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Ultra-processed foods and sarcopenic obesity among adults living in urban slums of India: a narrative review using the India-adapted NOVA framework

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Systematic Review

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Abstract

Background

Sarcopenic obesity is the coexistence of low muscle mass and function with excess body fat. It carries a higher risk of diabetes, disability and early death than either condition alone. At the same time, ultra-processed foods (UPFs) such as packaged biscuits, chips, instant noodles, sliced bread and sugary drinks are rapidly entering Indian diets. Adults living in urban slums may be especially exposed to both problems, yet they are rarely studied.

Aim

This narrative review brings together current evidence on the link between UPF consumption and sarcopenic obesity, and asks what this evidence means for adults living in India's urban slums. We pay special attention to the NOVA food classification and its recent adaptation for the Indian food environment.

Main findings:

Indian adults carry more body fat and less muscle at the same body mass index than many other populations, and the prevalence of sarcopenia in India is high. Work from India has now mapped UPFs for the Indian market and validated a short 24-item Nova-UPF Screener. Studies from other countries link higher UPF intake with low muscle mass, weak grip strength, frailty and, in one recent study, higher odds of sarcopenic obesity. Possible pathways include protein dilution, overeating, low-grade inflammation, insulin resistance and changes in gut bacteria. However, almost all of this evidence comes from outside India, most of it is cross-sectional, and no published study has examined UPF intake and sarcopenic obesity together in an Indian slum population.

Conclusion

The link between UPFs and sarcopenic obesity is biologically plausible and supported by early evidence, but it remains unproven for Indian slum dwellers. Community-based studies using India-specific tools for both muscle health and UPF intake, ideally with longitudinal and qualitative components, are urgently needed to guide prevention.

Introduction

Most of us picture an undernourished person as thin and an overnourished person as heavy. Real life, especially in low-income urban India, is often more complicated. Many adults today carry too much fat and too little muscle at the same time. When low muscle mass and poor muscle function occur together

with excess body fat, the condition is called sarcopenic obesity [1, 2]. It is more than a cosmetic or ageing issue. People with sarcopenic obesity tend to have more insulin resistance, more disability and a higher risk of type 2 diabetes and heart disease than people who have only obesity or only sarcopenia [1, 3, 4].

Globally, about 11% of older adults are estimated to have sarcopenic obesity [5]. Indian data are scarce, but one hospital-based study found sarcopenic obesity in about 30% of adults with type 2 diabetes [6]. These numbers matter because India already has more than 100 million people living with diabetes [7].

Diet is one of the few causes of sarcopenic obesity that we can change. Over the last two decades, the way people eat has shifted, with more and more energy coming from ultra-processed foods (UPFs). Under the NOVA classification, UPFs are industrial formulations made mostly from refined substances and additives, with little or no whole food in them [8]. Common examples in India include packaged biscuits, chips and namkeens, instant noodles, sliced bread, sugary drinks and confectionery [9]. Large reviews link high UPF intake with obesity, type 2 diabetes, heart disease and early death [10]. Sales of these products are growing fastest in middle-income countries such as India [11].

Urban slums sit where these two trends meet. About one in six urban Indians was living in a slum at the last census [12]. People living in slums often face crowded housing, insecure jobs, long working hours and poor access to fresh, affordable food [13]. Cheap packaged snacks and street foods fill the gap. At the same time, undernutrition has not disappeared; it now sits alongside rising overweight, sometimes within the same household [14]. This “double burden” provides fertile ground for a body that is both under-muscled and over-fat.

Until recently, a practical problem held back Indian research on UPFs: there was no agreed way to identify them in the Indian diet. Two recent studies have changed this. The first mapped UPFs available in India and grouped them into food categories [9]. The second developed and validated the Nova-UPF Screener (for India), a short 24-item tool that can be used in community surveys [15]. For simplicity, we refer to this India-specific application of NOVA as the “India-adapted NOVA framework” in this review.

