Reading list: muscle, protein and nutrition in older age

The published research behind CORUS: the condition, protein needs, how older muscle responds to protein, the evidence on each core ingredient, and the approaches clinicians already use. It is background reading, not evidence that CORUS works.

ABOUT THIS READING LIST

These studies examine ingredients, related formulas and clinical nutrition; they did not test CORUS. Each entry says who took part and what was measured. Summaries are ours, written from each paper's abstract or text; please read the original before relying on it.

Sarcopenia

Sarcopenia: revised European consensus on definition and diagnosis (EWGSOP2)

Cruz-Jentoft AJ, Bahat G, Bauer J, et al. Age Ageing. 2019;48(1):16-31. doi:10.1093/ageing/afy169

Type	Consensus definition from a European expert working group.
What it says	Sarcopenia is a muscle disease. Low muscle strength is the key characteristic, low muscle quantity or quality confirms the diagnosis, and poor physical performance marks it as severe. It is common in older adults but can occur earlier in life. The paper sets out a pathway for case-finding, diagnosis and severity, with cut-off points.
Study context	Defines and diagnoses the condition.

Global prevalence of sarcopenia and severe sarcopenia

Petermann-Rocha F, Balntzi V, Gray SR, et al. J Cachexia Sarcopenia Muscle. 2022;13(1):86-99. doi: 10.1002/jcsm.12783

Type	Systematic review and meta-analysis: 263 studies reviewed, 151 pooled (692,056 people, mean age 68.5).
What it found	Prevalence ranged from 10% to 27% in people aged 60 and older, and severe sarcopenia from 2% to 9%, depending on the classification and cut-off points used.
Study context	How common the condition is, not how to manage it.

Sarcopenia

Sayer AA, Cooper R, Arai H, et al. Nat Rev Dis Primers. 2024;10(1):68. doi:10.1038/s41572-024-00550-w

Type	Narrative review (primer).
What it says	Sarcopenia can lead to declining physical function and mobility and raises the risk of falls, fractures and premature mortality. Diagnosis increasingly centers on muscle strength. Resistance exercise is the mainstay of treatment but is not suitable for everyone, so other approaches are needed.
Study context	An overview of the condition.

Clinical guidance

ESPEN practical guideline: clinical nutrition and hydration in geriatrics

Volkert D, Beck AM, Cederholm T, et al. Clin Nutr. 2022;41(4):958-989. doi:10.1016/j.clnu.2022.01.024

Type	Clinical practice guideline: 82 recommendations, graded for evidence and consensus.
Who	Older persons in all care settings.
What it says	Screen all older persons for malnutrition routinely, with a validated tool (recommendation 12). Protein intake should be at least 1 g/kg body weight per day, adjusted to the person (2). For people with or at risk of malnutrition: individualized counseling, fortified food, snacks, and supplement drinks when those are not enough (21 to 26), adapted to each person's taste and eating capacities (31).
Study context	General practice guidance.

Evidence-based recommendations for optimal dietary protein intake in older people (PROT-AGE)

Bauer J, Biolo G, Cederholm T, et al. J Am Med Dir Assoc. 2013;14(8):542-559. doi:10.1016/j.jamda.2013.05.021

Type	Position paper from an international expert group.
Who	Adults older than 65.
What it says	Older adults need more dietary protein than younger adults. Average intake of at least 1.0 to 1.2 g protein/kg/day; 1.2 g/kg/day or more for people who exercise or are otherwise active; 1.2 to 1.5 g/kg/day for most with acute or chronic disease. People with severe kidney disease (eGFR below 30) who are not on dialysis may need to limit protein. Evidence on protein quality and timing is not yet sufficient for specific recommendations.
Study context	Intake targets, not evidence that any product helps people meet them.

Protein intake and exercise for optimal muscle function with aging: recommendations from the ESPEN Expert Group

Deutz NE, Bauer JM, Barazzoni R, et al. Clin Nutr. 2014;33(6):929-936. doi:10.1016/j.clnu.2014.04.007

Type	Expert group recommendations.
Who	Older people, healthy and ill.
What it says	At least 1.0 to 1.2 g protein/kg/day for healthy older people; 1.2 to 1.5 g/kg/day for those malnourished or at risk because of acute or chronic illness; daily physical activity or exercise for all older people for as long as possible. Protein combined with exercise is considered optimal for maintaining muscle function.
Study context	General recommendations.

