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Nutritional Transition, Ultra-Processed Food Consumption, and Metabolic Syndrome Risk Among Adolescents in Urban Pakistan

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Abstract

Adolescence represents a critical developmental period characterized by elevated nutritional demands and heightened vulnerability to dietary transitions. In urban Pakistan, approximately 40 million adolescents are experiencing a rapid nutritional shift driven by urbanization, aggressive digital food marketing, and poorly regulated school food environments. Traditional diets are increasingly being replaced by ultra-processed foods (UPFs), while sedentary lifestyles further exacerbate the rising burden of overnutrition. This review examines the double burden of malnutrition (DBM), the mechanistic links between UPF consumption and metabolic syndrome (MetS), and the limitations of current diagnostic frameworks in capturing cardiometabolic risk in South Asian adolescents. This narrative review synthesizes evidence on dietary patterns among Pakistani youth, obesogenic school environments, and the biological mechanisms underlying UPF-induced metabolic dysfunction. It also evaluates existing pediatric MetS diagnostic criteria in relation to the South Asian phenotype. Evidence indicates a simultaneous rise in overweight, obesity, and persistent undernutrition among urban adolescents in Pakistan. A substantial proportion of schoolchildren rely on school canteens where energy-dense, nutrient-poor foods are widely available, contributing to increased UPF consumption. Mechanistically, UPFs promote metabolic dysregulation through glycemic instability, hyperinsulinemia, and ectopic fat accumulation. They also disrupt gut microbiota composition by reducing dietary fiber intake and depleting short-chain fatty acid production, while food additives may compromise intestinal barrier integrity, contributing to systemic inflammation and metabolic endotoxemia. Genetically mediated susceptibility, including high rates of consanguinity and a distinct South Asian phenotype, predisposes Pakistani youth to insulin resistance and visceral adiposity at lower BMI thresholds. Consequently, conventional diagnostic criteria, such as those proposed by the IDF, may underestimate true risk, whereas alternative measures (modified NCEP-ATP III and waist-to-height ratio) indicate substantially higher prevalence of MetS in adolescents.

1. Introduction

Adolescence represents a critical developmental window characterized by accelerated physical, cognitive, and psychosocial growth. During this transitional phase, metabolic

demands escalate significantly, with individuals acquiring approximately 20% of their adult height, 50% of their adult body weight, and 50% of their peak bone mass (Dahl et al., 2018). Consequently, adequate macro- and micronutrient intake is paramount to sustain physiological systems and prevent long-term chronic ailments. However, the nutritional landscape of low- and middle-income countries (LMICs), particularly in South Asia, is undergoing a rapid, dysregulated transformation (Bruins et al., 2019). In Pakistan, where adolescents constitute approximately 23% of the population representing an estimated 40 million individuals this demographic is increasingly exposed to the adverse effects of urbanization, technological mechanization, and shifting food systems. This societal shift has catalyzed a profound "nutritional transition" characterized by a departure from traditional, minimally processed diets toward highly processed, energy-dense, and nutrient-poor options (Sathar et al., 2016). Concurrently, physical inactivity and sedentary behaviors have become highly prevalent among urban youth, driven by increased screen time and a lack of safe recreational infrastructure (Sallis et al., 2016).

The intersection of these lifestyle alterations has led to an alarming rise in metabolic syndrome (MetS) among urban Pakistani adolescents. MetS is a complex cluster of interconnected cardiometabolic risk factors including central obesity, hypertension, dyslipidemia, and impaired glucose tolerance that directly predisposes individuals to type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD) in adulthood. Understanding the metabolic risk of South Asian youth requires a nuanced approach due to the unique "South Asian phenotype" (Sheikh et al., 2026). This phenotype is characterized by a high predisposition to visceral adiposity, profound insulin resistance, and atherogenic dyslipidemia at a lower body mass index (BMI) compared to Western cohorts. This review paper examines the nutritional transition, quantifies the patterns and socio-environmental drivers of ultra-processed food (UPF) consumption, dissects the underlying biological mechanisms linking UPFs to metabolic dysfunction, and evaluates the prevalence and predictors of MetS among adolescents in urban Pakistan (Choe et aql., 2026).

2. Demographic Profile and the Double Burden of Malnutrition

The rapid progression of the nutritional transition in urban Pakistan has created a complex epidemiological phenomenon known as the double burden of malnutrition (DBM). This refers to the paradoxical coexistence of undernutrition (manifesting as stunting, wasting, and thinness) and overnutrition (manifesting as overweight and obesity) within the same population, household, or even the same individual (Farooq et al., 2025). While historic public health interventions in Pakistan have focused almost exclusively on maternal and child undernutrition, national surveys now indicate an escalating crisis of overnutrition that demands equal priority (Bhattacharjee et al., 2026). The scale of overnutrition in the broader population is underscored by global comparisons. According to global data, Pakistan ranks 165th out of 194 countries in terms of obesity and overweight issues, with more than 22.2% of individuals in Pakistan aged years exceeding the obesity threshold. This rate is higher than neighboring South Asian nations, including India (ranked 176th with a rate of 16.2%) and Afghanistan (ranked 179th with a rate of 15.1%). This trend is directly reflected in the younger cohorts (Khaliq et al., 2025). Data from the Pakistan National Nutrition Survey (NNS) 2018 reveal that overweight and obesity have risen steadily across all age groups. Among adolescent girls aged 10 to 19 years, the prevalence of overweight stands at 11.4%, compared to 10.2% among boys. Obesity affects approximately 7.7% of adolescent boys and 5.5% of adolescent girls nationally, with the burden being disproportionately concentrated in urban centers due to altered food environments and sedentary habits (Rehan & Sania, 2025).

At the same time, persistent undernutrition remains highly prevalent, illustrating the stark realities of the double burden of malnutrition (DBM) across different socio-demographic strata. A pooled analysis of Pakistani children and adolescents aged

5 to 15 years demonstrates an underweight prevalence of 25.1%, stunting of 23.0%, and wasting of 24.0%. In rural and rural-urban transition zones, such as the Tando Muhammad Khan (TMK) district, a representative study of 1,159 adolescents revealed an underweight prevalence of 18.3% (95% CI: 15.0–20.0%) and an overweight/obesity prevalence of 4.2% (95% CI: 3.0–5.0%) (Saxena et al., 2025). Multinomial logistic regression from this cohort identified that working adolescents (adjusted odds ratio [aOR] = 1.61, 95% CI: 1.01–2.50), lack of handwashing supplies (aOR = 1.47, 95% CI: 0.99–2.20), inadequate sleep (aOR = 1.86, 95% CI: 1.34–2.59), and mild to moderate depression (aOR = 1.76, 95% CI: 1.04–3.00) were significant risk factors for underweight, whereas being female (aOR = 0.57, 95% CI: 0.40–0.80) acted as a protective factor (Kreslake et al., 2025). Conversely, snacking between meals emerged as a strong risk factor for overweight/obesity (aOR = 2.00, 95% CI: 0.99–4.20), while larger family size (aOR = 0.44, 95% CI: 0.24–0.80) was protective (Giri et al., 2026).