The aim of this narrative review is to bring together evidence on (i) sarcopenic obesity and how it is defined and measured in Indian adults, (ii) UPFs and how they are classified in India, (iii) why urban slum residents may be at special risk, (iv) the evidence linking UPF consumption to muscle health and sarcopenic obesity, and (v) the likely biological pathways. We end by identifying research gaps and practical steps for public health.

Methods

This is a narrative review. We did not aim to perform a systematic review or meta-analysis. We searched PubMed/MEDLINE, Scopus and Google Scholar for English-language articles published mainly between January 2015 and September 2026. Search terms were combined using Boolean operators and included “sarcopenic obesity”, “sarcopenia”, “muscle mass”, “handgrip strength”, “ultra-processed food”, “NOVA”,

“processed food”, “urban slum”, “informal settlement”, “low-income”, “India” and “South Asia”. Reference lists of key papers were also checked.

We gave priority to systematic reviews, meta-analyses, consensus statements, large population studies and studies from India and South Asia. A small number of older papers were included where they remain the standard reference for a definition or a classification. Because the evidence base is still small and diverse, findings are summarised in narrative form rather than pooled.

Sarcopenic obesity: definitions and the Indian picture

What is sarcopenic obesity?

Sarcopenia is the gradual loss of skeletal muscle mass and strength. It was first seen as a disease of old age, but it can begin in middle age and can be speeded up by inactivity, chronic disease and poor diet [16,17]. The European (EWGSOP2) and Asian (AWGS 2019) working groups now treat low muscle strength as the main warning sign, with low muscle mass used to confirm the diagnosis and poor physical performance used to judge severity [16,18].

Sarcopenic obesity adds excess body fat to this picture. For many years, studies used different definitions, which made results hard to compare [3]. In 2022, the European Society for Clinical Nutrition and Metabolism (ESPEN) and the European Association for the Study of Obesity (EASO) published the first joint consensus. It recommends a two-step process: screening using a high body mass index (BMI) or waist circumference together with a clinical suspicion or a questionnaire such as SARC-F, and diagnosis based on low muscle strength, altered body composition (high fat percentage plus low muscle mass) and, where possible, assessment of physical function [2].

Why the Indian body is different

A key issue for India is that most cut-offs were developed in European and East Asian populations. South Asians tend to have less muscle and more body fat, especially around the abdomen and in the liver, at any given BMI [19]. This is sometimes called the “thin-fat” phenotype. It means that a person can look normal on the weighing scale while already having an unhealthy fat-to-muscle ratio. BMI alone therefore misses many cases.

Two regional documents address this problem. The South Asian Working Action Group on SARCOpenia (SWAG-SARCO) proposed a stepwise screening and diagnostic framework suited to South Asian populations, including the use of bioelectrical impedance analysis (BIA) for community screening [20]. More recently, an Indian consensus on sarcopenia proposed India-specific cut-offs: handgrip strength below 27.5 kg in men and 18.0 kg in women, and skeletal muscle index below 7.0 kg/m^2 in men and 5.7 kg/m^2 in women [21]. Importantly, this consensus also noted that formal Indian criteria for sarcopenic obesity have not yet been defined [21]. Researchers in India therefore have to combine Indian sarcopenia

cut-offs with fat-mass thresholds borrowed from the ESPEN–EASO framework, and they should report their choices clearly.

How common is the problem in India?

A 2026 meta-analysis of 44 Indian studies reported a pooled prevalence of confirmed sarcopenia of 35.4%, though this fell to 18.3% in community samples and rose to 42.2% in hospital samples [22]. The authors also found wide variation by diagnostic criteria and rated the certainty of evidence as low to very low [22]. They did not pool sarcopenic obesity data. In a community study of 745 adults aged 40 years and above from Western India, about 10% had sarcopenia. Rural residence, older age, low protein intake and lower socioeconomic status were linked to higher risk [23]. These findings suggest that the poor are not protected from muscle loss and may in fact be more exposed.

