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The Role of Milk and Dairy Foods for Bone Health in Athletes

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Potential conflicts of interest - last few years

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Research Funding

September 2020	Women in Ground Close Combat Review Team, UK MOD
June 2020	Fundação de Amparo à Pesquisa do Estado de São Paulo (Brazil).
March 2020	Natural Alternatives International
June 2019	British Milers Club
September 2018	Women in Ground Close Combat Review Team, UK MOD
October 2016	Coventry University
January 2016	English Institute of Sport

Honoraria

Natural Alternatives International	Production of material for blogs relating to beta-alanine supplementation and carnosine
GSSI	Participation and the GSSI XP 2019 event and presentation at ECSS Conference
Dairy Council	Seminar Presentation
Dairy Council NI	Seminar Presentation
Guru Performance Ltd	Lectures on the ISSN Diploma Course and CPD events for performance nutritionists
ISSN	Lectures at Conferences
English Institute of Sport	CPD lectures and webinar
Nutrition X	Presentation at Nutrition X seminar event

Other Research Support in Kind

Natural Alternatives International	Beta-alanine and placebo supplements free of charge to conduct our studies.
Natural Alternatives International	Support for publication open access charges.
Natural Alternatives International	Support to attend the International Congress on Carnosine and Anserine in Kentucky, USA.

What is 'bone health' for the athlete?

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Avoidance of bone injury
'It will influence my performance!'

Avoidance of osteoporosis
'I'm not bothered about this yet!'

Some sport/exercise is good for bone

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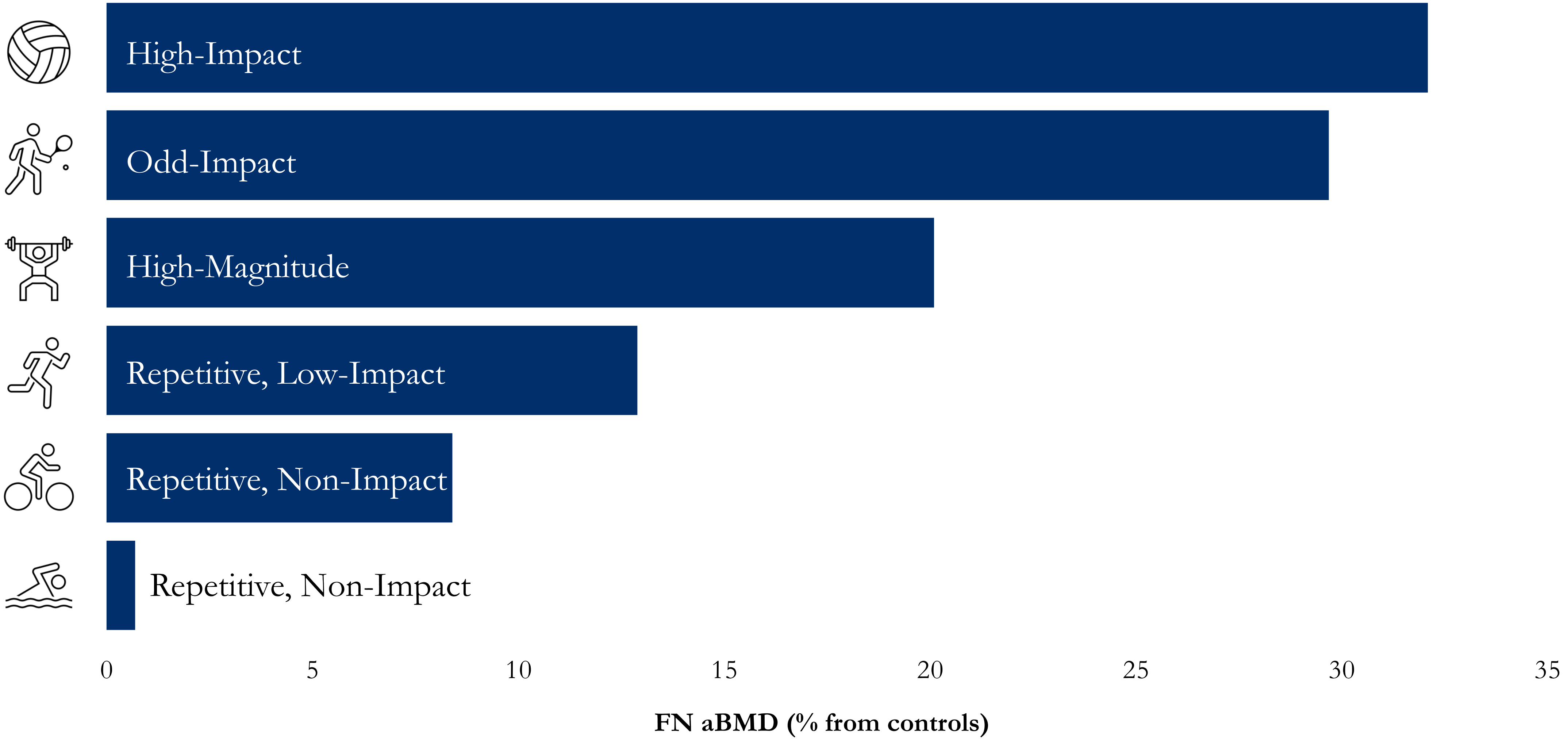

Nikander et al. 2005, *JBMR*, 20(3), 520-528.

Not all athletes have good skeletons

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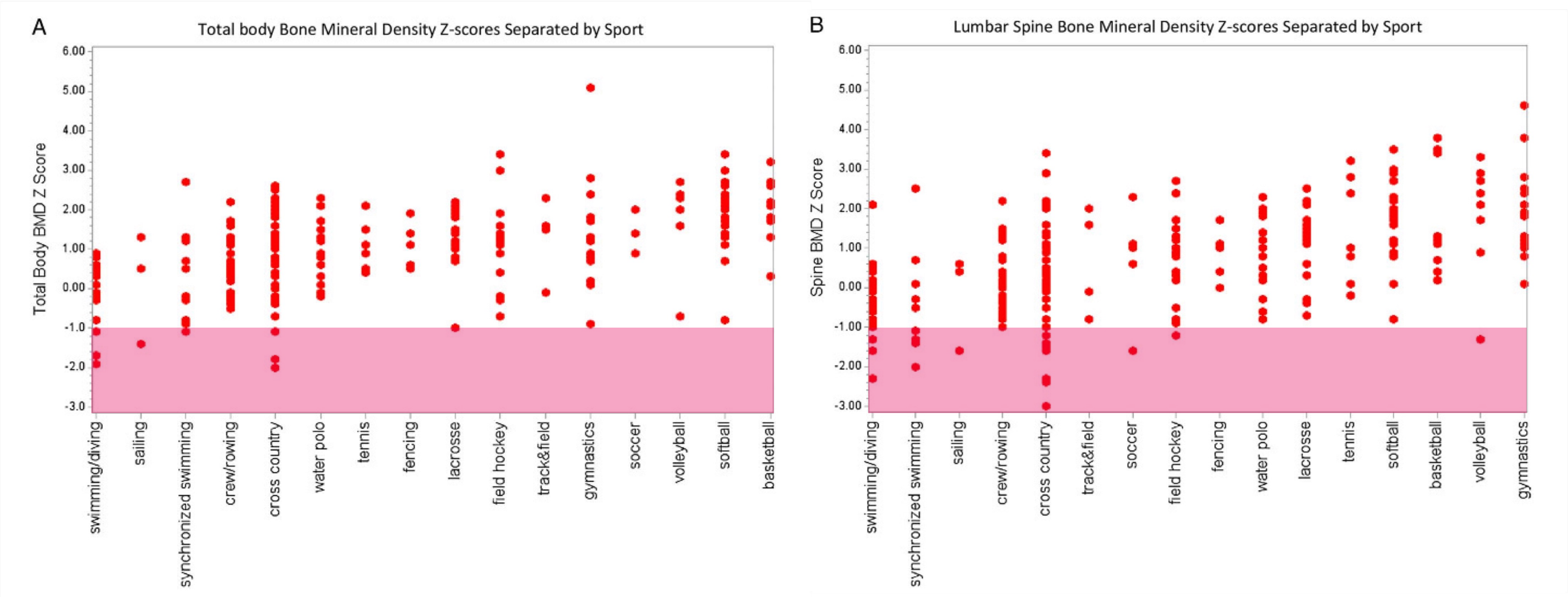

Tenforde et al. 2018, *MSSE* 50(12), 2536-2543.

Not all athletes have good skeletons

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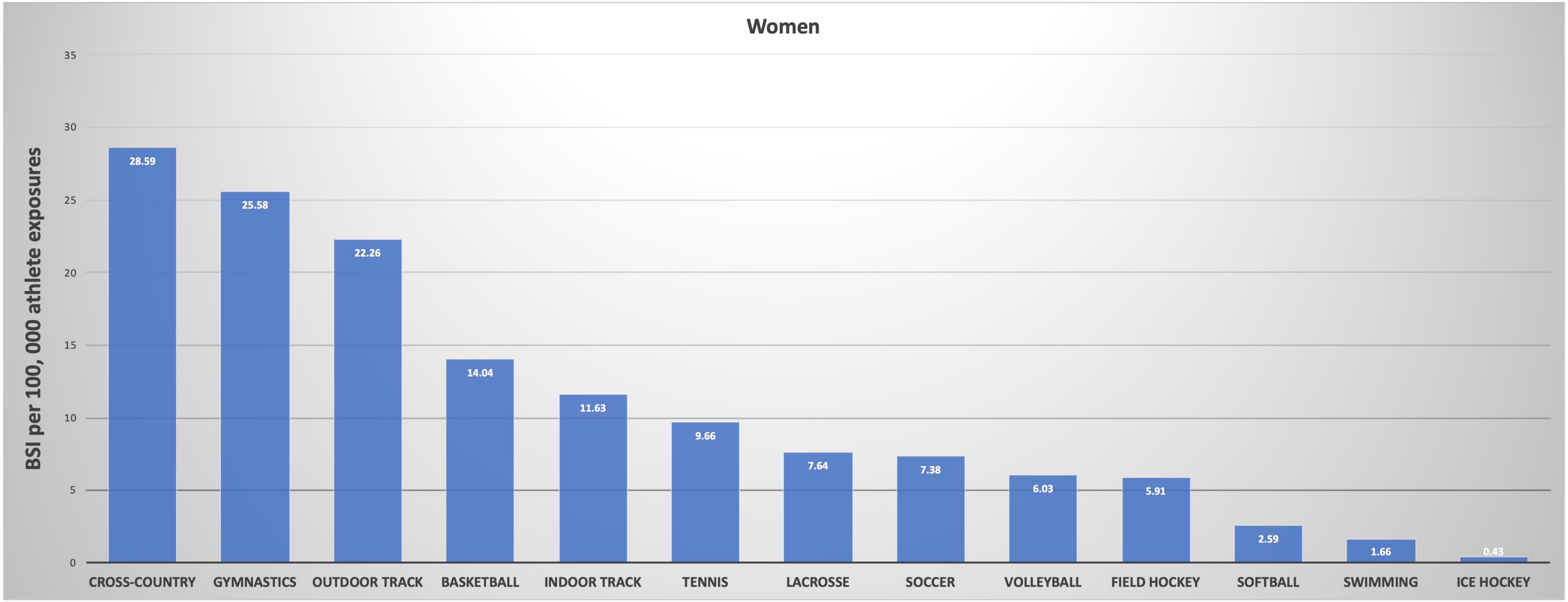

Rizzone et al. 2017, *J Athl Train, 52(10)*, 966-975.

Key nutrients for bone

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KEY NUTRIENTS FOR BONE FORMATION

Protein, Calcium, Phosphorus, Magnesium, Vitamin D

IMPORTANT NUTRIENTS TO UNDERPIN BONE METABOLISM

Vitamin A, Vitamin C, Vitamin K, Boron, Silicon, Copper, Iron, Zinc, Manganese, Lysine

Palacios (2006), Critical Reviews in Food Science and Nutrition, 46, 621-628.