This gendered and socio-demographic disparity is also evident in targeted adolescent studies. A pilot study focusing on school-going adolescent girls ($n = 84$) found an alarming underweight burden of 86.9%, with a mean weight of 34.4 ± 6.9 kg, a mean height of 143.9 ± 8.1 cm, and a mean body mass index (BMI) of only 16.4 ± 2.2 kg/m², highlighting extreme developmental vulnerability (Bahar et al., 2025).

The social and family dynamics surrounding child weight further complicate public health interventions. A cross-sectional study of 191 mothers conducted across medical centers in Karachi and Multan revealed that among their children (aged 5 to 15 years), 27.7% were obese and 21.5% were overweight. While these mothers possessed moderate knowledge (60.5%) regarding the long-term health risks of childhood obesity (with 75.4% recognizing long-term health risks and 62.8% associating it with diabetes), their capacity to implement healthy dietary practices was severely constrained by social and cultural pressures (Savcı & Yalçın, 2025). Specifically, 96.9% of the mothers reported witnessing the social stigmatization of obese children, yet 79.6% felt intense pressure from relatives and family members to overfeed their children, illustrating a cultural environment where childhood plumpness is still widely equated with health and prosperity (Ispas et al., 225).

Table 1: Anthropometric and Sociodemographic Predictors of Malnutrition in Urban and Rural-Transition Pakistani Cohorts

Study Location / Population	Sample Size & Demographics	Underweight / Thinness Prevalence	Overweight / Obesity Prevalence	Key Risk & Protective Factors (aOR / Percentages)
National Adolescent Survey	Representative national sample (10–19 years)	Significant regional variation	Girls: 11.4% overweight, 5.5% obese; Boys: 10.2% overweight, 7.7% obese	Shifting dietary habits, sedentary lifestyle common across urban/rural divides
Tando Muhammad Khan (TMK)	$n =$ 1,159 adolescents (10–19 years)	18.3% (95% CI: 15.0–20.0%)	4.2% (95% CI: 3.0–5.0%)	Underweight risk: working (aOR = 1.61), no soap (aOR = 1.47), poor sleep (aOR = 1.86), depression (aOR = 1.76); Overweight

				risk: snacking (aOR = 2.00); family size ≥5 was protective (aOR = 0.44)
Adolescent Girls Pilot	$n =$ 84 school-going girls	86.9% (Mean BMI: 16.4 ± 2.2 kg/m²)	0.0% (13.1% had normal BMI)	Severe developmental stunting and chronic energy deficiency; requires targeted school nutrition education
Multan & Karachi Maternal KAP	$n = 191$ mothers of children (5–15 years)	Not assessed	21.5% overweight, 27.7% obese	79.6% of mothers experienced familial pressure to overfeed; 96.9% witnessed obesity-related stigmatization

3. The Nutritional Transition and School Food Environments

The rapid shift in adolescent dietary patterns is heavily mediated by the micro-environments where they spend their formative years, primarily the school and the home. Dietary records of high school students in urban localities, such as Sialkot, show that adolescents fail to meet the estimated average requirements (EAR) or recommended daily allowances (RDA) for vital micronutrients (Wiesli, 2025). An evaluation of 328 high school students (46.67% female and 53.33% male; mean age 14.3 years) demonstrated that although macronutrient energy distribution was similar between sexes comprising 12.5% protein, 51.5% carbohydrates, and 36.3% fat female adolescents had a significantly lower total energy intake than males ($p < 0.001$) and failed to meet the RDA for vitamins A, C, D, and E, as well as calcium, iron, zinc, potassium, and magnesium. Conversely, males exhibited higher consumption of carbohydrates, sugars, and total fats, while females consumed significantly higher amounts of caffeine (Katie, 2025).

This nutritional deficit is exacerbated by the highly commercialized food options available within urban educational institutions. Observational research in Pakistani schools reveals that 83% of children do not bring a home-cooked lunch to school, relying instead on food purchased from canteens or surrounding vendors. Furthermore, 67% of students buy their lunch directly at school canteens one to three times per week, and 44% consume fast food during school hours at least one to three times per week (Falak et al., 2025).

A significant structural driver of this behavior is school policy: approximately 31% of urban schools permit commercial fast-food chain restaurants to operate outlets directly inside school premises during recess hours. Additionally, schools organize social and recreational trips to fast-food outlets for students, averaging 1.8 ± 0.8 excursions per week, which normalizes the consumption of energy-dense foods. Traditional meals are systematically replaced by high-density, processed options, with students consuming starches and meat-heavy products frequently while consuming vegetables and fruits rarely (often "never to once a month") (Mossenson et al., 2026).

This physical food landscape is reinforced by a pervasive digital and media environment. Adolescent media habits, screen time, and dietary patterns are closely linked. Elevated daily media exposure (via television, smartphones, and video games) is strongly correlated with increased body mass index (BMI) ($r = 0.48$) and elevated junk food consumption ($r = 0.51$). Crucially, media exposure and junk food intake exhibit a strong positive correlation ($r = 0.56$), indicating that screen time directly exposes adolescents to persuasive marketing campaigns for sugar-sweetened beverages and processed foods (Boyland, 2025). This triggers a conditioned psychological response ("I see, I remember, I want, I feel rewarded") that drives immediate overconsumption. Children also wield substantial purchasing influence, directing approximately 80% of family food expenditures toward these advertised convenience products (Gupta, 2025).

Additionally, sedentary behavior during leisure time is common: 77% of students report consuming meals or snacks while watching television one to three times per week, combining physical inactivity with the automatic consumption of energy-dense foods (Khajuria et al., 2026).

Table 2: Dietary Behaviors, Canteen Exposure, and Sedentary Metrics of Urban Adolescents

Behavioral/Environmental Parameter	Observed Prevalence / Metric	Key Dietary & Health Implications
No Home-Cooked School Lunch	83% of school children	Direct reliance on school canteens and external commercial food vendors
School Canteen Purchases	67% (1–3 times per week)	Exposure to low-cost, energy-dense, and highly refined processed foods
School Fast-Food Consumption	44% (1–3 times per week)	Displacement of micro-nutrient rich whole foods; excessive saturated fat intake
On-Campus Commercial Outlets	31% of urban schools	Structural facilitation of fast food (burgers, pizzas, fried chicken) during recess
School-Sponsored Fast-Food Trips	1.8 \pm 0.8 times per week	Institutional normalization of hyper-palatable, nutrient-poor eating habits
Snacking During Television Viewing	77% (1–3 times per week)	Passive overconsumption of simple sugars combined with physical inactivity
Sialkot Macronutrient Profile	Protein: 12.5%, Carbs: 51.5%, Fat: 36.3%	Fat intake exceeds standard recommended limits; carbohydrate intake is highly refined