Direct community data on sarcopenic obesity in India remain very limited. The hospital-based figure of 30% among adults with diabetes [6] is striking, but we could not find any published estimate for adults living in urban slums. This is a clear gap.

Why it matters: the link with diabetes

Muscle is the main site where the body disposes of glucose after a meal. When muscle mass and quality fall, glucose uptake falls too. Fat tissue, especially visceral fat, releases inflammatory signals and free fatty acids that worsen insulin resistance. Together, these changes make sarcopenic obesity a strong risk state for type 2 diabetes [3,24]. A recent prospective cohort from China found that sarcopenic obesity was linked with a higher risk of prediabetes and diabetes, measured by both fasting glucose and HbA1c, even after adjusting for other risk factors [25]. The relationship also seems to run in the other direction, as high blood sugar can speed up muscle loss [24].

This matters greatly for India. The ICMR-INDIAB study estimated that 101 million Indians have diabetes and 136 million have prediabetes [7]. In urban India, the pooled prevalence of type 2 diabetes rose from about 13% in 2000–2005 to about 21% in 2021–2025, while abdominal obesity rose even more sharply [26]. A recent multi-state study that included urban slum populations found diabetes in about one in five adults and hypertension in more than two in five [27]. Slum communities are clearly not spared.

Ultra-processed foods and the India-adapted NOVA framework

The NOVA classification in brief

NOVA groups foods by the extent and purpose of industrial processing, rather than by nutrients [8,28]. It has four groups:

- **Group 1 – Unprocessed or minimally processed foods:** for example, rice, wheat flour (atta), dals, fresh vegetables and fruits, milk, eggs, meat and fish.
- **Group 2 – Processed culinary ingredients:** for example, oils, ghee, sugar, jaggery and salt, used in home cooking.
- **Group 3 – Processed foods:** simple products made by adding salt, sugar or oil to Group 1 foods, such as some pickles, canned vegetables and freshly made bread.
- **Group 4 – Ultra-processed foods:** industrial formulations with ingredients rarely used in home kitchens, such as hydrogenated fats, protein isolates, maltodextrin, flavour enhancers, colours, emulsifiers and sweeteners [8].

Table 1 gives examples of common Indian foods in each group.

Adapting NOVA to the Indian kitchen

Applying NOVA in India is not straightforward. Indian diets include many traditional snacks and sweets that can be home-made, sold loose by local vendors or sold in branded packets with added emulsifiers and flavours. The same “namkeen” can therefore fall into different NOVA groups depending on how it is made. A formative study by Ghosh-Jerath and colleagues found that Indian research and policy documents used terms such as “junk food”, “fast food”, “packaged food” and “HFSS foods” loosely and interchangeably, without a uniform definition of UPFs [9]. By reviewing the literature and checking ingredient lists of 375 brands on an online grocery platform, they confirmed 81 food items as UPFs and grouped them into 23 categories. Breads, chips and sugary drinks were the most preferred by consumers. Notably, some packaged versions of traditional recipes also contained ultra-processed ingredients [9].

Building on this work, the same group developed the Nova-UPF Screener (for India) [15]. It asks about 24 UPF categories eaten “yesterday”, grouped as ready-to-eat items (such as biscuits, sliced bread, chocolates, namkeens and chips, ice creams, cakes and sauces), ready-to-cook items (such as instant noodles and soups, ready mixes and frozen snacks) and beverages. Each “yes” earns one point, giving a score of 0 to 24. A score of 5 or more corresponded to roughly a quarter or more of daily energy from UPFs on a 24-hour recall. The screener was found to be a quick and culturally suitable way to measure UPF intake in Indian adults [15]. For large community studies, especially in low-literacy settings where detailed dietary recalls are hard to do, this is a big step forward.

How much UPF do Indians eat?