GLIM criteria for the diagnosis of malnutrition

Cederholm T, Jensen GL, Correia MITD, et al. Clin Nutr. 2019;38(1):1-9. doi:10.1016/j.clnu.2018.08.002

Type	Global consensus report.
Who	Adults in clinical settings.
What it says	Diagnosis has two steps: screening with any validated tool, then assessment. It needs at least one phenotypic criterion (unintended weight loss, low body mass index, reduced muscle mass) and one etiologic criterion (reduced food intake or assimilation, inflammation or disease burden).
Study context	How malnutrition is diagnosed.

How much protein older adults eat

Prevalence of protein intake below recommended in community-dwelling older adults

Hengeveld LM, Boer JMA, Gaudreau P, et al. J Cachexia Sarcopenia Muscle. 2020;11(5):1212-1222. doi: 10.1002/jcsm.12580

Type	Population study: meta-analysis of four cohorts and four national surveys (PROMISS project).
Who	8,107 community-dwelling adults aged 55 and older in the Netherlands, the UK, Canada, the USA, Finland and Italy.
What it found	Pooled prevalence of protein intake below 0.8, 1.0 and 1.2 g/kg adjusted body weight per day: 21.5%, 46.7% and 70.8%. Prevalence was higher among women, people with higher body mass index and people with poor appetite.
Study context	It measures the size of a gap, not how to close it.

How older muscle responds to protein

Anabolic signaling deficits underlie amino acid resistance of wasting, aging muscle

Cuthbertson D, Smith K, Babraj J, et al. FASEB J. 2005;19(3):422-424. doi:10.1096/fj.04-2640fje

Type	Laboratory study.
Who	44 healthy young and older men of similar build, given different amounts of essential amino acids.
What it found	Resting muscle protein synthesis did not differ, but the older men showed less sensitivity and responsiveness to essential amino acids, with lower activation of signaling proteins such as mTOR.
Study context	A mechanism in healthy men.

Splanchnic and whole-body leucine kinetics in young and elderly men

Boirie Y, Gachon P, Beaufrère B. Am J Clin Nutr. 1997;65(2):489-495. doi:10.1093/ajcn/65.2.489

Type	Laboratory study.
Who	6 young (mean age 22.7) and 6 older (68.2) men, during a standard meal.
What it found	The gut and liver took up about twice as much dietary leucine in the older men (50 ± 11% against 23 ± 2%), which could lower the leucine reaching the rest of the body.
Study context	Twelve men, one meal.

A high proportion of leucine is required for optimal stimulation of the rate of muscle protein synthesis by essential amino acids in the elderly

Katsanos CS, Kobayashi H, Sheffield-Moore M, et al. Am J Physiol Endocrinol Metab. 2006;291(2):E381-E387. doi:10.1152/ajpendo.00488.2005

Type	Laboratory study.
Who	Two older and two young groups, each given 6.7 g of essential amino acids.
What it found	In the older adults, muscle protein synthesis rose only when the mix had a higher share of leucine (41%, against 26% in a mix patterned on whey protein). In the young adults it rose with both.
Study context	Free amino acid mixes in a laboratory, not food.

Protein ingestion to stimulate myofibrillar protein synthesis requires greater relative protein intakes in healthy older versus younger men

Moore DR, Churchward-Venne TA, Witard O, et al. J Gerontol A Biol Sci Med Sci. 2015;70(1):57-62. doi: 10.1093/gerona/glu103

Type	Laboratory data, pooled and analyzed retrospectively.
Who	Healthy older (about 71) and younger (about 22) men, given 0 to 40 g of protein.
What it found	Muscle protein synthesis reached a plateau at 0.40 ± 0.19 against 0.24 ± 0.06 g/kg body mass ($p = .055$), and 0.60 ± 0.29 against 0.25 ± 0.13 g/kg lean body mass ($p < .01$), in older against younger men. Older men were less sensitive to low protein intakes.
Study context	Single meals in healthy men.