4. Sourcing and Consumption Trends of Ultra-Processed Foods

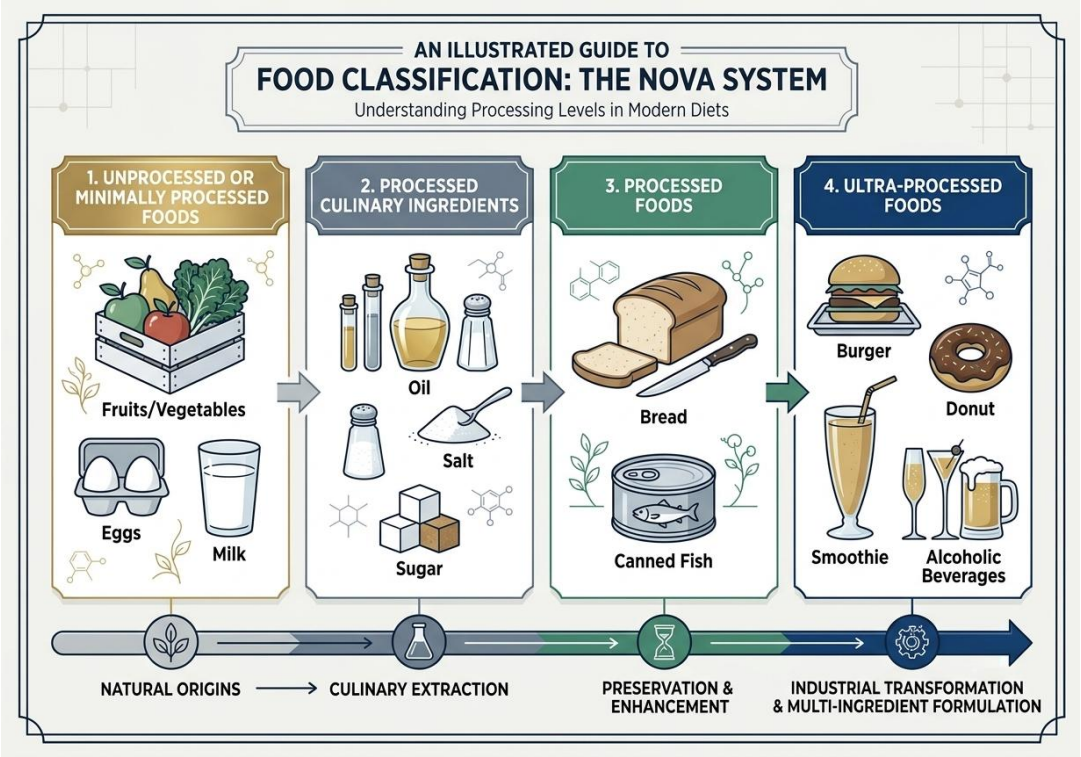
Under the NOVA food classification system, ultra-processed foods (UPFs) are defined as industrial formulations made entirely or mostly from substances extracted from foods (e.g., oils, fats, sugars, starches, proteins) or synthesized in laboratories from food substrates and other organic sources. These products typically contain cosmetic additives, preservatives, colorings, and flavor enhancers designed to maximize hyper-palatability, shelf-life, and profitability, while offering minimal intrinsic nutritional value in terms of vitamins, minerals, or dietary fiber (Louie, 2026). In South Asia, where the food retail sector is undergoing rapid commercialization, UPF sales are rising swiftly. In Pakistan, approximately 41% of individuals surveyed reported consuming at

least one UPF product during the previous day, with carbonated sweetened beverages, biscuits, and packaged salty snacks representing the most common sources (Hungund, 2025).

The socio-demographic distribution of UPF consumption reveals distinct patterns within Pakistani society. Younger age is strongly associated with a higher likelihood and volume of UPF consumption. Furthermore, any level of formal education above none (primary, secondary, or higher) is positively correlated with increased UPF intake, reflecting a cultural perception that packaged, industrially processed foods represent modern, hygienic, and prestigious food choices (Dawach et al., 2025). Single adolescents also consume significantly higher levels of UPFs compared to married or cohabiting counterparts, pointing to the protective effect of structured, family-centered household meal patterns (Blomdahl & Ana, 2025).

To contextualize Pakistan's position within the wider region, adolescent UPF intake can be compared to that of nearby countries. In Kuwait, for example, a cross-sectional study of 375 adolescents revealed a median UPF consumption of 443 g/day, which contributed an alarming 43.9% of their total daily energy intake (Bhagtani et al., 2025). This high intake was associated with lower protein and fiber consumption, and elevated intakes of total fat, saturated fat, trans fats, and sodium, indicating a severe decline in overall diet quality. While urban Pakistani adolescents have not yet reached the high absolute quantities observed in wealthier Gulf states, the rapid expansion of modern food systems, school canteen commercialization, and digital marketing suggests a similar upward trajectory (AlBaloul, 2026).

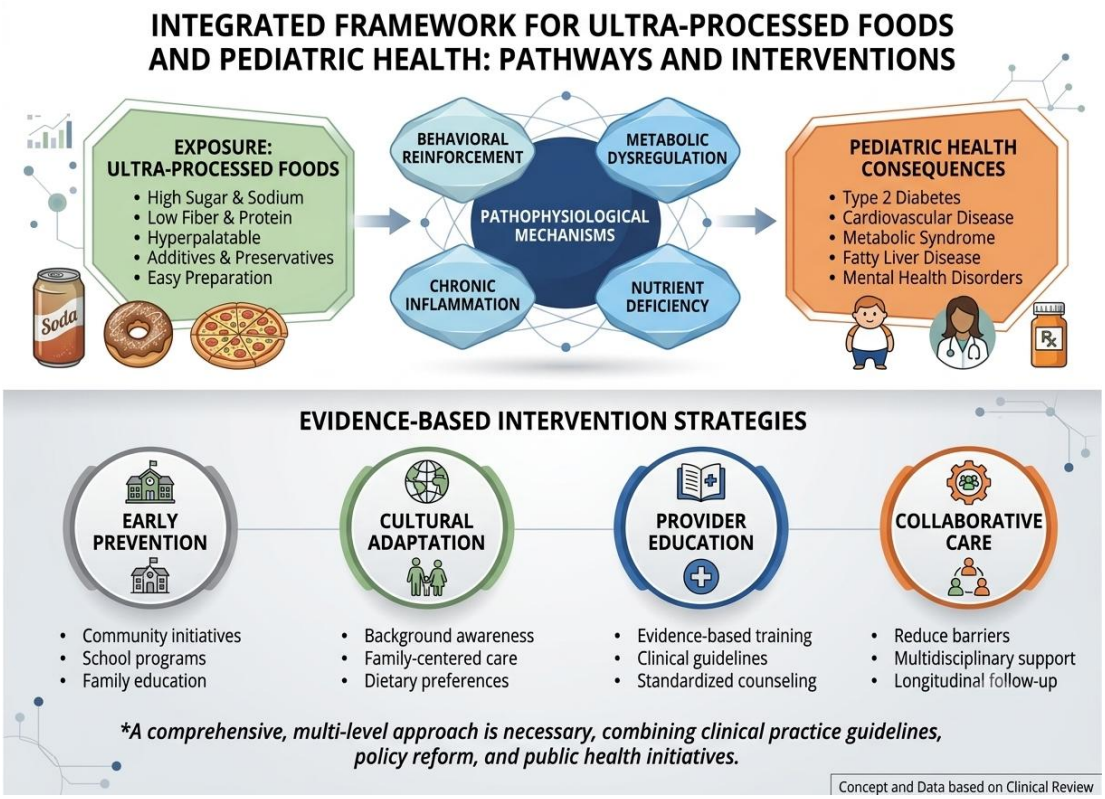
Figure 1: The NOVA Food Classification System for Categorizing Dietary Processing Levels.