Population-level data on UPF intake in India are still limited. Analysis of the South Asia Biobank found that among consumers, UPFs supplied about 13% to 17% of daily energy across the four countries studied [29]. Within India, about three in four respondents in the north had eaten at least one UPF in the previous 24 hours, compared with about two in five in the south. In North India, UPF intake was higher

among richer and better-educated people, whereas in South India the pattern was reversed, with higher intake among lower-income groups [29]. This suggests that UPFs are no longer a “rich person’s food” in all parts of India. As markets mature, cheap UPFs tend to spread to poorer groups, a pattern also seen in Latin America and elsewhere [11,30].

Indian diets were already low in quality protein before the UPF wave. An analysis of national consumption data showed that protein-rich foods supplied only 6% to 8% of total calories in Indian diets, compared with 29% in the EAT-Lancet reference diet. The gap was widest among the poorest households, and the average household got more calories from processed foods than from fruit [31]. Diets that are high in refined cereals and low in protein are a poor foundation for muscle health, and adding UPFs on top of such diets may make things worse.

Why urban slums deserve special attention

Slums are not just poor neighbourhoods. They share features such as crowding, poor housing, limited water and sanitation, insecure land tenure and informal work, and these features affect health beyond the effect of income alone [13]. Several of these features are directly relevant to diet and muscle health.

Food environment. Slum residents often depend on small kiosks, street vendors and local shops. A study of food environments in a Delhi slum and nearby rural villages found that commonly sold snacks contained about 30 g of fat per 100 g, and the cooking oils used were high in saturated and trans fats [32]. Many snacks were sold in unlabelled packets or open jars, so buyers had no information on what they were eating [32]. Packaged UPFs in small, low-priced sachets and packs are easy to buy on a daily wage.

Time and money. Long working hours, lack of kitchen space and fuel costs push families towards ready-to-eat foods. UPFs are cheap per calorie, have a long shelf life, need no refrigeration and require little or no cooking. For a family with limited time and money, these are rational choices, even if they are unhealthy ones.

The double burden. National analyses show that undernutrition and overweight now coexist in Indian households and that overweight is rising in all wealth groups [14]. In slums, early-life undernutrition, low protein intake and heavy manual work in youth may be followed by a shift to sedentary jobs and energy-dense diets in adulthood. This combination may favour the thin-fat body type described above [19].

Physical activity. Many slum residents do physically demanding work, but this is not the same as the regular resistance-type activity that maintains muscle. Women in particular may spend most of their time at home with low physical activity. Lack of safe open spaces limits exercise further [13].

Access to care. Screening for diabetes, obesity and muscle health is often patchy in slums, and services are rarely designed around the working hours and living conditions of residents [13,33].

Taken together, these factors make it likely that adults in urban slums face both high UPF exposure and high risk of sarcopenic obesity. Yet, to our knowledge, no published study has measured both in this population.

Evidence linking ultra-processed foods with muscle health and sarcopenic obesity

The evidence linking UPFs with muscle outcomes is new and growing fast. Table 2 summarises key studies. We discuss it under three headings.

UPFs and obesity

The link between UPFs and excess body fat is the best established part of the chain. Meta-analyses of observational studies show that higher UPF intake is associated with higher odds of overweight, obesity and abdominal obesity [34], and an umbrella review of 45 pooled analyses covering nearly 10 million participants found consistent associations of UPF exposure with obesity, type 2 diabetes and all-cause mortality, among 32 health outcomes [10]. Experimental evidence supports a causal role. In a tightly controlled inpatient trial, adults offered an ultra-processed diet ate about 500 kcal more per day and gained about 0.9 kg in two weeks, compared with when they were offered an unprocessed diet matched for presented calories, sugar, fat, fibre and salt [35].

