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REVIEW ARTICLE

Debunking the plant protein paradox: Emerging meta-analytical evidence for preserved muscular strength on plant-based diets

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ABSTRACT

The increasing adoption of plant-based diets (PBDs) has raised questions regarding their adequacy in supporting muscular strength and performance, particularly given concerns around the amino acid profile and bioavailability of plant proteins. This review synthesises current meta-analytical and clinical trial evidence to address the "*plant protein paradox*," which posits that plant proteins are inferior for maintaining muscle mass and strength. Recent high-quality data reveal no significant differences in muscular strength or athletic performance outcomes between plant-based and omnivorous diets when total protein intake and quality are optimised. Mechanistic studies demonstrate comparable muscle protein synthesis rates across protein sources, with soy and certain mixed plant proteins showing anabolic potential equivalent to animal proteins. Clinical recommendations emphasise attention to protein quantity, quality, leucine content, and micronutrient sufficiency to maximise muscle health on PBDs. Specific populations—including older adults and athletes—can safely adopt plant-based nutrition without compromising strength or functional performance. This evidence supports a shift beyond traditional, protein hierarchy models, positioning plant-based diets as a viable strategy for musculoskeletal health alongside their cardiovascular and environmental benefits.

Keywords: Plant-based diets, Muscular strength, Protein synthesis, Resistance training, Vegan nutrition.

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INTRODUCTION

Plant-based dietary patterns have gained remarkable global popularity in recent years, driven by strong evidence linking them to improved cardiovascular health, reduced risk of metabolic disorders, and a significantly lower environmental footprint. Ethical considerations including animal welfare and planetary health have also motivated many individuals to reduce or eliminate animal-derived foods from their diets. As plant-based nutrition transitions from a niche concept to mainstream practice, healthcare providers are increasingly supporting patients in adopting these diets, ensuring nutritional adequacy and long-term health.

Despite the proven benefits of plant-based diets (PBDs) in preventing chronic diseases and promoting sustainability, scepticism remains regarding their adequacy for muscular health. A major concern, based on historical beliefs and mechanistic assumptions, is whether plant proteins—often viewed as inferior in amino acid composition and bioavailability—can effectively support muscle mass and strength. This issue is particularly relevant among older adults at risk for sarcopenia, athletes with high-performance demands, and physically active individuals aiming to preserve lean mass during weight loss or dietary changes.

Traditionally, animal proteins have been considered superior in quality, influencing dietary recommendations in sports medicine and geriatric care. However, emerging evidence challenges this hierarchy. Isolated plant proteins such as soy, mycoprotein, and mixed legume blends have demonstrated anabolic effects comparable to animal proteins in controlled trials. Additionally, when considering the whole diet—including protein quantity, meal timing, and resistance training—the simplistic binary view of protein quality is becoming outdated.

Given this rapid evolution in the evidence base, a comprehensive synthesis of recent high-quality data is needed to reassess long-standing assumptions. This review evaluates current meta-analyses and randomised controlled trials (RCTs) on the effects of plant-based diets on muscular strength and physical function. The goal is to clarify the clinical implications, particularly for populations where muscle preservation is essential, and to inform evidence-based dietary recommendations that align with patient values, which are increasingly favouring plant-based nutrition.

CURRENT EVIDENCE: META-ANALYTICAL FINDINGS

The most comprehensive evaluation of the relationship between plant-based diets and muscular strength to date is a 2025 systematic review and meta-analysis by López-Moreno et al. (2025), published in *Sports Medicine — Open*. Adhering to PRISMA guidelines, the authors synthesised data from eight randomised controlled trials (RCTs) comprising 188 adults aged 20 to 65 years (46% female), all of which directly compared plant-based with omnivorous diets in the context of strength-related outcomes.

The results demonstrated no statistically significant differences in muscular strength across dietary groups. For upper-body strength, the standardised mean difference (SMD) was −0.12 (95% CI, −0.50 to 0.27); for lower-body strength, the SMD was 0.18 (95% CI, −0.31 to 0.67); and for overall strength, the SMD was 0.21 (95% CI, −0.16 to 0.58) (López-Moreno et al., 2025). These negligible effect sizes fall within the range of statistical variability, indicating functional equivalence between dietary patterns. The data, summarised in Table 1, represent the highest level of evidence currently available and strongly refute the long-standing clinical concern that plant-based diets inherently impair strength capacity.