The effect of leucine-enriched beta-lactoglobulin versus an isonitrogenous whey protein isolate on skeletal muscle protein anabolism in young healthy males

Ely IA, Paul M, Wall JJS, et al. Nutrients. 2025;17(21):3410. doi:10.3390/nu17213410

Type	Laboratory study, crossover. General science only.
Who	10 healthy young men (26 ± 2 years).
What it found	About 10 g of beta-lactoglobulin, a naturally leucine-rich protein found in whey, raised blood essential amino acids and leucine more than the same amount of whey protein isolate. Muscle protein synthesis rose similarly with both, at rest and after exercise.
Study context	Young men, not older adults. It shows that more leucine in the blood does not by itself mean more muscle building.

Trials of related formulas

Effects of a vitamin D and leucine-enriched whey protein nutritional supplement on measures of sarcopenia in older adults (PROVIDE)

Bauer JM, Verlaan S, Bautmans I, et al. J Am Med Dir Assoc. 2015;16(9):740-747. doi:10.1016/j.jamda.2015.05.021

Type	Trial: related formula. Randomized, double-blind, isocaloric control, 13 weeks.
Who	380 older adults with sarcopenia (SPPB 4 to 9, low muscle mass), mostly living independently.
What it found	Handgrip strength and SPPB, the primary outcomes, improved in both groups with no difference between them. Chair-stand time was 1.01 s faster and appendicular muscle mass 0.17 kg higher with the formula.
Study context	A different formula, with added leucine.

Improving rehabilitation in sarcopenia: a randomized-controlled trial utilizing a muscle-targeted food for special medical purposes

Rondanelli M, Cereda E, Klersy C, et al. J Cachexia Sarcopenia Muscle. 2020;11(6):1535-1547. doi:10.1002/jcsm.12532

Type	Trial: related formula. Randomized, double-blind, isocaloric control, 4 to 8 weeks.
Who	140 adults with sarcopenia (age 81 ± 6) in hospital physical rehabilitation.
What it found	Gait speed rose 0.063 m/s per month more than with the control formula. Muscle mass and the key secondary outcomes also favored the formula. 13 people, across both groups, stopped because they disliked the product.
Study context	A different formula with added leucine, given alongside rehabilitation exercise.

Whey protein, amino acids, and vitamin D supplementation with physical activity increases fat-free mass and strength, functionality, and quality of life and decreases inflammation in sarcopenic elderly

Rondanelli M, Klersy C, Terracol G, et al. Am J Clin Nutr. 2016;103(3):830-840. doi:10.3945/ajcn.115.113357

Type	Trial: related formula. Randomized, double-blind, placebo-controlled, 12 weeks.
Who	130 adults with sarcopenia (mean age 80.3), all in a controlled physical activity program.
What it found	Fat-free mass was 1.7 kg higher than with placebo. Handgrip strength and activities of daily living also favored the supplement.
Study context	A different formula with added amino acids, including leucine, given with exercise.

Effects of whey protein, leucine, and vitamin D supplementation in patients with sarcopenia

Chang MC, Choo YJ. Nutrients. 2023;15(3):521. doi:10.3390/nu15030521

Type	Review of trials: systematic review and meta-analysis of 3 trials (637 patients).
What it found	Appendicular muscle mass improved with or without exercise. Grip strength and SPPB improved only when exercise was added.
Study context	Three trials of formulas with added leucine.

HMB

Effect of beta-hydroxy-beta-methylbutyrate (HMB) on lean body mass during 10 days of bed rest in older adults

Deutz NE, Pereira SL, Hays NP, et al. Clin Nutr. 2013;32(5):704-712. doi:10.1016/j.clnu.2013.02.011

Type	Trial: HMB. Randomized, double-blind, inactive placebo.
Who	24 healthy adults aged 60 to 76 (20 women), 19 evaluable, on 10 days of complete bed rest.
What it found	The control group lost 2.05 kg of lean body mass; the HMB group lost 0.17 kg, with one participant excluded. Function did not differ. The authors call for a larger trial.
Study context	HMB on its own, in a small group of healthy volunteers.

