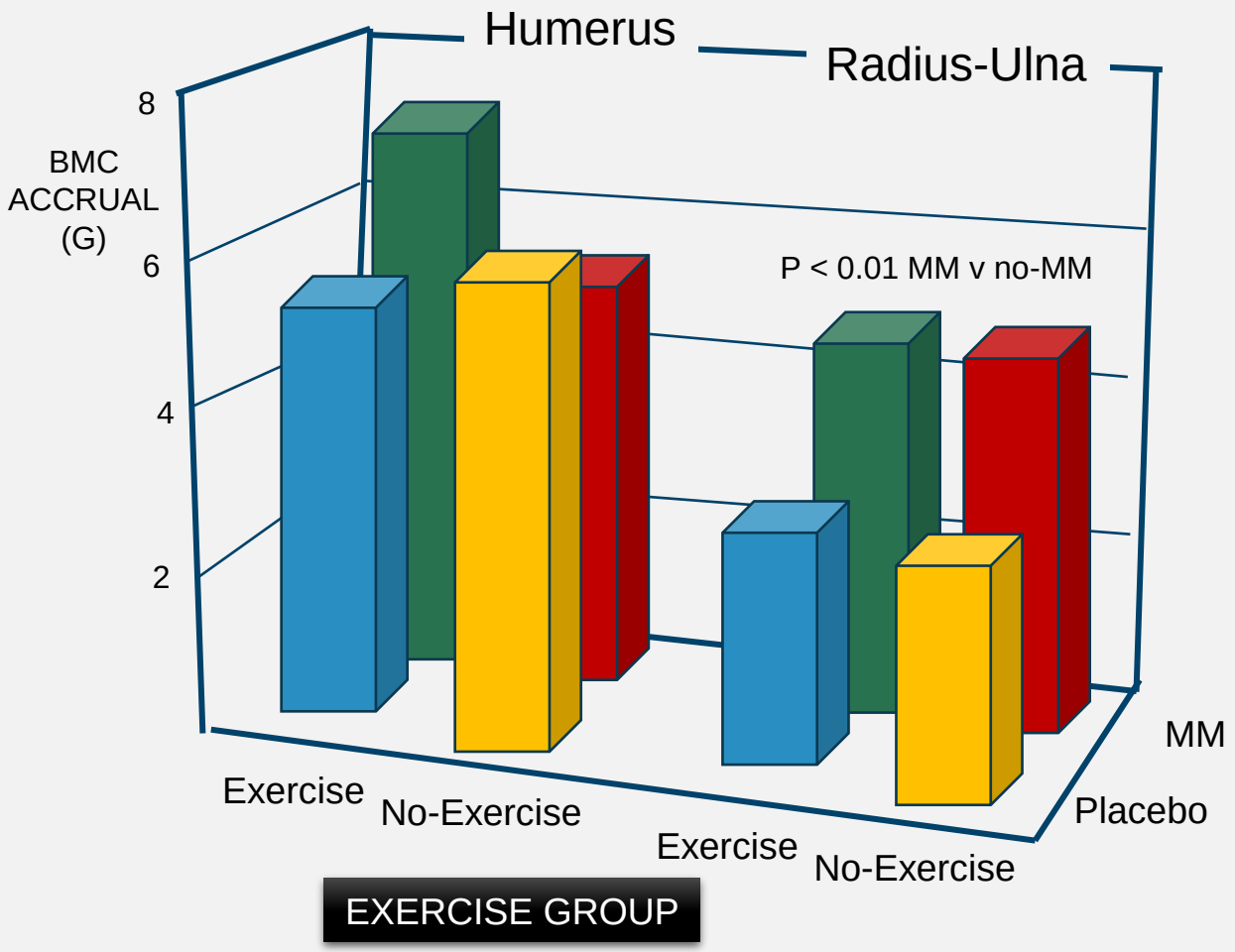
Improved bone accrual high-impact exercise
- Skipping
- Hopping
- Step aerobics

P < 0.05

Iuliano-Burns et al. JBMR 2003

School-based Exercise & Milk Mineral Program for Bone

9 yo girls
10 months

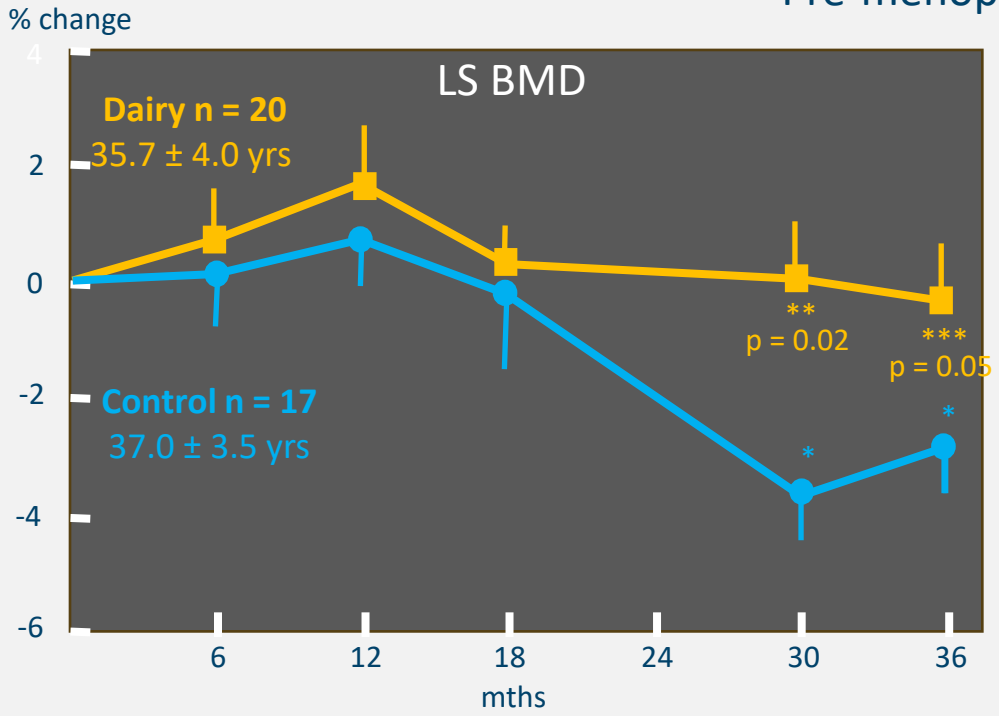


- 2g milk minerals / item
- 10 items per week
- 25 varieties of foods
- Compliance 70%
- Cal: 673 to 1121 mg/d

Iuliano-Burns et al. JBMR 2003

Dairy Supplementation During Adulthood

Pre-menopausal women



Calcium intake mg/d

Dairy	900	1300	1500
Control	900	800	800

Baran et al. JCEM 1989

Dairy Supplementation During Adulthood

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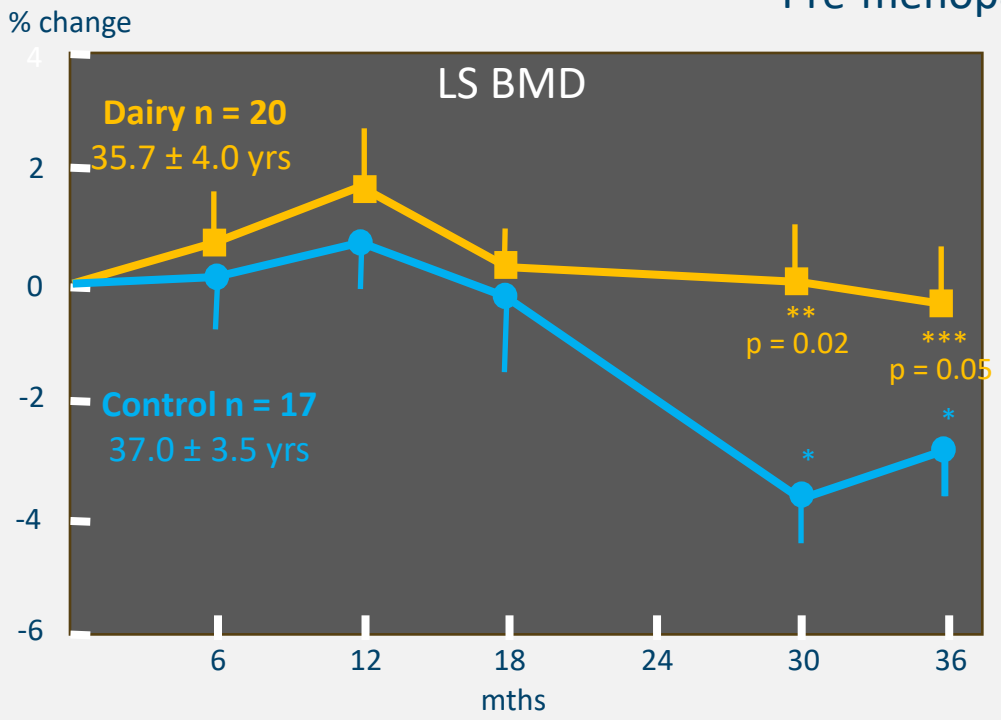
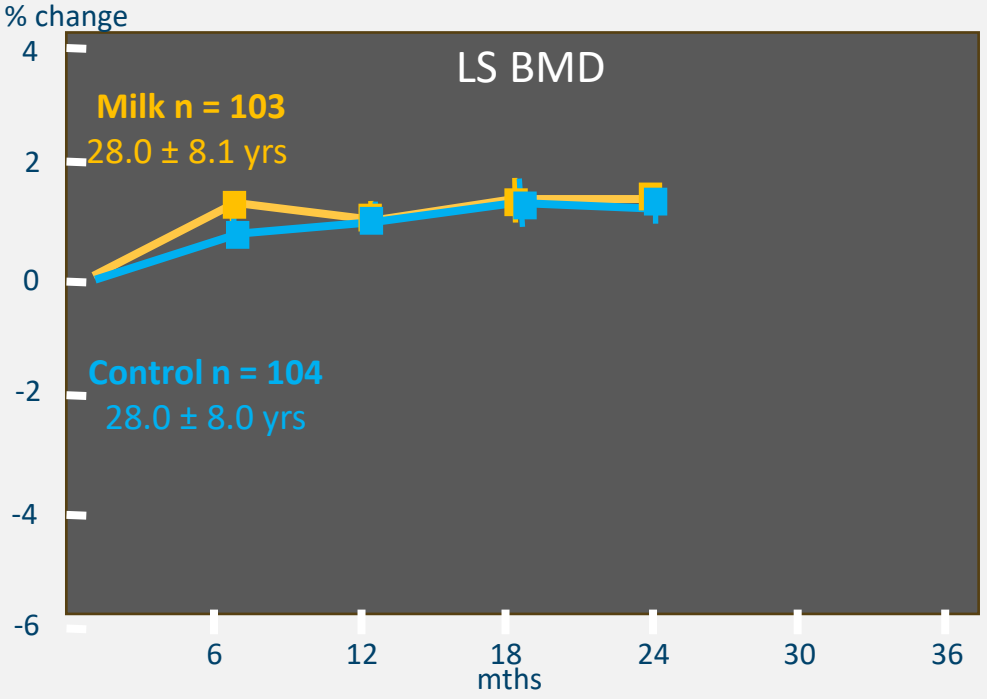