ATHLETIC PERFORMANCE AND FUNCTIONAL OUTCOMES

Beyond strength-specific parameters, broader metrics of athletic performance have also been systematically evaluated. A 2024 meta-analysis published in the *British Journal of Nutrition* examined the impact of plant-based diets on overall physical performance in both recreationally active and trained individuals (Damasceno et al., 2024). Notably, the study reported a moderate improvement in aerobic capacity among individuals consuming plant-based diets (effect size, 0.55), while finding no significant reductions in power or strength performance (SMD, −0.30; 95% CI, −0.67 to 0.07). Overall athletic performance was essentially unchanged between dietary groups (SMD, 0.01; 95% CI, −0.21 to 0.22), despite a modest reduction in body mass index (BMI) observed in the plant-based cohort.

Taken together, these findings have important clinical implications. For practitioners advising patients—particularly those engaged in regular physical activity or competitive sports—the evidence indicates that plant-based diets, when properly structured, can maintain both absolute strength and functional performance. This offers critical reassurance to individuals seeking to transition to plant-based nutrition without compromising musculoskeletal or athletic integrity.

Table 1. Summary of studies on plant-based diets and muscular strength.

Study reference	Study type	Participants	Intervention	Duration	Outcomes
López-Moreno et al. (2025)	Systematic Review & Meta-analysis	188 adults (20-65 yrs)	PBD vs Omnivorous	Varied (RCTs)	No significant difference in strength; SMD upper-body: -0.12, lower-body: 0.18, overall: 0.21
Damasceno et al. (2024)	Meta-analysis	Various	PBD vs Omnivorous	Varied	Improved aerobic performance; strength/power unaffected
Lim et al. (2021)	Meta-analysis	Various	Plant vs Animal protein	Varied	Small gain in muscle mass with animal protein; no difference in strength
Burd et al. (2019)	RCT	Healthy adults	Vegan vs Omnivorous whole foods	9 days	No difference in muscle protein synthesis rates
Monteyne et al. (2023)	RCT	Healthy young adults	High-protein PBD vs Omnivorous	10 weeks	Comparable protein synthesis and muscle adaptation
Berrazaga et al. (2023)	Systematic Review & Meta-analysis	Older adults	Plant-based proteins ± exercise	Varied	Improved lean mass and strength
Monteyne et al. (2021)	RCT	Older adults	Mycoprotein-based vegan vs Omnivorous	Daily synthesis assessment	Equivalent daily muscle protein synthesis rates
Wirnitzer et al. (2023)	Controlled Pilot Study	Trained individuals	Transition to PBD	16 weeks	No decrease in strength; stable performance

PROTEIN QUALITY AND MUSCLE PROTEIN SYNTHESIS

While strength outcomes appear equivalent between dietary patterns, understanding the underlying mechanisms requires examination of protein quality and muscle protein synthesis rates. A comprehensive meta-analysis of 43 randomised controlled trials comparing plant-based versus animal proteins revealed nuanced differences (Lim et al., 2021). Although animal proteins demonstrated a small but statistically

significant advantage for muscle mass (SMD −0.20; 95% CI −0.37 to −0.03), critically, no differences in muscle strength or performance were observed (Lim et al., 2021).

This apparent paradox—modest differences in muscle mass without corresponding strength deficits—highlights the complex relationship between muscle quantity and quality. From a clinical perspective, functional strength capacity appears preserved regardless of minor variations in muscle mass.

Protein source specificity emerged as an important consideration. Non-soy plant proteins (rice, potato, oat) showed larger deficits compared to animal proteins, while soy-based proteins matched animal protein outcomes for muscle mass development (Lim et al., 2021). This finding provides actionable guidance for clinical recommendations regarding optimal plant protein sources.