Dairy is a good nutrient source for bone

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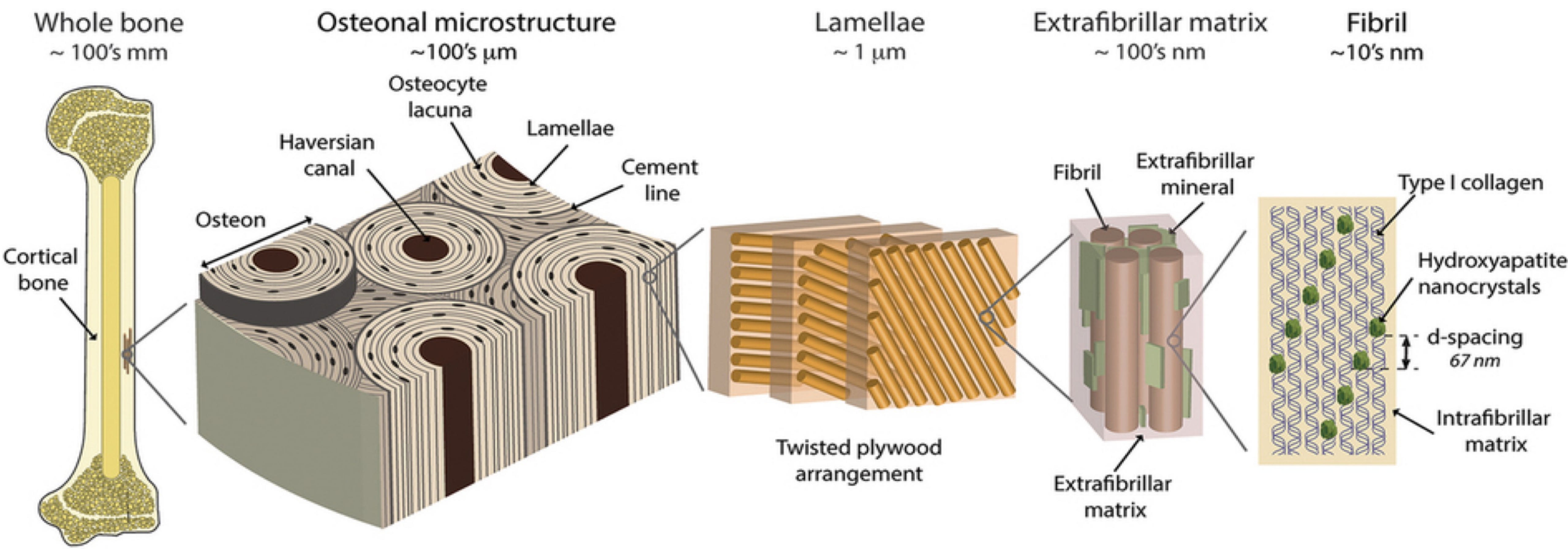
https://www.milk.co.uk/nutritious-dairy/

Dairy provides more protein per calorie than any other food but also contains many other nutrients of importance to the bone!

Dairy is also an important way to help meet calcium and phosphorus requirements!

Hierarchical structure of bone

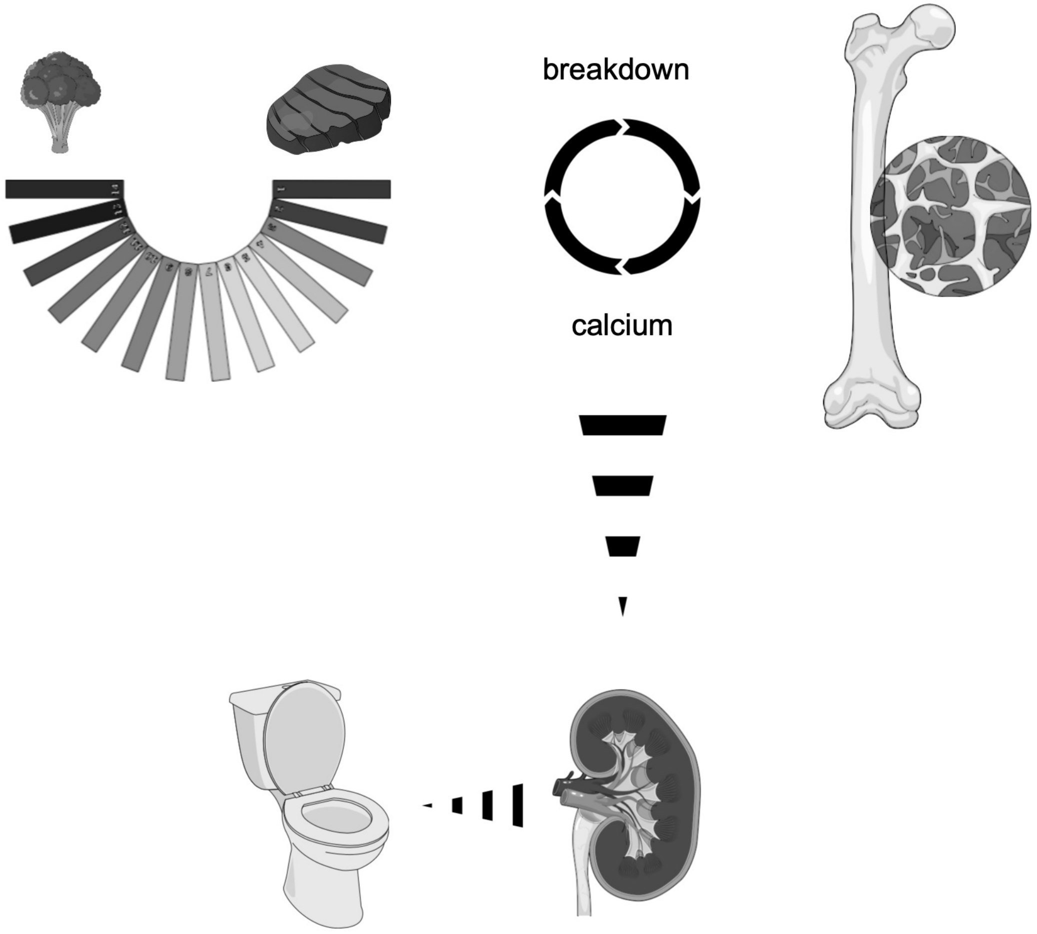


Bone consists of a **protein matrix** encased in a crystalline mineral. So, protein quality is essential to bone.

Bone strength is not solely dependent upon mineralisation!!

Zimmermann et al. 2015, BoneKEy Reports, 4 , 743.

Acid to ash hypothesis



1. Animal proteins are 'acidic'
2. Creates a high potential renal acid load (PRAL)
3. Significant challenge to acid-base balance
4. Body corrects this using alkaline minerals - calcium
5. 99% of calcium stored in the bone
6. So bone brokendown to release calcium to buffer PRAL
7. Excess calcium then excreted through the kidney and 'lost' in urine
8. Associated with increased rate of bone loss and lower BMD in long-term

Macdonald et al. 2005, *AJCN*, 81, 923-933.

Fenton et al. 2008, AJCN, 88, 1159-1166.

Even milk isn't safe

Debunking The Milk Myth: Why Milk Is Bad For You And Your Bones

But many scientific studies have shown an assortment of detrimental health effects directly linked to milk consumption. And the most surprising link is that not only do we barely absorb the calcium in cow's milk (especially if pasteurized), but to make matters worse, it actually increases calcium loss from the bones. What an irony this is!

Here's how it happens. Like all animal protein, milk acidifies the body pH which in turn triggers a biological correction. You see, calcium is an excellent acid neutralizer and the biggest storage of calcium in the body is – you guessed it… in the bones. So the very same calcium that our bones need to stay strong is utilized to neutralize the acidifying effect of milk. Once calcium is pulled out of the bones, it leaves the body via the urine, so that the surprising net result after this is an actual calcium deficit.

High protein or low calcium?

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Mangano et al. 2014, JBMR, 29, 500-506.

Table 2. Least Square Adjusted Means and SEs for BMD at Proximal Femur, Femoral Neck, and Lumbar Spine by Quartiles of Estimated NEAP: Data From the NHANES years 2005–2008

	NEAP quartile				
	1	2	3	4	*p* trend
Men					
n	282	286	285	365	
Dietary protein (g)	66 ± 2	83 ± 3	87 ± 2	91 ± 5	
Dietary calcium (mg)	913 ± 39	1018 ± 49	915 ± 33	795 ± 36	
Estimated NEAP, range	6.87–38.82	38.86–49.40	49.41–62.50	62.53–164.91	
Proximal femur BMD	0.989 ± 0.010	0.992 ± 0.010	0.980 ± 0.008	0.971 ± 0.009	0.46
Femoral neck BMD	0.780 ± 0.008	0.797 ± 0.009	0.787 ± 0.009	0.783 ± 0.008	0.48
Lumbar spine BMD	1.084 ± 0.018	1.091 ± 0.012	1.086 ± 0.017	1.072 ± 0.016	0.83
Women					
n	222	222	210	253	
Dietary protein (g)	51 ± 1	59 ± 2	69 ± 3	70 ± 2	
Dietary calcium (mg)	781 ± 26	782 ± 31	856 ± 54	687 ± 34	
Estimated NEAP, range	8.42–34.93	34.99–46.74	46.78–58.44	58.49–162.32	
Proximal femur BMD	0.836 ± 0.008	0.823 ± 0.009	0.854 ± 0.010	0.849 ± 0.010	0.10
Femoral neck BMD	0.706 ± 0.008	0.696 ± 0.007	0.718 ± 0.009	0.722 ± 0.011	0.16

1218 men aged >60 y of the NHANES cohort between 2005 and 2008.

Nutrient intakes from 2 x 24 h dietary recall - dietary acid load (NEAP and PRAL) and dietary and supplemental calcium.

Inverse association between PRAL and proximal femur BMD (but not other sites) in men consuming <800 mg of calcium per day.

No association in men consuming >800 mg of calcium per day.

No effects in women.

Low calcium has independent effects on bone!

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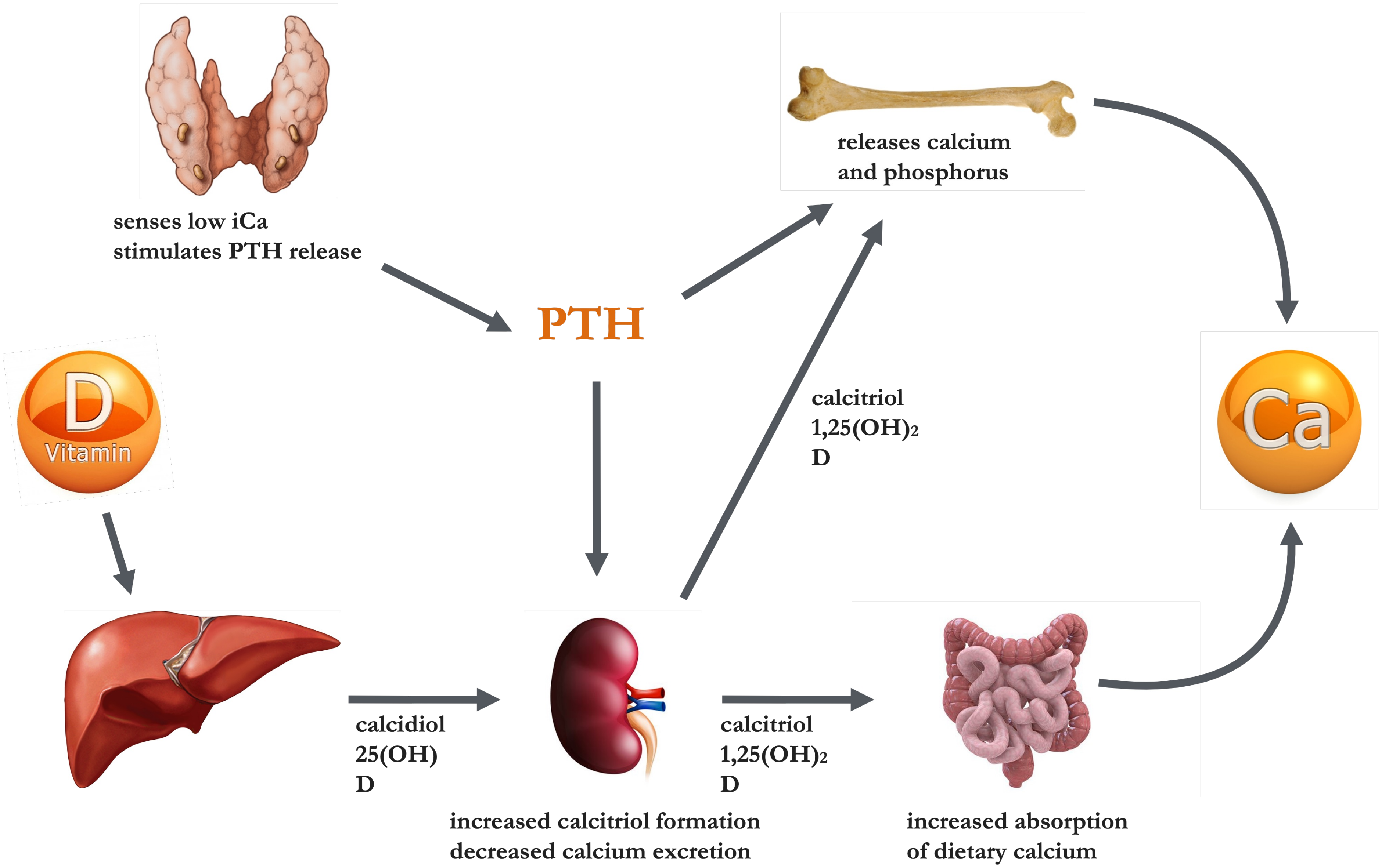