Effects of beta-hydroxy-beta-methylbutyrate supplementation on older adults with sarcopenia

Yang C, Song Y, Li T, et al. J Nutr Health Aging. 2023;27(5):329-339. doi:10.1007/s12603-023-1911-1

Type	Trial: HMB, with exercise. Randomized, double-blind, placebo-controlled, 12 weeks.
Who	34 adults aged 60 and older with sarcopenia; both groups did resistance training twice a week.
What it found	Handgrip strength, gait speed and chair-stand time were better than with placebo. Skeletal muscle mass did not differ.
Study context	HMB on its own, added to resistance training, in a small group.

Long-term effects of calcium beta-hydroxy-beta-methylbutyrate and vitamin D3 supplementation on muscular function in older adults with and without resistance training

Rathmacher JA, Pitchford LM, Khoo P, et al. J Gerontol A Biol Sci Med Sci. 2020;75(11):2089-2097. doi: 10.1093/gerona/glaa218

Type	Trial: HMB with vitamin D. Randomized, double-blind, controlled, 12 months, with or without resistance training.
Who	238 adults over 60 with insufficient vitamin D enrolled; 117 completed the 12-month trial and were included in the per-protocol analysis.
What it found	Among those not exercising, lean mass at 6 months, knee extension torque at 3 months and a composite function index at 3, 6 and 12 months were better than with control. Among those exercising, it added no further function benefit.
Study context	HMB and vitamin D without protein, in people with low vitamin D.

Effects of oral supplementation of beta-hydroxy-beta-methylbutyrate on muscle mass and strength in individuals over the age of 50

Li N, Chen S, He Y, et al. Front Nutr. 2025;12:1522287. doi:10.3389/fnut.2025.1522287

Type	Review of trials: meta-analysis of 21 trials (1,935 participants over 50).
What it found	Lean mass 0.28 kg higher (95% CI 0.16 to 0.41), with small differences in handgrip strength, chair-stand time and gait speed.
Study context	Many HMB products and populations, pooled.

An umbrella review of systematic reviews of beta-hydroxy-beta-methyl butyrate supplementation in ageing and clinical practice

Phillips SM, Lau KJ, D'Souza AC, Nunes EA. J Cachexia Sarcopenia Muscle. 2022;13(5):2265-2275. doi: 10.1002/jcsm.13030

Type	Review of reviews: 15 systematic reviews.
What it found	5 of 15 reviews found some evidence for lean soft-tissue mass and 4 of 12 for strength. None reported a positive effect on physical function. The authors describe "minor, inconsistent support" for HMB.
Study context	HMB in general, across many products and populations.

Vitamin D

The effects of vitamin D on skeletal muscle strength, muscle mass, and muscle power

Beaudart C, Buckinx F, Rabenda V, et al. J Clin Endocrinol Metab. 2014;99(11):4336-4345. PubMed 25033068

Type	Systematic review and meta-analysis of 30 randomized trials.
Who	Varied populations (5,615 participants), not limited to older adults.
What it found	Vitamin D supplementation had a small positive effect on muscle strength. The effect on muscle mass was not significant.
Study context	Vitamin D as a single nutrient, pooled across mixed populations and doses.

Effect of vitamin D monotherapy on indices of sarcopenia in community-dwelling older adults

Prokopidis K, Giannos P, Katsikas Triantafyllidis K, et al. J Cachexia Sarcopenia Muscle. 2022;13(3): 1642-1652. doi:10.1002/jcsm.12976

Type	Systematic review and meta-analysis of 10 randomized trials of vitamin D alone.
Who	Community-dwelling older adults.
What it found	Vitamin D on its own gave no improvement in muscle strength, muscle mass or physical performance.
Study context	Vitamin D monotherapy, not a combination formula. It helps interpret the vitamin D in the related formulas above.