MECHANISTIC INSIGHTS: RECENT CONTROLLED TRIALS

Recent mechanistic studies have elucidated the physiological basis for these equivalent strength outcomes. A well-controlled randomised trial led by Nicholas Burd at the University of Illinois directly compared muscle protein synthesis rates between mixed whole-food vegan and omnivorous diets in healthy adults undergoing resistance training (Burd et al., 2019). Despite protein intakes of only 1.1-1.2 g/kg/day—toward the lower end of recommendations—no differences in muscle protein synthesis rates emerged between dietary groups over nine days of observation (Burd et al., 2019).

These findings provide crucial mechanistic support for the clinical outcomes observed in larger meta-analyses. The data suggest that concerns about plant protein "*inadequacy*" for muscle maintenance are unfounded when total protein intake is sufficient and amino acid profiles are diverse.

These findings are further supported by a comprehensive 2023 randomized controlled trial in *The Journal of Nutrition*, which demonstrated that omnivorous and vegan diets can support comparable rested and exercised daily myofibrillar protein synthesis rates in healthy young adults consuming a high-protein diet, translating to similar skeletal muscle adaptive responses during prolonged high-volume resistance training, irrespective of dietary protein provenance (Monteyne et al., 2023). This 10-week study involved intensive resistance training and provided definitive evidence that plant-based diets do not compromise muscle adaptation processes.

Additionally, a 2023 systematic review and meta-analysis specifically examining plant-based protein interventions in older adults found positive effects on lean muscle mass accrual and strength over time (Berrazaga et al., 2023), directly addressing concerns about age-related muscle loss on plant-based diets.

CLINICAL RECOMMENDATIONS FOR OPTIMISATION

While evidence indicates that muscle strength is preserved with plant-based diets, specific strategies can further optimise outcomes for patients seeking to maximise muscular health:

Protein quantity

For individuals engaged in regular resistance training, intakes of 1.2–1.6 g protein/kg/day are recommended, which is slightly above the standard reference values to offset the typically lower protein density of plant-based foods (Phillips & Van Loon, 2011).

Protein quality

Clinicians should advise consumption of high-quality plant proteins—such as soy, pea, quinoa, chia seeds, and lentils—which offer more favourable amino acid profiles (Table 2). Notably, soy protein is well supported by evidence as equivalent to animal protein for muscular adaptation (Gorissen & Witard, 2018; Lim et al., 2021).

Table 2. Plant protein source and quality.

Protein source	Typical leucine content	Comments
Soy	High	Comparable to animal protein
Pea	Moderate	Good amino acid profile
Quinoa	Moderate	Complete protein
Chia seeds	Lower	Requires a combination with legumes
Lentils	Moderate	Benefits from complementary sources

Leucine distribution

As leucine is a potent stimulus for muscle protein synthesis but present in lower concentrations in many plant proteins, plant-based eaters should be encouraged to incorporate leucine-rich foods in several meals per day (Churchward-Venne et al., 2012).

Micronutrient vigilance

Monitor and supplement key nutrients that may be lower in plant-based diets, including vitamin B12, iron, zinc, iodine, omega-3 fatty acids, and vitamin D (Craig & Mangels, 2009). These nutrients support overall recovery, immune function, and metabolic health—all critical for maintaining strength capacity.

SPECIAL POPULATIONS AND CLINICAL CONSIDERATIONS

The evolving evidence base strongly supports the inclusion of well-planned plant-based diets (PBDs) in the management of specific patient populations, particularly those with cardiometabolic risk or elevated physical demands. Among patients with metabolic syndrome, hypertension, or dyslipidaemia, the cardiovascular advantages of PBDs are well established. Consumption of animal protein—particularly from red and processed meats—has been linked to higher risk of cardiovascular disease, type 2 diabetes, and all-cause mortality. In contrast, higher intake of plant-based protein is associated with improvements in blood pressure, lipid profiles, and insulin sensitivity, favourably modifying cardiometabolic risk factors (Zhubi-Bakija et al., 2021). Importantly, current data indicate that these diets do not compromise muscular strength or physical function, alleviating a key concern for clinicians managing multimorbid patients who require both metabolic control and preserved mobility (Glenn et al., 2019). Higher plant protein intake, compared to animal protein, is associated with reduced risk of overall and cardiovascular-specific mortality in large, long-term prospective cohorts. Replacing even a small percentage of energy intake from animal protein with plant protein has been linked with meaningful reductions in mortality risk (Huang et al., 2020).