UPFs and muscle mass, strength and frailty

Evidence on muscle is more recent. In a nationally representative US sample of 10,255 adults aged 20 to 59 years, those in the highest quarter of UPF intake had 60% higher odds of low muscle mass than those in the lowest quarter (odds ratio [OR] 1.60, 95% confidence interval [CI] 1.13–2.26) [36]. This finding is important because it shows the link is present before old age. In a Spanish cohort of older adults, higher UPF intake predicted a higher risk of developing frailty during follow-up [37]. In community-dwelling older adults in Iran, higher UPF intake was linked with lower muscle strength in women and poorer physical performance in men, although not with overall sarcopenia [38].

A 2025 systematic review and dose–response meta-analysis pooled 29 observational studies [39]. In cohort studies, higher UPF intake was linked with a 40% higher risk of frailty (relative risk [RR] 1.40, 95% CI 1.25–1.58), and each additional 100 g of UPF per day was linked with a 3% higher risk. In cross-sectional studies, higher UPF intake was linked with low muscle strength (RR 1.13, 95% CI 1.06–1.20), but not with sarcopenia or low muscle mass as such [39]. These mixed results probably reflect the small number of studies, differences in how sarcopenia was defined and the difficulty of measuring UPF intake.

UPFs and sarcopenic obesity

Only a handful of studies have looked at sarcopenic obesity directly. In a Korean community study of 535 adults aged 40 to 60 years, people with both abdominal obesity and probable sarcopenia ate more UPFs and fewer minimally processed foods than healthy controls. Each step up in quarter of UPF intake was associated with 37% higher odds of this sarcopenic obesity phenotype (OR 1.37, 95% CI 1.02–1.84) [40]. Notably, the authors used a Korean adaptation of NOVA, which is a useful model for Indian researchers using the India-adapted framework. Mechanistic reviews have also argued that UPFs may speed up the age-related appearance of sarcopenia, both directly and by promoting obesity [41].

We did not find any study from India, or from any urban slum population, that examined UPF intake and sarcopenic obesity together.

How might ultra-processed foods harm muscle while adding fat?

Several biological pathways could explain why UPFs might push the body towards sarcopenic obesity. They are summarised in Table 3 and described briefly below.

Protein dilution and overeating. UPFs are typically rich in refined starch, sugar and fat but poor in protein. The “protein leverage” idea suggests that people continue eating until they meet their protein need. When the diet is protein-poor, they may overshoot their energy needs. Data from the United States support this: as the UPF share of the diet rose, protein density fell and total energy intake rose [42]. The result is both too little protein for muscle and too much energy for fat. In India, where protein intake is already low [31], this effect may be stronger.

Poor micronutrient and antioxidant intake. UPFs often replace foods rich in fibre, vitamins and minerals. Low intake of antioxidants, vitamin D, magnesium and other micronutrients has been linked with poor muscle function [41].

Low-grade inflammation. Diets high in UPFs have been linked with higher levels of inflammatory markers [43]. Chronic inflammation drives muscle protein breakdown and blocks muscle repair, while also promoting fat gain. This shared inflammatory state is thought to be central to sarcopenic obesity [1,17].

Insulin resistance. Higher UPF intake is associated with a higher risk of type 2 diabetes [10,44] and with altered glucose regulation in young adults [45]. Insulin resistance reduces the anabolic effect of insulin on muscle, and high glucose levels damage muscle quality over time [24]. Fat infiltration into muscle further worsens both strength and insulin action [3].

Gut microbiota. Some additives used in UPFs, such as emulsifiers, may disturb the gut microbiota. In a controlled feeding study, the emulsifier carboxymethylcellulose reduced the diversity of gut bacteria and changed the metabolites they produced [46]. Changes in the gut microbiota are being studied as one route through which diet affects inflammation and muscle (the "gut–muscle axis"), but human evidence is still early.

Lifestyle clustering. People who eat more UPFs may also sit more, sleep less and smoke more. Some of the associations seen in observational studies may reflect this wider lifestyle pattern rather than the food itself. Good studies need to measure and adjust for these factors.

Research gaps

Our review highlights several gaps that future studies, particularly in India, should address.