Calcium intake mg/d

Dairy	900	1300	1500
Control	900	800	800

Baran et al. JCEM 1989

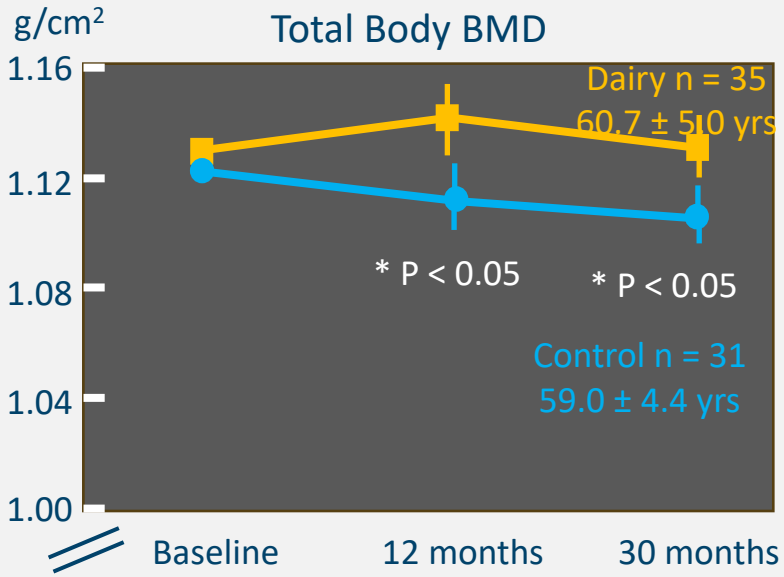
Calcium intake mg/d

450	1300	900
450	450	400

Woo et al. J Womens Health 2007

Compliance
Yr 1 75%
Yr 2 45%

Dairy Supplementation In Older Adults



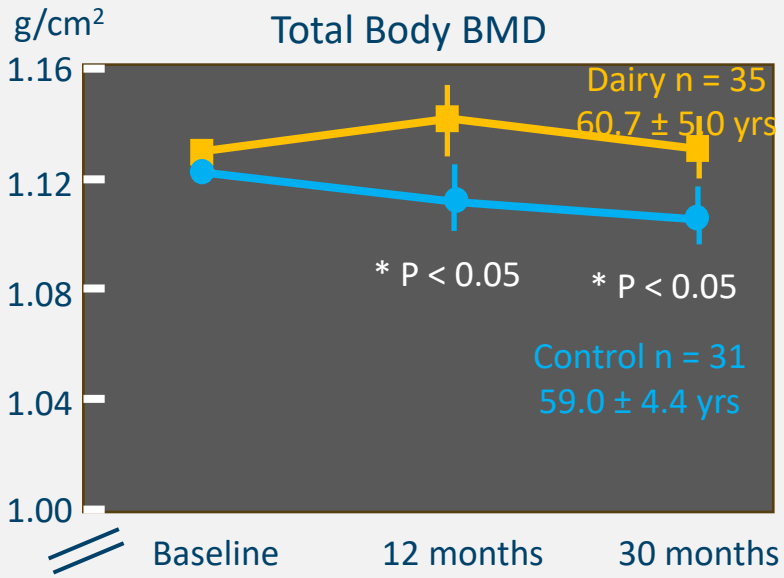
Calcium intake mg/d

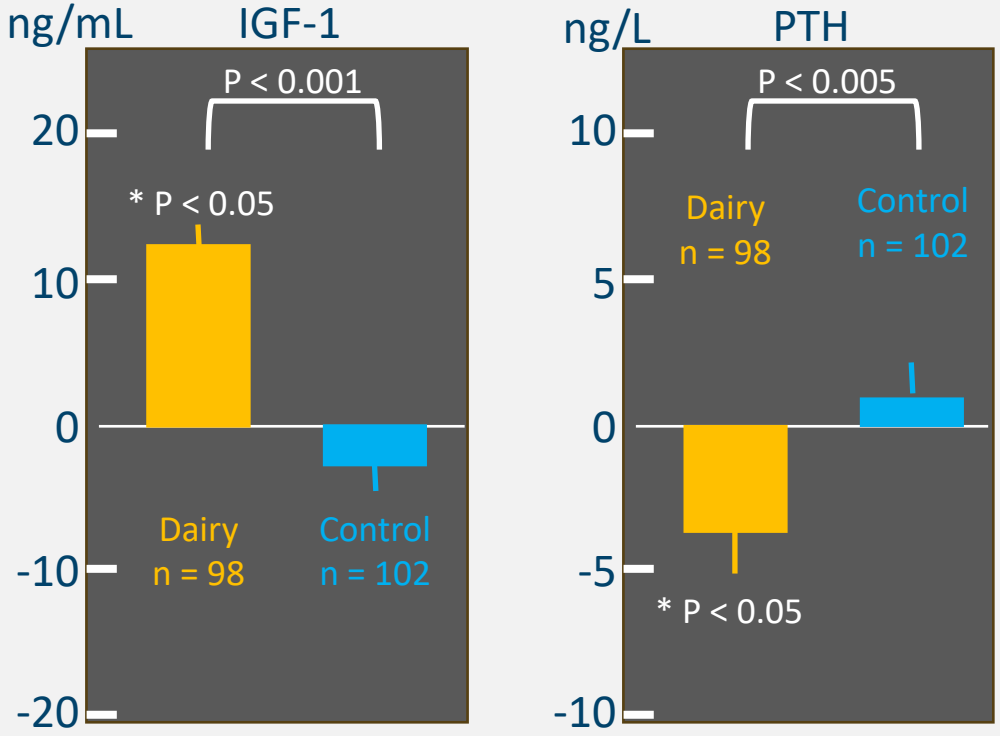
Dairy	683	1140	1183
Control	676	750	671

- Dairy (milk, yoghurt) Cal Vit D
- Post Menopausal women

Manios et al Am J Clin Nutr, 2007; Moschonis et al. Br J Nutr 2010

Dairy Supplementation In Older Adults





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- Post Menopausal women

Manios et al Am J Clin Nutr, 2007; Moschonis et al. Br J Nutr 2010

Δ 12 weeks

- 3 x milk drinks
- Ca/d ~1400mg v 700mg
- Men & Women ~ 65yo

Heaney et al. JADA, 1999

Protein Requirements In Older Adults

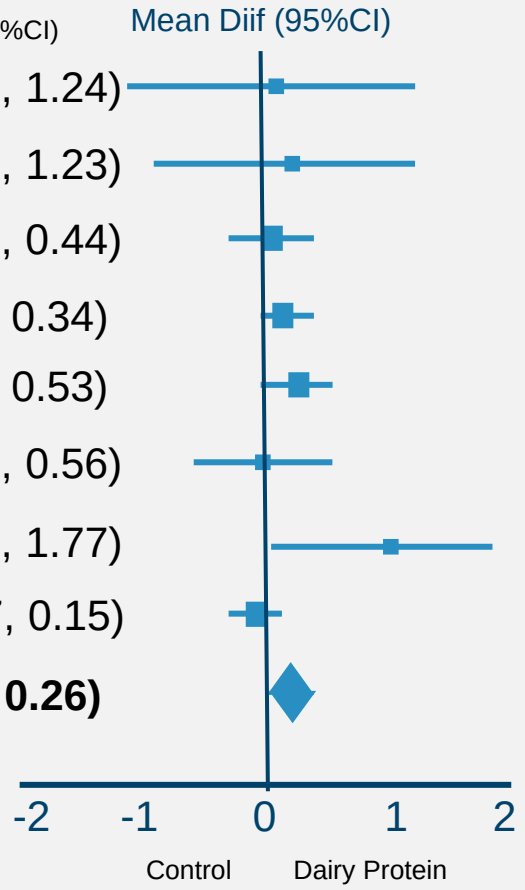
Condition	Daily Needs g/kg BW	
Healthy Adult	0.8	
Older Adult	1.2 – 1.5	On-going
Stress (trauma / infection / surgery)	1.5 - 2.0	Hospital
Presence of wound	1.5	
Restore weight lost	1.5	Recovery
Correct protein-energy malnutrition	1.5	

Demling Eplasty, 2009

Dairy Protein & Muscle Mass In Older Adults

Appendicular Lean Mass

Study	Participants	Intervention	Mean Diif (95%CI)
Alemain-Mateo,2012	Sarcopenic	Ricotta	0.10 (-1.04, 1.24)
Alemain-Mateo, 2014	Healthy	Ricotta	0.20 (-0.83, 1.23)
Amarson, 2013	Healthy	Whey	0.10 (-0.24, 0.44)
Bauer, 2015	Sarcopenic	Whey	0.17 (0.00, 0.34)
Norton, 2016	Healthy	Milk Pro	0.28 (0.03, 0.53)
Tieland, 2012	Frail	Milk Pro	0.00 (-0.56, 0.56)
Verreijen, 2015	Obese (WL)	Whey	0.90 (0.03), 1.77)
Zhu, 2015	Healthy	Skim milk	-0.06 (-0.27, 0.15)
TOTAL			**0.13 (0.01, 0.26)**



Hanach et al. Adv Nutr, 2019

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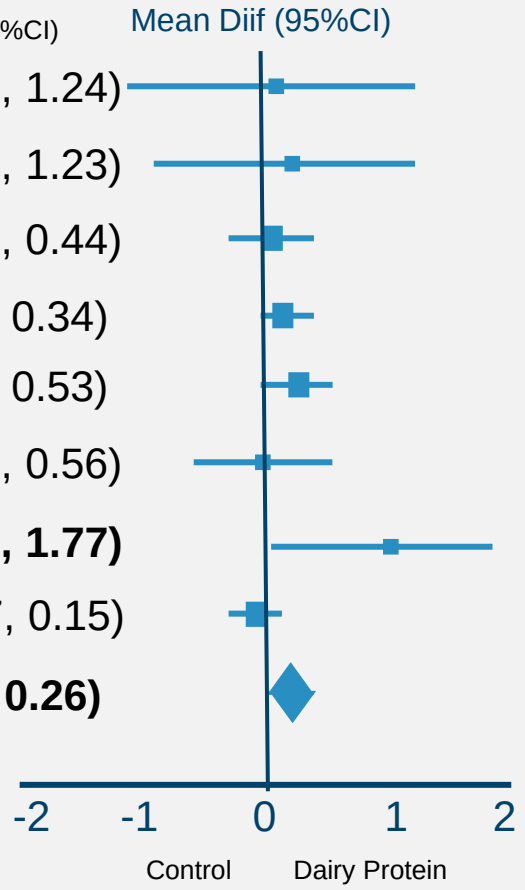

Hanach et al. Adv Nutr, 2019

Dairy Protein & Muscle Mass In Older Adults

Appendicular Lean Mass

- Compliance
- Deficiency
- Drop-outs

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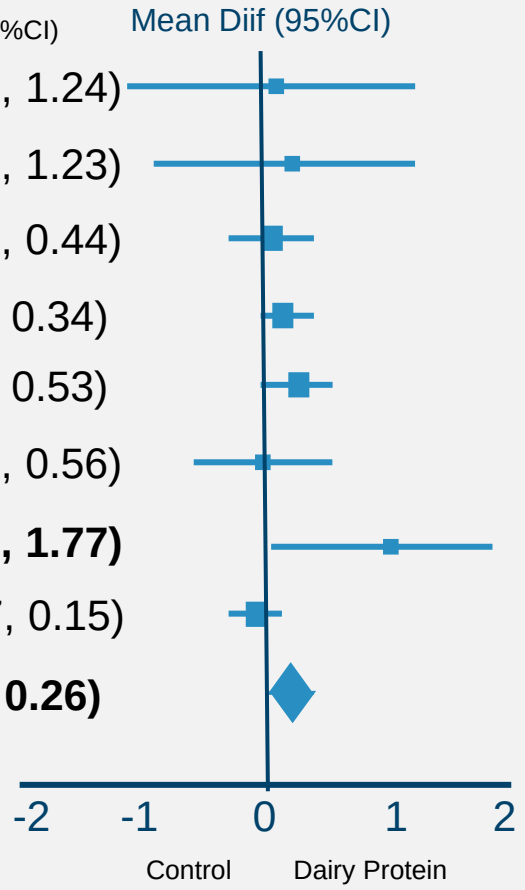
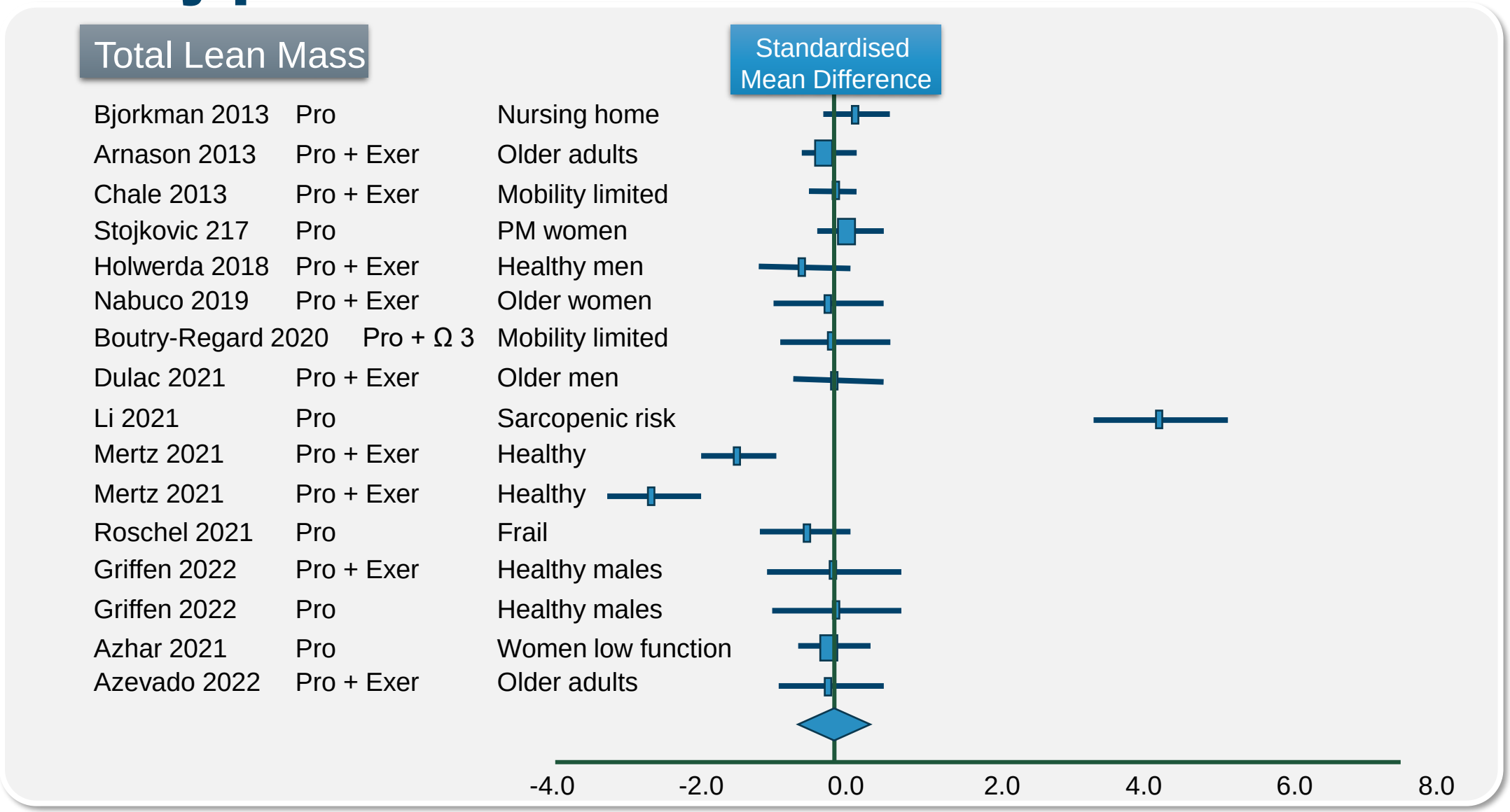