In older adults, who are at increased risk for sarcopenia and functional decline, the potential for anabolic resistance has historically raised concerns about the adequacy of plant-derived proteins. However, recent findings suggest that age-related reductions in muscle protein synthesis (MPS) can be effectively addressed within the context of plant-based nutrition (Coelho-Júnior et al., 2020). A 2021 randomised controlled trial by Monteyne et al. (2021) found that a high-protein, mycoprotein-based vegan diet supported daily myofibrillar protein synthesis rates equivalent to those observed in omnivorous controls. These findings suggest that, when total protein intake and quality are optimised, plant-based diets can support muscle maintenance in

ageing populations. Nevertheless, this population may benefit from dietary strategies that include higher protein doses per meal or enhanced leucine intake to overcome blunted anabolic sensitivity.

Athletes and highly active individuals represent another key group for whom protein adequacy is paramount. Multiple trials have confirmed that plant-based diets preserve muscular strength, power output, and functional recovery in both recreational and elite athletic contexts. In addition to maintaining performance metrics, PBDs may offer unique benefits through their anti-inflammatory and antioxidant properties, potentially facilitating improved recovery kinetics and reduced exercise-induced oxidative stress (Damasceno et al., 2024). A recent 2025 randomised controlled trial further demonstrated that resistance exercise-induced myofibrillar protein synthesis rates were comparable between vegan and omnivorous diets in young adults, including both males and females engaged in structured resistance training (Burd et al., 2025). These findings strengthen the case for the inclusion of plant-based strategies within sports nutrition protocols.

Taken together, the data suggest that plant-based diets, when appropriately planned, are not only safe but potentially advantageous across diverse clinical and performance-oriented populations.

LIMITATIONS AND FUTURE DIRECTIONS

Notwithstanding these robust findings, some limitations should inform clinical interpretation. Most intervention trials to date have been of relatively short duration (up to 12 weeks), and long-term data on strength preservation are still emerging. However, a notable exception is a 2023 controlled pilot study that examined strength performance over 16 weeks in trained individuals transitioning to plant-based diets, finding no effect on strength performance in the first 8 weeks and confirming non-inferiority throughout the study period (Wirnitzer et al., 2023). Elite strength athletes may require more tailored dietary approaches to ensure adequate energy and protein intake. The protein supplementation versus whole-food debate continues to evolve. While protein supplements may simplify the achievement of higher intake targets, whole-food approaches appear equally effective when properly planned and portioned.

CLINICAL BOTTOM LINE

The convergence of evidence from recent systematic reviews and well-controlled RCTs substantiates that properly structured plant-based diets do not impair muscular strength. Health professionals can confidently recommend plant-based dietary patterns to patients, emphasising cardiovascular and sustainability benefits, without concern for compromised strength. With appropriate attention to total protein, quality, and micronutrient sufficiency, plant-based nutrition can fully support muscle maintenance and functional health across diverse individuals.

This evidence-based reassurance, combined with appropriate nutritional guidance regarding protein intake and micronutrient supplementation, empowers clinicians to support patient dietary choices while maintaining focus on functional health outcomes. As the body of evidence continues to mature, plant-based nutrition increasingly represents a viable, health-promoting dietary strategy that preserves the muscular strength essential for healthy ageing and active lifestyles. Patients considering plant-based transitions should be encouraged by robust data showing no loss in strength or function, provided diets are thoughtfully planned.

AUTHOR CONTRIBUTIONS

Aniket V. Inamdar conceptualised the study, designed the review framework, and provided overall guidance throughout manuscript development. Aniket V Inamdar and Yashendra Sethi conducted the literature search, extracted relevant data, and drafted the initial manuscript. Aniket V Inamdar and Umesh Sharma critically revised the manuscript for intellectual content, policy relevance, and clinical applicability. All authors contributed to the interpretation of findings, approved the final version of the manuscript, and agreed to be accountable for all aspects of the work.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

CODE OF ETHICS

This review complies with the ethical standards for narrative reviews and aligns with the principles outlined in IR.MUI.NUREMA.REC.1401.175.

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