Nutrition and Mobility

“Aging, Muscle Health, and Dietary Intake”

Co-Presenters:

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and

Amanda Wilson, PT, DPT- UND Teaching Assistant Professor Physical Therapy

Objectives

1. Describe the importance of adequate nutrition in relation to strength/mobility with an older adult.
2. Understand the specific nutritional requirements of an older adult.
3. Complete appropriate strength, nutritional and food insecurity screening with all older adults.
4. Recognize the importance of referral to a dietician for individualized needs.
5. Apply knowledge of nutrition and mobility in a case application.

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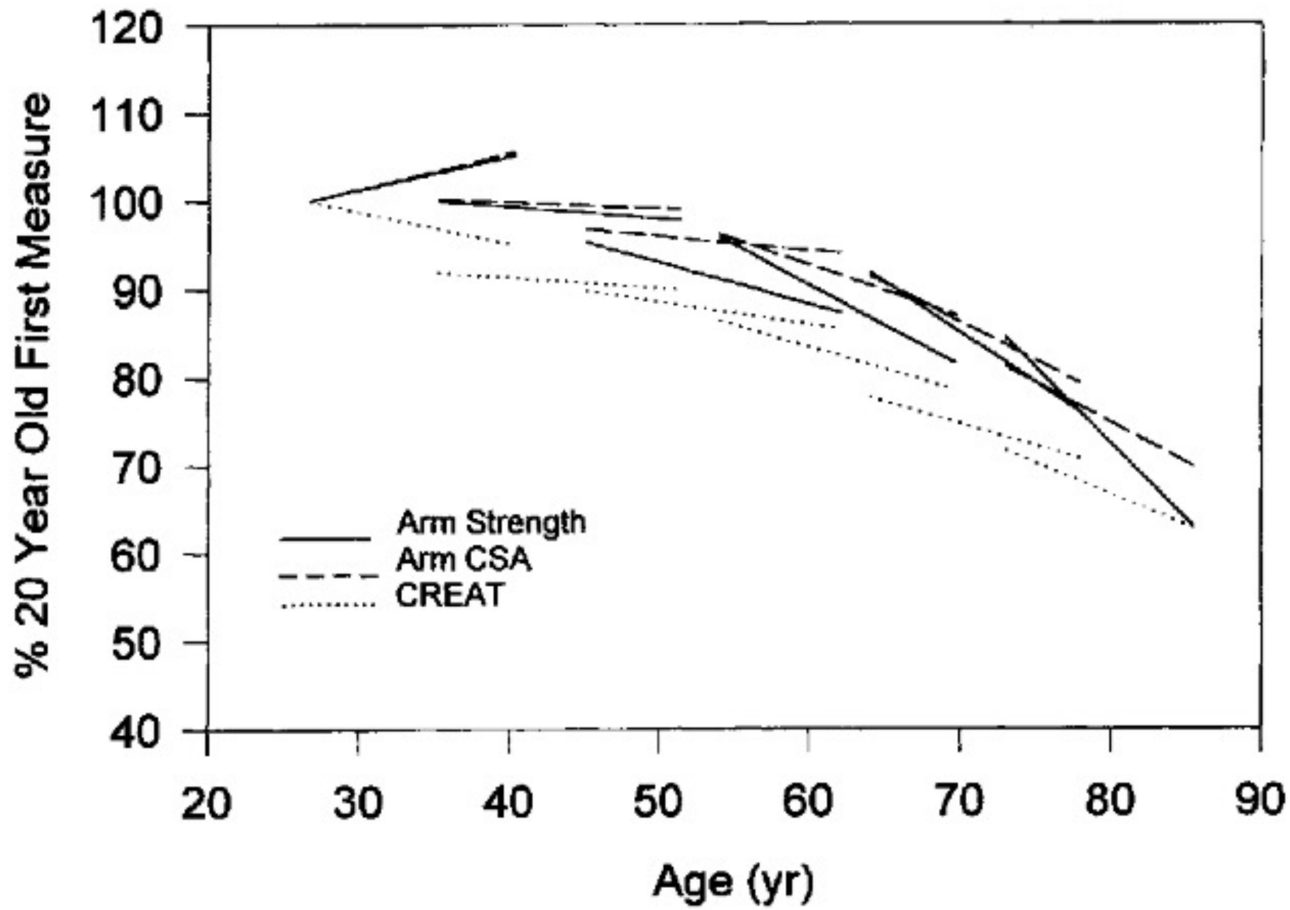
Case Application

- Mrs. Smith is a 70-year-old retired teacher who lives alone in a suburban community. She has a history of osteoarthritis in her knees, which limits her mobility and makes it difficult for her to engage in physical activities. Her husband passed away five years ago, and she has been living independently since then. Mrs. Smith enjoys cooking and gardening but has recently been experiencing some challenges in maintaining a balanced diet and staying active due to her arthritis. Mrs. Smith's diet consists mainly of convenience foods and processed meals because she finds it challenging to stand for long periods to cook. She tends to skip meals or opt for quick snacks instead of proper meals. Her diet lacks variety and often lacks essential nutrients. Due to her limited mobility and reduced strength, she has experienced some unintentional weight loss over the past few months, which further exacerbates her weakness and fatigue. She used to enjoy gardening, but now finds it difficult to kneel and bend due to joint pain.

Muscle, Strength, & Aging



Muscle mass and strength declines with age (Metter, 1999)

Older adults use close to their maximum **muscle power** to stand from a chair (Chiles, 2017)

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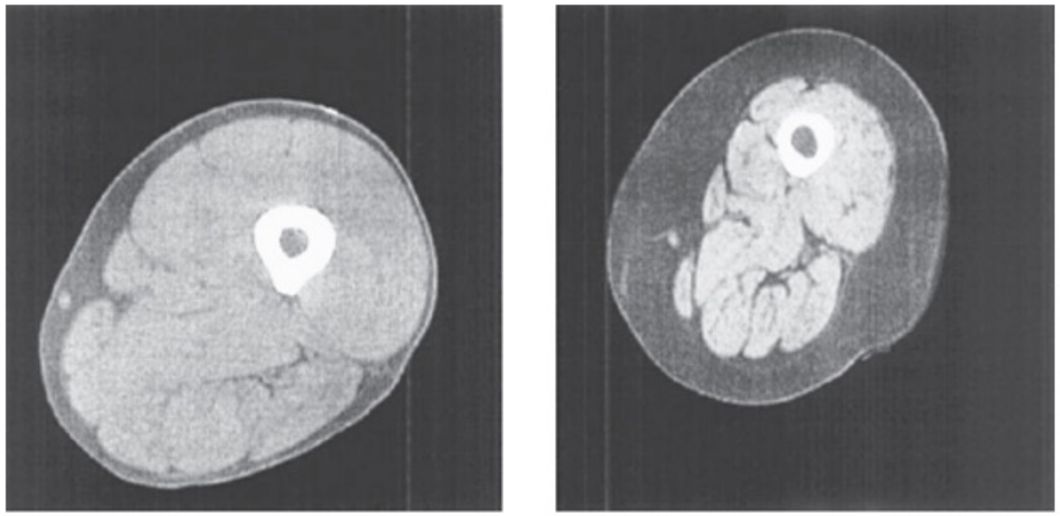
Sarcopenia

-Defined as progressive loss of muscle mass and strength with age.

-Diagnosed by 3 traits, decreased levels of:

1) muscle strength
2) muscle quantity/quality
3) physical performance

-New ICD-10 code for Sarcopenia as of 2016



Magnetic resonance images through the mid-thigh of a healthy 25-year-old (left) and a healthy 75-year-old (right), illustrating sarcopenia. The older adult's image shows smaller muscle mass (light gray), more subcutaneous fat (dark gray), and increased intramuscular fat (dark gray lines).(From Roubenoff, R. (2003). Sarcopenia: Effects on body composition and function. Journal of Gerontology: Series A. Biological Sciences and Medical Sciences, 58, 1012–1017, with permission.)

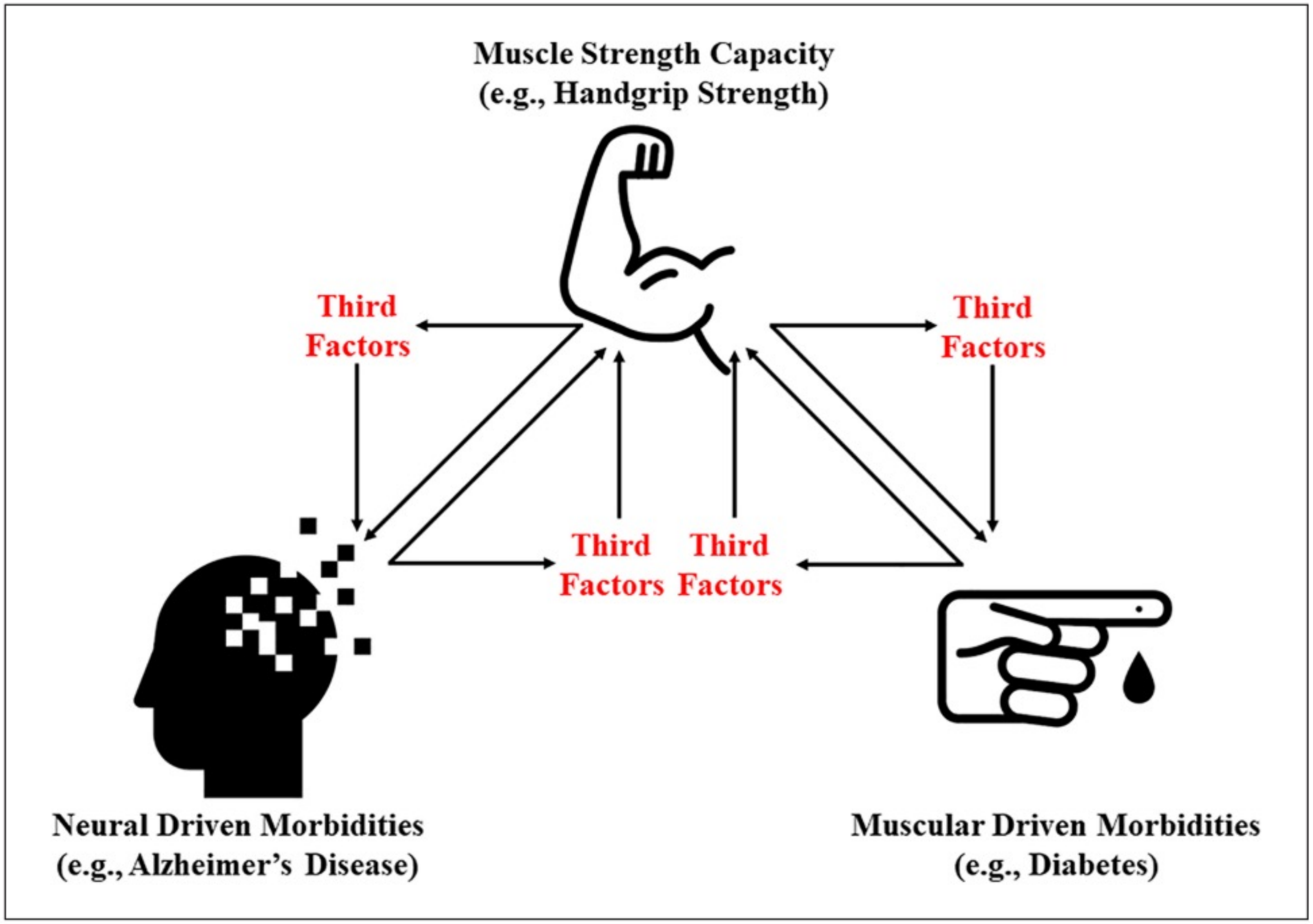
The Importance of Skeletal Muscle & Strength

- **Sarcopenia**
  - **Mortality** Odds Ratio**: 3.60 [2.96, 4.37]** (Beudart. 2017)
  - **Disability** Odds Ratio**: 3.03 [1.80, 5.12]** (Beudart. 2017)
- ≈ 40-50% of bodyweight (Lee, 2000)
  - ≈ 45% of total body proteins (Institute of Medicine, 1999)
- **Amino Acid Reservoir** (Carbone, 2019; Timmerman, 2008)
  - **Muscle** is catabolized during/after **trauma** (Reeds, 1994) and **negative energy balance** (Layman, 2003)

Older Adults & Muscle

Decreased strength is related to:

- Diabetes
- Cardiovascular disease
- Impaired Cognition
- Alzheimer's Disease
- Disability
- Death



McGrath, R., **Johnson, N.,** Klawitter, L., Mahoney, S., Trautman, K., Carlson, C., Rockstad, E., & Hackney, K. J. (2020). What are the association patterns between handgrip strength and adverse health conditions? A topical review. *SAGE Open Medicine*, *8*, 1–12. https://doi.org/10.1177/2050312120910358

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BMI & Mortality

Bhaskaran, K., dos-Santos-Silva, I., Leon, D. A., Douglas, I. J., & Smeeth, L. (2018). Association of BMI with overall and cause-specific mortality: a population-based cohort study of 3·6 million adults in the UK. *The Lancet Diabetes and Endocrinology*, *6*(12), 944–953. https://doi.org/10.1016/S2213-8587(18)30288-2