Hanach et al. Adv Nutr, 2019

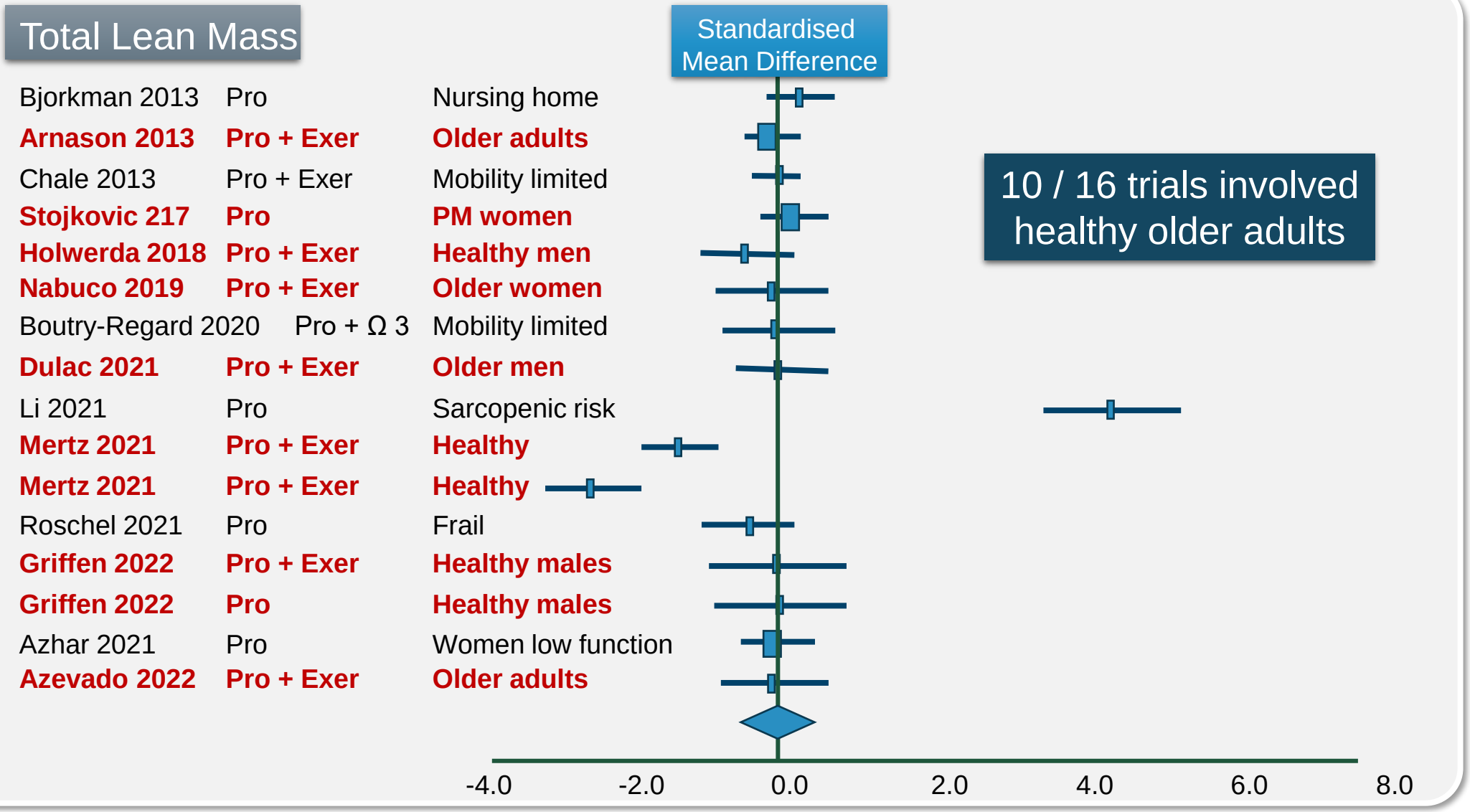
Whey protein & muscle mass in Older Adults



Nasimi et al. Adv Nutr 2023

Whey protein & muscle mass in Older Adults

Total Lean Mass



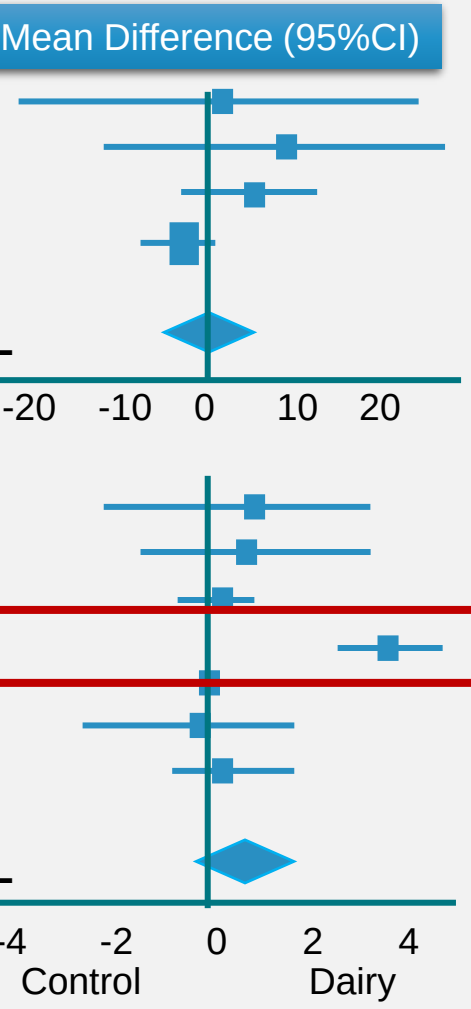
10 / 16 trials involved healthy older adults

Nasimi et al. Adv Nutr 2023

Dairy Protein & Muscle Strength In Older Adults

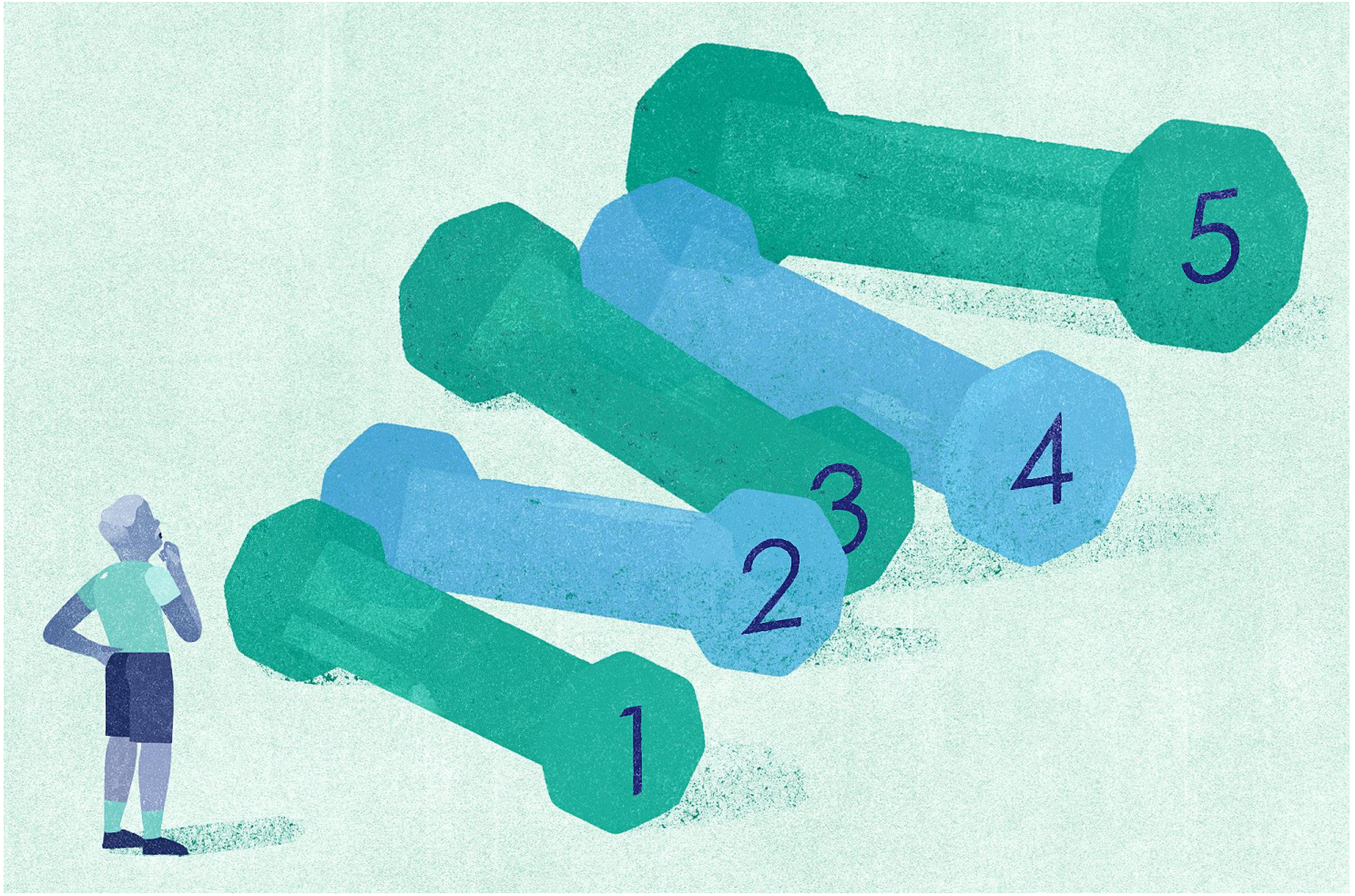
Leg Press (kg)			Mean Difference (95%CI)
Chale, 2012	Low mobility	Pro + Exer	1.8 (-21.5, 25.2)
Karelis, 2015	Older males	Whey + Exer	8.5 (-11.4, 28.4)
Tieland, 2012	Frail	Milk Pro	5.0 (-3.1, 13.1)
Verdjik, 2009	Older males	Pro+D+Exer	-3.0 (-7.7, 1.7)
OVERALL			

Handgrip (kg)			
Alemain-Mateo,2012	Sarcopenic	Ricotta	0.8 (-1.8, 3.4)
Alemain-Mateo, 2014	Healthy	Ricotta	0.7 (-1.6, 3.0)
Bauer, 2015	Sarcopenic	Whey	0.3 (-0.5, 1.0)
Rondanelli, 2016	Sarcopenic	Whey+D+Exer	3.7 (2.6, 4.8)
Tieland, 2012	Frail	Milk Pro	0.0 (-0.6, 0.6)
Verreijen, 2015	Obese (WL)	Whey	-0.2 (-2.4), 2.0)
Zhu, 2015	Healthy	Skim milk	0.4 (-0.7, 1.6)
OVERALL			