Increased calcium availability with high protein

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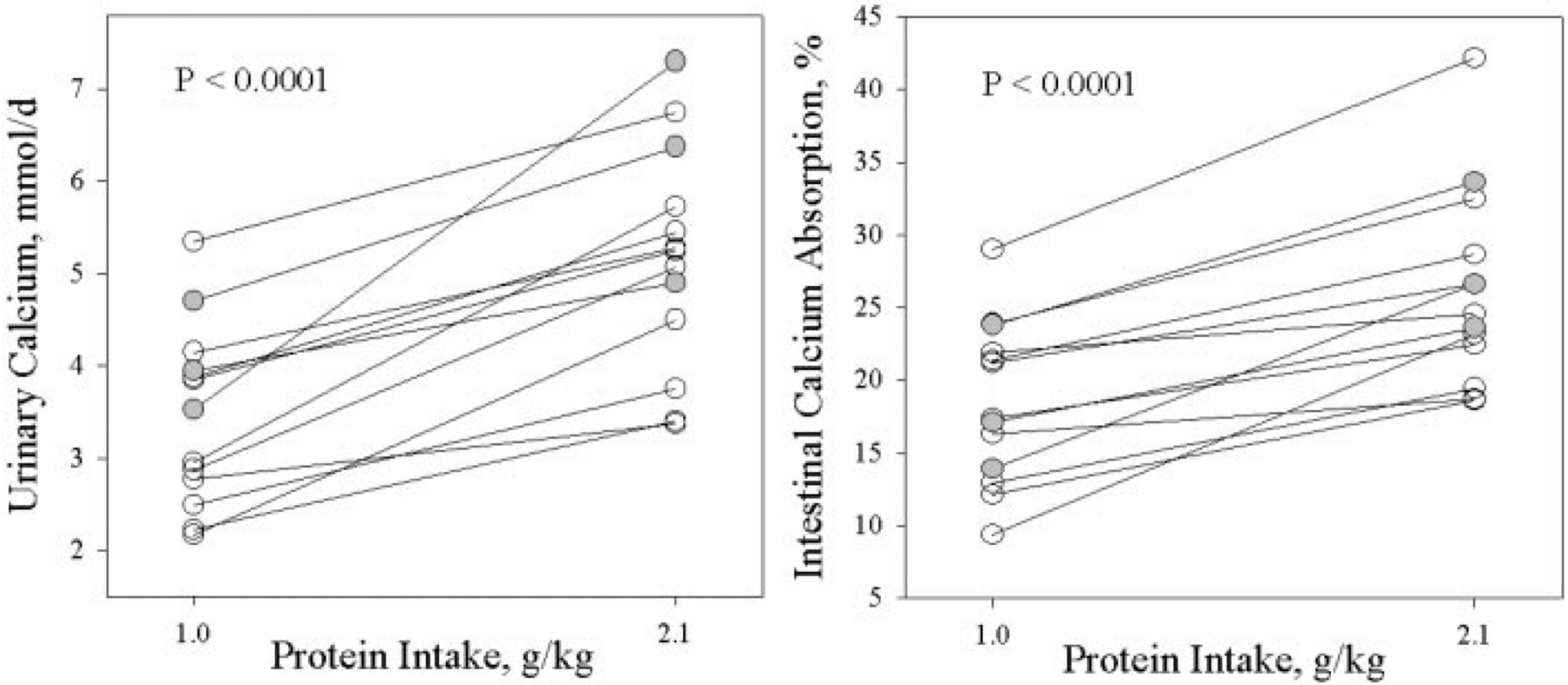
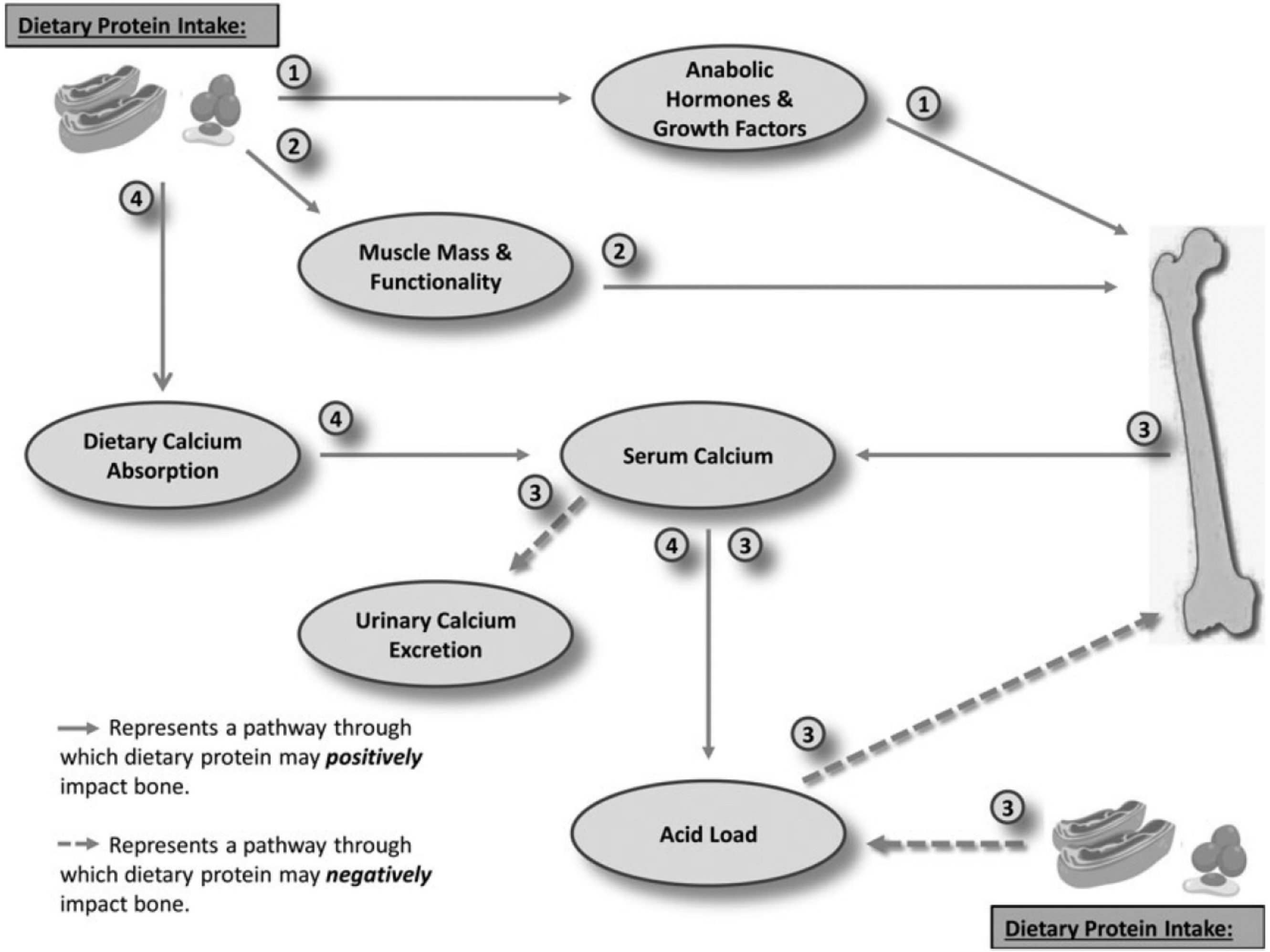


Do increased urinary calcium losses with high animal protein intakes come from bone **OR** from increased calcium availability??

Kerstetter et al. 2005, JCEM, 90(1), 26-31.

Summary of protein effects on bone

1. Dietary protein up-regulates the activity of anabolic hormones and growth factors, which can exert an osteogenic influence.
2. Dietary protein positively impacts muscle mass and functionality, with indirect benefit to bone through the increased mechanical loading that this provides.
3. Dietary protein increases the renal acid load, inducing a state of low-grade metabolic acidosis. Ca^{2+} and other alkaline minerals are leached from the bone in order to neutralise pH, reducing acid load. Ca^{2+} is subsequently lost through an increased urinary excretion, causing bone demineralisation.
4. Dietary protein increases dietary calcium absorption, thus increasing serum calcium availability, allowing for pH neutralisation, without undue detriment to bone.



Dolan and Sale 2019, *Proc Nutr Soc*, 78(1), 45-55.

Calcium questions – recommended amounts

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Around 200 mg of Ca removed from the adult skeleton and replaced every day

To supply this amount = consumption of at least 600 mg $\cdot$ d^{-1} - efficiency of absorption

To ensure that 95 percent of the US population gets this, the National Academy of Sciences established the following recommended intake levels:

- 1,000 mg $\cdot$ d^{-1} for those age 19 to 50 y olds
- 1,200 mg $\cdot$ d^{-1} for those age 50 y or over
- 1,000 mg $\cdot$ d^{-1} for pregnant/lactating adults

UK recommendations are a bit lower:

- 800-1000 mg $\cdot$ d^{-1} in 11-18 y olds
- 700 mg $\cdot$ d^{-1} in +19 y olds

Calcium questions – basic bone effects

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Calcium is required for the bone formation phase of bone remodelling - 99% of calcium found in bone.

Key structural role as a component of hydroxyapatite - main mineral component of the bone.

Dietary calcium (1,000 $mg \cdot d^{-1}$) reduces the bone remodelling rate by 10 to 20% in older men and women (Elders et al., 1994).

Reduced remodelling rate might account for increased BMD in the year following Ca supplementation (Dawson-Hughes, 2013).

What about athletes and athletic individuals!?