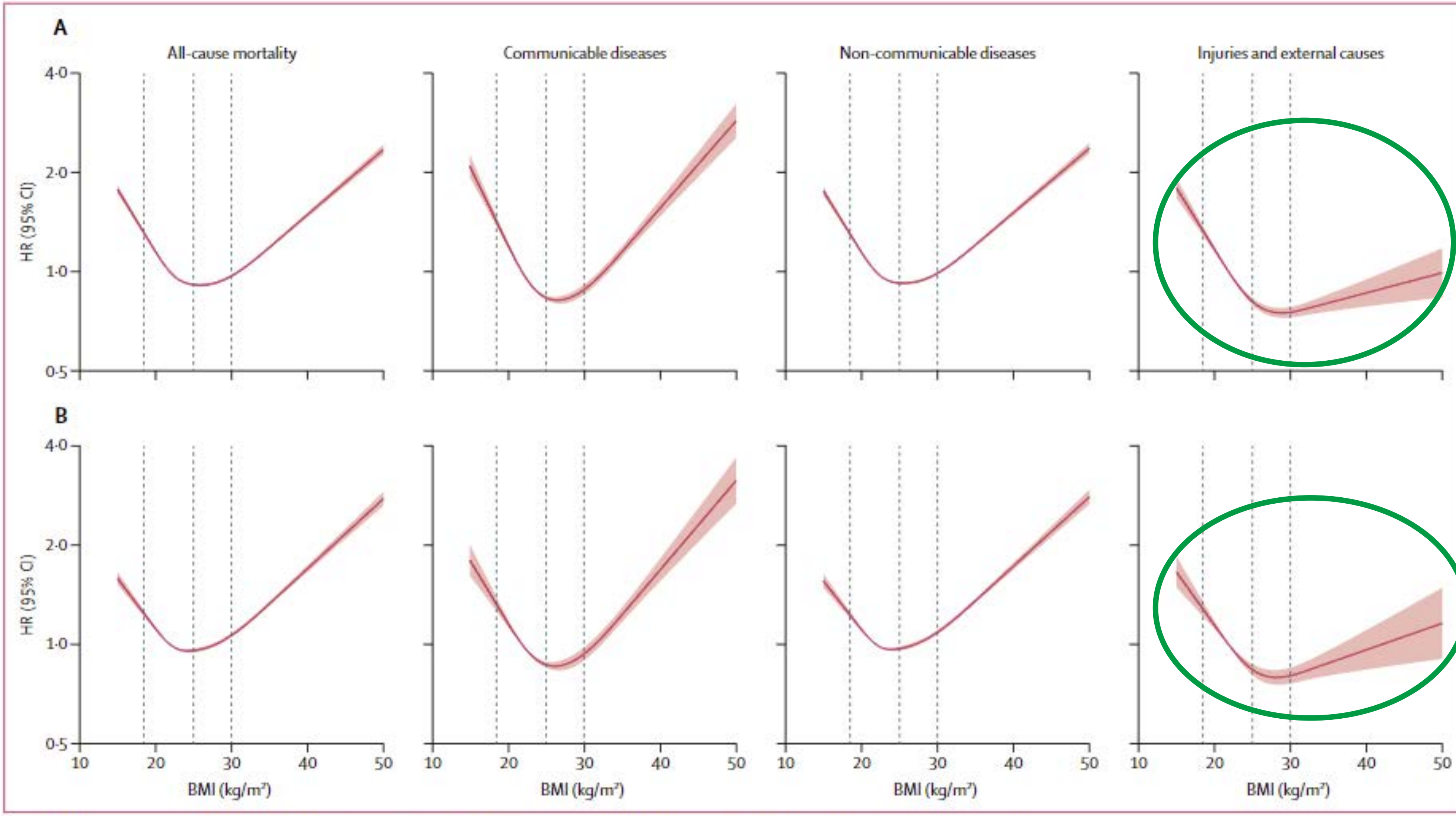
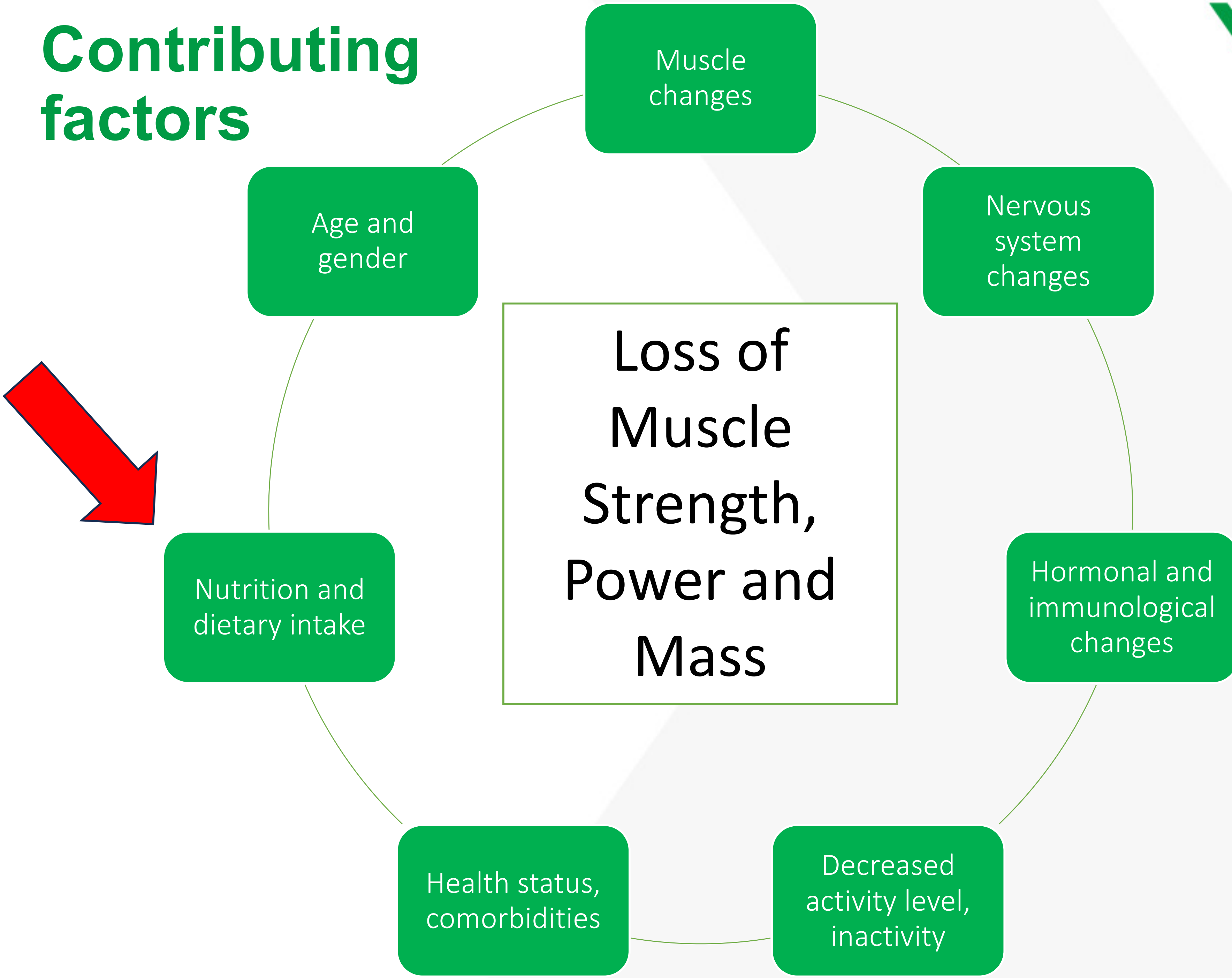


Figure 1: All-cause mortality and Level 1 cause-specific mortality outcomes in total study population (A) and in never-smokers only (B)
We used a three-level hierarchical classification of causes of death as used by the Global Burden of Diseases, Injuries, and Risk Factors Study.[16] All Level 1 outcomes (communicable diseases, non-communicable diseases, and injuries and external causes) were studied. 5-year exclusion period applied for person-time and events after a BMI record. Dashed vertical lines represent WHO BMI category thresholds of 18·5 kg/m² (underweight to healthy), 25 kg/m² (healthy weight to overweight), and 30 kg/m² (overweight to obese). Estimates adjusted for age at BMI record, deprivation, calendar year, diabetes, alcohol status, and smoking (all as defined at date of BMI measure) and stratified for sex. The p values for overall association and p values for non-linearity were less than 0·0001 for all outcomes, in both full and never-smoker populations. HR=hazard ratio.

Contributing factors



Dietary Intake & Aging

- As we get older:
  - Taste decreases (Barragán, 2018)
  - Oral health worsens (Hatta, 2021)
  - Our ability to chew decreases (Fledman, 1980)
- Dietary intake decreases by 25% from 40 to 70 (Nieuwenhuizen, 2010)
  - **Predisposing people to nutrient deficiencies**
- Energy expenditure also decreases (Geisler, 2016)
  - We can lose muscle tissue and gain fat resulting in sarcopenic obesity (Lee, 2016)

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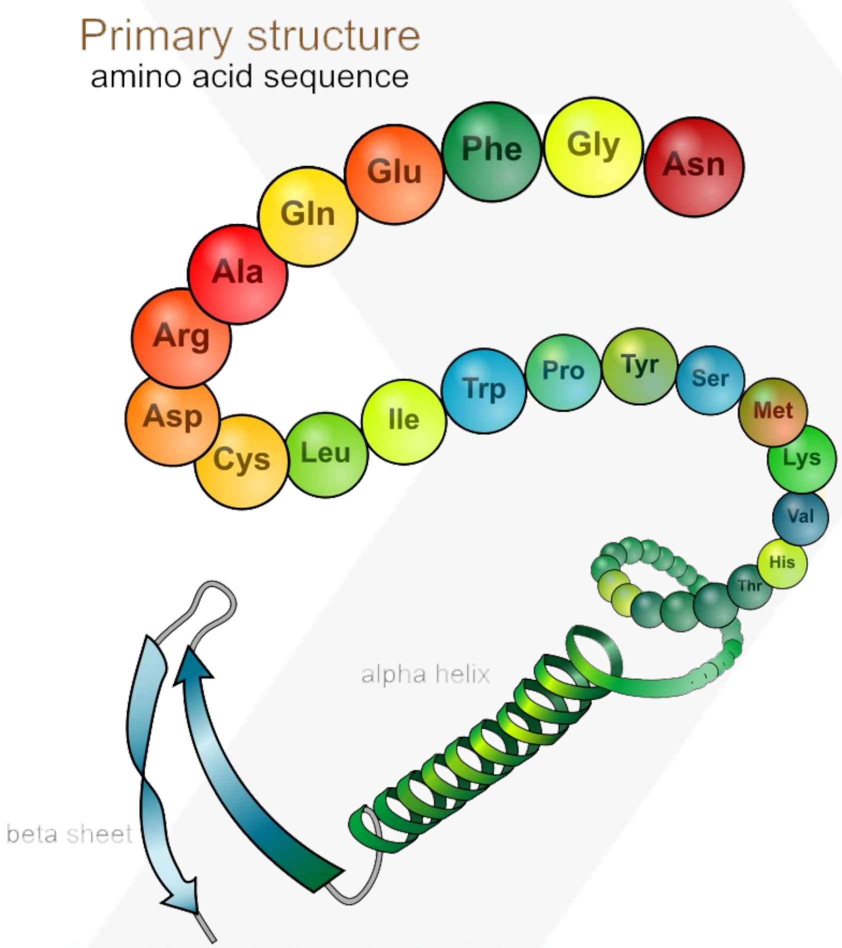
Dietary Protein & Muscle



- Dietary **protein** can directly stimulate **muscle protein synthesis** (Kim, 2018; Dickinson, 2011; Bauer, 2013; Paddon-Jones, 2009, Bar-Peled, 2014, Gingras, 2001)
- By activating the mammalian target of rapamycin complex 1 - **mTORC1** (Dickinson, 2011; Bar-Peled, 2014)
  - mTORC1 controls **translation** (Gingras, 2001)

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Keys to Protein Success

1. Quantity

2. Distribution

3. Quality

Dietary Protein & Aging

Moore DR, Churchward-Venne TA, Witard O, et al. Protein ingestion to stimulate myofibrillar protein synthesis requires greater relative protein intakes in healthy older versus younger men. Journals of Gerontology - Series A Biological Sciences and Medical Sciences. 2015;70(1):57-62. doi:10.1093/gerona/glu103

The amount of protein needed during one meal to maximally stimulate muscle protein synthesis increases with aging

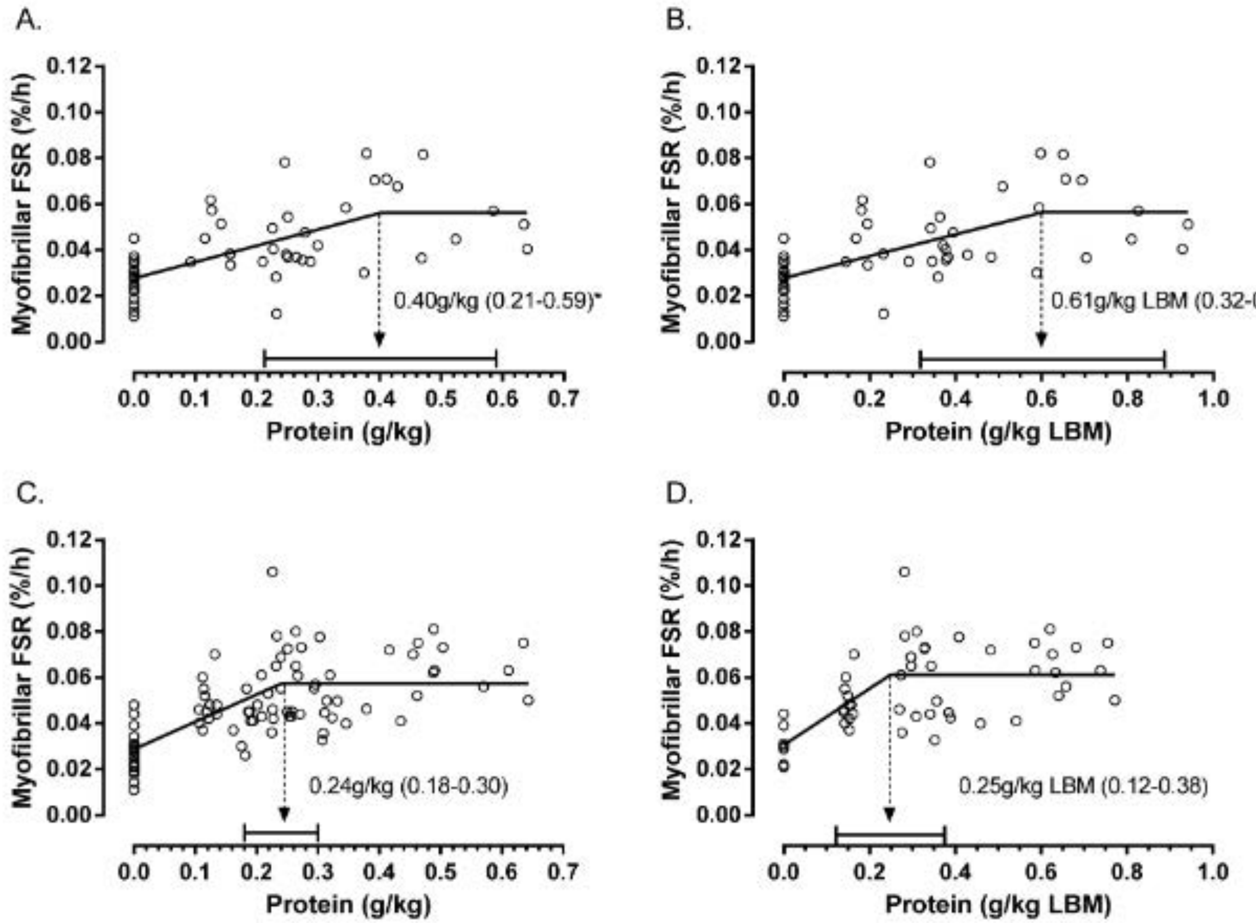

Figure 1. Biphase linear regression analyses of relative protein intake per kg body mass (BM; panels A and C) and per kg lean body mass (LBM; panels B and D) and rested myofibrillar fractional synthetic rate (FSR) in healthy older (A and B) and younger (C and D) men. *p = .055 vs younger men. **p < .01 vs young men.

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Dietary Protein & Aging

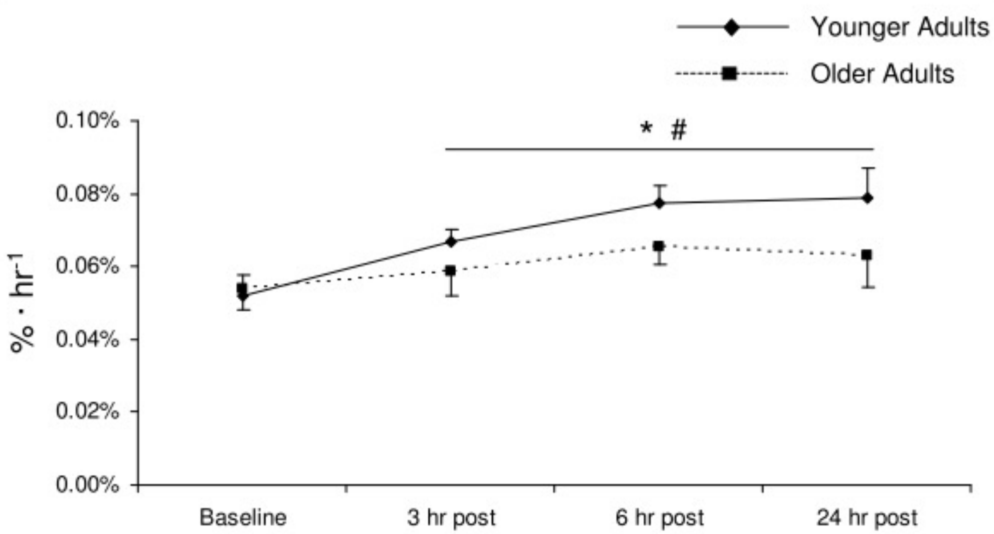

Figure 5 Mixed muscle protein fractional synthetic rate (FSR). Muscle protein synthesis as expressed by the mixed muscle FSR (%/hour) in younger and older subjects at rest and at 3, 6 and 24 hours after exercise. *Main effect for time (*P* <0.05); #significantly different from older subjects (*P* <0.05).