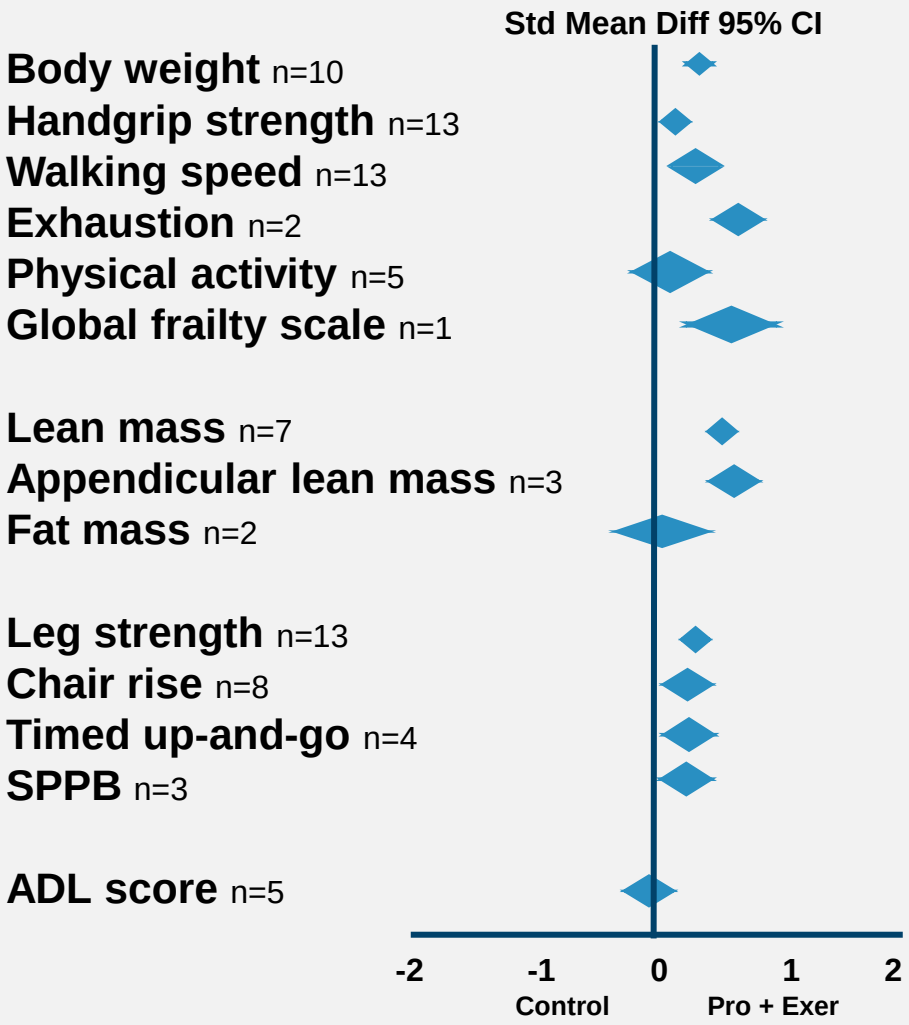
Hanach et al Adv Nutr 2019

Muscle is Plastic



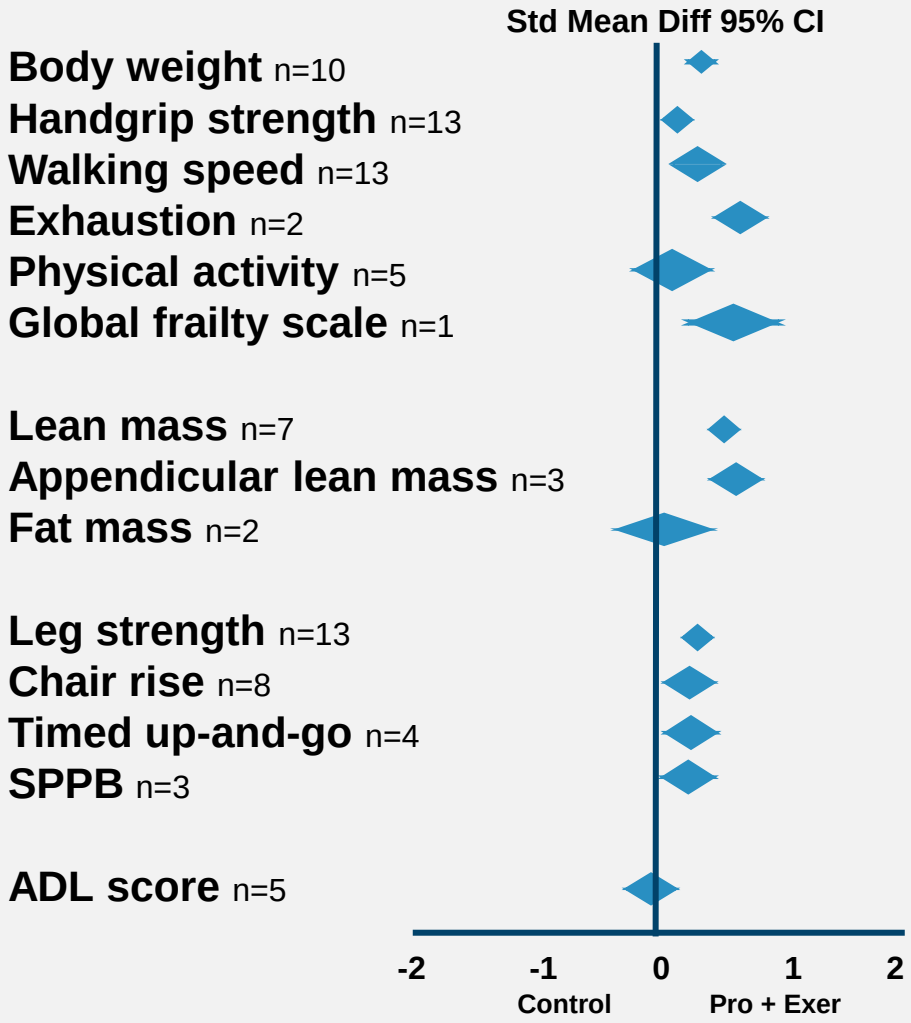
New Your Times

Protein & Exercise In Frail Older Adults



Liao et al. Nutrients, 2018

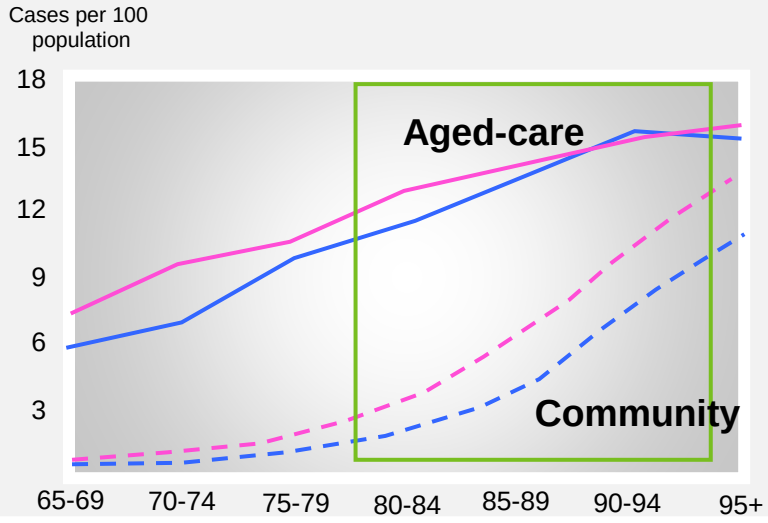
Protein & Exercise In Frail Older Adults



- Combination of exercise & nutritional support (protein) more likely to improve function.
- Need to consider a wholistic approach to care for at-risk older adults

Liao et al. Nutrients, 2018

Falls & Fractures in Older Adults

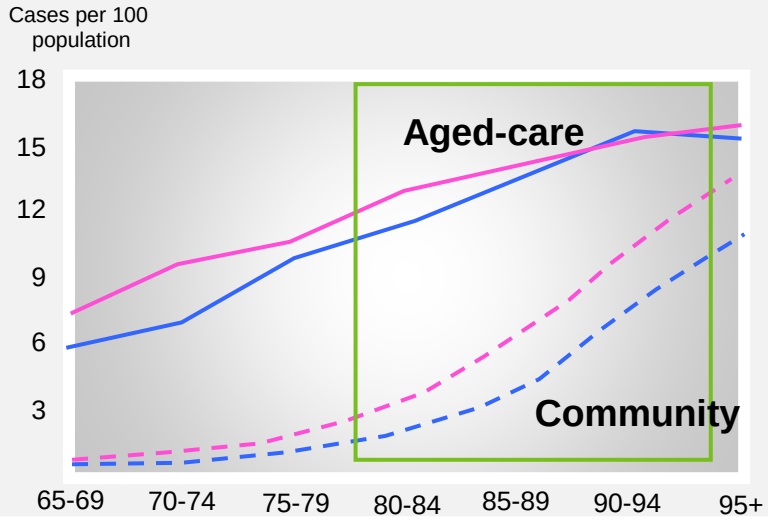


- 22% of older adults fall annually (Sth Afr)
- Falls: leading cause of hospitalized injuries

  67% of injuries were falls-related (Sth Afr)
- Falls rate: 5 x higher in aged care (Aust)

healthybonesaustralia.org.au; AIHW; Williams et al. BMC Med 2015; Kalula et al. BMC Geriatrics, 2016

Falls & Fractures in Older Adults



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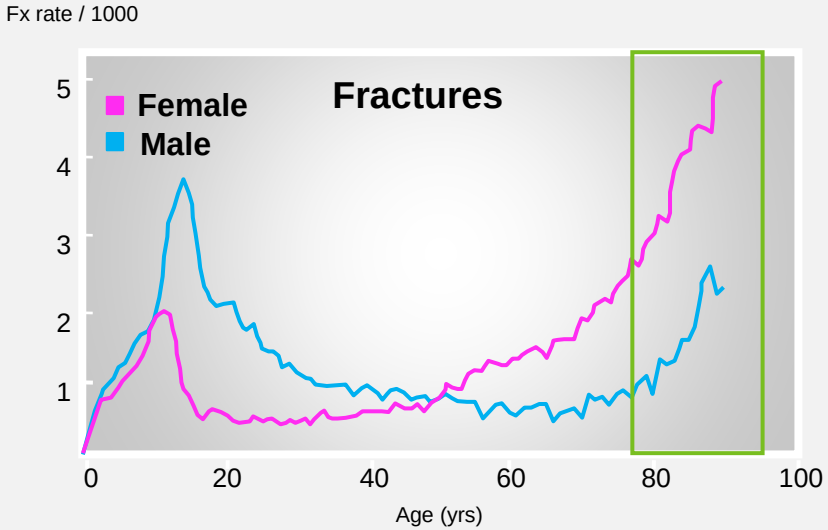
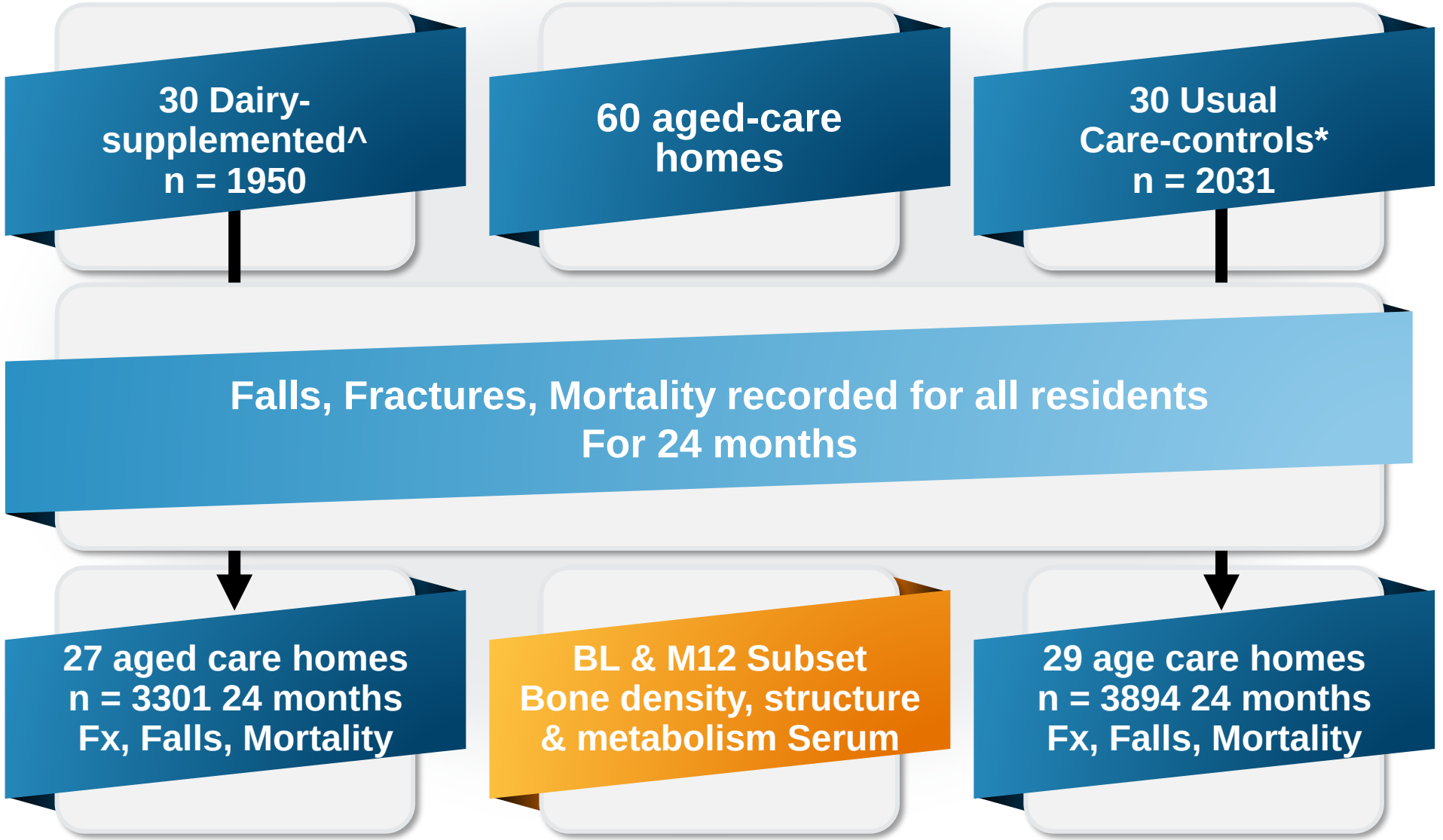


- Fractures: 50% of hospitalised falls (Aust)
- 30% of hip fractures from aged-care (Aust+)
- Hip fractures: R114,428 to health system (SA)

healthybonesaustralia.org.au; AIHW; Williams et al. BMC Med 2015; Kalula et al. BMC Geriatrics, 2016

Can Nutrition Inadequacy in Older Adults be Corrected Using Food to Prevent Fractures and Falls?