Ca and PO4 control PTH with exercise

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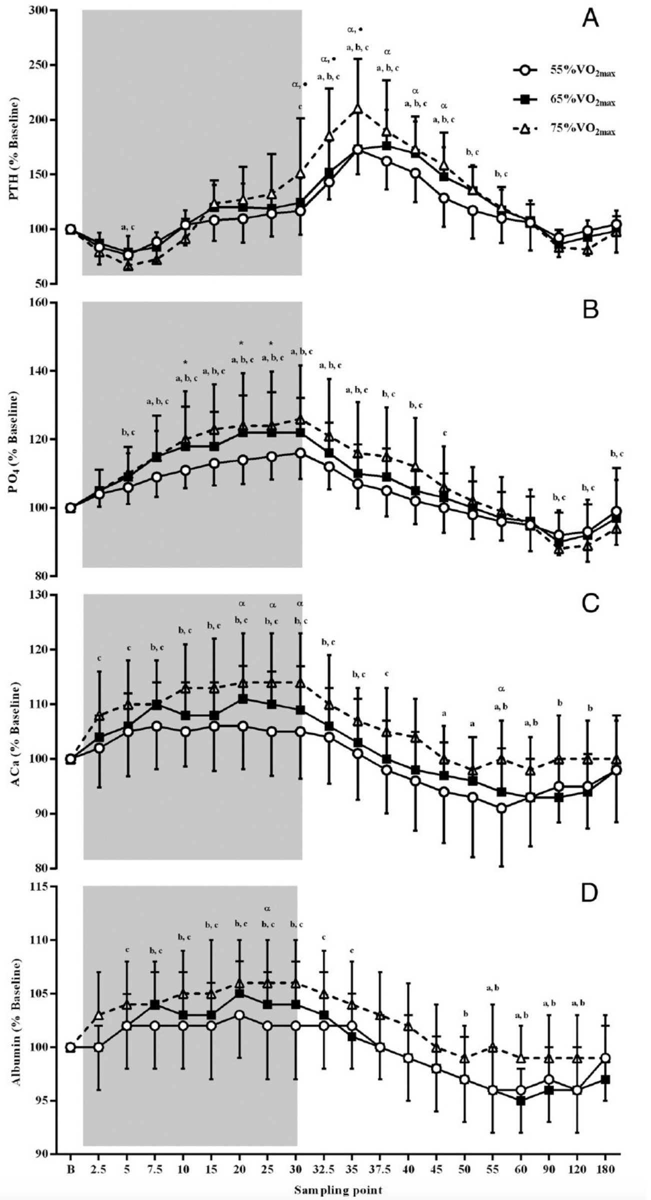
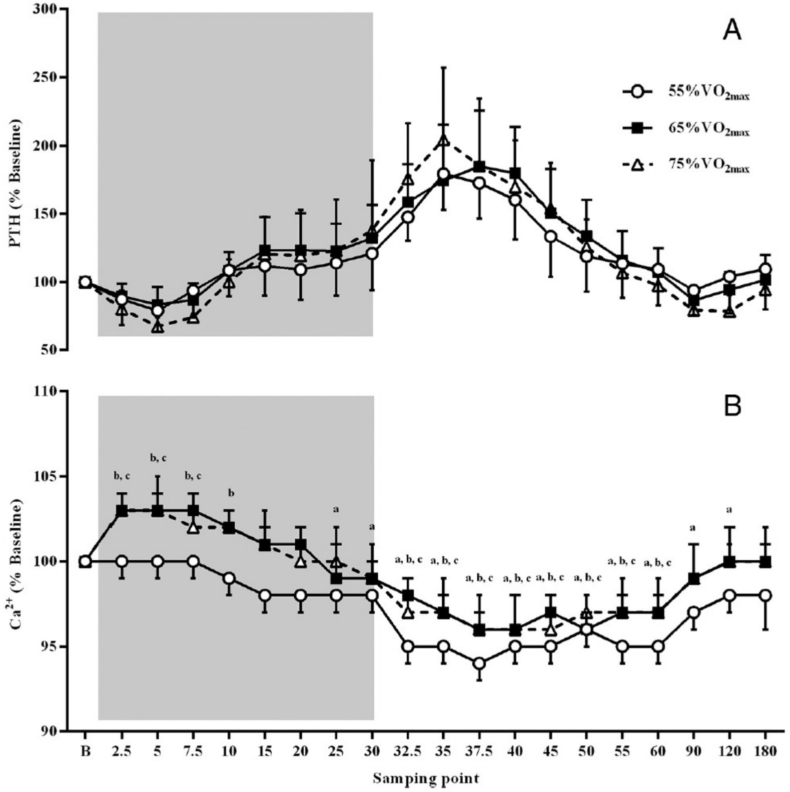


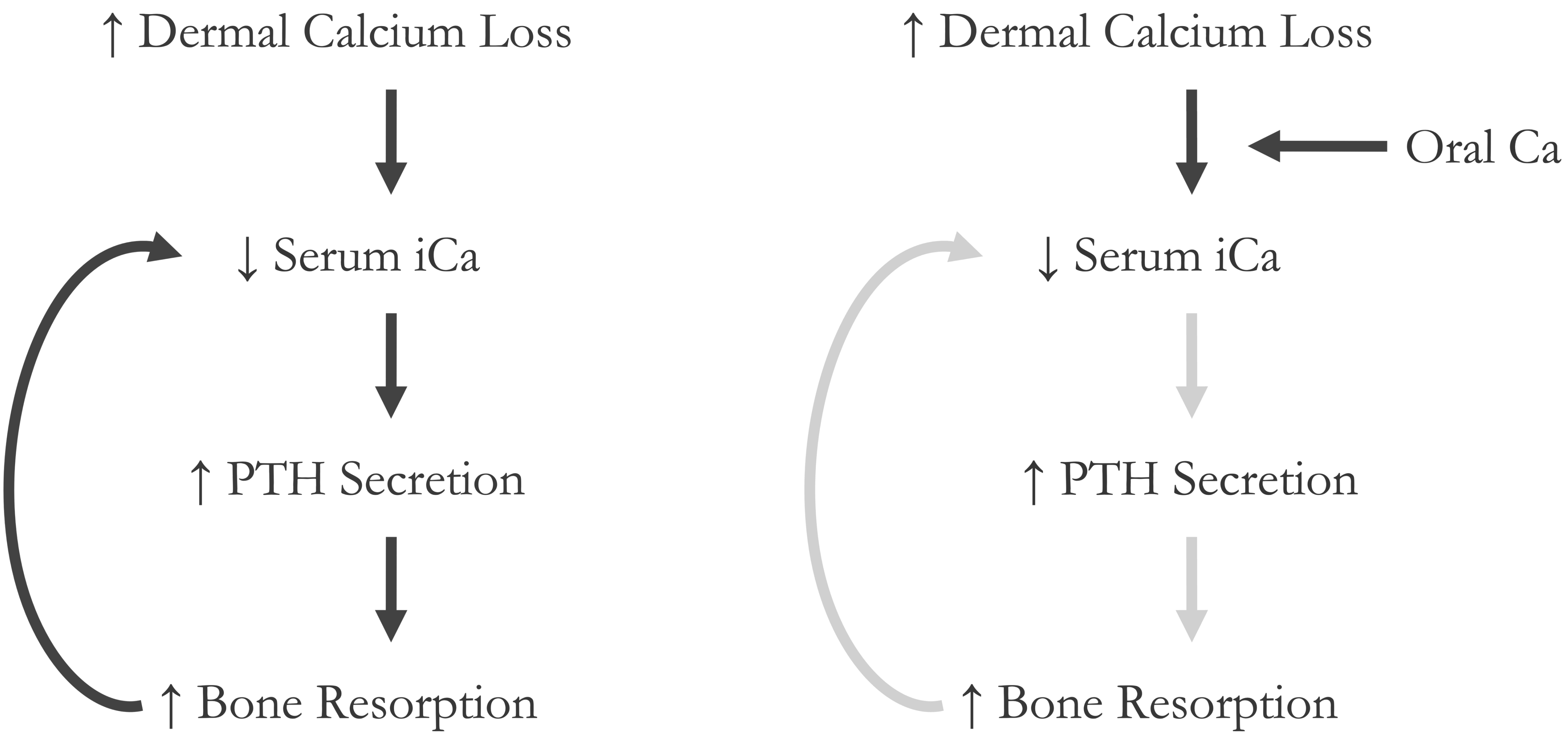


Changes in Ca and PO4 occur in close temporal relation to changes in PTH.

Cross-correlational analysis suggests PTH secretion during exercise and recovery is controlled by a combination of changes in Ca and PO4.

Townsend et al. 2016, *JCEM*, 101, 3231-3239.

Calcium loss and supplementation with exercise



Dermal calcium loss possibly not so important?

Dermal Calcium Loss Is Not the Primary Determinant of Parathyroid Hormone Secretion during Exercise

WENDY M. KOHRT[1,2], PAMELA WOLFE[3], VANESSA D. SHERK[4], SARAH J. WHERRY[1,2], TOBY WELLINGTON[1], EDWARD L. MELANSON[1,2,4], CHRISTINE M. SWANSON[4], CONNIE M. WEAVER[5], and REBECCA S. BOXER[1,2]

[1]*Division of Geriatric Medicine, Department of Medicine, University of Colorado Denver, Aurora, CO;* [2]*Eastern Colorado VA Geriatric Research, Education, and Clinical Center, Aurora, CO;* [3]*Department of Preventive Medicine and Biometrics, University of Colorado Denver, Aurora, CO;* [4]*Division of Endocrinology, Metabolism and Diabetes, Department of Medicine, University of Colorado Denver, Aurora, CO; and* [5]*Department of Nutrition Science, Purdue University, West Lafayette, IN*

TABLE 2. Sweating responses to exercise.

	All		Women		Men	
	Warm	Cool	Warm	Cool	Warm	Cool
Sweat volume, L*,**	0.9 (0.4)	0.6 (0.4)	0.7 (0.2)	0.3 (0.2)	1.1 (0.4)	0.9 (0.4)
Sweat calcium concentration, $mg \cdot dL^{-1}$	3.6 (1.6)	3.5 (1.2)	3.5 (1.7)	3.3 (1.3)	3.7 (1.7)	3.6 (1.2)
Estimated sweat calcium loss, mg*,**	33 (19)	22 (15)	26 (16)	11 (6)	40 (20)	32 (14)

* Warm vs cool, $P < 0.01$; ** women vs men, $P < 0.01$; $n = 24$ for sweat Ca and sweat Ca loss.

60 min of cycling at ~75% of peak aerobic power in cool (18°C) and warm (26°C) conditions.

Sweat and blood obtained during exercise

Sweat volume and estimated sweat Ca loss were 50% higher for the warm condition than the cool condition.

Despite this, no differences between thermal conditions in the changes in iCa, PTH or CTX

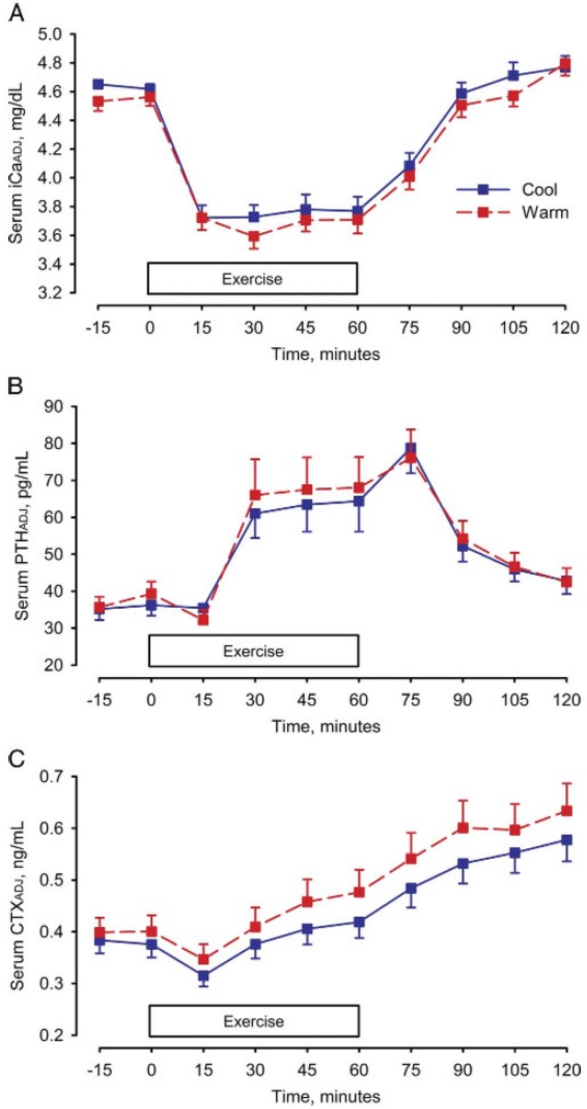


FIGURE 2—PV-adjusted changes in serum iCa (iCa_{AJD}; A), PTH (PTH_{ADJ}; B), and CTX (CTX_{ADJ}; C) in 25 women and men in response to exercise performed under cool (*solid line*) and warm (*dashed line*) conditions.