- **The anabolic response to exercise is blunted with age**
  - Less muscle is produced in response to the same exercise

Fry, C. S., Drummond, M. J., Glynn, E. L., Dickinson, J. M., Gundermann, D. M., Timmerman, K. L., Walker, D. K., Dhanani, S., Volpi, E., & Rasmussen, B. B. (2011). Aging impairs contraction-induced human skeletal muscle mTORC1 signaling and protein synthesis. *Skeletal Muscle*, *1*(1), 11. https://doi.org/10.1186/2044-5040-1-11

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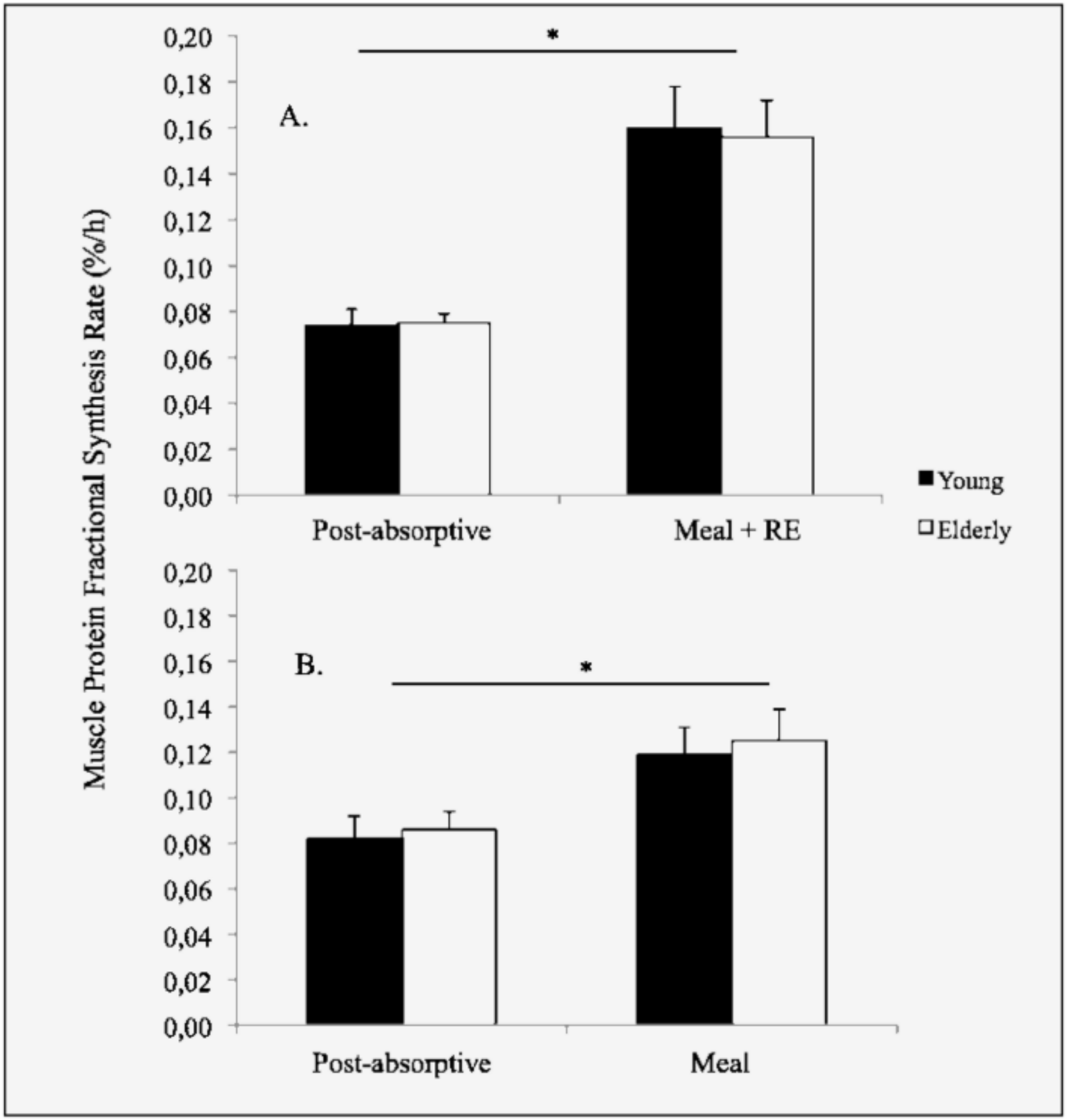
Dietary Protein & Aging



- **The anabolic response to exercise is blunted with age**
  - Less muscle is produced in response to the same exercise
- **Protein intake after exercise alleviates difference**
  - Older adults **need protein** after exercise

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Protein Quantity & Muscle

- NIH recommends = **0.8 g/kg/day**
- Experts in aging and muscle health **recommend more**
  - 1.0 to 1.2 g/kg/day (Bauer, 2013; Deutz, 2014; Morley, 2010)
  - Or 25 to 30 g per meal (Paddon-Jones, 2009; Morley, 2010)

Keys to Protein Success

1. Quantity

2. Distribution

3. Quality

Protein Quantity & Muscle

- The same studies (Rand, 2003) that informed the **0.8 g/kg/day** recommendation only included works where participants **ate three or more iso-nutrient meals**
  - **Thus, protein intake was exactly evenly distributed**
- **Breakpoint** analysis of muscle protein synthesis indicates (Moore, 2015):
  - **0.24** g/kg/meal for younger adults
  - **0.40** g/kg/meal for older adults
  - Maximally stimulates muscle protein synthesis
- In other words, we should **not eat** all of our **protein at once**

Dietary Protein Intake Distribution

VARIABLES	PERIOD			
	BREAKFAST MEAN ± SEM [95% CI]	LUNCH MEAN ± SEM [95% CI]	DINNER MEAN ± SEM [95% CI]	TOTAL MEAN ± SEM [95% CI]
Total protein (g)	17.4 ± 0.8 [15.9, 18.9]	28.1 ± 0.9 [26.3, 29.8]	39.8 ± 1.1 [37.7, 42.0]	85.3 ± 1.8 [81.6, 88.9]
Relative protein (g/kg)	0.255 ± 0.012 [0.232, 0.278]	0.418 ± 0.015 [0.388, 0.448]	0.588 ± 0.018 [0.553, 0.623]	1.262 ± 0.033 [1.197, 1.326]
Percent of energy (%)	3.5 ± 0.2 [3.2, 3.8]	5.7 ± 0.2 [5.4, 6.0]	8.0 ± 0.2 [7.7, 8.4]	17.3 ± 0.3 [16.6, 17.9]
Percent of total protein (%)	20.0 ± 0.7 [18.6, 21.4]	33.2 ± 0.8 [31.6, 34.7]	46.8 ± 0.8 [45.2, 48.4]	100*

Abbreviations: 95% CI, 95% confidence interval; SEM, standard error of the mean.
*Standard error and 95% confidence interval could not be calculated as all values were 100.

Johnson, N. R., Kotarsky, C. J., Mahoney, S. J., Sawyer, B. C., Stone, K. A., Byun, W., Hackney, K. J., Mitchell, S., & Stastny, S. N. (2022). Evenness of dietary protein intake is positively associated with lean mass and strength in healthy women. *Nutrition and Metabolic Insights*, *15*, 1–9. https://doi.org/10.1177/11786388221101829

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Dietary Protein Intake Distribution

Table 4. Model summaries of separate multiple linear regression models and coefficients evaluating 2 different methods of defining protein intake distribution when controlling for age, BMI, MVPA, relative energy intake, and percent of energy from protein.

OUTCOME	PROTEIN INTAKE VARIABLE*	MODEL			COEFFICIENT	
		R	R^2_{ADJ}	P	B ± SE	P
Lean mass (kg)	≥25 g/period	.710	.489	<.001	1.067 ± 0.273	<.001
	0.24/0.4 g/kg/period†	.700	.474	<.001	0.754 ± 0.244	.002
Percent body fat (%)	≥25 g/period	.835	.687	<.001	−0.715 ± 0.563	.205
	0.24/0.4 g/kg/period	.833	.684	<.001	−0.033 ± 0.497	.948
Maximal handgrip strength (kg)	≥25 g/period	.517	.243	<.001	3.274 ± 0.737	<.001
	0.24/0.4 g/kg/period	.495	.221	<.001	2.451 ± 0.658	<.001
Thirty second chair stand test (repetitions)	≥25 g/period	.306	.064	.006	0.348 ± 0.588	.555
	0.24/0.4 g/kg/period	.303	.062	.006	0.07 ± 0.519	.893
Mean 6 m gait speed (s)	≥25 g/period	.359	.100	<.001	0.007 ± 0.073	.927
	0.24/0.4 g/kg/period	.380	.117	<.001	−0.119 ± 0.064	.063
Summed lower-body peak torque (Nm)	≥25 g/period	.583	.319	<.001	22.858 ± 7.918	.004
	0.24/0.4 g/kg/period	.561	.293	<.001	8.019 ± 7.099	.260
Summed lower-body muscular endurance (J)	≥25 g/period	.544	.273	<.001	170.522 ± 88.159	.055
	0.24/0.4 g/kg/period	.551	.303	<.001	184.852 ± 77.185	.018

Abbreviations: BMI, body mass index; MVPA, moderate-to-vigorous physical activity; SE, standard error.
*Mean protein intakes during 3 periods from 3-day food diaries, waking to 11:30 (breakfast), afternoon (lunch) 11:31 to 16:30, and evening after 16:30 (dinner), equal to or greater than the listed cut-offs were coded as "1s" and were then summed to create ordinal levels with 4 levels, meeting the cut-off at 0, 1, 2, or 3 periods.
†For those 60 and under 0.24 g/kg/period; for those 60 and over 0.4 g/kg/period.

Johnson, N. R., Kotarsky, C. J., Mahoney, S. J., Sawyer, B. C., Stone, K. A., Byun, W., Hackney, K. J., Mitchell, S., & Stastny, S. N. (2022). Evenness of dietary protein intake is positively associated with lean mass and strength in healthy women. *Nutrition and Metabolic Insights*, *15*, 1–9. https://doi.org/10.1177/11786388221101829

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Keys to Protein Success

1. Quantity
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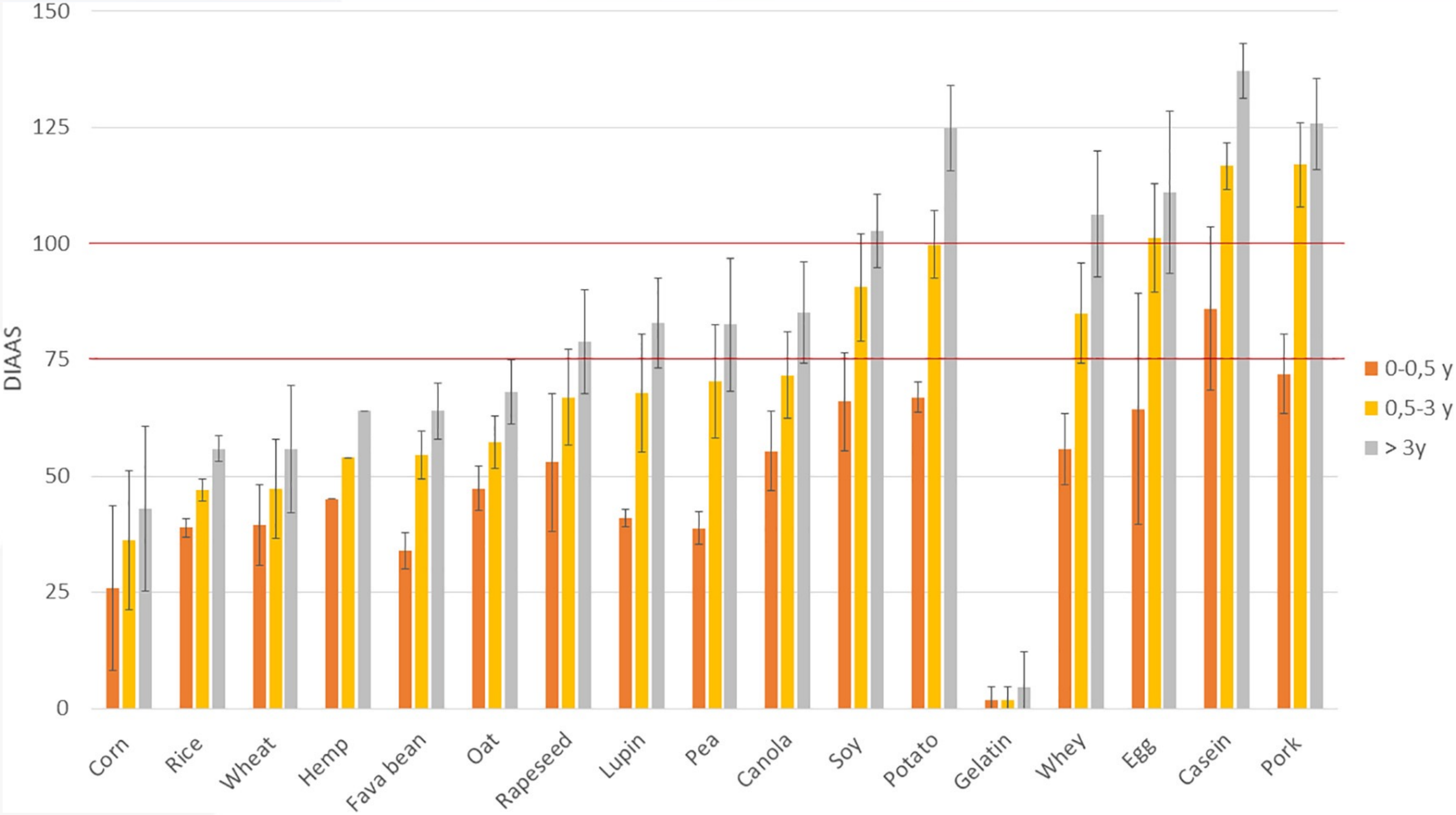
Dietary Protein Quality

- 100≥ Complete protein
- 99-75 good source of protein
- ≤75 poor quality protein



Herreman, L., Nommensen, P., Pennings, B., & Laus, M. C. (2020). Comprehensive overview of the quality of plant- And animal-sourced proteins based on the digestible indispensable amino acid score. *Food Science and Nutrition*, *8*(10), 5379–5391. https://doi.org/10.1002/fsn3.1809

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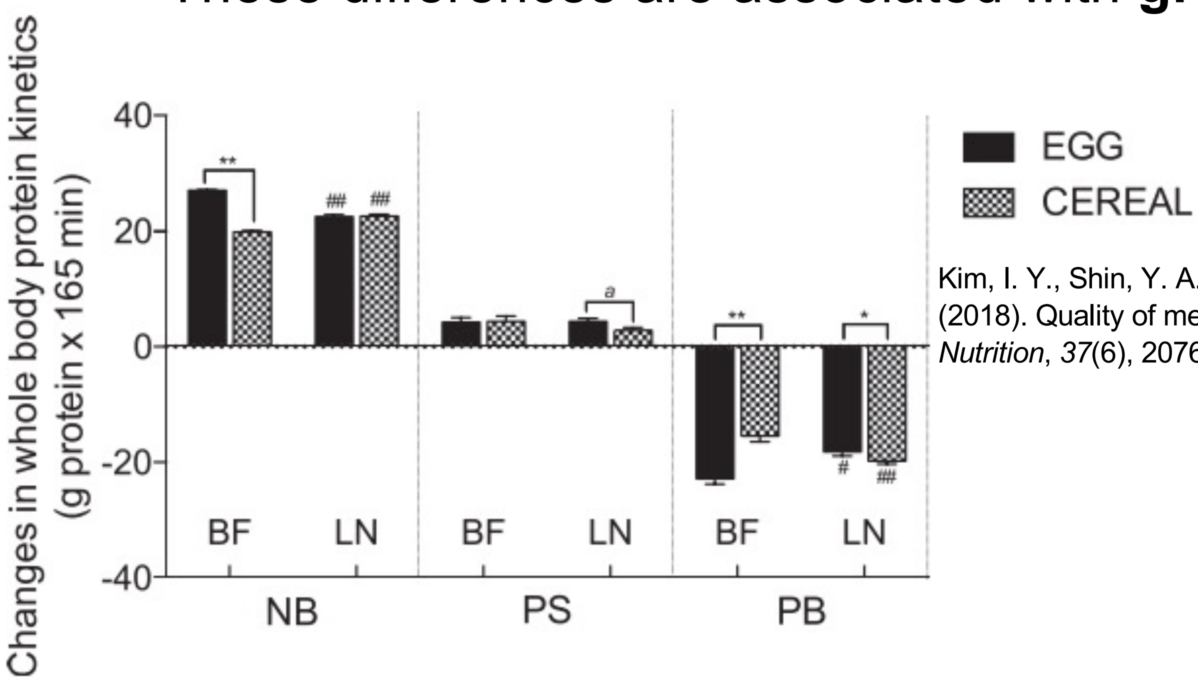
Protein Quality

- **Animal-based proteins** have better protein quality than **plant-based proteins**
  - **Largely driven by amino acid score**
- When matched for protein and energy
  - Egg results in greater **EAA** and in particular **leucine**
  - These differences are associated with **greater net protein balance**



Kim, I. Y., Shin, Y. A., Schutzler, S. E., Azhar, G., Wolfe, R. R., & Ferrando, A. A. (2018). Quality of meal protein determines anabolic response in older adults. *Clinical Nutrition*, *37*(6), 2076–2083. https://doi.org/10.1016/j.clnu.2017.09.025

Table 1

Proinflammatory SA secretome in senescent cells, aged tissues, and human tissues.