5. Pathophysiological Mechanisms of Metabolic Decline

The physiological transition from frequent UPF consumption to the clinical manifestation of metabolic syndrome is driven by a series of complex, interrelated biological pathways. These mechanisms involve acute glycemic distress, profound alterations in the gut microbiome, intestinal barrier degradation, systemic low-grade inflammation, and neurological adaptations that drive compulsive overeating (Wang et al., 2026).

Figure 2: Conceptual Framework Linking Ultra-Processed Food Exposure to Pediatric Health Consequences and Multilevel Intervention Strategies.



5.1 Hyperinsulinemia, Glycemic Volatility, and Insulin Resistance

UPFs are typically engineered with high quantities of simple sugars, high-fructose corn syrup, and highly refined starches stripped of their structural fiber matrix. Upon ingestion, these "fast carbohydrates" are rapidly hydrolyzed and absorbed in the proximal small intestine, causing acute, steep elevations in postprandial blood glucose (Juul et al., 2025). The pancreas responds with a compensatory surge in insulin secretion. Over time, chronic hyperinsulinemia driven by the repeated ingestion of highly glycemic meals induces down-regulation and desensitization of insulin receptors on target tissues, including skeletal muscle, hepatocytes, and adipocytes (Xie et al., 2025).

As peripheral tissues develop insulin resistance, glucose uptake is severely compromised. Hepatocytes fail to suppress gluconeogenesis, while adipocytes undergo uncontrolled lipolysis, releasing excess free fatty acids (FFAs) into the portal circulation. These circulating FFAs undergo ectopic deposition in non-adipose organs such as the liver, skeletal muscle, and pancreas (Młynarska et al., 2025). This lipotoxic environment further disrupts intracellular insulin signaling pathways, specifically inhibiting insulin receptor substrate-1 (IRS-1) activation via protein kinase C activation, creating a pathological loop that accelerates insulin resistance and promotes visceral adiposity (Razi et al., 2025).

5.2 Gut Microbiota Dysbiosis and Short-Chain Fatty Acid Depletion

The human gut microbiome acts as a critical intermediary in metabolic health, and its composition is highly sensitive to dietary patterns. Beneficial commensal bacteria, such as *Bifidobacterium* and certain species of the *Bacteroidetes* and *Firmicutes* phyla, depend on complex, fermentable dietary fibers (prebiotics) as their primary energy substrate. Because industrial processing strips UPFs of these complex fibers, a diet high in UPFs effectively starves these beneficial microbes. Concurrently, the excess refined sugars, saturated fats, and additives in UPFs serve as metabolic fuel for pathobionts, leading to intestinal dysbiosis (Sanz et al 2025).

A direct consequence of this dysbiosis is the drastic reduction in the bacterial fermentation of fiber into short-chain fatty acids (SCFAs), such as acetate, propionate, and butyrate. SCFAs are vital signaling molecules that bind to G-protein coupled

receptors (specifically GPR41 and GPR43) on enteroendocrine cells, stimulating the release of satiety hormones (Pînzariu et al., 2025):

- **Glucagon-like peptide-1 (GLP-1)**, which enhances glucose-dependent insulin secretion and delays gastric emptying.
- **Peptide YY (PYY)**, which acts on the hypothalamic arcuate nucleus to promote satiety.

The depletion of SCFAs resulting from a UPF-dominated diet leads to the suppression of GLP-1 and PYY secretion, impairing satiety signals and contributing to chronic overeating, insulin resistance, and erratic glucose control (Liu et al., 2026).

5.3 Intestinal Barrier Erosion, Endotoxemia, and Systemic Inflammation

The integrity of the intestinal epithelial barrier is maintained by a specialized, protective mucus layer and a network of apical junctional complexes (tight junctions). Common chemical emulsifiers and additives used in UPFs such as carboxymethylcellulose, polysorbate-80, and artificial sweeteners directly degrade this mucosal barrier. These compounds act as detergents, thinning the mucus layer and allowing viable bacteria and their metabolic byproducts to come into direct contact with the epithelial layer (Choi et al., 2025).

This barrier disruption leads to a hyper-permeable state, often termed "leaky gut". This state permits the systemic translocation of lipopolysaccharides (LPS) pro-inflammatory endotoxins derived from the outer membranes of Gram-negative gut bacteria into the portal and systemic circulation. Circulating LPS binds to Toll-like receptor 4 (TLR4) on macrophages and adipocytes, triggering an intracellular signaling cascade mediated by nuclear factor kappa B (NF-κB) (Floyd et al., 2025). This cascade drives the expression of pro-inflammatory cytokines, including tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and C-reactive protein (CRP). This chronic, low-grade systemic inflammation directly impairs insulin signaling by inducing serine phosphorylation of insulin receptor substrate-1 (IRS-1), further linking ultra-processed food (UPF) consumption, gut dysbiosis, and the development of metabolic syndrome (Vella et al., 2025).

5.4 Genetic Predispositions and Phenotypic Factors

The metabolic risks of UPF consumption do not occur in isolation but are significantly amplified by unique genetic and phenotypic factors characteristic of the Pakistani population. Two key factors contribute to this heightened susceptibility (Benachour et al., 2026):

- **Consanguinity:** Marriages between first or second cousins are highly prevalent in Pakistan. This high rate of consanguinity increases homozygosity, which can lead to the clustering of genetic risk factors associated with dyslipidemia, impaired glucose tolerance, and pediatric MetS (Saleem et al., 2025).
- **The "Lean MetS" Phenotype:** Pakistan exhibits a high prevalence of type 2 diabetes mellitus (T2DM). The lean, non-obese offspring of parents with T2DM exhibit a higher baseline degree of insulin resistance, making them exceptionally vulnerable to developing MetS even without presenting with overt obesity. This phenotypic vulnerability is further underscored by clinical studies in tertiary care settings, such as a hospital in Rawalpindi, where non-ketotic hyperglycinemia was identified as the most common diagnosed metabolic disorder associated with MetS, indicating severe underlying disruptions in metabolic homeostasis (Mohan, 2025).

6. Diagnostic Ambiguity and Prevalence of Metabolic Syndrome

The diagnosis of metabolic syndrome (MetS) in pediatric and adolescent populations is complicated by the lack of a single, universally accepted diagnostic framework. Researchers utilize several clinical guidelines, including those of the International Diabetes Federation (IDF), the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) modified for age, the de Ferranti et al. criteria, and the Cruz and Goran criteria (Anton-Păduraru et al., 2025).