Kohrt et al. 2019, *MSSE*, 51(10), 2117-2124

Calcium losses in elite triathlon

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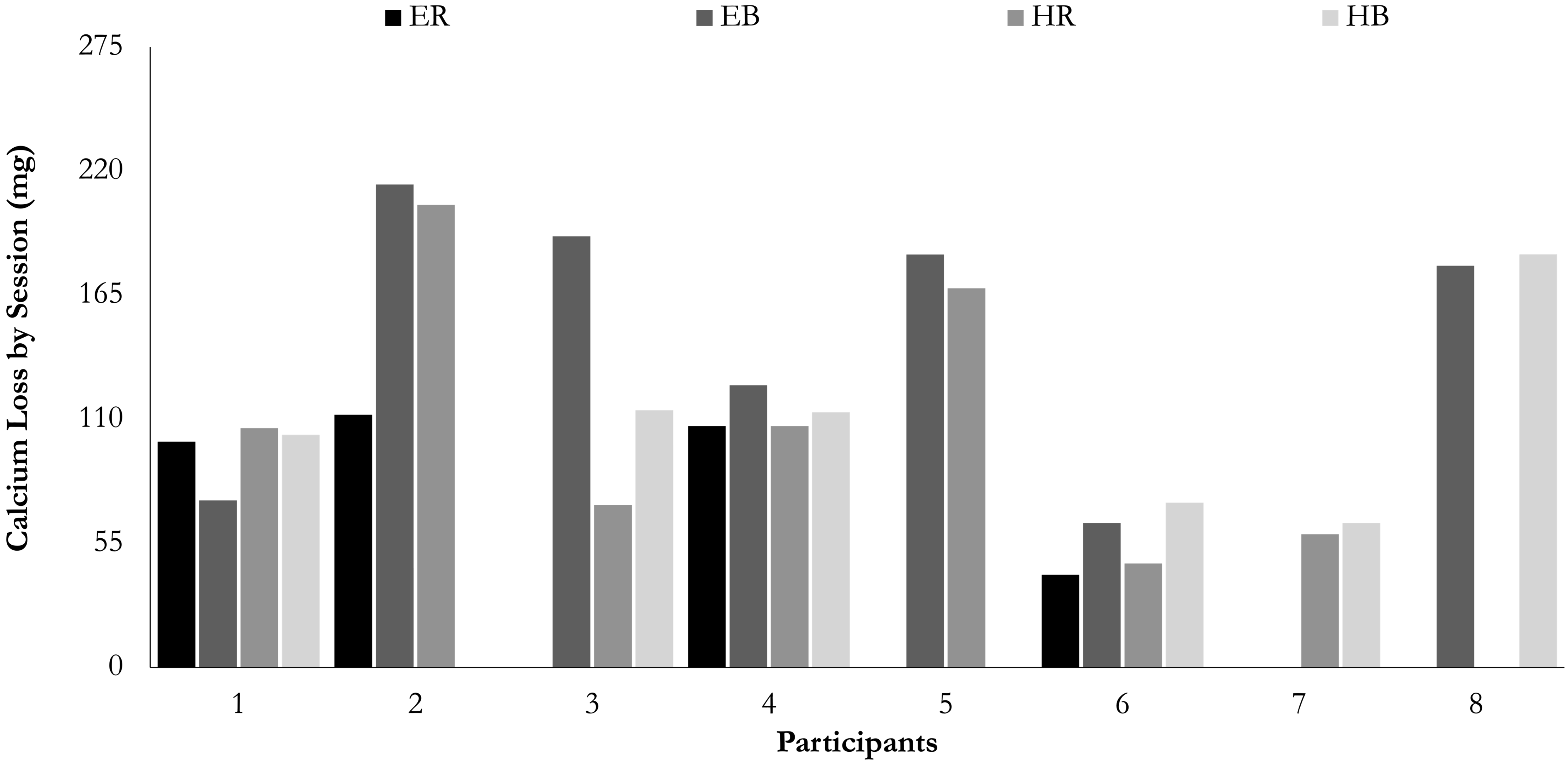

Becky Townsend - PhD Thesis

Calcium loss and maintenance with exercise

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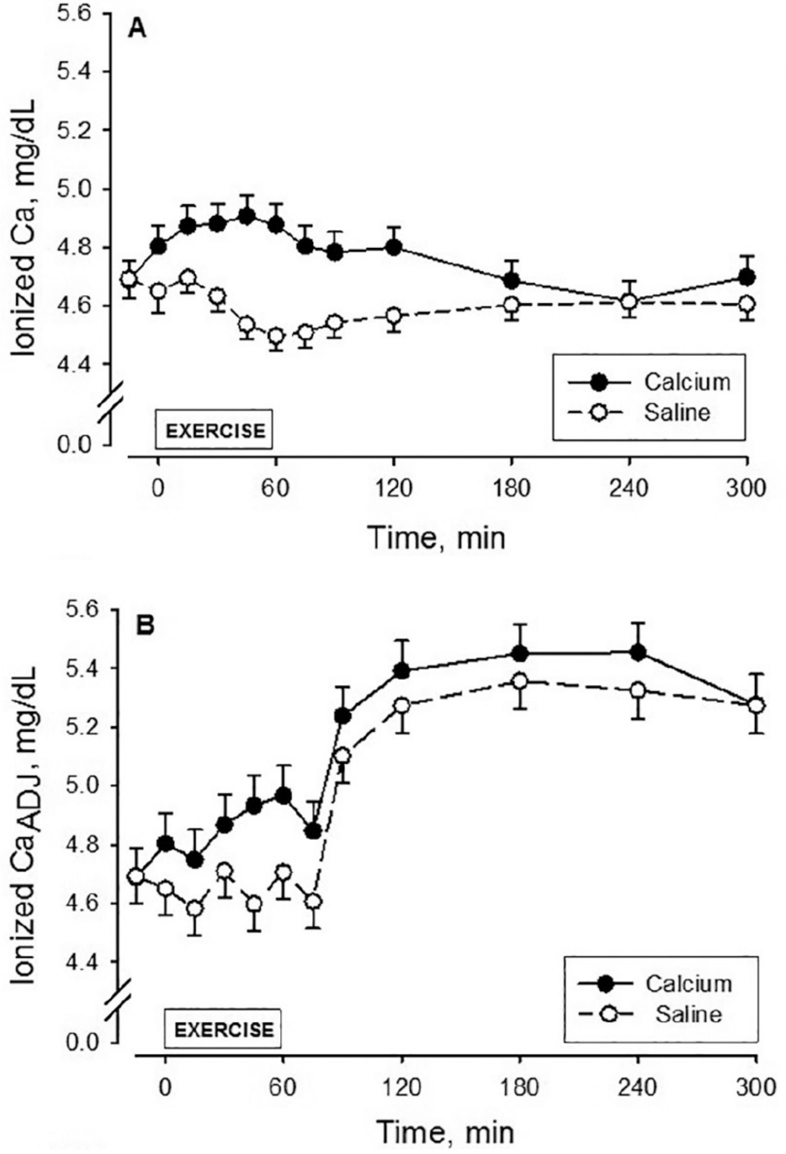
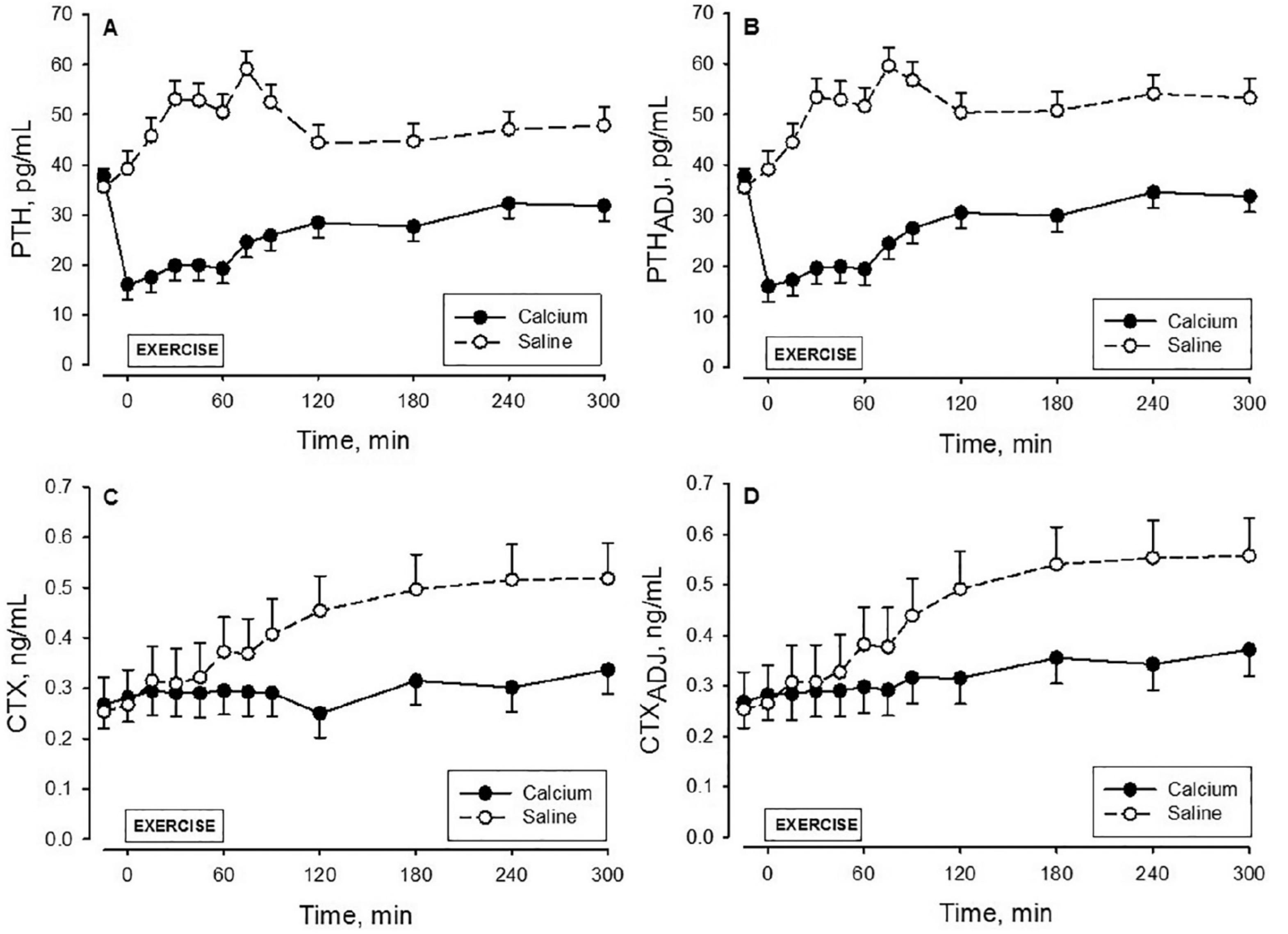
Wherry et al. 2021, *Bone*, 153, 116108