Appetite in older age

Anorexia of aging: risk factors, consequences, and potential treatments

Landi F, Calvani R, Tosato M, et al. Nutrients. 2016;8(2):69. doi:10.3390/nu8020069

Type	Narrative review.
What it describes	Anorexia of aging, a decline in appetite or food intake in old age, is common and contributes to undernutrition. It is not an unavoidable part of aging, and its causes include physiological change, disease, and social and environmental factors.
Study context	Background on why intake falls.

Fortifying everyday food

Effects of dietary enrichment with conventional foods on energy and protein intake in older adults

Trabal J, Farran-Codina A. Nutr Rev. 2015;73(9):624-633. doi:10.1093/nutrit/nuv023

Type	Systematic review of nine studies.
What it tested	Enriching meals with conventional foods or powdered modules to raise energy and protein density without much more volume.
What it found	Enrichment can improve energy intake. It seems to increase protein intake, but the evidence was not of sufficient quality to confirm that, or to judge other outcomes.
Study context	Other foods and modules. The evidence on protein was limited even for those.

Can fortified foods and snacks increase the energy and protein intake of hospitalised older patients?

Mills SR, Wilcox CR, Ibrahim K, Roberts HC. J Hum Nutr Diet. 2018;31(3):379-389. doi:10.1111/jhn.12529

Type	Systematic review of ten articles (546 patients).
Who	Hospital and rehabilitation patients with a mean age of 60 to 83.
What it found	Compared with usual care, six studies of energy- or protein-based fortification or snacks significantly increased energy (250 to 450 kcal/day) or protein (12 to 16 g/day) intake. Four studies reported good acceptability.
Study context	Hospital settings and other products.

Impact of food-based fortification on nutritional outcomes and acceptability in older adults

Geny A, Petitjean M, Van Wymelbeke-Delannoy V, Sulmont-Rossé C. Front Nutr. 2023;10:1232502. doi: 10.3389/fnut.2023.1232502

Type	Systematic review of 44 studies (3,384 participants).
Who	Adults aged 60 and older, at home, in institutions or in hospital.
What it found	Compared with a standard diet, adding fortificants to everyday recipes seems to be a valuable way to raise energy and protein intake, but there was no strong evidence of an effect on nutritional status. The authors call for more acceptability research.
Study context	Other recipes and fortificants.

Older adults' acceptability of and preferences for food-based protein fortification in the UK, France and Norway

Smith R, Methven L, Clegg ME, et al. Appetite. 2024;197:107319. doi:10.1016/j.appet.2024.107319

Type	Discussion groups, then a home-use trial (Fortiphy project).
Who	Discussions with 37 older adults and 15 caregivers; a home trial with 158 healthy adults aged 70 and older.
What it found	Participants were largely unaware of the role of protein in aging and did not want to fortify their own food at present, but were positive about the idea. Taste, familiar ingredients and preferred ways of preparing food mattered, and preferences differed by country.
Study context	Other recipes, made by healthy volunteers.

Supplement drinks in practice

A systematic review of compliance to oral nutritional supplements

Hubbard GP, Elia M, Holdoway A, Stratton RJ. Clin Nutr. 2012;31(3):293-312. doi:10.1016/j.clnu.2011.11.020

Type	Systematic review of 46 studies (4,328 participants).
What it found	Mean compliance with oral nutritional supplements was 78%: 67% in hospital and 81% in the community. Compliance was higher with more energy-dense supplements.
Note	The first author's listed affiliation is a supplement manufacturer's medical affairs department.
Study context	It concerns supplement drinks, not powders added to food.

Screening tools clinicians use

Validation of the Mini Nutritional Assessment short-form (MNA-SF)

Kaiser MJ, Bauer JM, Ramsch C, et al. J Nutr Health Aging. 2009;13(9):782-788. doi:10.1007/s12603-009-0214-7

Type	Validation study pooling twelve datasets.
Who	2,032 older participants with a mean age of 82.3.
What it found	The revised short form, which can use calf circumference when body mass index is unavailable, is a valid nutrition screening tool for geriatric health professionals.
Study context	A clinician's screening tool, not a product assessment.

Citations checked against PubMed and Crossref on 2 November 2026.

CORUS reading list. Updated November 2026. Prelaunch materials. Background reading only. Nothing here is evidence about CORUS, and nothing here is medical advice.

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