1. **No data from urban slums.** We found no published study on UPF intake and sarcopenic obesity among adults in Indian urban slums, even though this group may be among the most exposed.
2. **No Indian definition of sarcopenic obesity.** India now has sarcopenia cut-offs [21], but not sarcopenic obesity criteria. Studies should report clearly which muscle and fat thresholds they use and, where possible, show results under more than one definition.
3. **Measurement of UPF intake.** The Nova-UPF Screener for India [15] makes large community studies possible. Its performance in slum populations, in regional languages and in older adults with lower literacy still needs to be checked. Loose foods sold by vendors are harder to classify than branded products [9].
4. **Mostly cross-sectional evidence.** Most studies measure diet and muscle at the same time. Longitudinal and intervention studies are needed to show whether UPF intake comes before muscle loss and fat gain.
5. **The glycaemic link.** Few studies have looked at UPFs, sarcopenic obesity and blood glucose together, even though the three are closely connected [24,25].
6. **Why people eat UPFs.** Numbers alone cannot explain why slum residents choose UPFs. Qualitative studies on cost, time, taste, marketing, cooking facilities and social norms would help design interventions that actually fit people's lives. Mixed-methods designs are well suited to this.
7. **Women and middle-aged adults.** Most sarcopenia research focuses on older adults. Yet muscle loss and fat gain begin earlier, and the Kong study showed links in adults under 60 [36]. Women in slums, who may have low protein intake and low physical activity, deserve particular attention.

Implications for public health practice

While research continues, some practical steps are reasonable now, as they are low-risk and likely to bring wider benefits.

- **Use simple screening in primary care.** Handgrip strength, waist circumference and, where available, BIA can be added to existing NCD screening at urban primary health centres and Ayushman Arogya Mandirs. A short UPF screener can be used alongside them.
- **Shift dietary messages from "eat less" to "eat better".** Advice to people with obesity in slums should protect muscle. That means encouraging affordable protein sources such as dals, chana, soybean, eggs and milk, while reducing packaged snacks and sugary drinks.
- **Promote muscle-strengthening activity.** Simple home-based resistance exercises that need no equipment can be taught by community health workers.
- **Support food policy.** Clear front-of-pack warning labels, limits on marketing of UPFs and taxes on sugary drinks have slowed UPF growth elsewhere [30]. India's ongoing debate on front-of-pack labelling should consider low-literacy users in slums. Making healthy foods available through the Public Distribution System and other schemes could also help.
- **Involve communities.** Slum improvement programmes work best when residents take part in planning [33]. Nutrition and exercise programmes should be co-designed with the people they are meant to help.

Strengths and limitations of this review

This review brings together, for the first time to our knowledge, evidence on UPFs, sarcopenic obesity and the urban slum setting in India, and it draws on the new India-specific NOVA tools. However, it is a narrative and not a systematic review. Study selection may have been influenced by our judgement, and we did not formally assess study quality. Most of the evidence on UPFs and muscle comes from high-income and East Asian countries, and may not fully apply to Indian slum populations. Different definitions of sarcopenia, sarcopenic obesity and UPF intake across studies make direct comparisons difficult.

Conclusion

Adults living in India's urban slums face a double threat. Their diets are increasingly shaped by cheap ultra-processed foods, and their bodies may be prone to losing muscle while gaining fat. Evidence from other countries suggests that UPFs may contribute to low muscle mass, weak muscles, frailty and sarcopenic obesity through protein dilution, overeating, inflammation and insulin resistance. However, the Indian evidence is almost absent. With the new India-adapted NOVA tools and Indian sarcopenia cut-offs now available, well-designed community studies in urban slums are both possible and urgently needed. Their findings could help protect not only the waistline but also the muscles of some of India's most vulnerable adults.

Declarations

Conflicts of interest:

The author(s) declare no conflicts of interest.

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Dr. Sameena Ahmad is the sole author of this manuscript and was responsible for conceptualization, literature search, data synthesis, interpretation of findings, and preparation of the manuscript. The author has reviewed and approved the final version of the manuscript and takes full responsibility for its content.