SASP Factors	Senescent cells	Aged tissues	Human tissues
Cytokines, chemokines, and regulators			
IL-1α	↑↑↑	-	
IL-1β	↑↑	↑↑	
IL-6	↑↑↑	↑↑↑	
IL-7	↑↑↑	↑↑	↑
IL-13	↑↑	-	↑
IL1R1	↑	↑	
IL11	↑	↑↑↑	
IL15	↑	-	
IL6R	↑	↑↑	
IL27Rα	↑	-	
IL2RA	↑	↑↑↑	↑
IL-8	↑↑↑	-	
GRO-α (CXCL1)	↑↑↑	-	↑
GRO-β (CXCL2)	↑↑↑	-	↑
GRO-γ (CXCL3)	↑↑↑	-	↑
MCP-1 (CCL2)	↑↑↑	↑↑↑	
MCP-2	↑↑↑	-	
MIP-1α (CCL3)	↑↑↑	-	↑
MIP-3α	↑↑	↑↑↑	
TNF-α	-	↑	↑

Inflammation & aging

- **Aging is associated with increased markers of inflammation**

Chung, H. Y., Kim, D. H., Lee, E. K., Chung, K. W., Chung, S., Lee, B., ... & Yu, B. P. (2019). Redefining chronic inflammation in aging and age-related diseases: proposal of the senoinflammation concept. *Aging and disease*, *10*(2), 367.

Omega 3:6

- **Omega-3** and **omega-6** are used to create **eicosanoids**, an **autocrine/paracrine hormone**
- **Omega-6s** are converted into **arachidonic acid** and then into **proinflammatory** hormones
- **Omega-3s** are converted into **EPA** and then into **anti-inflammatory** hormones
- **The omega 3:6 ratio affects inflammation**

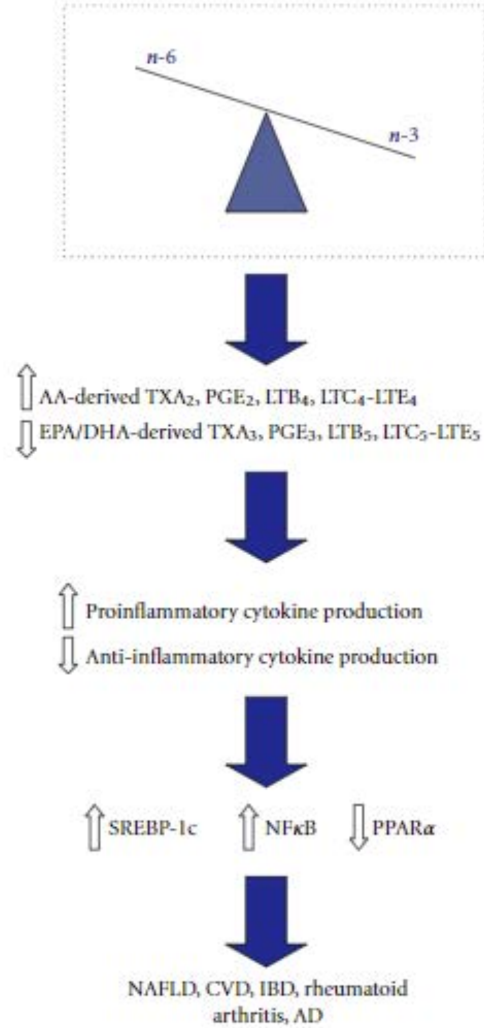


FIGURE 2: Effects of unbalanced n-6 : n-3 dietary fatty acid intake on development of various diseases of inflammation. Dietary imbalance in the consumption of n-6 and n-3 PUFA, representative of the Western diet. Greater consumption of n-6 PUFA leads to an increase in their metabolism to their LC-PUFA derivatives (AA). Decreases in n-3 PUFA consumption leads to a decrease in their metabolism to their LC-PUFA derivatives (EPA/DHA). The increase in AA in cell membrane phospholipids leads to an increase in COX and LOX enzyme production of AA-derived eicosanoids and a decrease in EPA/DHA-derived eicosanoids, leading to an increase in inflammation and proinflammatory cytokine production. This in turn leads to a decrease in PPARα gene expression, while there is an increase in both SREBP-1c and NFκB gene expression. This change in gene expression can also cause an increase in lipogenesis, as well as increasing inflammation. The result is an increase in various diseases of inflammation, some of which are highlighted in the figure.

Patterson, E., Wall, R., Fitzgerald, G. F., Ross, R. P., & Stanton, C. (2012). Health implications of high dietary omega-6 polyunsaturated fatty acids. In *Journal of Nutrition and Metabolism* (Vol. 2012). Hindawi Limited. https://doi.org/10.1155/2012/539426

Eicosanoids

n-3 and n-6 Fatty Acid–Derived Messengers and Their Physiological Effects

Messenger Classes	Arachidonic Acid (n-6)–Derived Messengers	Physiological Effects	EPA- and DHA (n-3)–Derived Messengers	Physiological Effects
Prostaglandins	PGD_2		PGD_3	
	PGE_2	Proarrhythmic	PGE_3	Antiarrhythmic
	PGF_2		PGF_3	
	PGI_2	Proarrhythmic	PGI_3	Antiarrhythmic
Thromboxanes	TXA_2	Platelet activator	TXA_3	Platelet inhibitor
	TXB_2	Vasoconstriction	TXB_3	Vasodilation
Leukotrienes	LTA_4		LTA_5	
	LTB_4	Proinflammatory	LTB_5	Antiinflammatory
	LTC_4		LTC_5	
	LTE_4		LTE_5	
	LTD_4		LTD_5	
Epoxyeicosatrienoic derivatives	5,6-EET			
	8,9-EET			
	11,12-EET	Proinflammatory		
	14,15-EET			
Hydroxyleicosatetraenoic derivatives	5-HETE			
	12-HETE			
	15-HETE			
Lipoxins	LXA_4			
Resolvins			RVE1	Antiinflammatory
			RVD	Antiinflammatory
Neuroprotectin			NPD1	Antiinflammatory

Omega 3 Intake & Strength

- **Omega 3 supplementation increases muscle strength in older adults**

Study or Subgroup	Omega-3 Mean	Omega-3 SD	Omega-3 Total	Placebo Mean	Placebo SD	Placebo Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
1.3.1 No Resistance Training								
Alkhedhairi 2022	11	26	49	-5	29	45	26.4%	0.58 [0.16, 0.99]
Felix-Soriano 2021b	0.13	0.12	15	0	0.12	17	8.1%	1.06 [0.31, 1.80]
Smith 2015	5	8.7	29	-1.6	9	15	10.9%	0.74 [0.09, 1.38]
Subtotal (95% CI)			**93**			**77**	**45.3%**	**0.70 [0.39, 1.02]**
Heterogeneity: Chi² = 1.22, df = 2 (P = 0.54); I² = 0%								
Test for overall effect: Z = 4.36 (P < 0.0001)								
1.3.2 Resistance Training								
Brook 2021	23	5	8	25	5	8	4.6%	-0.38 [-1.37, 0.61]
Cornish 2009 (F)	23	29	11	27	29	12	6.7%	-0.13 [-0.95, 0.69]
Cornish 2009 (M)	25	23	14	20	23	14	8.2%	0.21 [-0.53, 0.95]
Cornish 2018	44	30	11	36	19	12	6.6%	0.31 [-0.51, 1.13]
Daboit 2017 (F)	54	7	10	11	10	13	1.6%	4.69 [2.99, 6.39]
Daboit 2017 (M)	39	25	13	44	26	14	7.9%	-0.19 [-0.95, 0.57]
Dalle 2021	52	43	11	40	58	10	6.1%	0.23 [-0.63, 1.09]
Felix-Soriano 2021	0.4	0.34	16	0.31	0.26	19	10.1%	0.29 [-0.37, 0.96]
Rodacki 2012	52	7	15	20	10	15	3.1%	3.61 [2.39, 4.82]
Subtotal (95% CI)			**109**			**117**	**54.7%**	**0.41 [0.12, 0.70]**
Heterogeneity: Chi² = 58.13, df = 8 (P < 0.00001); I² = 86%								
Test for overall effect: Z = 2.79 (P = 0.005)								
Total (95% CI)			**202**			**194**	**100.0%**	**0.54 [0.33, 0.75]**
Heterogeneity: Chi² = 61.16, df = 11 (P < 0.00001); I² = 82%								
Test for overall effect: Z = 4.99 (P < 0.00001)								
Test for subgroup differences: Chi² = 1.81, df = 1 (P = 0.18), I² = 44.7%								

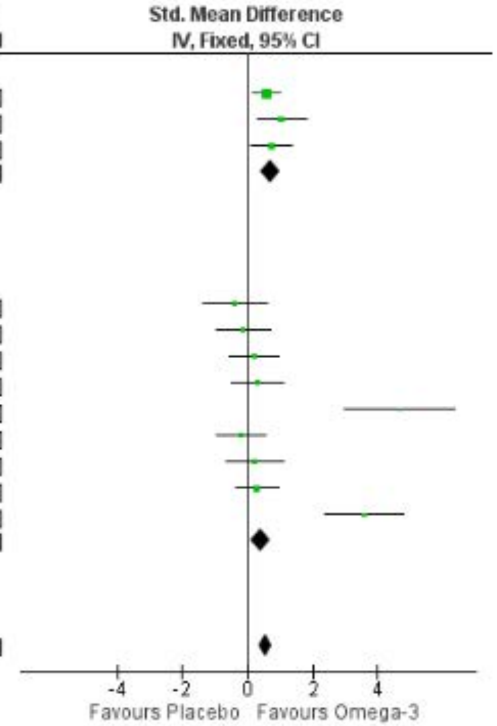
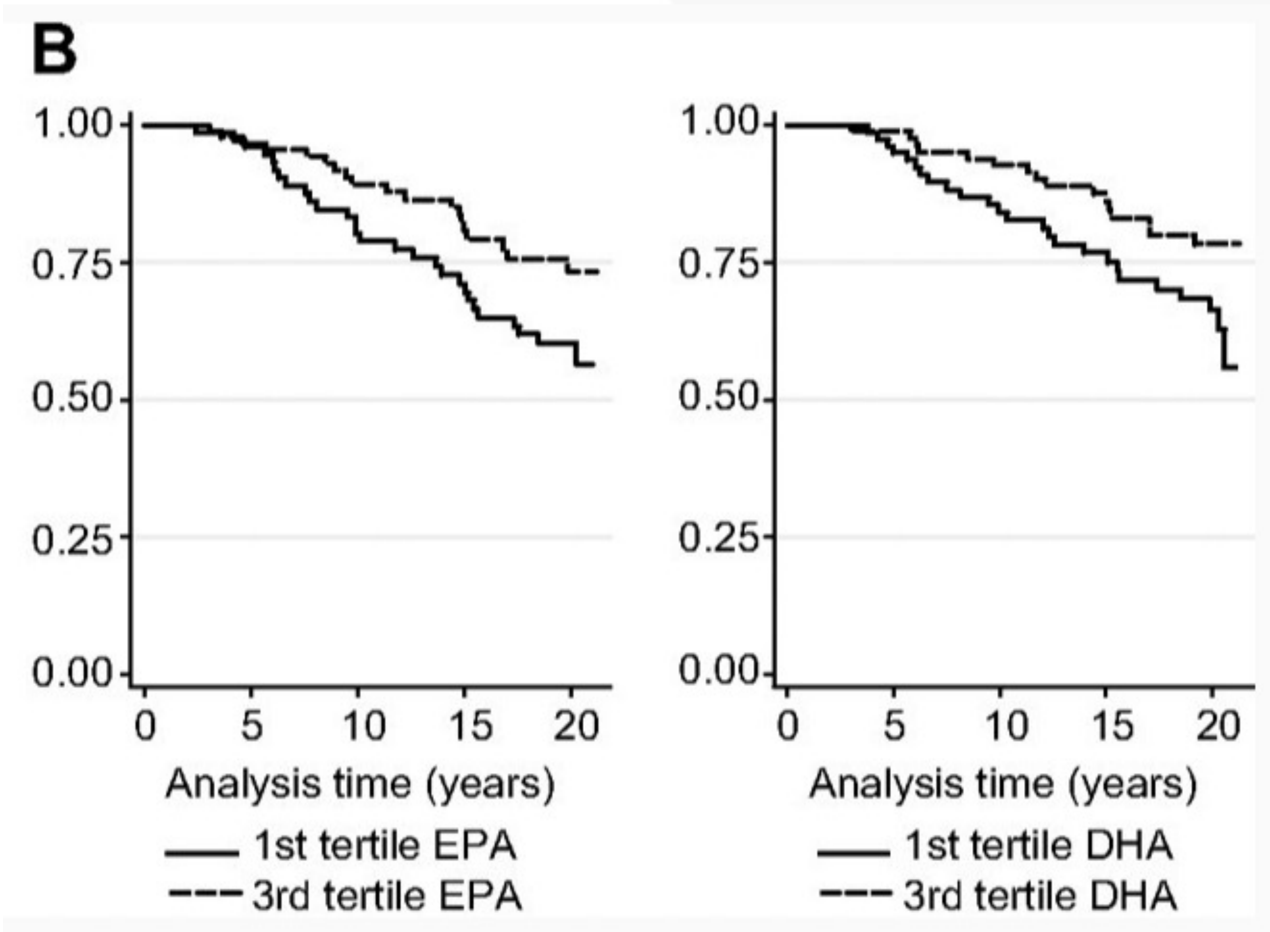


Figure 3. Pooled analysis of the impact of omega-3 supplementation on lower body strength with and without resistance training [27,31,33,35–37,40,42].