The choice of diagnostic criteria significantly impacts the estimated prevalence of MetS in clinical studies. Epidemiological assessments of adolescents in major Pakistani cities, such as Karachi and Lahore, highlight this variability. The IDF criteria, which mandate central obesity as a prerequisite, yield the lowest prevalence rates, ranging from 1.8% to 6.1% (Alrabbaie et al., 2025). This represents an underestimation of metabolic risk in South Asian populations. Because South Asians possess a high propensity for metabolic dysfunction even within a "healthy" BMI range, mandating a high waist circumference cutoff underdiagnoses individuals with normal-weight obesity or "lean" metabolic syndrome (Lim et al., 2026).

In contrast, the modified NCEP-ATP III criteria reveal a much higher burden, with prevalence rates of 16.69% to 17.5% among school children and young adults. The Cruz and Goran criteria demonstrate the highest sensitivity, identifying 22.93% of studied adolescents as positive for MetS. This elevated prevalence is observed even among marginalized populations, such as school-going adolescents in urban slums (Korangi and Baldia in Karachi), where the overall MetS prevalence was recorded at 16.7% using NCEP-ATP III criteria (Obeidat et al., 2025).

The prevalence rates of individual component abnormalities among Pakistani youth are highly concerning. The most common clinical abnormality is elevated blood pressure (above the 90th percentile), which is present in 54% to 67.7% of adolescents screened. Hypo-HDL-emia (low high-density lipoprotein cholesterol) is the second most common component, affecting 36.5% to 64.5% of adolescents. Elevated waist circumference (above the 75th percentile) is present in 30.6% of youth. Fasting hypertriglyceridemia and elevated fasting blood glucose are also prevalent, driven by refined carbohydrate diets and physical inactivity (Chanchlani et al., 2026).

Multivariate logistic regression analyses have identified critical predictors for the development of metabolic syndrome (MetS) among Pakistani youth. Body mass index (BMI) and glycated hemoglobin (HbA1c) are the strongest independent predictors. An increase of one unit (1 kg/m²) in BMI is associated with a 3.32-fold increase in the odds of developing MetS (adjusted odds ratio [aOR] = 3.323, $P < 0.042$). Similarly, a one-point elevation in HbA1c (%) increases the odds of MetS by a factor of five (aOR = 5.014, $P < 0.001$) (Saleem et al., 2026). Other significant predictors include:

- A positive family history of metabolic disorders, such as maternal T2DM, which can promote insulin resistance in offspring.
- Underweight status (paradoxically linked to dyslipidemia in malnourished slums, illustrating a severe form of metabolic vulnerability under the double burden of malnutrition).

Table 3: Comparative Analysis of Pediatric Metabolic Syndrome Diagnostic Criteria and Observed Prevalence in Pakistan

Diagnostic Criteria	Thresholds (WC, TG, HDL, BP, Glucose)	Target Study Population	Observed Prevalence in Pakistan (%)	Associated Risk Factors & Predictors
Cruz and Goran	WC ≥ 90th, TG ≥ 90th, HDL ≤ 10th, BP ≥ 90th, FPG ≥ 90th percentile	*n* = 689 adolescents in Karachi slums	22.93% (Highest Sensitivity)	Sedentary lifestyle, low fruit intake, low physical activity, underweight (7.7%)
Modified NCEP-ATP III	WC ≥ 90th, TG ≥ 110 mg/dL, HDL ≤ 40 mg/dL, BP ≥ 90th,	*n* = 325 first-year medical students, Karachi	17.5% (52.6% female, mean age 18.77 ± 0.45	Waist circumference, elevated fasting sugars; 46% had healthy lifestyle

	FPG ≥ 110 mg/dL		years)	knowledge but no correlation with MetS
NCEP-ATP III	WC ≥ 90th, TG ≥ 110 mg/dL, HDL ≤ 40 mg/dL, BP ≥ 90th, FPG ≥ 110 mg/dL	*n* = 689 school-going adolescents, Karachi slums	16.7%	Low HDL (33.96 ± 5.21 mg/dL), high TG (161.45 ± 63.09 mg/dL), high glucose (112.59 ± 28.92 mg/dL)
IDF (2007 consensus)	WC ≥ 90th, TG ≥ 150 mg/dL, HDL < 40/50 mg/dL, BP ≥ 130/85, FPG ≥ 100 mg/dL	*n* = 509 undergraduate students, Lahore	6.1%	Hypertension (67.7%), hypo-HDL-emia (64.5%), sedentary lifestyle (33%), sleep deprivation (50%)
IDF (General Pediatric)	WC ≥ 90th, TG ≥ 150 mg/dL, HDL < 40/50 mg/dL, BP ≥ 130/85, FPG ≥ 100 mg/dL	*n* = 689 school-going adolescents, Karachi slums	2.17% (Lowest Sensitivity)	Misses metabolic risk in lean or normal-weight individuals due to mandatory waist cutoff

7. Policy Responses, Regulatory Landscape, and Fiscal Interventions

To address the metabolic and nutritional crisis among urban Pakistani adolescents, the government has introduced several regulatory and programmatic initiatives, though substantial implementation gaps remain (Zaidi, 2025).

7.1 Trans Fatty Acid and Fiscal Regulations

In March 2025, Pakistan passed a national standard restricting industrially produced trans fatty acids (iTFAs) to less than 2% of total fat in all food products. This regulation was implemented using a phased approach, starting with six food categories in 2023 and expanding to 58 categories in 2024, before establishing the unified nationwide threshold (Facts, 2025).

Regarding fiscal policy, the Pakistani government approved significant increases in the Federal Excise Tax (FED) on carbonated and sweetened beverages. Under the 2023 tax reforms, the excise tax on carbonated beverages was increased from 13% to 20% of the retail price, and a new 10% tax was established on fruit juices, syrups, squashes, and sweetened fruit-based drinks. Furthermore, imported sweetened beverages and aerated waters are subject to a 25% sales tax (Rub, 2026).

However, public health experts argue that a flat-rate ad valorem tax is less effective than a progressive tax linked to sugar content. Progressive taxation incentivizes the food industry to reformulate products to lower sugar concentrations while encouraging consumers to choose healthier alternatives. The food ministry has resisted these changes, arguing that high taxes on documented beverage manufacturers could drive consumers toward cheaper, unregulated, and potentially unsafe local alternatives (de la Feria, 2025).

7.2 School Food Policies and the National School Meal Roadmap

The National Education Policy Development Framework (NEPDF) 2024 integrates school meal programs to improve access, equity, and nutritional outcomes. Building on this, the federal and provincial governments collaborated with the World Food Programme (WFP) to establish the National School Meal Roadmap. Under this

roadmap, provincial governments have committed to expanding structured school meal initiatives (Mazur-Włodarczyk et al., 2025):

- **Islamabad Capital Territory, Gilgit-Baltistan, and Azad Jammu & Kashmir** are expanding meals to marginalized communities, with Gilgit-Baltistan aiming to enact a formalized School Meal Policy by 2026.
- **Punjab** is expanding its School Milk Programme to cover 25% of its districts.
- **Sindh and Balochistan** are implementing pilot school meal programs, intending to expand to 8 additional districts in Balochistan by 2030.