Dairy and Fracture Study



Study Design

Food service supported to increase dairy options on the menu

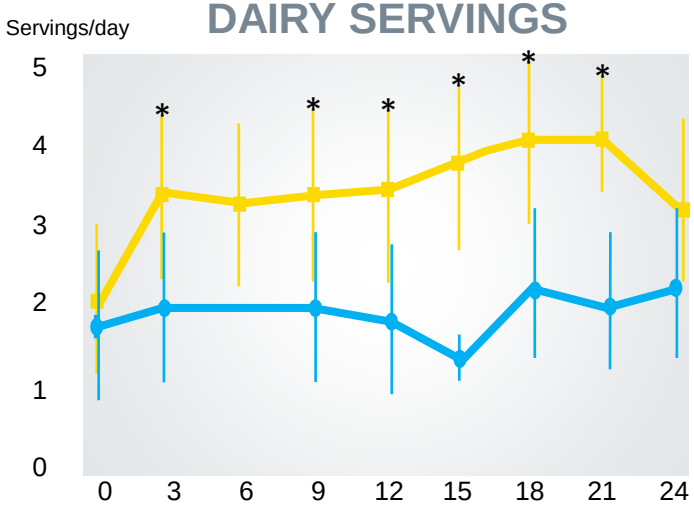
Demographics of Aged Care Residents

	Intervention n=3301	Controls n=3894
Women (n; %)	2194 (66%)	2680 (69%)
Age (yrs)	87 (8)	86 (8)
Height (m)	1·60 (0·1)	1·60 (0·1)
Weight (kg)	66.5 (15.6)	66.2 (15.8)
Medications (n)*	12 (6)	12 (7)
Medical Conditions (n)*	10 (5)	10 (7)
	n=170	n=130
25(OH)D (nmol/L)	72 (29)	73 (26)

Improved Nutrient intake Using Dairy Foods

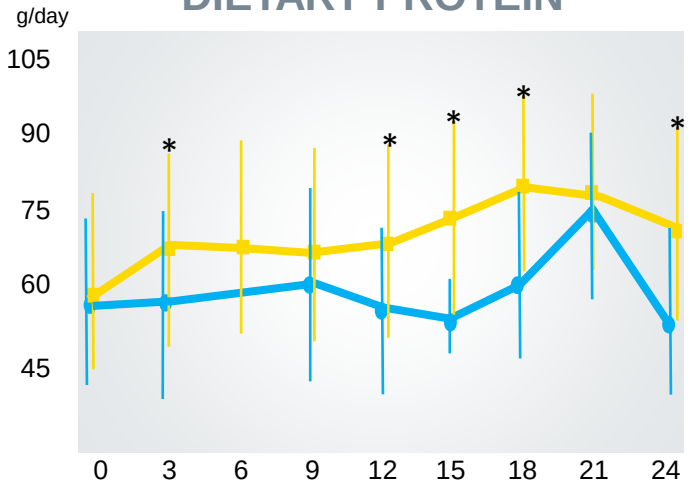
~3.5 Servings daily

DAIRY SERVINGS



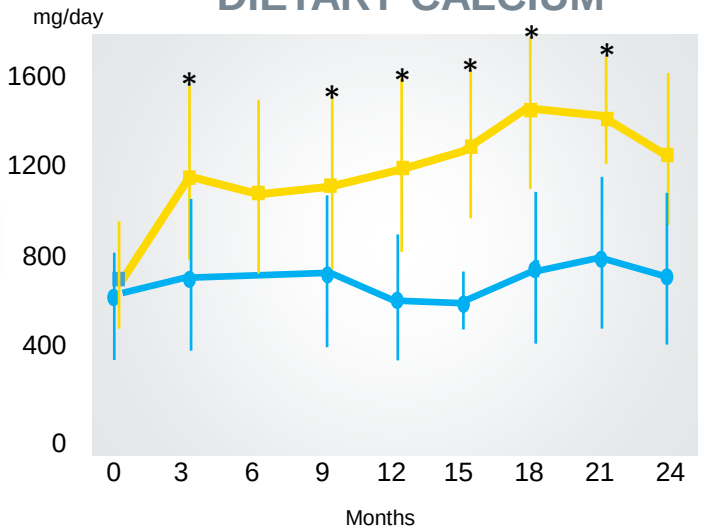
72g/day
1.1g/kg BW

DIETARY PROTEIN



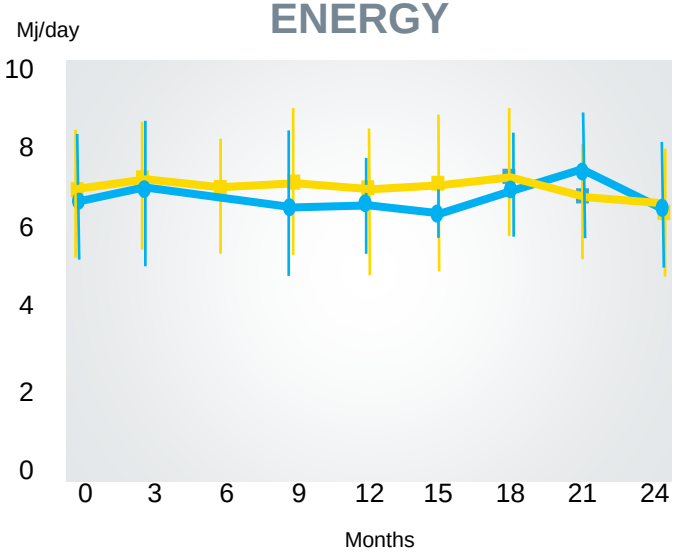
~1100 Mg/day

DIETARY CALCIUM

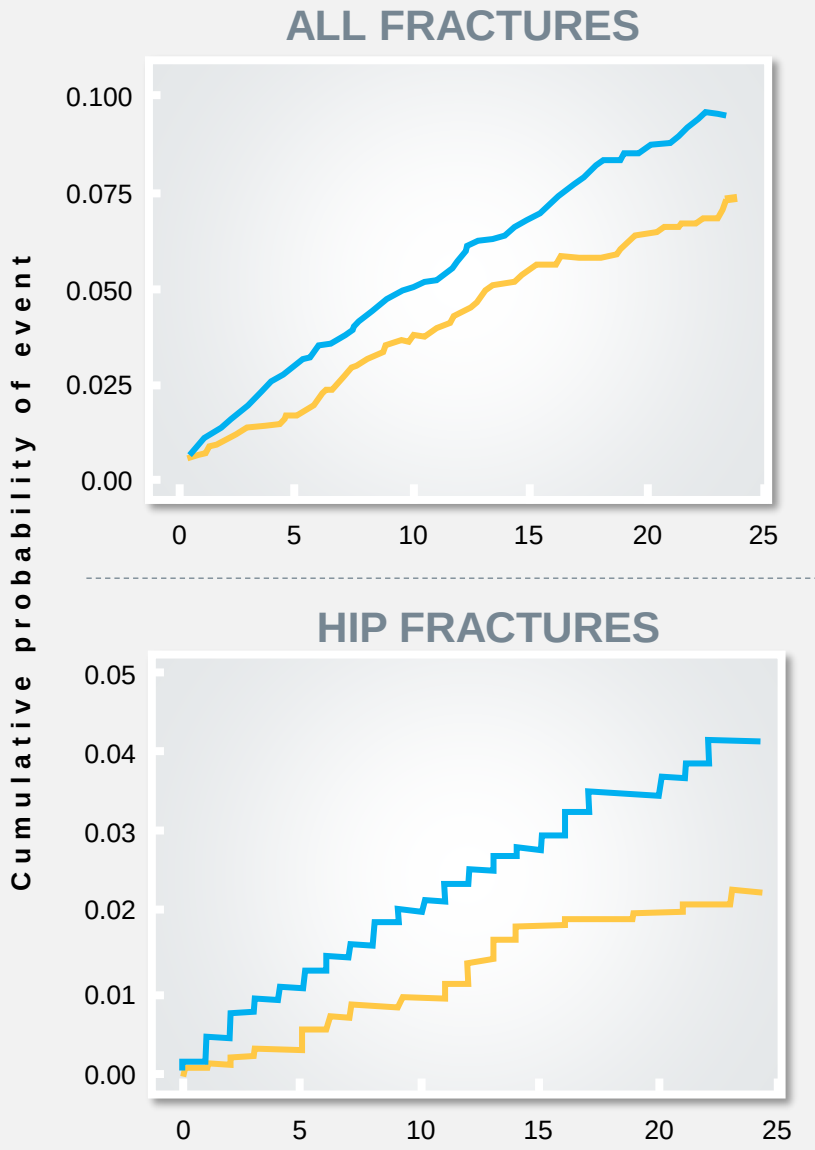


No Change

ENERGY

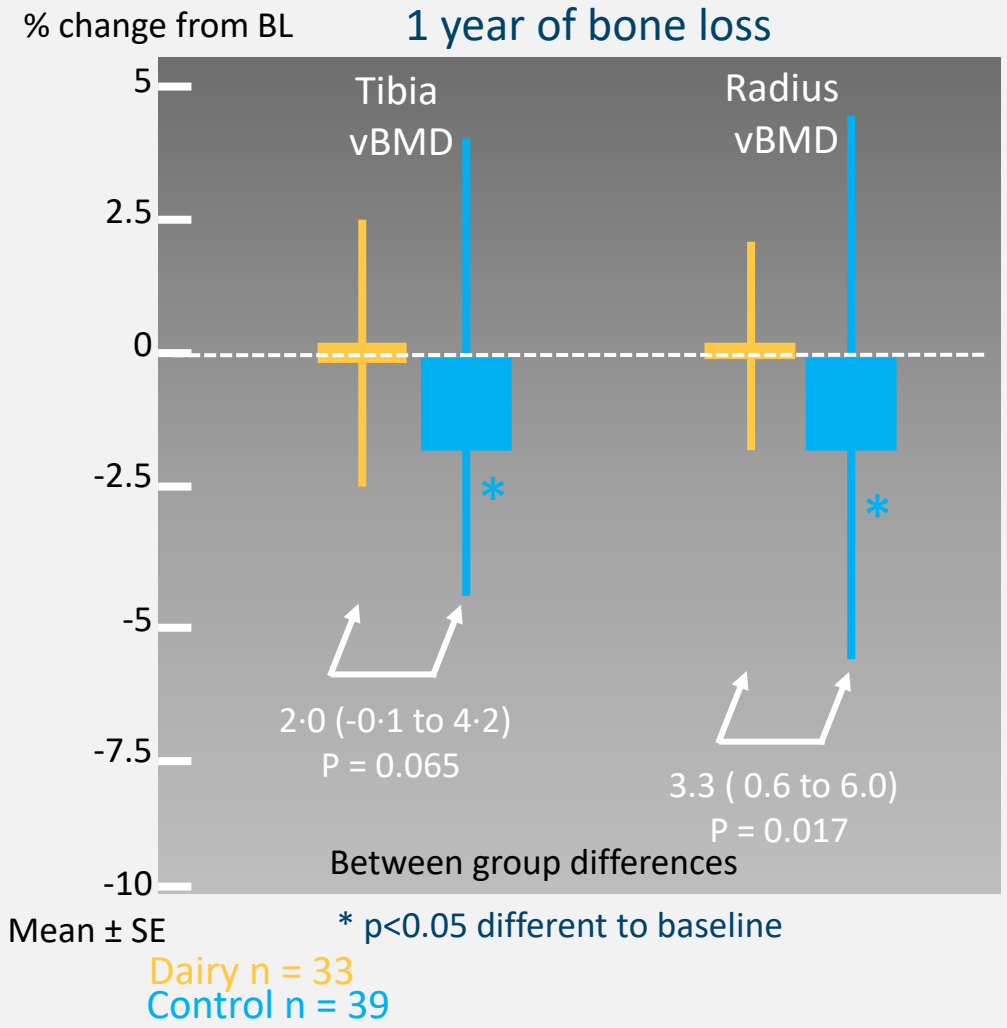


Reduced Fractures with Dairy Foods



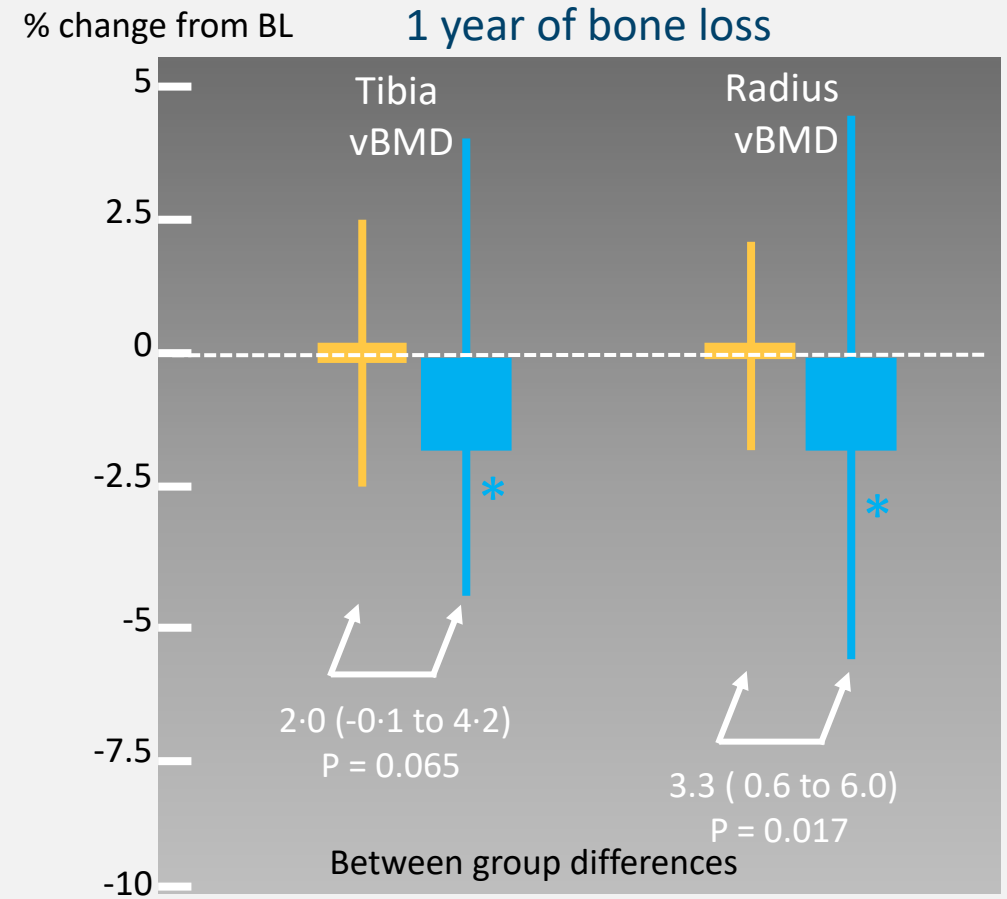
- **33% ↓ in all fractures**
- **Bone density maintained in dairy group, declined in controls**
- **Bone resorption maintained in dairy group, increased in controls**
- **46% ↓ in hip fractures**