Cornish, S. M., Cordingley, D. M., Shaw, K. A., Forbes, S. C., Leonhardt, T., Bristol, A., Candow, D. G., & Chilibeck, P. D. (2022). Effects of Omega-3 Supplementation Alone and Combined with Resistance Exercise on Skeletal Muscle in Older Adults: A Systematic Review and Meta-Analysis. *Nutrients*, *14*(11). https://doi.org/10.3390/nu14112221

Omega 3 intake & Mortality



Anderson, S. G., Sanders, T. A. B., & Cruickshank, J. K. (2009). Plasma fatty acid composition as a predictor of arterial stiffness and mortality. *Hypertension*, *53*(5), 839–845. https://doi.org/10.1161/HYPERTENSIONAHA.108.123885

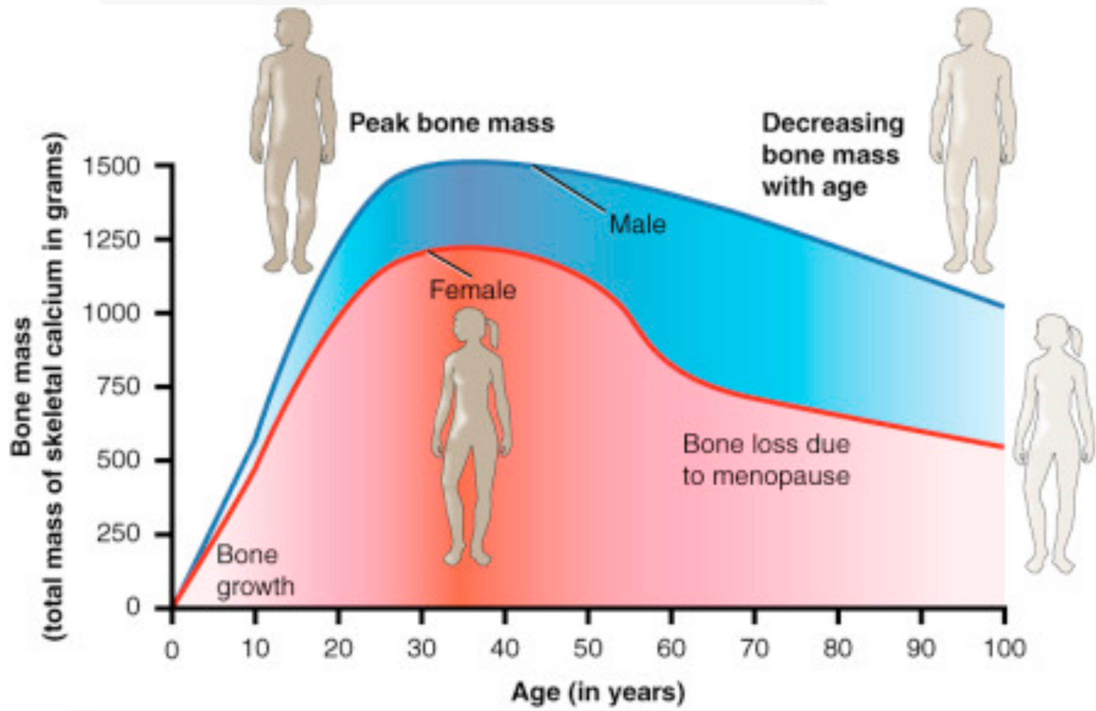
Aging & Vitamin D

- Older adults produce less **provitamin D,** or **7-dehydrocholesterol** leading to less **vitamin D** being produced in response to **sun exposure**
- Older adults have decreased expression of ***1-hydroxylase,*** limiting the production of **calcitriol**
- Older adults **eat less** in general, amplifying the effects of aging on **Vitamin D**

RDAs
19-70 = 600 IU
>70 = 800 IU

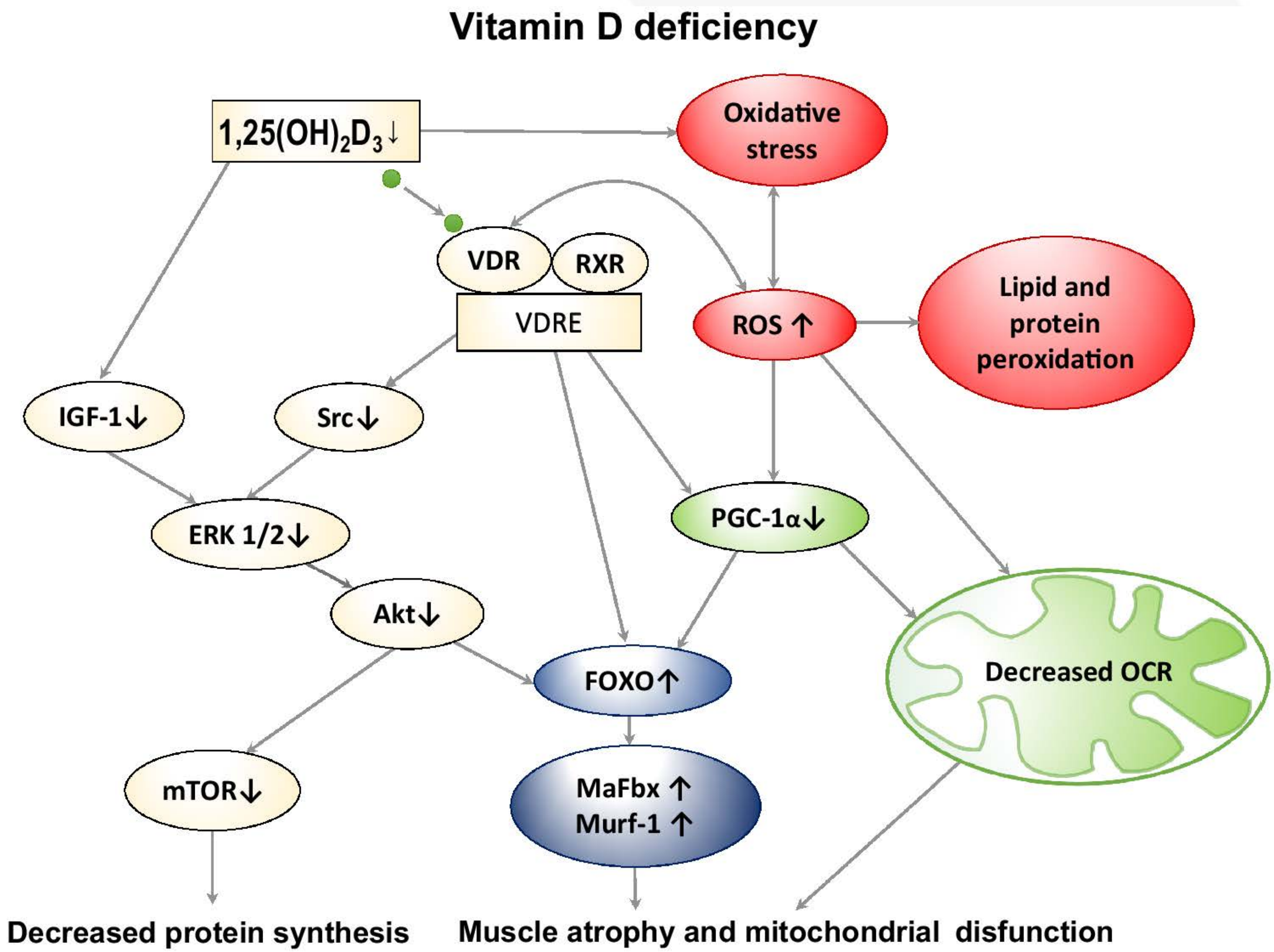
Bones & Aging

- **Bone mass** peaks when we are **young**
  - 20-30 years
  - Stays high until 40
  - High peak bone mass protects us from bone loss
- After 40, we lose bone mass
  - Can be partially reversed with some medications
- **Women** are at greater risk
  - Lower peak bone mass
  - Greater loss after menopause due to low estrogen
    - **Estrogen increases expression of vitamin D binding protein**



https://en.m.wikipedia.org/wiki/File:615_Age_and_Bone_Mass.jpg

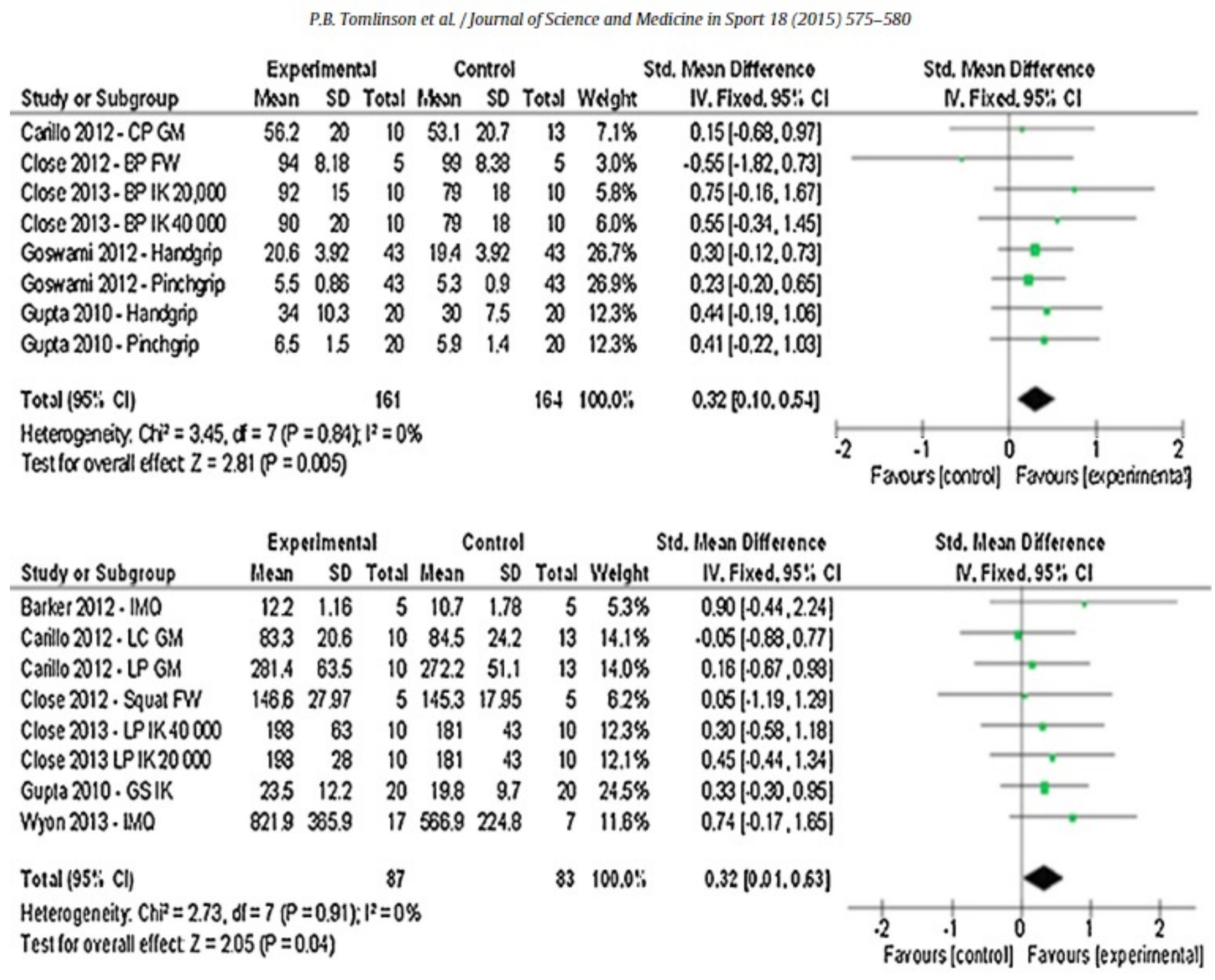
Vitamin D & Muscle Strength



Dzik, K. P., & Kaczor, J. J. (2019). Mechanisms of vitamin D on skeletal muscle function: oxidative stress, energy metabolism and anabolic state. *European Journal of Applied Physiology*, *119*(4), 825–839. https://doi.org/10.1007/s00421-019-04104-x

Vitamin D & Muscle Strength

- Vitamin D supplementation increases muscle strength



Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Carillo 2012 - CP GM	56.2	20	10	53.1	20.7	13	7.1%	0.15 [-0.68, 0.97]
Close 2012 - BP FW	94	8.18	5	99	8.38	5	3.0%	-0.55 [-1.82, 0.73]
Close 2013 - BP IK 20,000	92	15	10	79	18	10	5.8%	0.75 [-0.16, 1.67]
Close 2013 - BP IK 40 000	90	20	10	79	18	10	6.0%	0.55 [-0.34, 1.45]
Goswami 2012 - Handgrip	20.6	3.92	43	19.4	3.92	43	26.7%	0.30 [-0.12, 0.73]
Goswami 2012 - Pinchgrip	5.5	0.86	43	5.3	0.9	43	26.9%	0.23 [-0.20, 0.65]
Gupta 2010 - Handgrip	34	10.3	20	30	7.5	20	12.3%	0.44 [-0.19, 1.06]
Gupta 2010 - Pinchgrip	6.5	1.5	20	5.9	1.4	20	12.3%	0.41 [-0.22, 1.03]
Total (95% CI)			161			164	100.0%	0.32 [0.10, 0.54]

Heterogeneity: $Chi^2 = 3.45$, df = 7 (P = 0.84); $I^2 = 0\%$
Test for overall effect: Z = 2.81 (P = 0.005)

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Barker 2012 - IMQ	12.2	1.16	5	10.7	1.78	5	5.3%	0.90 [-0.44, 2.24]
Carillo 2012 - LC GM	83.3	20.6	10	84.5	24.2	13	14.1%	-0.05 [-0.88, 0.77]
Carillo 2012 - LP GM	281.4	63.5	10	272.2	51.1	13	14.0%	0.16 [-0.67, 0.98]
Close 2012 - Squat FW	146.6	27.97	5	145.3	17.95	5	6.2%	0.05 [-1.19, 1.29]
Close 2013 - LP IK 40 000	193	63	10	181	43	10	12.3%	0.30 [-0.58, 1.18]
Close 2013 LP IK 20 000	193	28	10	181	43	10	12.1%	0.45 [-0.44, 1.34]
Gupta 2010 - GS IK	23.5	12.2	20	19.8	9.7	20	24.5%	0.33 [-0.30, 0.95]
Wyon 2013 - IMQ	821.9	385.9	17	566.9	224.8	7	11.8%	0.74 [-0.17, 1.65]
Total (95% CI)			87			83	100.0%	0.32 [0.01, 0.63]

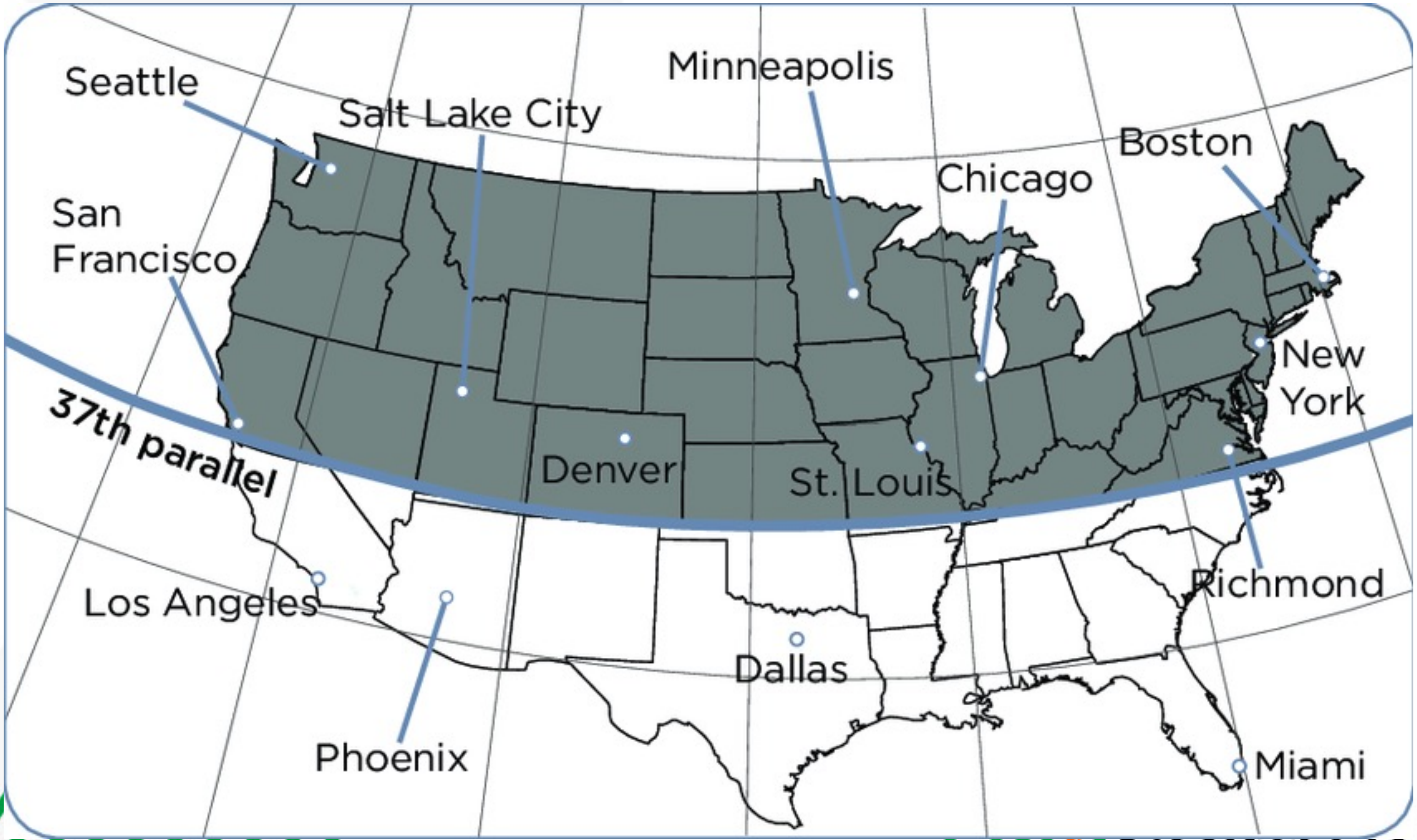
Heterogeneity: $Chi^2 = 2.73$, df = 7 (P = 0.91); $I^2 = 0\%$
Test for overall effect: Z = 2.05 (P = 0.04)

Fig. 2. Effects of vitamin D supplementation on lower and upper body muscle strength.