Calcium supplementation pre-exercise - cycling

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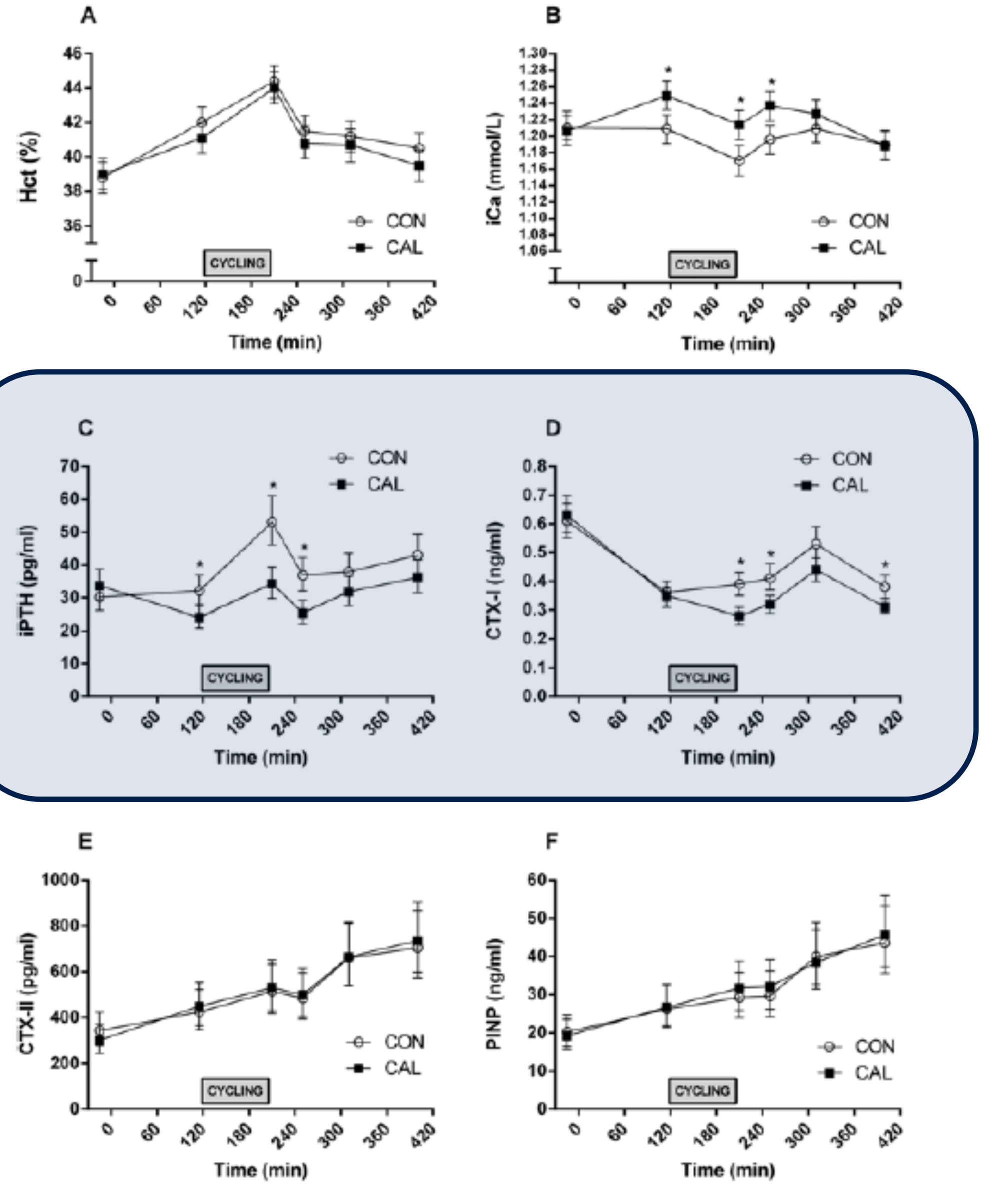

Table 1. Macronutrient composition and calcium content of standardised diets for the control (CON) and calcium-rich (CAL) trials.

	24 h dietary standardisation		*Pre-exercise breakfast*	
Nutrient	***CON ($\bar{X}$ ± SD)***	***CAL ($\bar{X}$ ± SD)***	***CON ($\bar{X}$ ± SD)***	***CAL ($\bar{X}$ ± SD)***
Energy (kJ/kg)	170 ± 4	169 ± 4	54 ± 2	54 ± 2
CHO (g/kg)	5.1 ± 0.2	5.1 ± 0.2	2.0 ± 0.0	2.0 ± 0.0
Protein (g/kg)	1.5 ± 0.0	1.5 ± 0.0	0.2 ± 0.0	0.6 ± 0.1
Fat (g/kg)	1.5 ± 0.0	1.5 ± 0.0	0.4 ± 0.0	0.3 ± 0.0
Calcium (mg)	640 ± 226	1658 ± 174	46 ± 7	1352 ± 53

Haakonssen et al. 2015, *PLoS One*, 10(5), e0123302

Calcium supplementation pre-exercise - rowing

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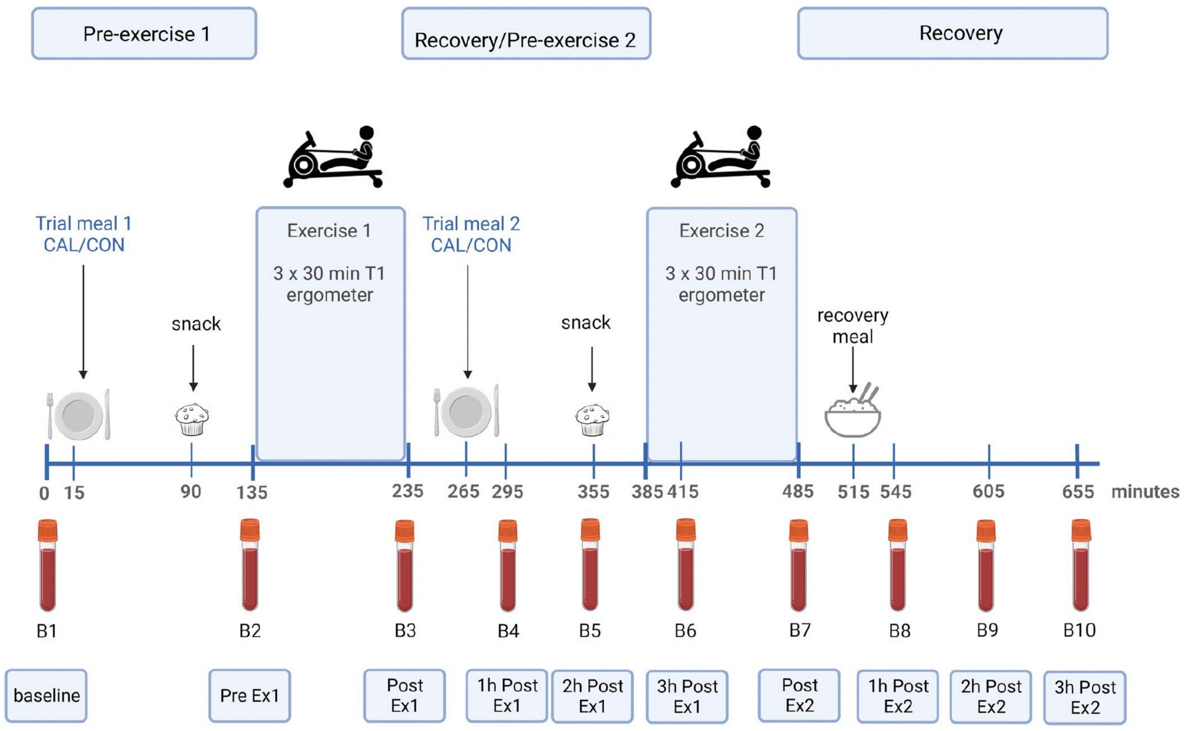

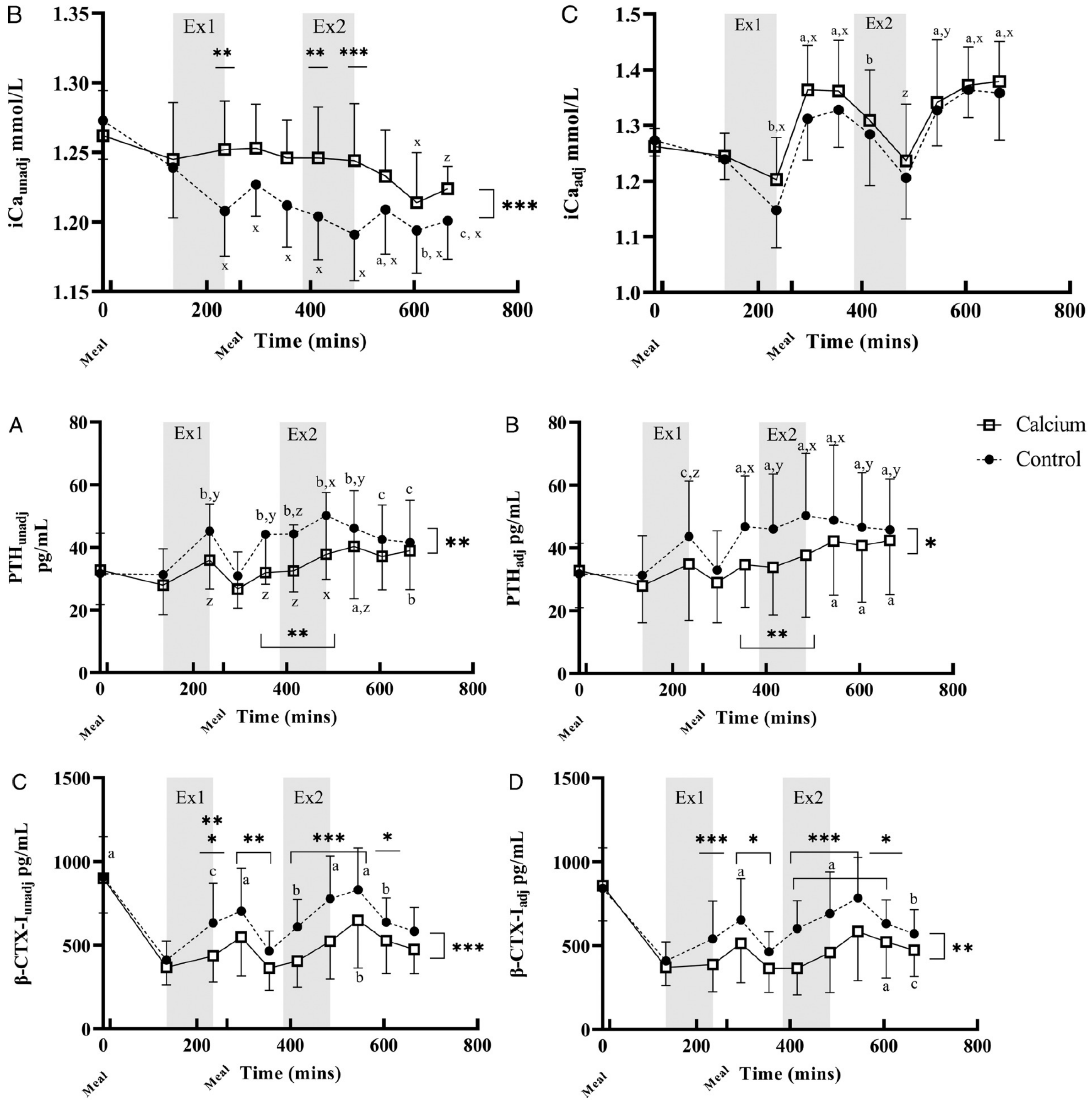

Lundy et al. (in press), *MSSE*, doi: 10.1249/MSS.0000000000003022

Calcium and Vit D synergistic effects!