While these school meal initiatives represent progress, they are primarily implemented in resource-poor public schools to combat undernutrition and boost enrollment. There remains a regulatory vacuum regarding school canteens in middle- and upper-income private schools. The lack of strict, enforceable standards allows commercial fast-food vendors to operate inside private schools, leaving wealthier urban adolescents highly exposed to obesogenic environments (Noubani, 2026).

7.3 Food Labeling Requirements

The statutory regulatory framework for food labeling in Pakistan is governed by SRO 237 (1) issued by the Ministry of Commerce in 2019, alongside regulations from provincial entities like the Punjab Food Authority (PFA). SRO 237 mandates that all imported processed foods carry nutritional value labeling and usage instructions in both Urdu and English, and must maintain at least 66% of their shelf-life at the time of customs clearance (Sultan et al., 2025).

However, Pakistan lacks a mandatory, standardized, front-of-pack (FOP) warning label system. Nutritional information panels are typically printed in small, highly technical tables on the back of packaging. This format is difficult for the general public to interpret, particularly in a population with varying literacy rates. Front-of-pack warning labels such as high-sugar, high-sodium, or high-saturated-fat stop signs have proven effective internationally in reducing UPF purchases but remain absent from Pakistani regulations (Ghazal et al., 2025).

8. Clinical and Public Health Recommendations

Addressing the metabolic risks associated with the nutritional transition in urban Pakistan requires a comprehensive, multi-sectoral approach targeting both clinical practices and the wider food environment (Cacciatore et al., 2025).

8.1 Progressive Taxation and Product Reformulation

The current uniform ad valorem excise taxes should be reformed into a progressive taxation model linked directly to the sugar content of beverages and ultra-processed foods. Under this model, tax rates scale progressively with sugar concentration (e.g., grams of sugar per 100 mL), encouraging manufacturers to reformulate their products to fall below the highest tax thresholds. This strategy has been shown internationally to reduce sugar consumption while maintaining market stability, minimizing the risk of consumers shifting toward unregulated, informal products (Behrens et al., 2025).

8.2 Mandatory Nutritional Standards for School Canteens

National and provincial education departments must move beyond public school meal provision and enact mandatory, strictly enforced nutritional standards for all educational canteens, particularly in the private sector (Marzulina et al., 2025). This includes banning commercial fast-food chain franchises from operating on school grounds and prohibiting school-sponsored excursions to fast-food outlets. canteens should be restricted to selling fresh, minimally processed foods, whole grains, and dairy products, with strict enforcement carried out by provincial food authorities through unannounced audits and penalties (Lyubomudrov et al., 2025).

8.3 Implementation of Front-of-Pack Warning Labels

To overcome the limitations of complex, back-of-pack nutritional panels, the Ministry of Commerce and provincial food authorities should legislate a mandatory front-of-pack (FOP) warning label system. Utilizing clear, intuitive graphic indicators (such as high-sugar, high-sodium, or high-saturated-fat stop signs) allows consumers, regardless

of literacy level, to quickly identify nutritionally poor products. This intervention is critical to counteract the persuasive marketing of processed foods to children and adolescents (Latief, 2025).

8.4 Clinical Adoption of South Asian Phenotype Diagnostic Cutoffs

To prevent the underdiagnosis of metabolic syndrome in South Asian youth, pediatric and clinical guidelines in Pakistan must adopt modified, population-specific diagnostic thresholds. Rather than relying on rigid adult cutoffs or mandatory waist circumference prerequisites that miss normal-weight metabolic dysfunction, clinicians should screen adolescents utilizing sensitive, age-standardized percentiles (Boddu et al., 2025).

9. Conclusion

Pakistan is undergoing a rapid and largely unregulated nutritional transition that is contributing to a growing burden of metabolic syndrome among adolescents. This dual burden of malnutrition where undernutrition coexists with rising obesity poses a significant threat to future population health, particularly in relation to type 2 diabetes and cardiovascular disease. At the biological level, frequent consumption of ultra-processed foods disrupts metabolic homeostasis through multiple interconnected pathways, including glycemic instability, hyperinsulinemia, lipid dysregulation, and accumulation of visceral and ectopic fat. These effects are further amplified by gut microbiota alterations, reduced fiber intake, and increased intestinal permeability, resulting in chronic low-grade systemic inflammation and impaired insulin signaling. When combined with inherent genetic susceptibility and the South Asian phenotype, these factors contribute to metabolic risk even in individuals who do not present with overt obesity. Current screening and policy frameworks remain insufficiently sensitive and poorly implemented. To mitigate the escalating burden of adolescent metabolic disorders, Pakistan requires urgent structural reforms, including sugar-based taxation policies, strict regulation of school food environments, and mandatory front-of-pack warning systems. In parallel, clinical practice must shift toward context-specific diagnostic tools, such as waist-to-height ratio and other age-adjusted measures, to enable earlier identification and intervention in at-risk youth.

REFERENCES

AlBaloul, A. H. (2026). Ultra-processed food consumption and its relationship with nutrient intake and dietary patterns in adolescents. *Frontiers in Nutrition*, *13*, 1748813.

Alrabbaie, H., Al-Wardat, M., Etoom, M., Beauchamp, M., Goldstein, R., & Brooks, D. (2025). The prevalence of metabolic syndrome in chronic obstructive pulmonary disease: a systematic review and meta-analysis. *Chronic respiratory disease*, *22*, 14799731251346194.

Anton-Păduraru, D. T., Mindru, D. E., Stănescu, R. S., Trofin, F., Cobuz, C., Cobuz, M., ... & Cosmescu, A. (2025). Unraveling Metabolic Syndrome in Youth: The Obesity Epidemic's Hidden Complication. *Children*, *12*(4), 482.

Bahar, O. S., Byansi, W., Ibrahim, A., Boateng, A., Kumbelim, K., Nartey, P. B., ... & McKay, M. M. (2025). Preliminary impact of a combination intervention on intention to migrate and school absence among adolescent girls: Results from a pilot cluster-randomized clinical trial in Northern Ghana. *Children and Youth Services Review*, *171*, 108205.

Behrens, P., Champagne, C. M., Halford, J. C., Moodie, M., Proietto, J., Rutter, G. A., ... & Holly, J. M. (2025). Obesity and climate change: co-crises with common solutions. *Frontiers in Science*, *3*, 1613595.

Benachour, Y., Maloukh, L., & Geusens, B. (2026). Integrative Machine Learning of Genetic and Lifestyle Factors for Personalized Skin Health. *IEEE Journal of Translational Engineering in Health and Medicine*.

Bhagtani, D., Adams, J., Imamura, F., Lahiri, A., Pradeepa, R., Mahmood, S., ... & Forouhi, N. G. (2025). Quantification of regional variation in ultra-processed

food consumption and its sociodemographic correlates across Bangladesh, India, Pakistan, and Sri Lanka: insights from the South Asia Biobank. *The Lancet Regional Health-Southeast Asia*, *39*.