Tomlinson, P. B., Joseph, C., & Angioi, M. (2015). Effects of vitamin D supplementation on upper and lower body muscle strength levels in healthy individuals. A systematic review with meta-analysis. In *Journal of Science and Medicine in Sport* (Vol. 18, Issue 5, pp. 575–580). Elsevier Ltd. https://doi.org/10.1016/j.jsams.2014.07.022

Vitamin D & Sunlight

If living above 37°latitude, the body can only make vitamin D from May to October

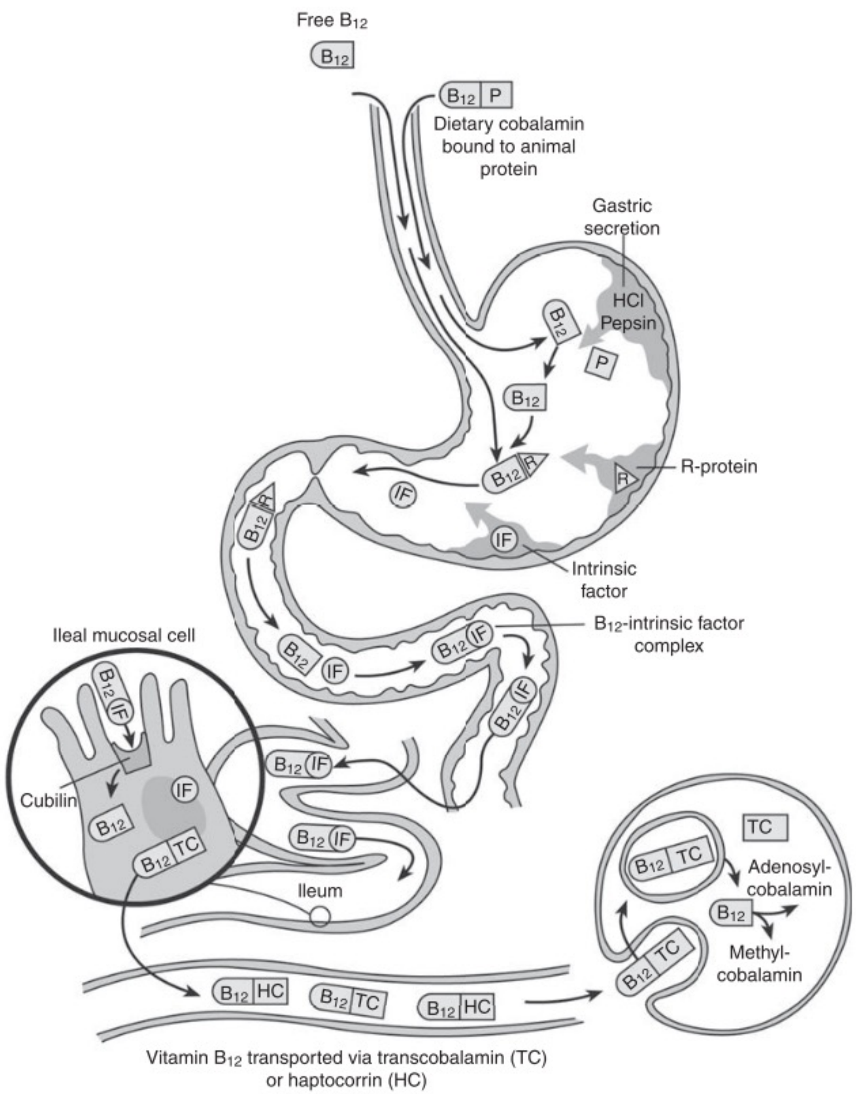


Wickham, R. (2012). Cholecalciferol and Cancer: Is It a Big D3-eal? *Journal of the Advanced Practitioner in Oncology*, *3*(4). https://doi.org/10.6004/jadpro.2012.3.4.6

Issues Making Vitamin D From Sunlight

- **Increased risk of melanoma with increased sun exposure**
- **Difficulty getting outside during midday**
- **Lower production from sunlight with darker skin**
  - **Melanin**, the pigment in our skin, **absorbs UV-B light**
    - By absorbing EM rays, melanin protects us from skin cancer, but hinders vitamin D production
  - **Need more time in sun if your skin is darker**
- **Decreased production from sunlight with aging**
  - **We make less vitamin D as we get older**
- **Sun must be 30°above horizon**
  - **Location Matters**

B12 & Aging



- Deficiency of **B12** or **Folate**
  - Pernicious or megaloblastic anemia
  - Cognitive impairment
  - Frailty
- As we get older, we **absorb less B12**
  - Due to reduced production of stomach acid
    - **Use of heartburn medications**
      - **Limits Stomach acid secretion**
  - Also, effects **folate**

Hughes, C. F., Ward, M., Hoey, L., & McNulty, H. (2013). Vitamin B12 and ageing: Current issues and interaction with folate. *Annals of Clinical Biochemistry*, *50*(4), 315–329. https://doi.org/10.1177/0004563212473279

B12

- Cobalamin is needed for:
  - DNA synthesis
  - Amino acid metabolism
  - Homocysteine metabolism
  - Nerve myelination
- Decreased serum [B12] is related to decreased muscle mass

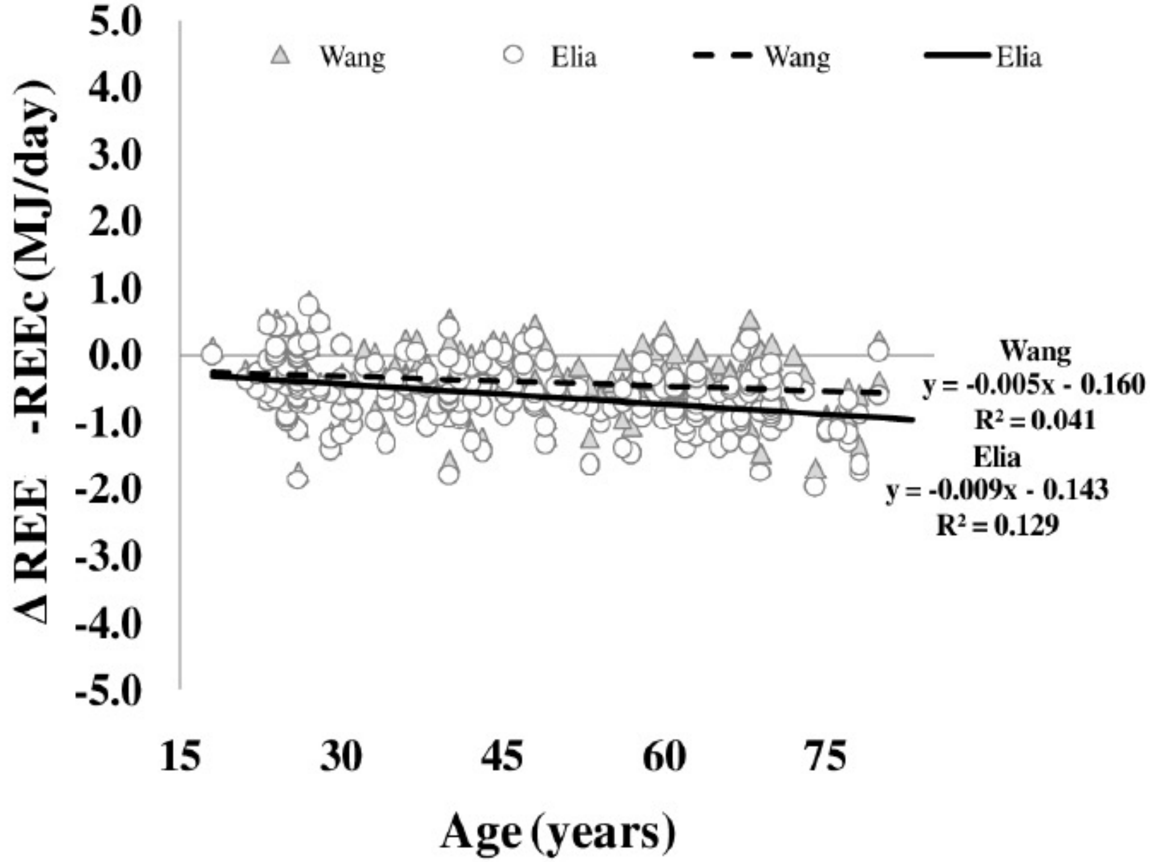
Table 3. Logistic regression analysis of sarcopenia definition and parameters by vitamin B12 level: Insufficiency group (<350 pg/mL) and sufficiency (≥350 pg/mL).

	Unadjusted Model		**Fully Adjusted Model**	
	OR (95% CI)	***p***	**OR (95% CI)**	***p***
Muscle strength				
Low HGS †	0.987 (0.728–1.338)	0.932	0.816 (0.592–1.124)	0.213
Muscle mass				
Low ASMI †	1.596 (1.242–2.051)	<0.001 *	1.744 (1.301–2.339)	<0.001 *
Physical performance				
Low SPPB †	1.182 (0.857–1.629)	0.308	1.088 (0.769–1.538)	0.634
Sarcopenia ††	1.188 (0.815–1.731)	0.37	0.991 (0.659–1.489)	0.965
Severe sarcopenia §	1.24 (0.664–2.316)	0.500	1.038 (0.540–1.996)	0.911

Abbreviations: OR, odds ratio; CI, confidence interval; HGS, hand grip strength; ASMI, appendicular skeletal muscle mass index; SPPB, short physical performance battery. † Low HGS (<28 kg for men and <18 kg for women); Low ASMI, <7.0 kg/m for men and <5.4 kg/m for women; Low SPPB ≤ 9 for both sexes; †† Sarcopenia: low HGS and low ASMI. § Severe sarcopenia, low HGS, low ASMI, and low SPPB. The fully adjusted model was adjusted for age, sex, depression, osteoarthritis, osteoporosis, diabetes mellitus, hypertension, smoking, alcohol consumption, location of residence, and body mass index. * $p < 0.05$.

Chae, S. A., Kim, H. S., Lee, J. H., Yun, D. H., Chon, J., Yoo, M. C., Yun, Y., Yoo, S. D., Kim, D. H., Lee, S. A., Chung, S. J., Soh, Y., & Won, C. W. (2021). Impact of vitamin b12 insufficiency on sarcopenia in community-dwelling older korean adults. *International Journal of Environmental Research and Public Health*, *18*(23). https://doi.org/10.3390/ijerph182312433

Energy Expenditure & Aging

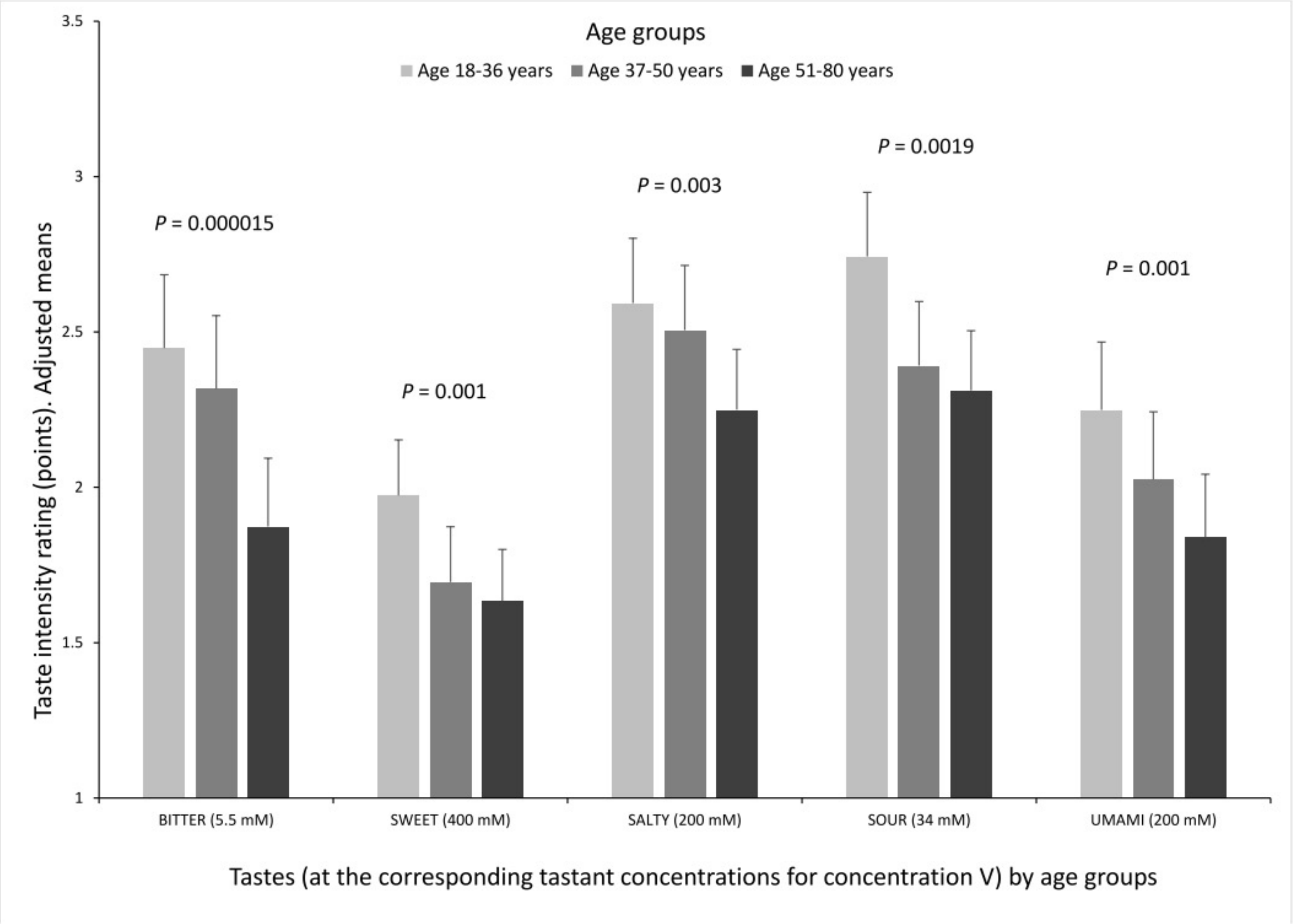


Geisler, C., Braun, W., Pourhassan, M., Schweitzer, L., Glüer, C. C., Bosy-Westphal, A., & Müller, M. J. (2016). Age-dependent changes in resting energy expenditure (REE): insights from detailed body composition analysis in normal and overweight healthy caucasians. *Nutrients*, *8*(322), 1–11. https://doi.org/10.3390/nu8060322