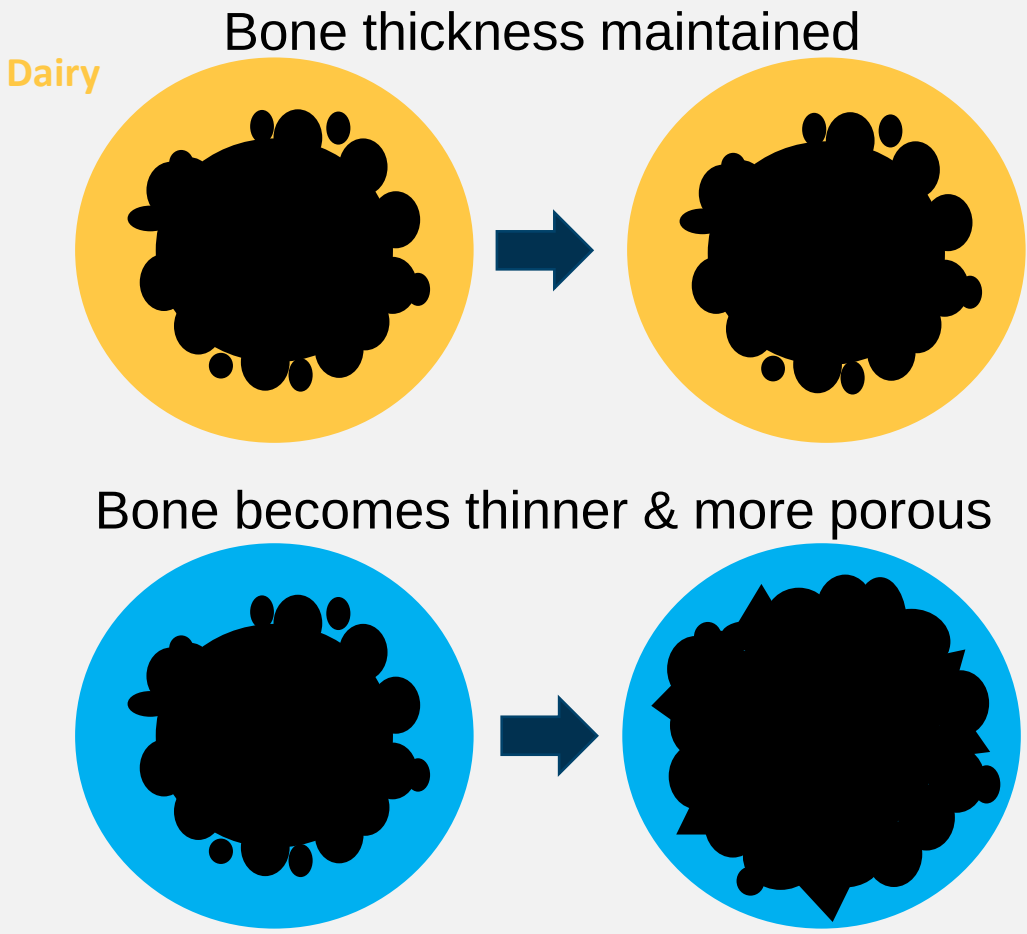
Dairy Supplementation & Bone in Older Adults



Iuliano et al, BMJ, 2021

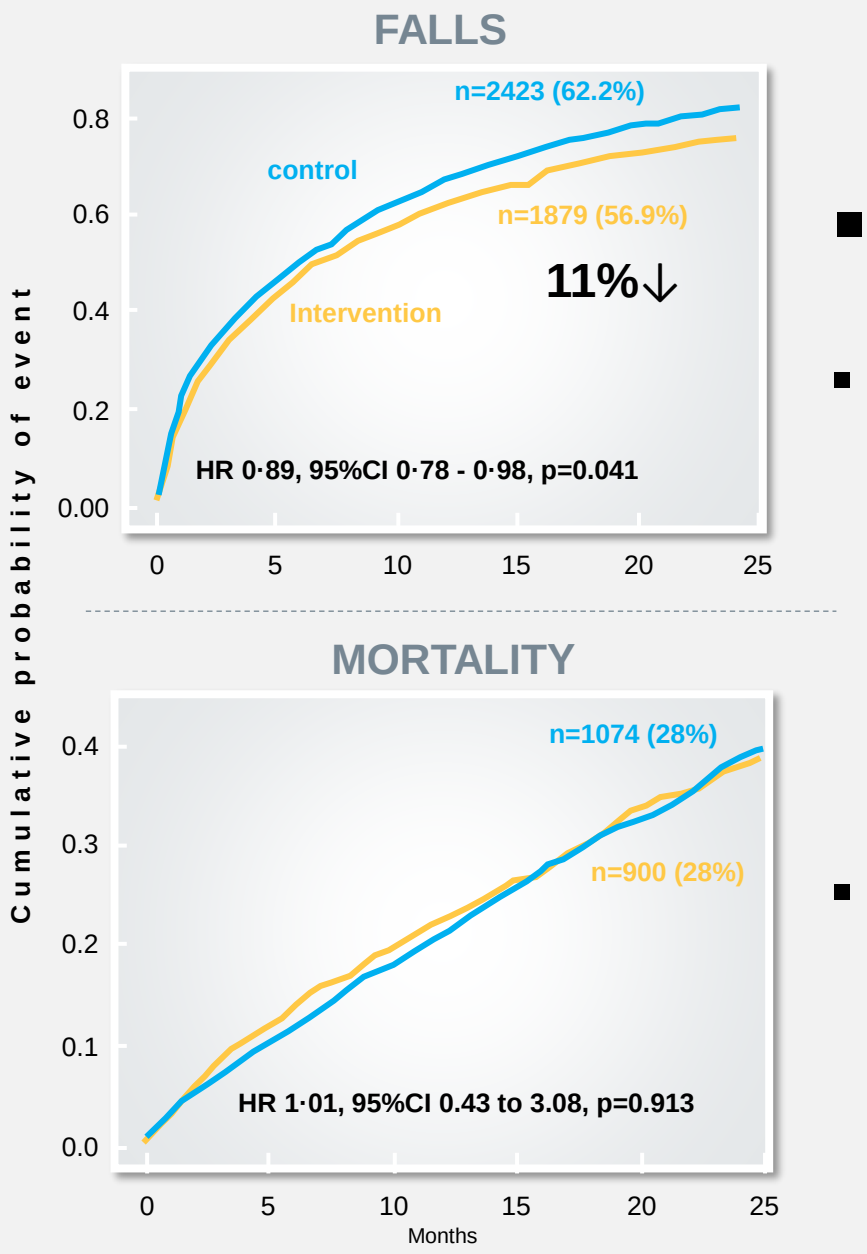
Dairy Supplementation & Bone in Older Adults





Iuliano et al, BMJ, 2021

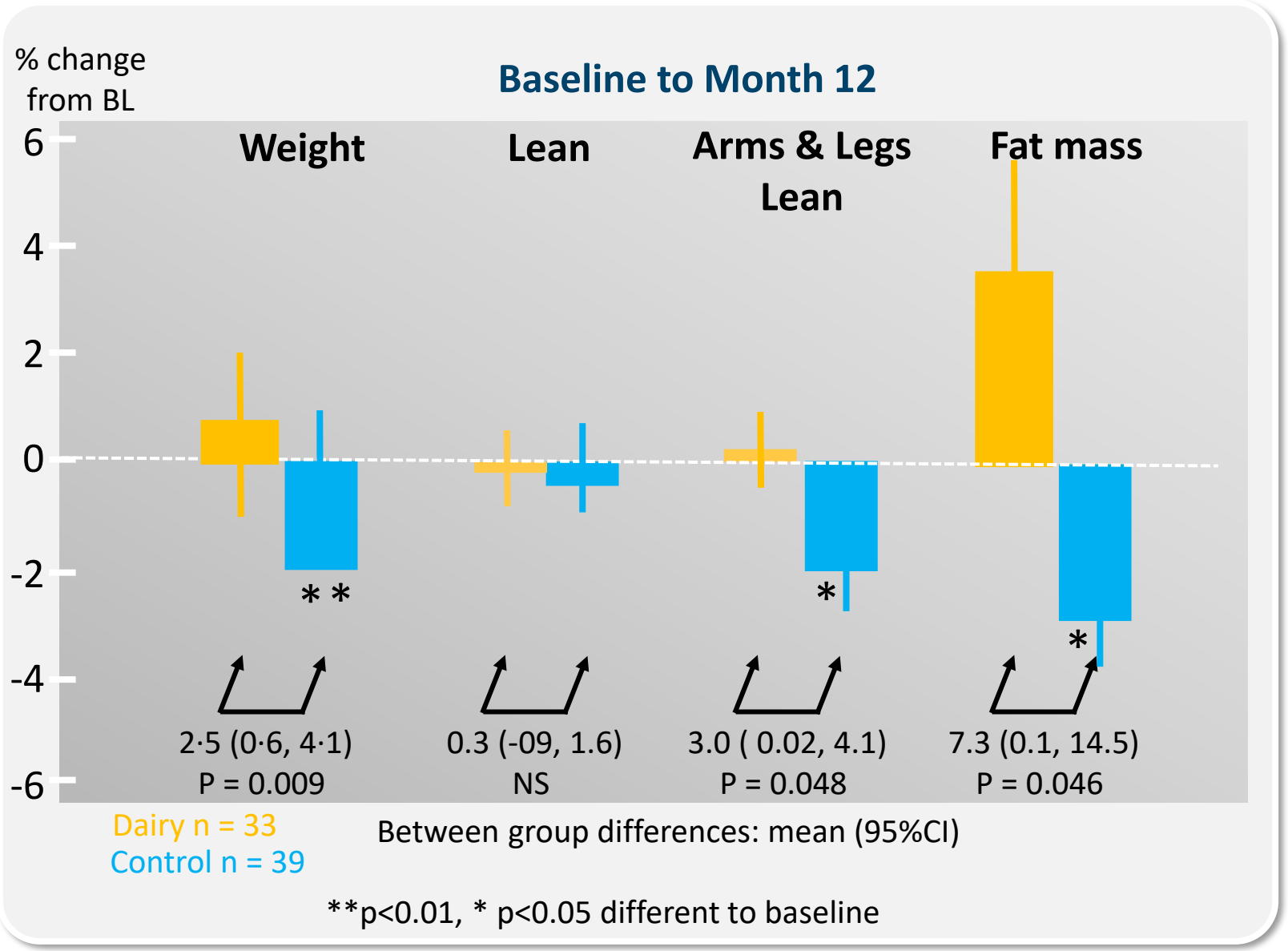
Reduced Falls & Unchanged Mortality with Dairy Foods



- **11% ↓ in falls**
- **Maintained:**
  (i) weight
  (ii) muscle at arms & legs
  (iii) nutritional status
- **Same life expectancy with fewer falls & fractures**