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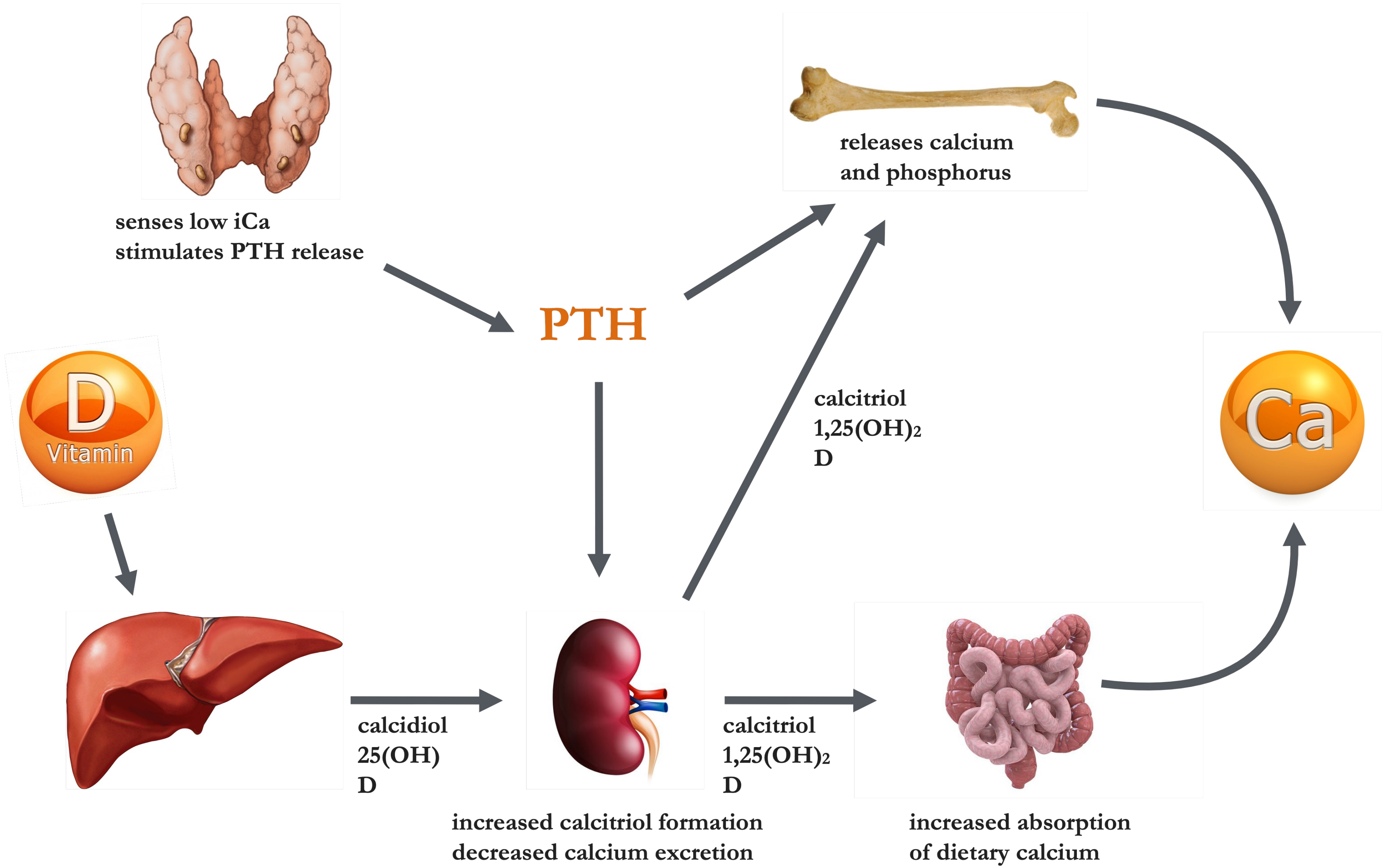

Vitamin D is important

In general, probably enough to get to 50 nmol/L (20 ng/mL) or above for protection of bone.

If needing to supplement, oral dose daily and avoid mega doses!

Clinical Review: Focused

Evaluating the Relationship of Calcium and Vitamin D in the Prevention of Stress Fracture Injuries in the Young Athlete: A Review of the Literature

Adam S. Tenforde, MD, Lauren C. Sayres, BA, Kristin L. Sainani, PhD, Michael Fredericson, MD

To date, no prospective studies have been conducted in male athletes or in adolescent athletes. In most studies, males and nonwhite participants were poorly represented. Evidence regarding the relationship of vitamin D intake with the prevention of fractures in athletes is also limited. More prospective studies are needed to evaluate the role of calcium and vitamin D intake in prevention of stress fracture injuries in both male and female adolescent athletes, particularly those participating in sports with greater incidences of stress fracture injury.

PM R 2010;2:945-949

Low vitamin D = increased SFx risk

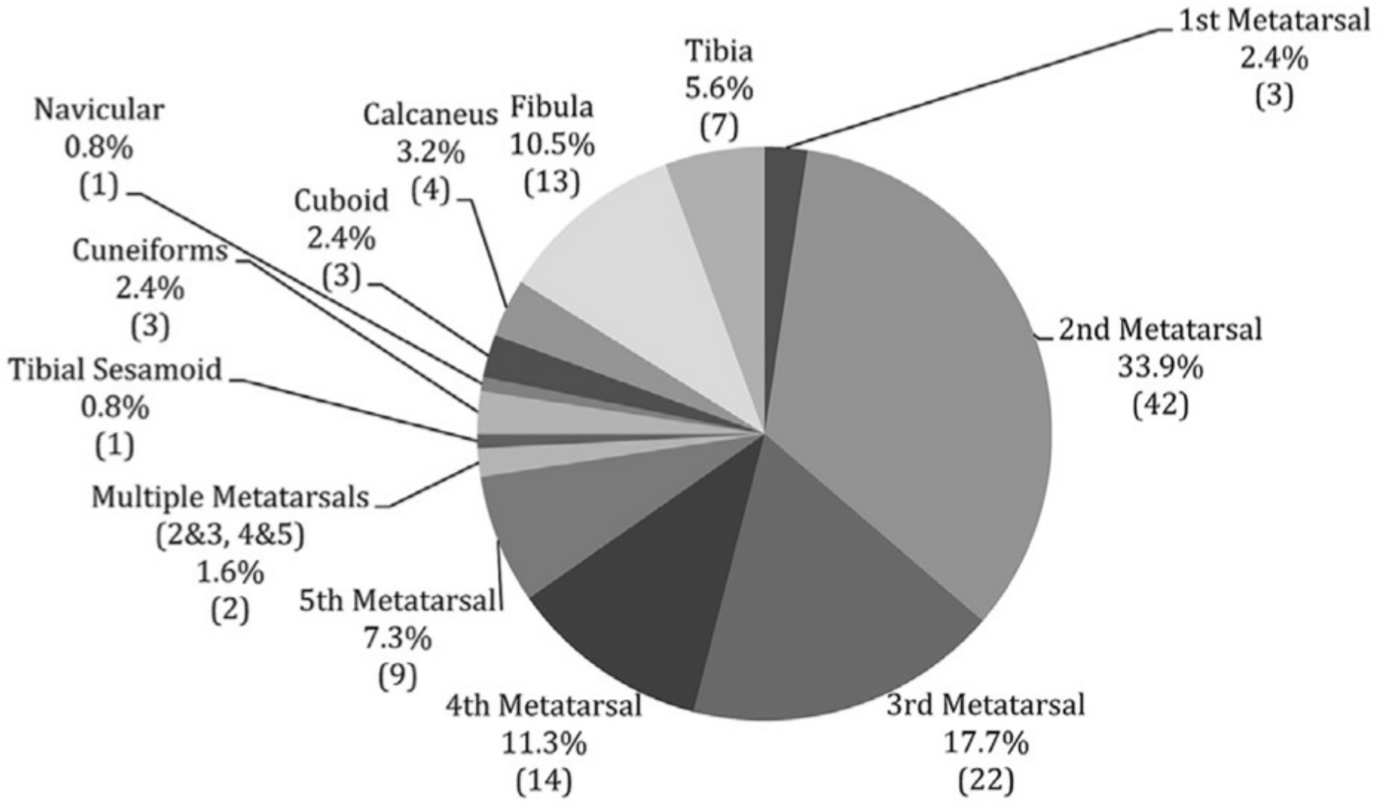

Fig. 2. Anatomic location of stress fractures (N = 124 patients).

Serum 25(OH)D measured in 53 of the 124 SFx patients

44 (83%) of these patients had insufficient or deficient levels of circulating vitamin D

Authors suggested that higher vitamin D levels might be protective - although this is something of an assumption

Miller et al. (2016), *The Journal of Foot & Ankle Surgery*, 55, 117-120

Decreased SFx with vitamin D + calcium

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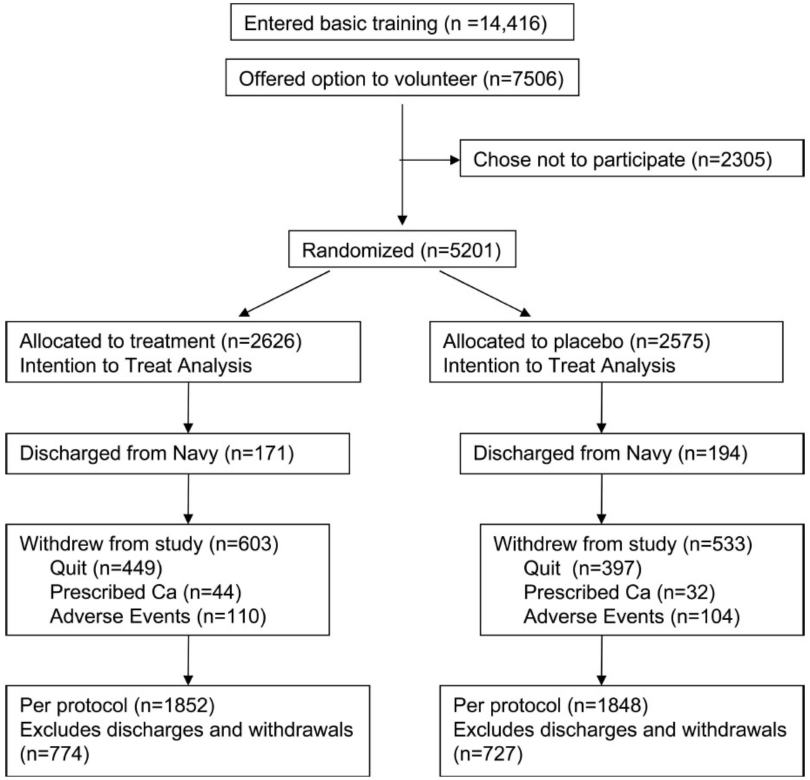

FIG. 1. Flow diagram of progress through study phases. Intention-to-treat included all subjects enrolled in the study. Subjects that were discharged or withdrew from study were not included in the per protocol analysis.

5201 female Navy recruits randomised to 2000 mg calcium and 800 IU vitamin D/d or placebo. SFx confirmed with radiography or technetium scan.

TABLE 3. FRACTURES BY SKELETAL SITE AND TREATMENT GROUP

Skeletal site	*Calcium and vitamin D group*	*Placebo group*
Tibia/fibula	138	179
Foot	38	34
Pelvis	3	8
Femur	20	22
Other	27	27
Total	226	270

Per protocol analysis, including only the 3700 recruits who completed the study, showed a 21% lower incidence of SFx in the supplemented versus the control group.

Lappe et al. 2008, *JBMR*, 23, 741-749.