Bhattacharjee, S., Mishra, T., Kandapan, B., Reja, T., & Pradhan, J. (2026). Reassessing the Nutrition Policy Landscape: Analysing Policy Mapping and Malnutrition in selected South Asian Countries. *Nutrition*, 113115.

Blomdahl, R., & Ana, B. (2025). Ultra Processed Food-Towards Healthier Supermarkets: Assessing Consumer Value and the Need for Socially Sustainable Value Propositions in Swedish Supermarkets.

Boddu, S. K., Giannini, C., & Marcovecchio, M. L. (2025). Metabolic disorders in young people around the world. *Diabetologia*, *68*(11), 2374-2385.

Boyland, E. (2025). Would Reducing Children's Exposure to Food Advertising Prevent Unhealthy Weight Gain?. *Current obesity reports*, *14*(1), 55.

Bruins, M. J., Van Dael, P., & Eggersdorfer, M. (2019). The role of nutrients in reducing the risk for noncommunicable diseases during aging. *nutrients*, *11*(1), 85.

Cacciatore, S., Mao, S., Nuñez, M. V., Massaro, C., Spadafora, L., Bernardi, M., ... & Landi, F. (2025). Urban health inequities and healthy longevity: traditional and emerging risk factors across the cities and policy implications. *Aging clinical and experimental research*, *37*(1), 143.

Chanchlani, R., Brady, T., Kruger, R., & Sinha, M. D. (2026). Under pressure: the lifelong cardiovascular health of children and youth with primary hypertension. *The Lancet Child & Adolescent Health*, *10*(3), 203-215.

Choe, H. J., Almas, T., Neeland, I. J., Lim, S., & Després, J. P. (2026). Obesity phenotypes and atherogenic dyslipidemias. *European Journal of Clinical Investigation*, *56*(1), e70151.

Choi, S. Y., & Moon, W. (2025). Ultra-Processed Foods and Inflammatory Bowel Disease: A Narrative Review of Epidemiology, Mechanisms, and Dietary Implications. *Nutrients*, *17*(24), 3852.

Dahl, R. E., Allen, N. B., Wilbrecht, L., & Suleiman, A. B. (2018). Importance of investing in adolescence from a developmental science perspective. *Nature*, *554*(7693), 441-450.

Dawach, M. A., Qadri, S. M. H., & Khan, S. (2025). Awareness and Attitude Regarding the Health Risks and the Consumption of Ultra-Processed Foods. *ASSAJ*, *4*(01), 3227-3238.

de la Feria, R. (2025). Tax fairness: reconceptualising taxation and Inequalities. *Taxation and Inequalities (Amsterdam: IBFD, 2025)*.

Facts, N. (2025). Islamic Republic of Pakistan.

Falak, F., Ahmad, A. M. R., Mahmood, H., Malik, Z. I., Shah, S. H. B. U., Abid, J., & Irfan, M. (2025). Diet quality and its associated factors among adolescents in high schools of Rawalpindi and Islamabad. *Frontiers in Public Health*, *13*, 1651903.

Farooq, I., Imran, M., & Ahmad, N. (2025). Double Burden of Malnutrition among Children Under Five in Pakistan: Evidence from Pakistan Demographic and Health Survey 2017–18: Double Burden of Malnutrition in Pakistan: Evidence from PDHS 2017–18. *Pakistan BioMedical Journal*, 43-49.

Floyd, J. L., Prasad, R., Dupont, M. D., Adu-Rutledge, Y., Anshumali, S., Paul, S., ... & Grant, M. B. (2025). Intestinal neutrophil extracellular traps promote gut barrier damage exacerbating endotoxaemia, systemic inflammation and progression of diabetic retinopathy in type 2 diabetes. *Diabetologia*, *68*(4), 866-889.

Ghazal, P., Waheed, M., & Muneer, S. (2025). Utilization of nutritional food label for management of non-communicable diseases among Pakistani population. *International Journal of Health Promotion and Education*, 1-13.

Giri, N., & Nag, K. (2026). Association of dietary practices with overweight and obesity among women in India based on National Family Health Survey 2019 to 2021. *Discover Public Health*, *23*(1), 607.

Gupta, R. (2025). Stress and Psychological Models of Learning, Memory, Motivation and Personality. *Textbook of Psychiatry-E-Book: Textbook of Psychiatry-E-Book*, 10.

Hungund, S. (2025). Ultra-Processed Foods in India: A Comprehensive Market and Health Risk Analysis. *medRxiv*, 2025-12.

Ispas, A. G., Forray, A. I., Lacurezeanu, A., Petreuș, D., Gavrilaș, L. I., & Chereches, R. M. (2025). Talking About Weight with Children: Associations with Parental Stigma, Bias, Attitudes, and Child Weight Status. *Nutrients*, *17*(18), 2920..

Juul, F., Martinez-Steele, E., Parekh, N., & Monteiro, C. A. (2025). The role of ultra-processed food in obesity. *Nature Reviews Endocrinology*, *21*(11), 672-685.

Katie, A. (2025). Evaluation of nutrient intake gaps and nutritional status in urban Ivorian school-aged children and women of reproductive age: associations with socio-economic status.

Khajuria, A., Yadav, S. S., Somanadhapai, S., Thapa, R., Singh, M. J., Bansal, P., ... & Singh, S. S. (2025). Influence of Dietary Habits and Lifestyle Practices on the Health and Well-Being of University Students: A Survey Investigation. *Journal of Lifestyle Medicine*, *15*(2), 66.

Khaliq, A., Ashar, B., Rehman, H. A., Junaid, M., Rizwan, Y., Aijaz, N., ... & Davoudabadi, M. J. (2025). Global, regional and national estimates of coexisting forms of malnutrition among the neonates, infants and young children–A secondary data analysis of Demographic & Health Surveys (DHS) from 2006 to 2024. *F1000Research*, *14*, 1414.

Kreslake, J. M., Cordova, J., Seidenberg, A. B., Ali, F. R. M., Schillo, B., & Marynak, K. (2025). Youth and young adult flavour expectancies for new 'non-menthol'cigarettes introduced following California's ban on flavoured tobacco products. *Tobacco control*, *34*(6), 805-812.

Latief, A. (2025). *An evaluation of on-package marketing and nutrients of concern of infant formula, follow-up formula, young child formula and commercially available complementary foods and compliance thereof by manufacturers in South Africa* (Doctoral dissertation, University of the Western Cape).

Li, S., Zhou, J., Xiao, W., Zhang, C., Su, D., Zhao, D., ... & Song, P. (2026). Healthy lifestyle synergy and its association with overweight and obesity among parent-child dyads. *Public Health*, *257*, 106348.

Lim, S., Ji, L., Tham, K. W., Misra, A., & Kadowaki, T. (2026). Clinical obesity in Asian people: bridging the gap between adiposity and disease. *Nature Reviews Endocrinology*, 1-10.

Liu, C., Ren, N., Zhang, H., & Ma, J. (2026). The role of PYY in improving insulin resistance. *Frontiers in Endocrinology*, *17*, 1784709.

Louie, J. C. Y. (2026). The industrial formulation fallacy: a critical appraisal of the Nova classification system. *Critical Reviews in Food Science and Nutrition*, 1-12.