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Tables

Table 1. Examples of common foods in India classified by the NOVA framework [8,9,15]

NOVA group	What it means	Examples in Indian diets
Group 1: Unprocessed / minimally processed	Natural foods, or foods only cleaned, dried, milled, boiled or pasteurised	Rice, atta, dals, chana, rajma, fresh vegetables and fruits, milk, curd, eggs, fresh meat and fish, plain roasted chana
Group 2: Processed culinary ingredients	Substances taken from foods or nature, used to cook Group 1 foods	Mustard and other vegetable oils, ghee, butter, sugar, jaggery, salt
Group 3: Processed foods	Group 1 foods with added salt, sugar or oil, made by simple methods	Home-style pickles (achar), salted paneer, canned vegetables, freshly baked bakery bread made with few ingredients
Group 4: Ultra-processed foods	Industrial formulations with additives such as emulsifiers, flavours, colours, sweeteners, hydrogenated fats	Packaged biscuits and cookies, chips and branded namkeens, instant noodles and soups, sliced packaged bread, buns and rusks with additives, carbonated and sugary drinks, packaged fruit drinks, chocolates and candies, ice creams, ketchup and instant gravies, frozen ready-to-cook snacks, fast-food items

Note: Some traditional foods (for example namkeens, sweets and breads) can fall into different groups depending on whether they are made at home, sold loose or produced industrially with additives. Ingredient lists should be checked where available [9].

Table 2. Selected studies on ultra-processed food intake and muscle-related outcomes or sarcopenic obesity

Study (year)	Country / setting	Design and sample	UPF measure	Main finding
Kong et al. (2024) [36]	USA (NHANES 2011–2018)	Cross-sectional; 10,255 adults aged 20–59 years	% energy from UPF (NOVA)	Highest vs lowest quartile: OR 1.60 (1.13–2.26) for low muscle mass
Jang et al. (2026) [40]	South Korea, rural community	Cross-sectional; 535 adults aged 40–60 years	FFQ, Korean-adapted NOVA	Each quartile increase in UPF: OR 1.37 (1.02–1.84) for sarcopenic obesity phenotype
Hallajzadeh et al. (2025) [38]	Iran, community	Cross-sectional; 368 adults aged ≥60 years	FFQ, NOVA	UPF linked with low muscle strength (women) and poor physical performance (men); no link with overall sarcopenia
Sandoval-Insausti et al. (2020) [37]	Spain, Seniors-ENRICA cohort	Prospective cohort; older adults	Diet history, NOVA	Higher UPF intake associated with higher risk of incident frailty
Hojjati Kermani et al. (2025) [39]	Multiple countries	Systematic review and dose–response meta-analysis; 29 studies	Various	Frailty RR 1.40 (1.25–1.58); low muscle strength RR 1.13 (1.06–1.20); no significant pooled link with sarcopenia or low muscle mass
—	India / urban slums	No published study identified	—	Evidence gap

Abbreviations: FFQ, food frequency questionnaire; NHANES, National Health and Nutrition Examination Survey; OR, odds ratio; RR, relative risk; UPF, ultra-processed food.

Table 3. Proposed pathways linking ultra-processed food consumption with sarcopenic obesity

Pathway	Effect on muscle	Effect on fat	Key sources
Protein dilution and protein leverage	Low protein intake limits muscle protein synthesis	Higher total energy intake	[31,42]
High energy density, fast eating	—	Passive overeating and weight gain	[35]
Low micronutrient and antioxidant intake	Poorer muscle function and repair	—	[41]
Low-grade inflammation	Increased muscle breakdown	Fat gain and fat infiltration into muscle	[1,43]
Insulin resistance and hyperglycaemia	Reduced anabolic signals, poorer muscle quality	Fat storage, especially visceral	[24,44,45]
Additives and gut microbiota	Possible effects through the gut–muscle axis	Possible metabolic effects	[46]