Older Adults

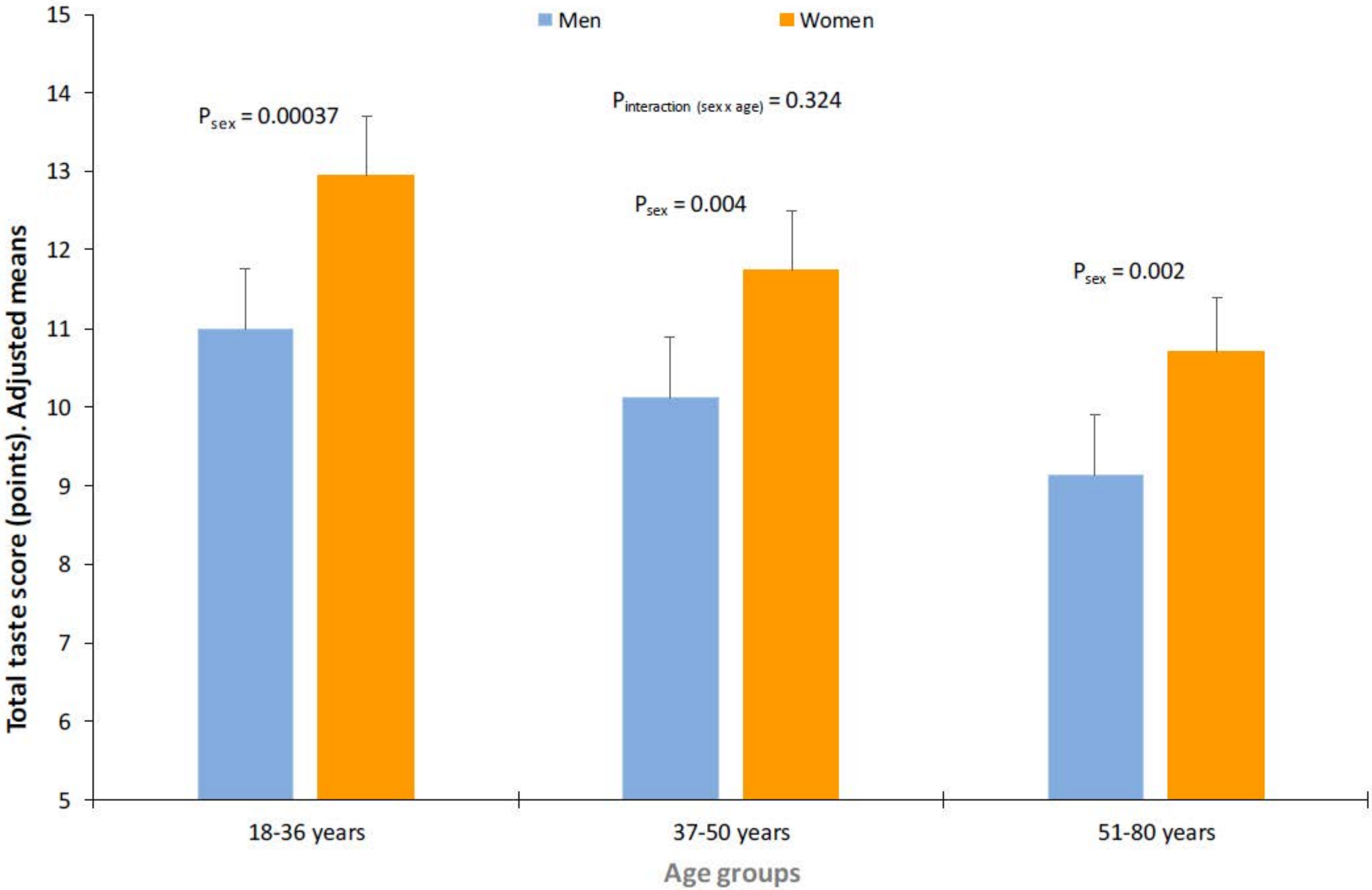
- Older adults **need less energy** than younger adults, but even if as **physically active** and same **muscle mass** need **greater intakes of:**
  - **Protein**
    - Due to anabolic resistance
  - **Calcium**
    - Due to decreased absorption
  - **Vitamin D**
    - Due to decreased synthesis of vitamin D in skin
    - Due to decreased rate of the conversion of vitamin D into calcitriol
  - **Vitamin B12**
    - Due to decreased stomach acid production
- "**Empty Calories**" are a big concern for older adults
  - **Choosing nutrient dense food is a priority**
  - **Added sugar = empty calories**

Taste & Aging (1)



Barragán, R., Coltell, O., Portolés, O., Asensio, E. M., Sorlí, J. V., Ortega-Azorín, C., González, J. I., Sáiz, C., Fernández-Carrión, R., Ordovas, J. M., & Corella, D. (2018). Bitter, sweet, salty, sour and umami taste perception decreases with age: Sex-specific analysis, modulation by genetic variants and taste-preference associations in 18 to 80 year-old subjects. *Nutrients*, *10*(10). https://doi.org/10.3390/nu10101539

Taste & Sex



Barragán, R., Coltell, O., Portolés, O., Asensio, E. M., Sorlí, J. V., Ortega-Azorín, C., González, J. I., Sáiz, C., Fernández-Carrión, R., Ordovas, J. M., & Corella, D. (2018). Bitter, sweet, salty, sour and umami taste perception decreases with age: Sex-specific analysis, modulation by genetic variants and taste-preference associations in 18 to 80 year-old subjects. *Nutrients*, *10*(10). https://doi.org/10.3390/nu10101539

Taste & Aging (2)

- **Our perception of taste decreases as we age**
- **Older people prefer food that tastes stronger:**
  - **Excess sugar intake**
    - **Increasing empty calorie intake**
    - A risk factor for type 2 diabetes mellitus
  - **Excess sodium intake**
    - A risk factor for hypertension

Video Summary #1

- **Aging results in loss of muscle mass and strength**
  - A factor in disability, mortality, cognitive impairment and other disease and conditions
- **Due to worsened oral health and ability to chew and taste dietary intake decreases by about 25%**
  - Increased odds of nutrient decencies
  - Worsened taste increases added sugar and sodium intake
- **To support muscle older adults need greater intakes of:**
  - Protein
  - Omega-3s
  - Vitamin D
  - Vitamin B12

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Video Summary #2

- **To support muscle older adults need greater intakes of:**
  - **Protein**
    - Due to anabolic resistance to exercise and dietary protein
  - **Omega-3 fatty acids**
    - Due to increased inflammation associated with aging
  - **Vitamin D**
    - Due to decreased synthesis of vitamin D in skin
    - Due to decreased rate of the conversion of vitamin D into calcitriol
  - **Vitamin B12**
    - Due to decreased stomach acid production

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Video Summary #3

- **Energy expenditure decrease as we get older, so older adults need less total energy**
  - But more nutrients than younger adults
- **Worsened taste increases added sugar and sodium intake**
  - Added sugar are "empty calories" that only provide energy and not other nutrients
- **Older adults must focus on consuming nutrient dense foods**
  - Nutrient density = nutrient/Calories

Case Application

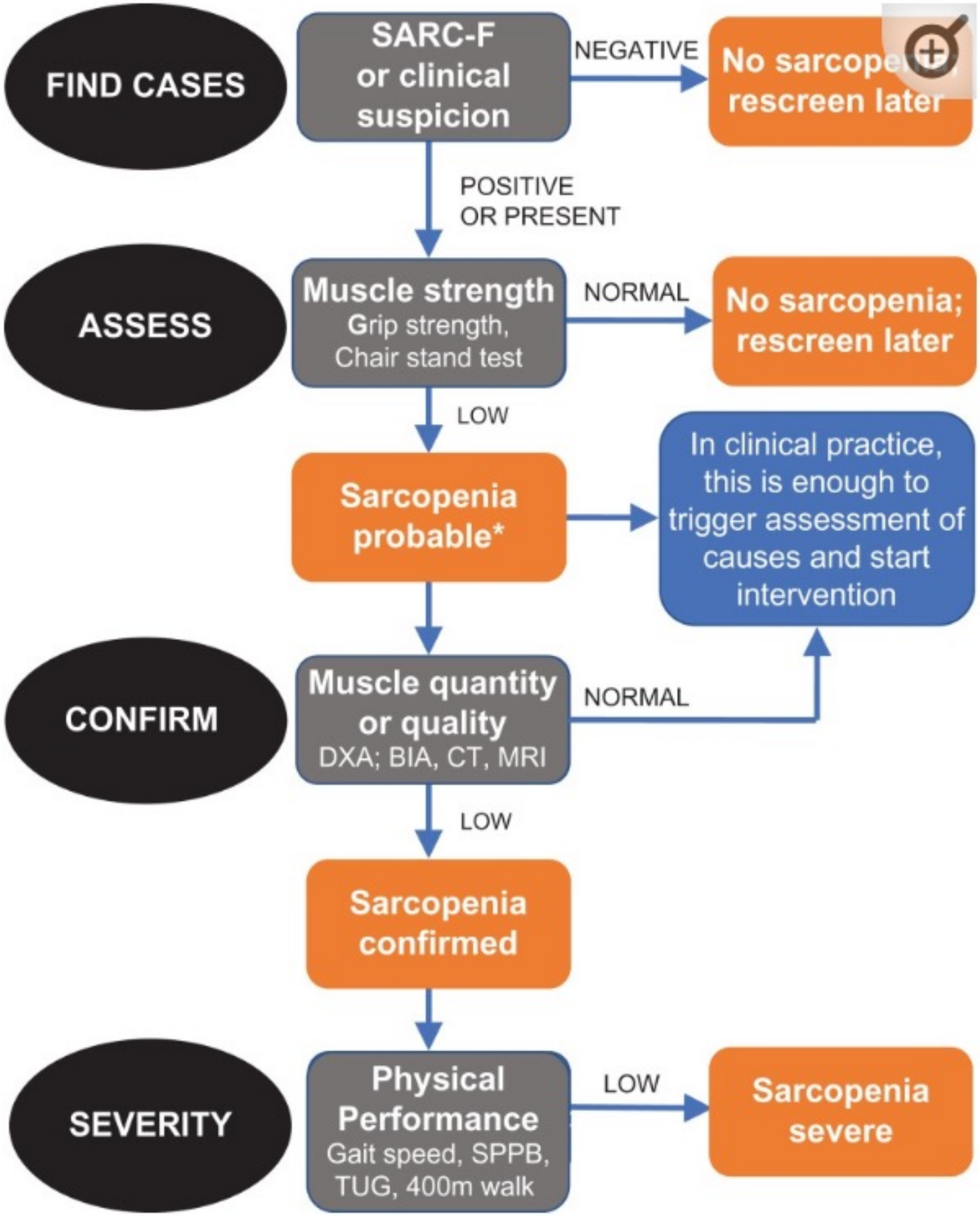
- Mrs. Smith is a 70-year-old retired teacher who lives alone in a suburban community. She has a history of osteoarthritis in her knees, which limits her mobility and makes it difficult for her to engage in physical activities. Her husband passed away five years ago, and she has been living independently since then. Mrs. Smith enjoys cooking and gardening but has recently been experiencing some challenges in maintaining a balanced diet and staying active due to her arthritis. Mrs. Smith's diet consists mainly of convenience foods and processed meals because she finds it challenging to stand for long periods to cook. She tends to skip meals or opt for quick snacks instead of proper meals. Her diet lacks variety and often lacks essential nutrients. Due to her limited mobility and reduced strength, she has experienced some unintentional weight loss over the past few months, which further exacerbates her weakness and fatigue. She used to enjoy gardening, but now finds it difficult to kneel and bend due to joint pain.

Question 1: What are the key nutrition and mobility factors from the case example?

- Convenience/processed foods
- Lack of essential nutrients
  - All of which contribute to reduced strength-further impacting mobility
- Unintentional weight loss
- Limited standing endurance/tolerance for cooking
- Lack of ability to garden-less access to healthy foods
- Living alone-difficulty in cooking

Question 2: What screening/assessments should be completed within the interdisciplinary team?

- SARC-F, score ≥4 requires further assessment
- Grip strength
- Chair stand test, 5x
- Gait speed
- Short Physical Performance Battery (SPPB) SPPB form
- DXA
- Nutrition screening
  - Mini Nutritional Assessment (MNA)
  - Simplified Nutritional Appetite Questionnaire (SNAQ)
- Food security screening
  - USDA



Cruz-Jentoft AJ, Bahat G, Bauer J, et al. Sarcopenia: revised European consensus on definition and diagnosis [published correction appears in Age Ageing. 2019 Jul 1;48(4):601]. *Age Ageing*. 2019;48(1):16-31. doi:10.1093/ageing/afy169

Sarcopenia test and cut-off scores: European Working Group on Sarcopenia in Older People

Criteria		Test and Cut-Off	Diagnosis
-	Low muscle strength by chair stand and grip strength *	Grip strength (males) < 27 kg Grip strength (females) < 16 kg Chair standing > 15 s for five rises	Probable Sarcopenia
-	Low muscle quantity or quality **	ASM (males) < 20 kg ASM (females) < 15 kg ASM/height2 (males) < 7.0 kg/m^2 ASM/height2 (females) < 5.5 kg/m^2	Sarcopenia
-	Low muscle performance ***	Gait speed ≤ 0.8 m/s Short Physical Performance Battery (SPPB) ≤ 8 points score Timed Up-and-Go Test ≥ 20 s 400 m walk test, noncompletion or ≥6 min for completion	Severe Sarcopenia

* Probable sarcopenia is identified by Criterion 1 (Low muscle strength). ** The diagnosis is confirmed by additional documentation from Criterion 2 (Low muscle quantity or quality). *** If Criteria 1, 2, and 3 (poor physical performance) are all met, sarcopenia is considered severe. ASM: appendicular skeletal muscle mass.

Giovannini S, Brau F, Forino R, et al. Sarcopenia: Diagnosis and Management, State of the Art and Contribution of Ultrasound. *J Clin Med*. 2021;10(23):5552. Published 2021 Nov 26. doi:10.3390/jcm10235552

Mini Nutritional Assessment
MNA®

Nestlé NutritionInstitute

Last name: ______ First name: ______

Sex: ______ Age: ______ Weight, kg: ______ Height, cm: ______ Date: ______

Complete the screen by filling in the boxes with the appropriate numbers. Total the numbers for the final screening score.

Screening

A Has food intake declined over the past 3 months due to loss of appetite, digestive problems, chewing or swallowing difficulties?
0 = severe decrease in food intake
1 = moderate decrease in food intake
2 = no decrease in food intake ☐

B Weight loss during the last 3 months
0 = weight loss greater than 3 kg (6.6 lbs)
1 = does not know
2 = weight loss between 1 and 3 kg (2.2 and 6.6 lbs)
3 = no weight loss ☐

C Mobility
0 = bed or chair bound
1 = able to get out of bed / chair but does not go out
2 = goes out ☐

D Has suffered psychological stress or acute disease in the past 3 months?
0 = yes 2 = no ☐

E Neuropsychological problems
0 = severe dementia or depression
1 = mild dementia
2 = no psychological problems ☐

F1 Body Mass Index (BMI) (weight in kg) / (height in m)^2 ☐
0 = BMI less than 19
1 = BMI 19 to less than 21
2 = BMI 21 to less than 23
3 = BMI 23 or greater ☐

IF BMI IS NOT AVAILABLE, REPLACE QUESTION F1 WITH QUESTION F2.
DO NOT ANSWER QUESTION F2 IF QUESTION F1 IS ALREADY COMPLETED.

F2 Calf circumference (CC) in cm
0 = CC less than 31
3 = CC 31 or greater ☐

Screening score
(max. 14 points) ☐☐

12-14 points: ☐ Normal nutritional status
8-11 points: ☐ At risk of malnutrition
0-7 points: ☐ Malnourished

Save
Print
Reset

Ref. Vellas B, Villars H, Abellan G, et al. *Overview of the MNA® - Its History and Challenges.* J Nutr Health Aging 2006;10:456-465.
Rubenstein LZ, Harker JO, Salva A, Guigoz Y, Vellas B. *Screening for Undernutrition in Geriatric Practice: Developing the Short-Form Mini Nutritional Assessment (MNA-SF).* J. Geront 2001;56A: M366-377.
Guigoz Y. *The Mini-Nutritional Assessment (MNA®) Review of the Literature - What does it tell us?* J Nutr Health Aging 2006; 10:466-487.
Kaiser MJ, Bauer JM, Ramsch C, et al. *Validation of the Mini Nutritional Assessment Short-Form (MNA®-SF): A practical tool for identification of nutritional status.* J Nutr Health Aging 2009; 13:782-788.