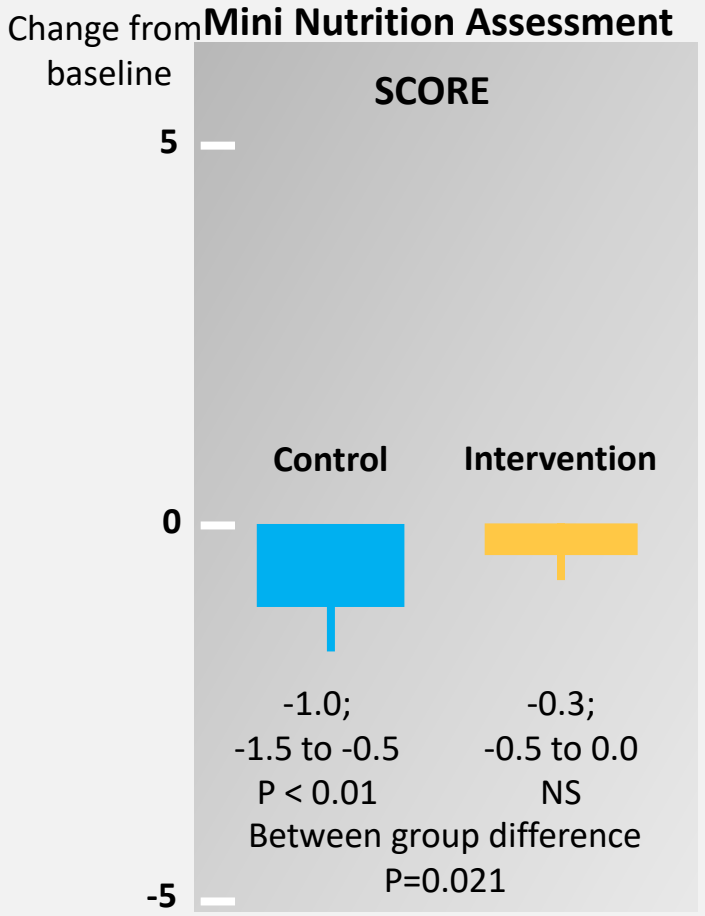
Iuliano et al, BMJ, 2021

Weight & Lean Mass of Arms & Legs Maintained with Dairy Foods

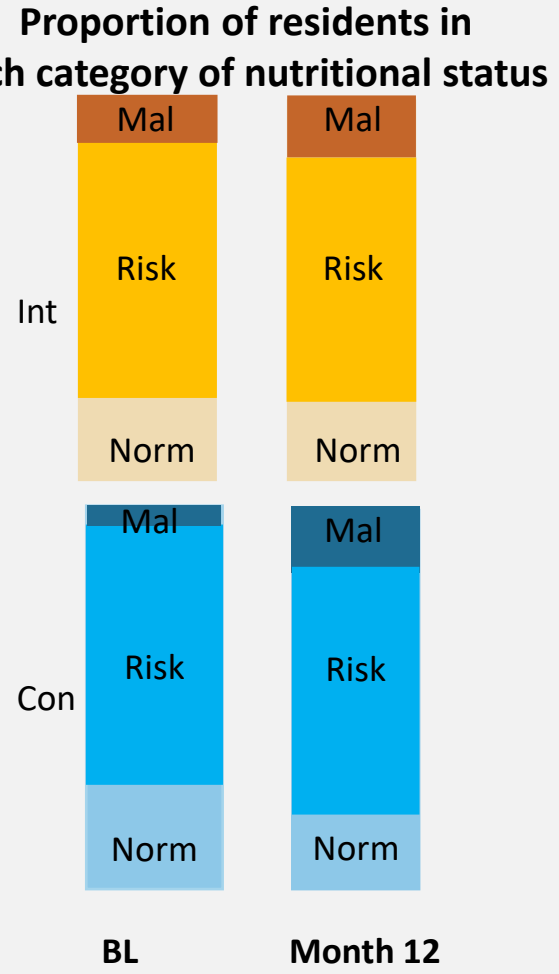


Iuliano et al, BMJ, 2021

Nutritional Status & Dairy Supplementation



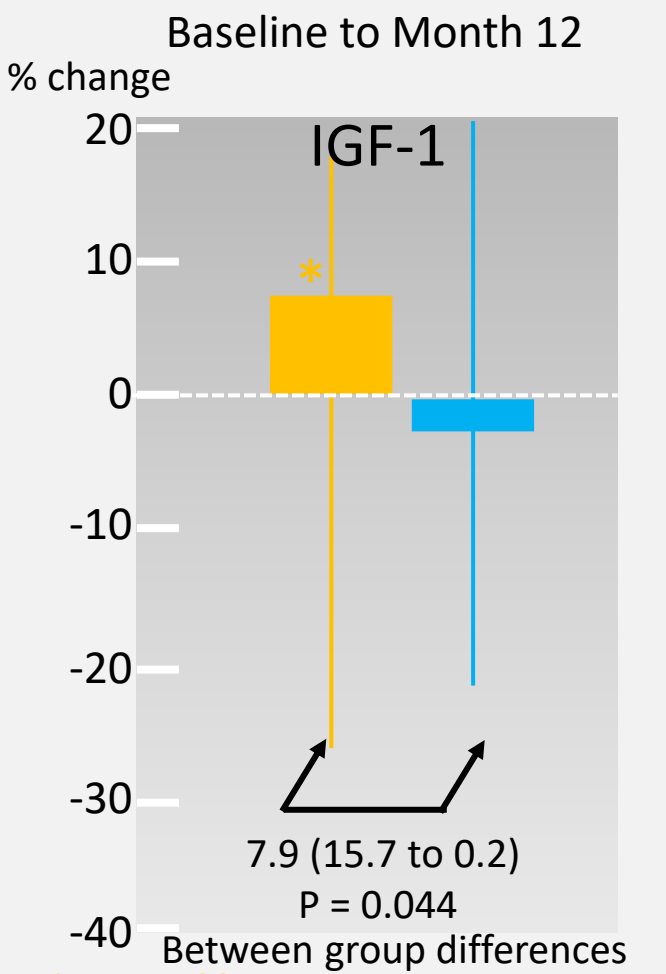
Mean; 95%CI



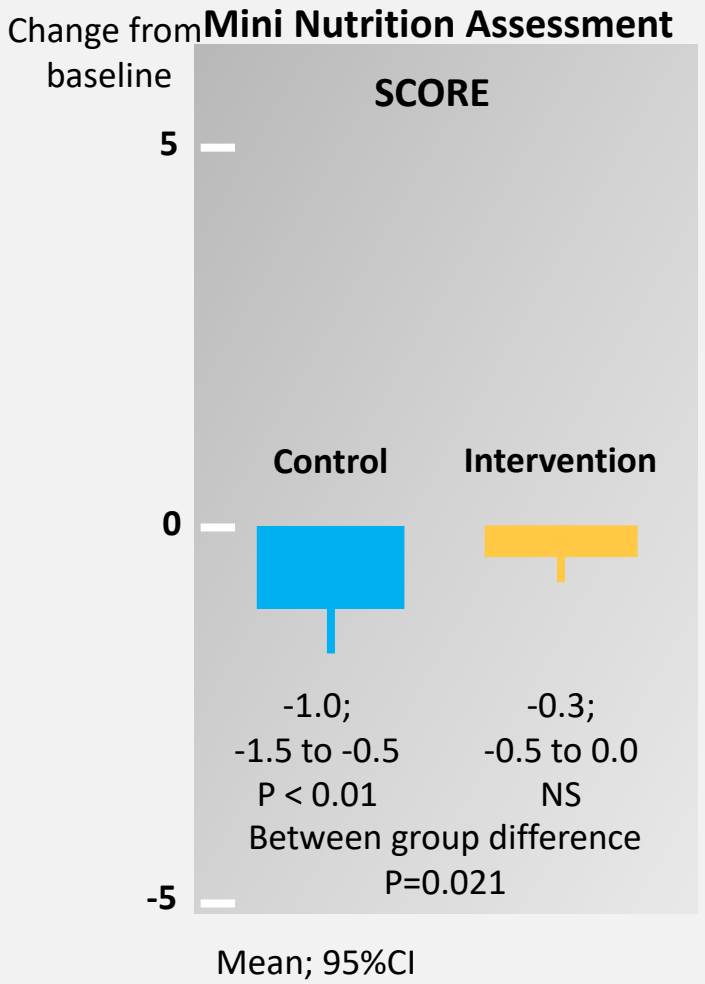
Decline in Nutritional Status
Int 22% v Con 32%, p = 0.019

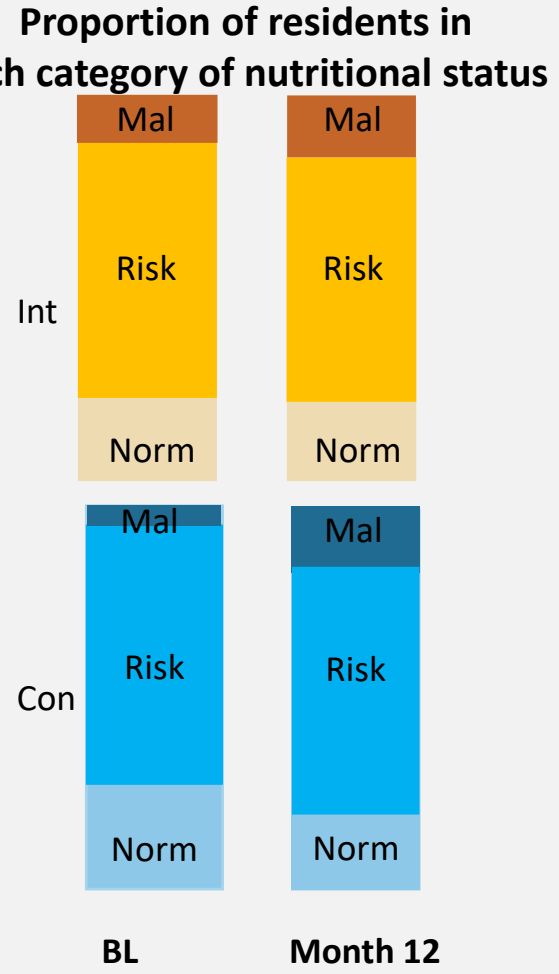
Iuliano, et al. BMJ, 2021; Iuliano et al., J Nurt Health Ageing, 2023

Nutritional Status & Dairy Supplementation



p<0.05 different to baseline





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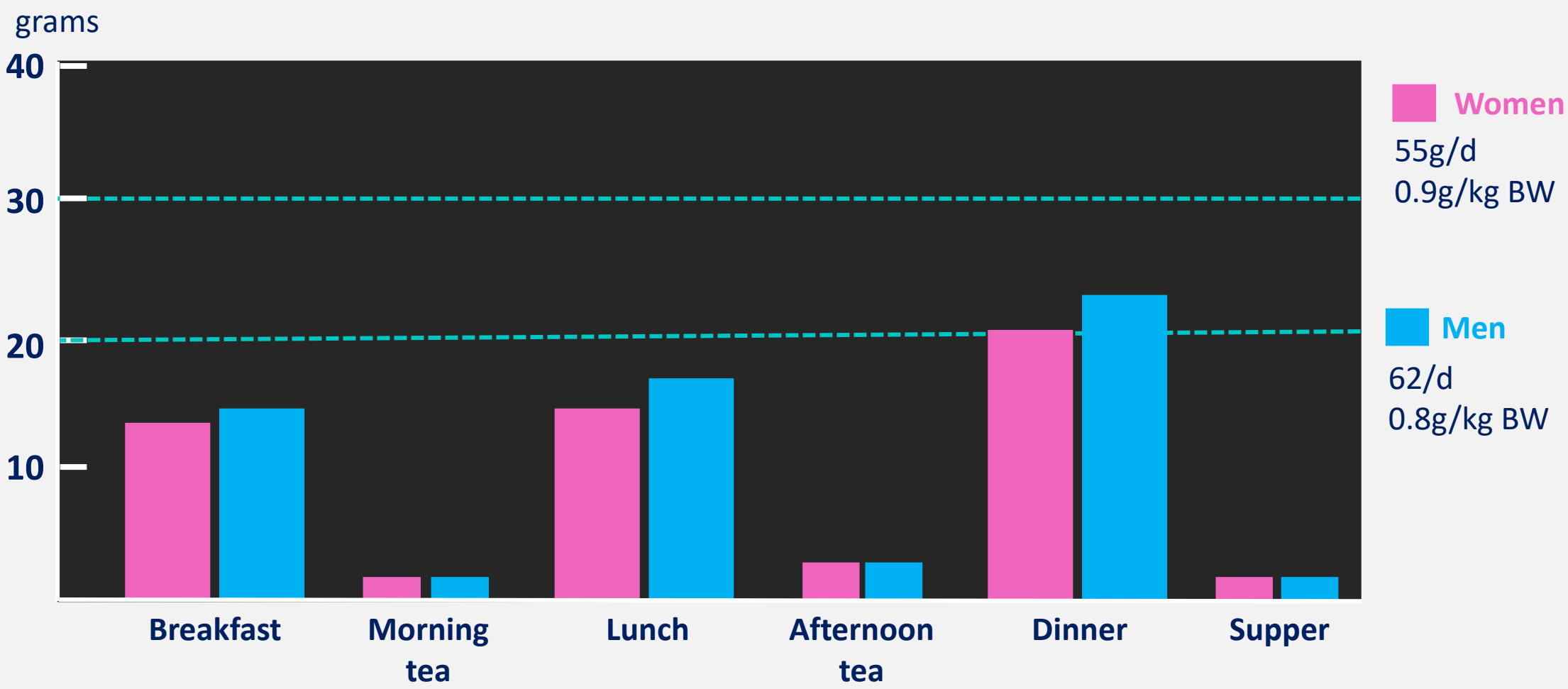
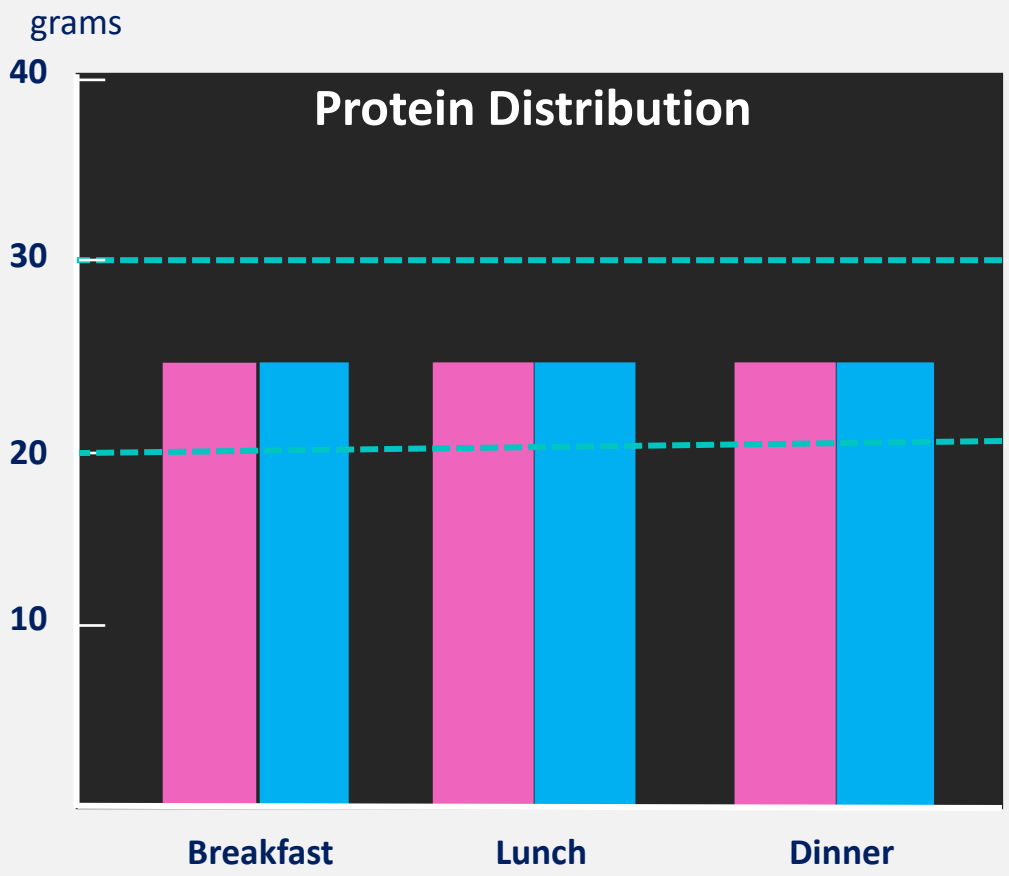
Protein Intake in Older Adults in Aged Care