Dairy and stress fracture risk

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Table 4a. *Adjusted* annual rates of change in spine, hip, and whole-body mineral density (BMD) and whole-body bone mineral content (BMC) and skeletal area by nutrients and dietary patterns*

Nutrient (SD)	Spine BMD (g/cm^2/year ± SE)	Total Hip BMD (g/cm^2/year ± SE)	Whole-body BMD (g/cm^2/year ± SE)	Whole-body BMC (g/year ± SE)
Animal protein, g/day/kg body weight	0.00150 ± 0.00229	0.00350 ± 0.00216	0.00602 ± 0.00219†	16.4 ± 5.1‡
Vegetable protein, g/day/kg body weight	−0.00284 ± 0.00210	0.00093 ± 0.00200	−0.00308 ± 0.00205	3.6 ± 4.8
Fat, per 1 SD (29g)	−0.00068 ± 0.00098	−0.00026 ± 0.00093	0.000376 ± 0.00096	−0.8 ± 2.3
Fiber, per 1 SD (17 g)	0.00057 ± 0.00079	0.00012 ± 0.00075	−0.00119 ± 0.00077	0.7 ± 1.8
Calcium, per 1 SD (655 mg)	0.00160 ± 0.00089	0.00216±0.00083*	0.0025 ± 0.00085‡	6.6 ± 2.0‡
Vitamin C, per 1 SD (182 mg)	0.00084 ± 0.00104	−0.00009 ± 0.00098	0.00108 ± 0.00101	1.9 ± 2.4
Vitamin D, per 1 SD (145 IU)	0.00229±.00100*	0.00251±.00095†	0.00136 ± 0.00099	4.0 ± 2.3
Phosphorous, per 1 SD (206 mg)	0.00143 ± 0.00107	0.00063 ± 0.00102	0.00234 ± 0.00104*	3.9 ± 2.4
Potassium, per 1 SD (897 mg)	0.00198 ± 0.00102	0.00236 ± 0.00095*	0.00259 ± 0.001*	6.0 ± 2.3*
Iron, per 1 SD (10.8 mg)	0.00139 ± 0.00101	0.00108 ± 0.00096	−0.00185±0.00098	−1.6 ± 2.3
Fruits and vegetables, per serving	−0.00012 ± 0.00025	−.00004 ± 0.00024	.00030 ± 0.00024	1.1 ± 0.6
Dairy, per serving	0.00069 ± 0.00058	.00127 ± 0.00054*	.00129 ± 0.00056*	4.1 ± 1.3‡
Skim milk, per additional cup/day	0.00095 ± .00096	.00258 ± .00089‡	.00132±.00094	5.2 ± 2.2*
Total milk, per additional cup/day	0.00063 ± .00093	.00262 ± .00086‡	.00103±0.00092	5.1 ± 2.1*
Coffee, per additional cup /day	0.00148 ± .00067*	.00170 ± .00063†	.00099±0.00067	−0.4 ± 1.5
Dietary pattern 1	0.00179 ± 0.00137	.00280 ± 0.0013	.00091 ± 0.00135	4.9 ± 3.2
Dietary pattern 2	0.00125 ± 0.00118	.00036 ± 0.00113	.00369 ± 0.00113‡	7.3 ± 2.7†
Dietary pattern 3	−0.00080 ± 0.00108	−.00028 ± 0.00103	−.00237 ± 0.00104*	−1.4 ± 2.5
Dietary pattern 4	0.00302 ± 0.00192	.00211 ± 0.00184	−.00362 ± 0.00189	2.4 ± 4.5

Dietary pattern 1 = high dairy, low fat; dietary pattern 2 = high fruits and vegetables, high fiber, low fat; dietary pattern 3 = high animal protein, high fat, low fruits and vegetables, low fiber; dietary pattern 4 = high protein (both animal and vegetable).

Baseline nutrient intake for calcium, vitamin C, vitamin D, phosphorous, potassium, iron, fiber, and fat is adjusted for caloric intake using the residual [54].

Units for dairy, fruits, and vegetables are servings per day; units for animal and vegetable protein are grams per day per kilogram of body weight.

*Annual rates of change are estimated from linear mixed models, adjusted for clinical site, age, annual menses, and treatment assignment in the randomized trial. Dietary patterns were derived from a Reduced Rank Regression method. Am J Epidemiol 2004;159:935-944.

Table 3. *Adjusted* hazard ratios (and 95% confidence interval) for associations between nutrients and stress fractures (n = 125)*

Nutrient	Hazard Ratio (95% CI)
Kilocalories, per 1 standard deviation (913 kcal)	0.63 (0.34-1.15)
Animal protein, g/day/kg body weight	0.42 (0.15-1.20)
Vegetable protein, g/day/kg body weight	0.57 (0.11-2.91)
Fat, per 1 standard deviation (29 grams/day)	1.02 (0.58-1.70)
Fiber, per 1 standard deviation (17 grams/day)	1.11 (0.49-2.52)
Calcium, per 1 standard deviation (655 mg)	0.53 (0.29-0.97)†
Vitamin C, per 1 standard deviation (182 mg)	1.26 (0.69-2.30)
Vitamin D, per 1 standard deviation (145 IU)	0.67 (0.34-1.31)
Phosphorous, per 1 standard deviation (206 mg)	1.00 (0.51-1.96)
Potassium1, per 1 standard deviation (897 mg)	0.76 (0.39-1.47)
Iron, per 1 standard deviation (11 mg)	1.43 (0.82-2.49)
Fruits and vegetables, per serving	0.89 (0.74-1.07)
Dairy products, per serving	0.60 (0.40-0.89)†
Skim milk, cups/day	0.38 (0.16-0.90)†
Total milk, cups/day	0.43 (0.20-0.89)†
Coffee, cups/day	0.94 (0.63-1.40)
Dietary pattern 1	0.32 (0.10-0.96)†
Dietary pattern 2	0.63 (0.32-1.24)
Dietary pattern 3	1.06 (0.54-2.09)
Dietary pattern 4	1.54 (0.31-7.48)

In young female runners, low-fat dairy products and the major nutrients in milk (calcium, vitamin D, and protein) were associated with greater bone gains and a lower stress fracture rate.

Nieves et al. 2010, *PM R*, 2, 740-750.

Summary of calcium effects on bone????

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1. Only been v. limited investigation of the effects of dairy on bone IN ATHLETES.
2. So, we have to extrapolate to key nutrient effects…
3. Calcium intakes should be adequate but probably a little more than 700 mg·d^{-1} (around 1000-1500 mg·d^{-1}) for an elite endurance athlete?
4. Likely important if the athlete is consuming a high animal protein diet.
5. Perhaps 1500 mg·d^{-1} to reduce SFX risk
6. Perhaps a need to consider dermal calcium losses during hard training phases, but the importance of this for bone is still not well established.
7. Pre-exercise supplementation with calcium (possibly around 1000 mg·d^{-1}) might be useful to offset calcium losses with exercise and the associated rise in PTH release and bone resorption. What about phosphorus levels?
8. That said, probably not a good idea to do this constantly, since targeted bone remodelling is important for the repair of damaged bone and consistently down regulating bone resorption might cause the accumulation of older/weaker bone – this remains an important area for future research.
9. It is important to consider combined impact of vitamin D and calcium – there are some positive indications for stress fracture risk here.

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No effects of dairy on bone markers

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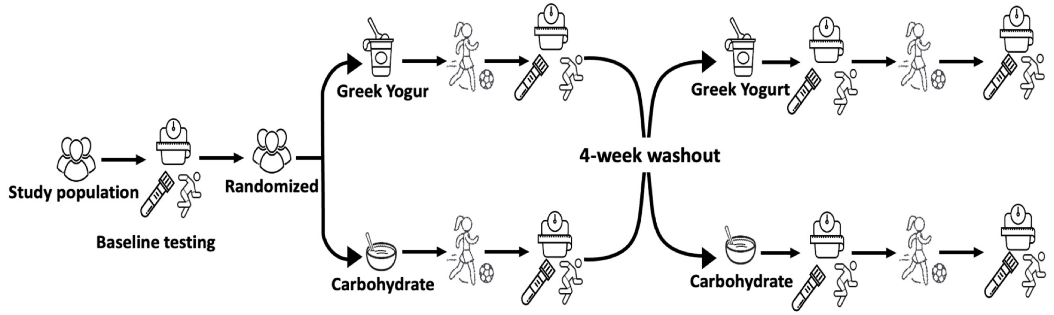

Table 3. Resting, morning concentrations of bone turnover markers and osteokines during each intervention condition in female adolescent soccer players.

Marker	Group	Pre-Training	Post-Training
tOC (ng·mL^{-1})	GY	74.0 ± 29.1 (39%)	74.0 ± 29.9 (40%)
	CHO	73.2 ± 30.2 (41%)	78.0 ± 33.5 (43%)
unOC (ng·mL^{-1}) *,#	GY	8.9 ± 4.5 (50%)	6.6 ± 3.5 (54%)
	CHO	8.6 ± 4.5 (52%)	8.4 ± 4.6 (54%)
unOC/tOC (%) *	GY	12.4 ± 6.1 (49%)	9.4 ± 5.0 (53%)
	CHO	11.6 ± 4.6 (40%)	10.5 ± 4.4 (42%)
CTX (pg·mL^{-1})	GY	0.17 ± 0.11 (65%)	0.16 ± 0.10 (62%)
	CHO	0.16 ± 0.11 (68%)	0.16 ± 0.11 (68%)
OPG (pg·mL^{-1})	GY	1388.2 ± 475.9 (34%)	1223.8 ± 233.0 (19%)
	CHO	1206.8 ± 363.4 (30%)	1273.1 ± 344.9 (27%)
RANKL (pg·mL^{-1})	GY	34.3 ± 22.1 (64%)	29.8 ± 21.4 (72%)
	CHO	30.3 ± 21.4 (71%)	35.0 ± 17.9 (51%)
OPG/RANKL (ratio)	GY	57.4 ± 48.5 (84%)	69.5 ± 57.1 (82%)
	CHO	57.1 ± 48.2 (84%)	50.6 ± 44.7 (88%)

Values are mean ± standard deviation (% coefficient of variation); t-OC= total osteocalcin (N = 13); unOC = undercarboxylated osteocalcin (N = 10); unOC/tOC = relative undercarboxylated osteocalcin to total osteocalcin (N = 10); CTX = C-terminal telopeptide of type I collagen (N = 10); OPG = osteoprotegerin (N = 13); RANKL = receptor activator nuclear factor kappa-β ligand (N = 10); OPG/RANKL ratio (N = 10); * denotes significant main effect for time; # denotes significant time by condition interaction.

Klentrou et al. 2021, *Children*, 8, 961.

Nobody is forgetting green leafy veg etc!

Diet and stress fracture risk

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Table 1 The Study groups' daily nutritional intake (mean ± SD) at induction and after 4-months basic training (BT)in relation (%) to the Nutritional Standards for Operational and Restricted Rations (NSOR) requirements

	NSF (N = 62)		SF (N = 12)	
	Induction	End BT	Induction	End BT
Energy (kcal)	2824 ± 1086 (78.4%)	2587 ± 879 (71.9%)	2325 ± 974 (64.6%)	2447 ± 879 (68.0%)
Proteins (g)	128.6 ± 62.8 (141%)	114.0 ± 42.4 (125%)	111.7 ± 43.1 (123%)	131.7 ± 48.3 (145%)
Carbohydrates (g)	369 ± 165* (74.7%)	335 ± 178 (67.8%)	272 ± 104 (55.1%)	285 ± 129 (57.7%)
Total Fat (g)	100.3 ± 40.5 (32.0%)	89.7 ± 31.5 (31.2%)	84.5 ± 14.8 (34.5%)	108.0 ± 35.0 (34.4%)
Iron (mg)	18.0 ± 7.7# (120%)	15.2 ± 5.5 (101%)	16.1 ± 5.1 (107%)	14.6 ± 4.8 (97.3%)
Folate (μg DFE)	448 ± 198# (112%)	364 ± 132 (91.0%)	362 ± 108 (90.5%)	332 ± 126 (83.0%)
Vitamin D (IU)	157.4 ± 93.3*# (78.7%)	119.2 ± 53.1 (59.6%)	117.9 ± 34.3 (59.0%)	121.6 ± 46.1 (60.8%)
Vitamin B_6 (mg)	3.0 ± 1.3# (231%)	2.3 ± 0.8 (177%)	2.8 ± 1.1 (215%)	2.3 ± 0.9 (177%)
Vitamin B_{12} (μg)	7.1 ± 4.0# (296%)	4.8 ± 2.3 (200%)	5.9 ± 3.2 (246%)	6.2 ± 3.0 (258%)
Calcium (mg)	964 ± 373*# (96.4%)	679 ± 236 (67.9%)	589 ± 92 (58.9%)	609 ± 171 (60.9%)
Zinc (mg)	15.8 ± 6.6# (105%)	12.5 ± 4.3 (83.3%)	14.7 ± 4.6 (98.0%)	12.4 ± 2.6 (82.9%)
Magnesium (mg)	394 ± 155# (93.8%)	338 ± 118 (80.5%)	320 ± 129 (76.2%)	318 ± 108 (75.7%)

* $p < 0.05$ NSF vs. SF at the same phase

# $p < 0.05$ for the same group at different phases

Moran et al. 2012, *JISSN*, 9, 6