For more information: www.mna-elderly.com

- < 11 at risk for malnutrition
- <7 malnourished
- Mini Nutritional Assessment (MNA) | APTA
- What is the MNA®? | MNA Elderly (mna-elderly.com)

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SNAQ – Simplified Nutritional Assessment Questionnaire

- My appetite is – very poor(1), poor(2), average(3), good(4), or very good (5)
- When I eat – I feel full after eating only a few mouthfuls(1), after eating 1/3 of a meal(2), after over ½ of a meal(3), after most of the meal(4) or hardly ever feel full(5)
- Food tastes – very bad(1), bad(2), average(3), good(4), or very good(5)
- Normally I eat – <1meal(1),1 meal/day(2), 2 meals/day(3), 3 meals/day(4) or > 3 meals/day(5)

- ≤ 15 at risk for malnutrition in healthy community-dwelling older adults

Lau S, Pek K, Chew J, et al. The Simplified Nutritional Appetite Questionnaire (SNAQ) as a Screening Tool for Risk of Malnutrition: Optimal Cutoff, Factor Structure, and Validation in Healthy Community-Dwelling Older Adults. *Nutrients*. 2020;12(9):2885. Published 2020 Sep 21. doi:10.3390/nu12092885

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USDA food security questionnaire

- Food that (I/we) bought just didn't last, and we didn't have money to get more in the last 12 months.
- (I/we) couldn't afford to eat balanced meals in the last 12 months.
- In the last 12 months, since last (current month) did you or other adults in your household ever cut the size of your meals or skip meals because there wasn't enough money for food?
  - How often did this happen?
- In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food?
- In the last 12 months, were you ever hungry but didn't eat because there wasn't enough money for food?

- Raw score: 0-1 High or marginal food security
- Raw score: 2-4 Low food security
- Raw score: 5-6 Very low food security
- Six-item Short Form Food Security Survey Module (usda.gov)
- https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-u-s/measurement/

Question 3: What would be appropriate for referral(s)?

- Meals on wheels
- NDSU extension service
  - Nourish Your Body
    - https://www.ndsu.edu/agriculture/extension/extension-topics/food-and-nutrition/health-and-nutrition/nourish-your-body
  - "Cooking for One or Two"
    - https://www.ndsu.edu/agriculture/extension/publications/cooking-one-or-two
- Dietician for individualized plan
- Occupational Therapy for meal prep management and modification of hobbies to encourage participation
- Physical Therapy for strengthening and management of OA/pain
- Social Worker for additional resources/services
- MD due to unintentional weight loss, DXA or imaging

Thanks For Your Time!

Any Questions?

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Nathaniel.Johnson.4@und.edu

References #1

- Anderson, S. G., Sanders, T. A. B., & Cruickshank, J. K. (2009). Plasma fatty acid composition as a predictor of arterial stiffness and mortality. *Hypertension*, *53*(5), 839–845. https://doi.org/10.1161/HYPERTENSIONAHA.108.123885
- Anker SD, Morley JE, von Haehling S. Welcome to the ICD-10 code for sarcopenia. *J Cachexia Sarcopenia Muscle*. 2016;7(5):512-514. doi:10.1002/jcsm.12147
- Ardeljan AD, Hurezeanu R. Sarcopenia. [Updated 2023 Jul 4]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK560813/
- Bar-Peled L, Sabatini DM. Regulation of mTORC1 by amino acids. *Trends Cell Biol*. 2014;24(7):400-406. doi:10.1016/j.tcb.2014.03.003
- Barragán R, Coltell O, Portolés O, et al. Bitter, sweet, salty, sour and umami taste perception decreases with age: sex-specific analysis, modulation by genetic variants and taste-preference associations in 18 to 80 year-old subjects. *Nutrients*. 2018;10(1539):1-23. doi:10.3390/nu10101539
- Bauer J, Biolo G, Cederholm T, et al. Evidence-based recommendations for optimal dietary protein intake in older people: a position paper from the PROT-AGE Study Group. *J Am Med Dir Assoc*. 2013;14(8):542-559. doi:10.1016/j.jamda.2013.05.021
- Beaudart C, Zaaria M, Pasleau F, Reginster JY, Bruyère O. Health outcomes of sarcopenia: a systematic review and meta-analysis. *PLoS One*. 2017;12(1):1-16. doi:10.1371/journal.pone.0169548
- Bhaskaran, K., dos-Santos-Silva, I., Leon, D. A., Douglas, I. J., & Smeeth, L. (2018). Association of BMI with overall and cause-specific mortality: a population-based cohort study of 3·6 million adults in the UK. *The Lancet Diabetes and Endocrinology*, *6*(12), 944–953. https://doi.org/10.1016/S2213-8587(18)30288-2
- Bonder B., Bello-Haas V. *Functional Performance in Older Adults, 4th edition.* F.A. Davis Company; 2018
- Carbone JW, McClung JP, Pasiakos SM. Recent advances in the characterization of skeletal muscle and whole-body protein responses to dietary protein and exercise during negative energy balance. *Adv Nutr*. 2019;10:70-79. doi:10.1093/advances/nmy087
- Chae, S. A., Kim, H. S., Lee, J. H., Yun, D. H., Chon, J., Yoo, M. C., Yun, Y., Yoo, S. D., Kim, D. H., Lee, S. A., Chung, S. J., Soh, Y., & Won, C. W. (2021). Impact of vitamin b12 insufficiency on sarcopenia in community-dwelling older korean adults. *International Journal of Environmental Research and Public Health*, *18*(23). https://doi.org/10.3390/ijerph182312433
- Chiles Shaffer, N., Fabbri, E., Ferrucci, L., Shardell, M., Simonsick, E. M., & Studenski, S. (2017). Muscle Quality, Strength, and Lower Extremity Physical Performance in the Baltimore Longitudinal Study of Aging. *The Journal of Frailty & Aging*, *6*(4), 183–187. https://doi.org/10.14283/jfa.2017.24
- Chung, H. Y., Kim, D. H., Lee, E. K., Chung, K. W., Chung, S., Lee, B., ... & Yu, B. P. (2019). Redefining chronic inflammation in aging and age-related diseases: proposal of the senoinflammation concept. *Aging and disease*, *10*(2), 367.
- Committee on Military Nutrition Research, Institute of Medicine. *The Role of Protein and Amino Acids in Sustaining and Enhancing Performance*. Washington, D.C.: National Academy Press; 1999.*Nutr*. 2000;72(3):796-803. doi:10.1093/ajcn/72.3.796
- Cornish, S. M., Cordingley, D. M., Shaw, K. A., Forbes, S. C., Leonhardt, T., Bristol, A., Candow, D. G., & Chilibeck, P. D. (2022). Effects of Omega-3 Supplementation Alone and Combined with Resistance Exercise on Skeletal Muscle in Older Adults: A Systematic Review and Meta-Analysis. *Nutrients*, *14*(11). https://doi.org/10.3390/nu14112221.

References #2

- Deutz, N. E. P., Bauer, J. M., Barazzoni, R., Biolo, G., Boirie, Y., Bosy-Westphal, A., Cederholm, T., Cruz-Jentoft, A., Krznariç, Z., Nair, K. S., Singer, P., Teta, D., Tipton, K., & Calder, P. C. (2014). Protein intake and exercise for optimal muscle function with aging: recommendations from the ESPEN Expert Group. *Clinical Nutrition*, *33*, 929–936. https://www.sciencedirect.com/science/article/pii/S0261561414001113
- Dickinson JM, Fry CS, Drummond MJ, et al. Mammalian target of rapamycin complex 1 activation is required for the stimulation of human skeletal muscle protein synthesis by essential amino acids. *J Nutr*. 2011;141(5):856-862. doi:10.3945/jn.111.139485
- Dzik, K. P., & Kaczor, J. J. (2019). Mechanisms of vitamin D on skeletal muscle function: oxidative stress, energy metabolism and anabolic state. *European Journal of Applied Physiology*, *119*(4), 825–839. https://doi.org/10.1007/s00421-019-04104-x
- Feldman RS, Kapur KK, Alman JE, Chauncey HH. Aging and mastication: changes in performance and in the swallowing threshold with natural dentition. *J Am Geriatr Soc*. 1980;28(3):97-103. doi:https://doi.org/10.1111/j.1532-5415.1980.tb00240.
- Fry, C. S., Drummond, M. J., Glynn, E. L., Dickinson, J. M., Gundermann, D. M., Timmerman, K. L., Walker, D. K., Dhanani, S., Volpi, E., & Rasmussen, B. B. (2011). Aging impairs contraction-induced human skeletal muscle mTORC1 signaling and protein synthesis. *Skeletal Muscle*, *1*(1), 11. https://doi.org/10.1186/2044-5040-1-11
- Geisler C, Braun W, Pourhassan M, et al. Age-dependent changes in resting energy expenditure (REE): insights from detailed body composition analysis in normal and overweight healthy caucasians. *Nutrients*. 2016;8(322):1-11. doi:10.3390/nu8060322
- Gingras AC, Raught B, Sonenberg N. Regulation of translation initiation by FRAP/mTOR. *Genes Dev*. 2001;15(7):807-826. doi:10.1101/gad.887201
- Giovannini S, Brau F, Forino R, et al. Sarcopenia: Diagnosis and Management, State of the Art and Contribution of Ultrasound. *J Clin Med*. 2021;10(23):5552. Published 2021 Nov 26. doi:10.3390/jcm10235552
- Hatta K, Ikebe K. Association between oral health and sarcopenia: a literature review. *J Prosthodont Res*. 2021;65(2):131-136. doi:10.2186/jpr.jpor_2019_567
- Herreman, L., Nommensen, P., Pennings, B., & Laus, M. C. (2020). Comprehensive overview of the quality of plant- And animal-sourced proteins based on the digestible indispensable amino acid score. *Food Science and Nutrition*, *8*(10), 5379–5391. https://doi.org/10.1002/fsn3.1809
- Johnson, N. R., Kotarsky, C. J., Mahoney, S. J., Sawyer, B. C., Stone, K. A., Byun, W., Hackney, K. J., Mitchell, S., & Stastny, S. N. (2022). Evenness of dietary protein intake is positively associated with lean mass and strength in healthy women. *Nutrition and Metabolic Insights*, *15*, 1–9. https://doi.org/10.1177/11786388221101829
- Kim IY, Shin YA, Schutzler SE, Azhar G, Wolfe RR, Ferrando AA. Quality of meal protein determines anabolic response in older adults. *Clin Nutr*. 2018;37(6):2076-2083. doi:10.1016/j.clnu.2017.09.025
- Lau S, Pek K, Chew J, et al. The Simplified Nutritional Appetite Questionnaire (SNAQ) as a Screening Tool for Risk of Malnutrition: Optimal Cutoff, Factor Structure, and Validation in Healthy Community-Dwelling Older Adults. *Nutrients*. 2020;12(9):2885. Published 2020 Sep 21. doi:10.3390/nu12092885
- Layman DK, Boileau RA, Erickson DJ, et al. A reduced ratio of dietary carbohydrate to protein improves body composition and blood lipid profiles during weight loss in adult women. *J Nutr*. 2003;133:411-417. doi:10.1093/jn/133.2.411
- Lee DC, Shook RP, Drenowatz C, Blair SN. Physical activity and sarcopenic obesity: definition, assessment, prevalence and mechanism. *Futur Sci OA*. 2016;2(3):1-19. doi:10.4155/fsoa-2016-0028
- Lee RC, Wang Z, Heo M, Ross R, Janssen I, Heymsfield SB. Total-body skeletal muscle mass: development and cross-validation of anthropometric prediction models. *Am J Clin Nutr*. 2000;72(3):796-803. doi:10.1093/ajcn/72.3.796

References #3

- Liu GY, Sabatini DM. mTOR at the nexus of nutrition, growth, ageing and disease. *Nat Rev Mol Cell Biol*. 2020;21(4):183-203. doi:10.1038/s41580-019-0199-y
- Mathai JK, Liu Y, Stein HH. Values for Digestible Indispensable Amino Acid Scores (DIAAS) for some dairy and plant proteins may better describe protein quality than values calculated using the concept for Protein Digestibility-Dorrected Amino Acid Scores (PDCAAS). *Br J Nutr*. 2017;117(4):490-499. doi:10.1017/S0007114517000125
- McGrath, R., **Johnson, N.,** Klawitter, L., Mahoney, S., Trautman, K., Carlson, C., Rockstad, E., & Hackney, K. J. (2020). What are the association patterns between handgrip strength and adverse health conditions? A topical review. *SAGE Open Medicine*, *8*, 1–12. https://doi.org/10.1177/2050312120910358
- Metter EJ, Lynch N, Conwit R, Lindle R, Tobin J, Hurley B. Muscle quality and age: cross-sectional and longitudinal comparisons. *Journals Gerontol - Ser A Biol Sci Med Sci*. 1999;54A(5):B207-B218. doi:10.1093/gerona/54.5.B207
- Moore DR, Churchward-Venne TA, Witard O, et al. Protein ingestion to stimulate myofibrillar protein synthesis requires greater relative protein intakes in healthy older versus younger men. Journals of Gerontology - Series A Biological Sciences and Medical Sciences. 2015;70(1):57-62. doi:10.1093/gerona/glu103
- Morley, J. E., Argiles, J. M., Evans, W. J., Bhasin, S., Cella, D., Deutz, N. E. P., Doehner, W., Ken, C., Fearon, H., Ferrucci, L., Hellerstein, M. K., Kalantar-, K., Lochs, H., Macdonald, N., Mulligan, K., Muscaritoli, M., Ponikowski, P., Posthauer, M. E., Fanelli, F. R., … Reynolds, D. W. (2010). Nutritional recommendations for the management of sarcopenia. *Journal of the American Medical Directors Association*, *11*(6), 391–396. https://doi.org/10.1016/j.jamda.2010.04.014
- Nakai N, Kawano F, Murakami T, Nakata K, Higashida K. Leucine supplementation after mechanical stimulation activates protein synthesis via L-type amino acid transporter 1 in vitro. *J Cell Biochem*. September 2017:1-8. doi:10.1002/jcb.26371
- Nieuwenhuizen WF, Weenen H, Rigby P, Hetherington MM. Older adults and patients in need of nutritional support: review of current treatment options and factors influencing nutritional intake. *Clin Nutr*. 2010;29(2):160-169. doi:10.1016/j.clnu.2009.09.003
- Paddon-Jones D, Rasmussen BB. Dietary protein recommendations and the prevention of sarcopenia. *Curr Opin Clin Nutr Metab Care*. 2009;12(1):86-90. doi:10.1097/MCO.0b013e32831cef8b
- Patterson, E., Wall, R., Fitzgerald, G. F., Ross, R. P., & Stanton, C. (2012). Health implications of high dietary omega-6 polyunsaturated fatty acids. In *Journal of Nutrition and Metabolism* (Vol. 2012). Hindawi Limited. https://doi.org/10.1155/2012/539426
- Reeds PJ, Fjeld CR, Jahoor F. Do the differences between the amino acid compositions of acute-phase and muscle proteins have a bearing on nitrogen loss in traumatic states? *J Nutr*. 1994;124(6):906-910. doi:10.1093/jn/124.6.906
- Risso DS, Giuliani C, Antinucci M, et al. A bio-cultural approach to the study of food choice: the contribution of taste genetics, population and culture. *Appetite*. 2017;114:240-247. doi:10.1016/j.appet.2017.03.046
- Robinson Ramírez-Vélez, M. López Sáez De Asteasu, J.E. Morley, C.A. Cano-Gutierrez, M. Izquierdo, Performance of the Short Physical Performance Battery in Identifying the Frailty Phenotype and Predicting Geriatric Syndromes in Community-Dwelling Elderly. *The Journal of nutrition, health and aging.* 2021; 25(2):209-217. doi.org/10.1007/s12603-020-1484-3.
- Timmerman KL, Volpi E. Amino acid metabolism and regulatory effects in aging. *Curr Opin Clin Nutr Metab Care*. 2008;11(1):45-49. doi:10.1097/MCO.0b013e3282f2a592
- Tomlinson, P. B., Joseph, C., & Angioi, M. (2015). Effects of vitamin D supplementation on upper and lower body muscle strength levels in healthy individuals. A systematic review with meta-analysis. In *Journal of Science and Medicine in Sport* (Vol. 18, Issue 5, pp. 575–580). Elsevier Ltd. https://doi.org/10.1016/j.jsams.2014.07.022