50,000 menu items
Sample menu: most consumed items

Li et al, Nutr Diet, 2023

Can Protein Adequacy be Achieved In Older Adults?



Strategies used

- Fortified milk (SMP)
- Dairy-based desserts
- Cheese / white sauce
- Soup with cheese
- Milk-based drinks
- Cheese, yoghurt, for snacks

1.3 and 1.2 g / Kg body weight for women and men

Li et al, Nutr Diet, 2023

Practical Considerations to Achieve Calcium Adequacy

Most tubs are not 200g & cheese slices not 20g

200g yoghurt

40 g cheese

250 ml milk = 7 cups of broccoli

½ cup evap. milk

½ cup ricotta

Think of recipe ideas

100g almonds

= 64 almonds

100g Firm tofu

Processing determines calcium

60g sardines

100g pink salmon

Bones need to be eaten

plant-based beverage

Check it is fortified

Dried figs

1 cup = 1 ½ cup

Have milk, maas or yoghurt every day

Bone Mineral Content Accrual & Recommended Calcium Intake

Recommended Calcium Intake (mg/day)

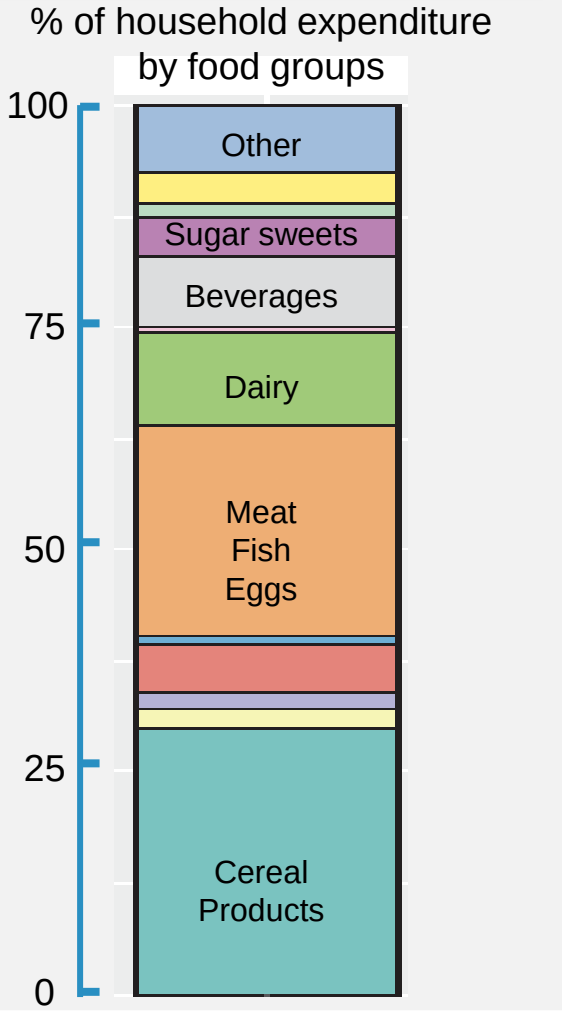
Children 4-8 yrs	Adolescents 9 - 18 yrs	Adults 19-50 yrs	Women 50-64 yrs	Older adults 65+ yrs
Constant accrual	Accelerated accrual	Maintenance	Accelerated loss	Constant loss

Recommended Dairy Servings

Bowley et al., Maternal & Child Nutr, 2007

Household expenditure on food in South Africa*

30% of total expenditure on Food



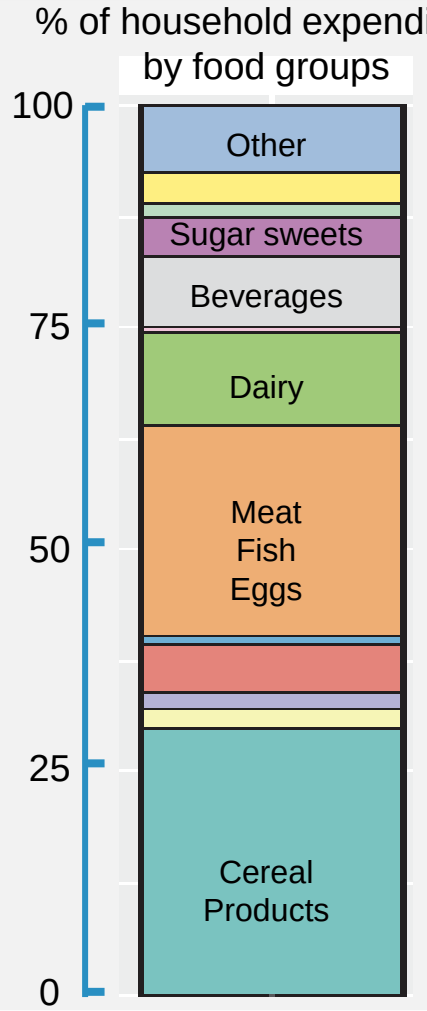
Inadequacies
- Calcium
- Iron
- Vitamin A

* Homes with young children

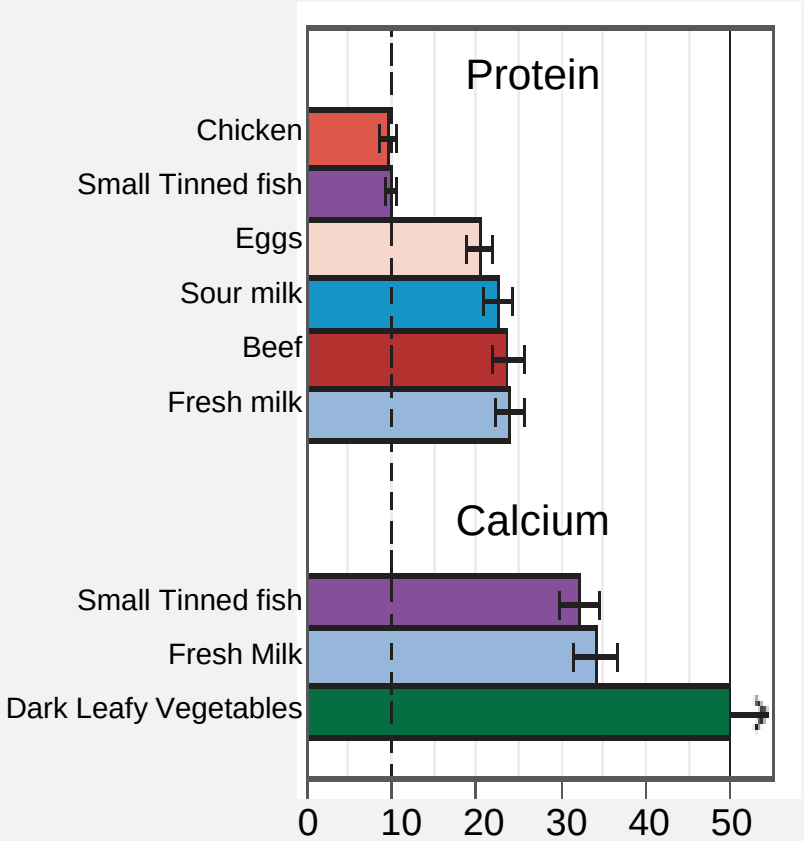
Ryckman et al., Nutr, Reviews 2021

Household expenditure on food in South Africa*

30% of total expenditure on Food



Household food expenditure per adult



Inadequacies
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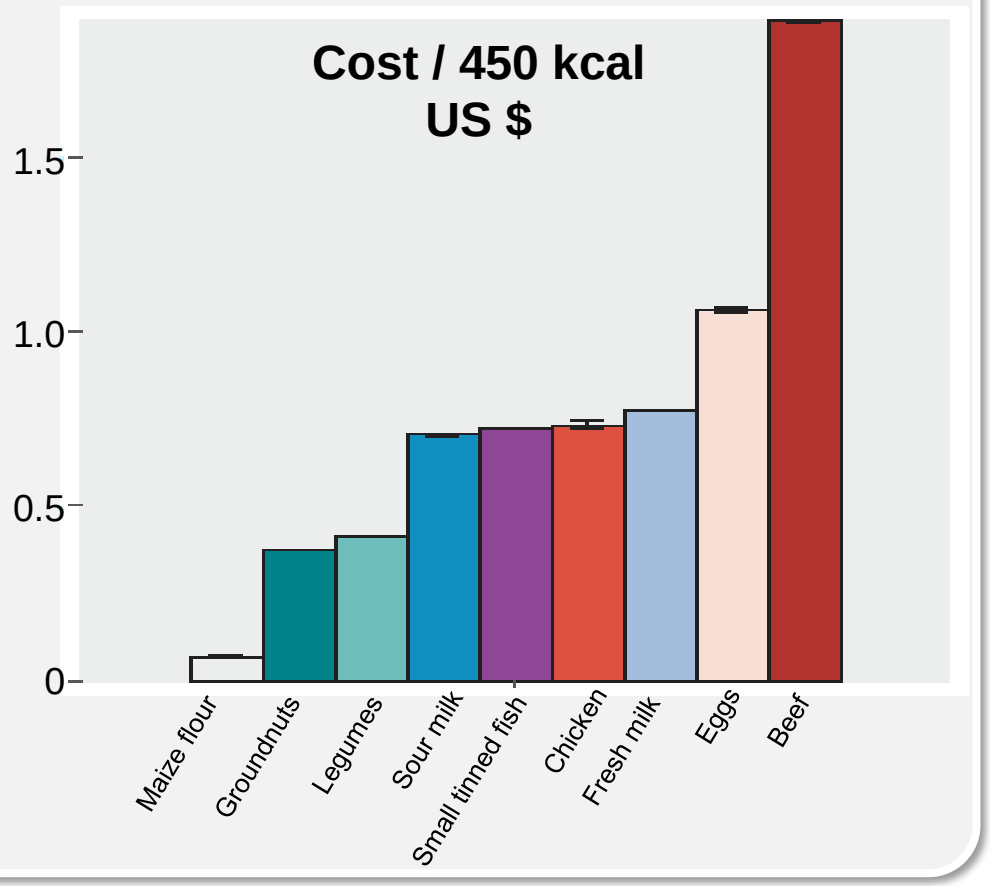

* Homes with young children

Ryckman et al., Nutr, Reviews 2021

Cost of Food Items per serve (calcium & protein vs others)

R0.00 R7.50 R15.00

Maas
R3.56
200ml

Milk
R4.68
250ml

Cheese
R5.66
40g

Doughnut
R6.99
1 item

Yoghurt
R7.91
200ml

Crisps
R8.50
36g

Soft drink
R11.99
330ml

Soft drink
R14.99
500ml

Sardines
R3.93
60g

Chicken
R4.64
100g

Summary

- Bone is added during growth so adequate nutrition (calcium) is needed to maximise peak bone mass
- Adequate dairy consumption in older adults is associated with reduced fractures and falls
- Adequate dairy consumption in combination with exercise is associated with enhanced bone accrual during growth & improved muscle mass and function in older adults
- Consideration needs to be made as to how increases in dairy consumption can be messaged and implemented across the lifespan, particularly in older adults

Thank you
&
Questions

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