Lyubomudrov, D., Mistry, O., Shetty, S., Gallardo, A. C., & Sentes, L. (2025). Fast Food Impact on Public Health, Social Trends, and Economy in North America.

Marzulina, L., Mukminin, A., & Harto, K. (2025). Feeding Minds, Building Dignity: Indonesia's Free Nutritious Meal Policy (MBG), Barriers, Prospects, and Policy Recommendations. *Edukasi: Jurnal Pendidikan dan Pengajaran*, *12*(2), 848-876.

Mazur-Włodarczyk, K., & Łukaniszyn-Domaszewska, K. (2025). EMPOWERING MIGRANTS THROUGH CRAFT-BASED SKILLS: SOCIAL ECONOMY INITIATIVES FOR INTEGRATION AND INCLUSION. *Scientific Papers of*

Silesian University of Technology. Organization & Management/Zeszyty Naukowe Politechniki Slaskiej. Seria Organizacji i Zarzadzanie, (221).

Młynarska, E., Czarnik, W., Dzieża, N., Jędraszak, W., Majchrowicz, G., Prusinowski, F., ... & Franczyk, B. (2025). Type 2 diabetes mellitus: new pathogenetic mechanisms, treatment and the most important complications. *International journal of molecular sciences*, *26*(3), 1094.

Mohan, V. (2025). Lessons learned from epidemiology of type 2 diabetes in South Asians: Kelly West Award Lecture 2024. *Diabetes Care*, *48*(2), 153-163.

Mossenson, S., Klug, F., Mandzufas, J., Francis, J., Hickling, S., Thornton, L., & Trapp, G. (2026). Slushies before school: exploring how nearby food outlets impact the eating behaviours of secondary students in Perth, Western Australia. *BMC Public Health*.

Noubani, A. (2026). Food Insecurity and Adolescent Mental Health: A Mixed-Methods Investigation of School-Based Interventions in Sierra Leone and South Sudan.

Obeidat, A. A., Ahmad, M. N., Ghabashi, M. A., Alazzeh, A. Y., Habib, S. M., Abu Al-Haijaa, D., & Azzeh, F. S. (2025). Developmental trends of metabolic syndrome in the past two decades: a narrative review. *Journal of Clinical Medicine*, *14*(7), 2402.

Pînzariu, A. C., Leonte, S. M., Trofin, A. G., Trandafir, L. M., Moscalu, M., Manole, L. M., ... & Şerban, I. L. (2025). Gut Microbiota and Short-Chain Fatty Acids: Key Factors in Pediatric Obesity and Therapeutic Targets. *International Journal of Molecular Sciences*, *26*(23), 11503.

Razi, O., de Moraes, C., Zamani, N., Saeidi, A., Hadjicharalambous, M., Hackney, A. C., ... & Zouhal, H. (2025). From obesity to muscle insulin resistance: the mediating roles of intramyocellular lipids, inflammation, and oxidative stress. *Diabetes/metabolism research and reviews*, *41*(7), e70094.

Rehan, K. Z., & Sania, Z. (2025). Child Malnutrition in Pakistan: Evidence from National Nutritional Survey 2018. *CEERAT Journal of Society and Development*, *2*(1), 9-22.

Rub, A. (2026). Fiscal policy repurposing as a tool to enable healthy diets: A review of available evidence.

Saleem, F., Shahzad, F., Ishaque, A., Haider, S., Iqbal, Q., Farooqui, M., & Bashaar, M. (2026). Profile and predictors of metabolic syndrome among young adults attending a Medical College in Quetta City, Pakistan. *Journal of Pharmaceutical Policy and Practice*, *19*(1), 2602966.

Saleem, M. U., Khatir, A. G., Shah, A. A., & Jiang, Q. (2025). Consanguineous marriages and child ever Born The moderating role of working women. *American Journal of Human Biology*, *37*(5), e70043.

Sallis, J. F., Cerin, E., Conway, T. L., Adams, M. A., Frank, L. D., Pratt, M., ... & Owen, N. (2016). Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. *The lancet*, *387*(10034), 2207-2217.

Sanz, Y., Cryan, J. F., Deschasaux-Tanguy, M., Elinav, E., Lambrecht, R., & Veiga, P. (2025). The gut microbiome connects nutrition and human health. *Nature Reviews Gastroenterology & Hepatology*, *22*(8), 534-555.

Sathar, Z., Kamran, I., Sadiq, M., & Hussain, S. (2016). Youth in Pakistan: Priorities, realities and policy responses.

Savcı, R. G., & Yalçın, S. S. (2025). Maternal perception and childhood overweight: examining parenting styles and eating behaviors among preschoolers: a cross-sectional study from Samsun, Türkiye. *Nutrients*, *17*(1), 195

Saxena, V., Jasrotia, A., Sharma, S., & Khapre, M. (2025). Double Burden of Malnutrition as a Rising Public Health Problem: Indian Scenario. In *Handbook of Public Health Nutrition: International, National, and Regional Perspectives* (pp. 1-28). Cham: Springer Nature Switzerland.

Sheikh, S., Khoja, A., Naeem, U., Fayyaz, M., Junaid, V., Hoodbhoy, Z., ... & Virani, S. S. (2026). Longitudinal study of cardiovascular-kidney-metabolic syndrome risk assessment among adolescents and young adults (10–45 years) in Pakistan (LIFECARD): Study design and methodology. *Progress in Cardiovascular Diseases*.

Sultan, M. T., Noman, A. M., & Raza, H. (2025). Food laws of Pakistan: Current flaws and strategic future reforms. *Legal Research & Analysis*, *3*(1), 70-78.

Vella, R., Panci, D., Carini, F., Malta, G., Vieni, S., David, S., ... & Argo, A. (2025). Cytokines in sepsis: a critical review of the literature on systemic inflammation and multiple organ dysfunction. *Frontiers in Immunology*, *16*, 1682306.

Wang, X., Chen, H., Xu, Y., Xu, Q., Cui, H., & Liu, F. (2026). The collapse of the food matrix: how ultra-processed foods impact satiety and metabolism by altering physical structure beyond nutrient composition. *Frontiers in Nutrition*, *13*, 1737280.

Wiesli, T. X. (2025). Meat consumption among different social groups and specific options for reducing it: a literature review of empirical research. *Frontiers in Sociology*, *10*, 1547663.

Xie, C., Yuan, Y., Wang, Y., Qi, C., Wang, W., An, C., ... & Gao, H. (2025). Beyond Discrete Diagnoses: Conceptualizing Obesity-associated Metabolic Disorders as a Unified, Dynamic Continuum. *Current Obesity Reports*, *14*(1), 81.

Zaidi, S. (2025). The Political Economy of Multi-sectoral Programming of Adolescent Nutrition: Global Discourse and Emerging Lessons from Pakistan. In *Nutrition Across Reproductive, Maternal, Neonatal, Child, and Adolescent Health Care: Focus on Low and Middle Income Countries* (pp. 289-301). Cham: Springer Nature Switzerland.