

## Metabolic Health and the Future of Public Health

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### What Is Metabolic Health?

Metabolic health is more than mere absence of disease. It reflects the efficient and balanced functioning of the body's fundamental biochemical systems—energy production, nutrient utilisation, hormonal signalling, and cellular regulation. A metabolically healthy individual maintains normal blood glucose, favourable lipid levels, healthy blood pressure and waist circumference, and, importantly, adequate insulin sensitivity without relying on medication.<sup>1</sup>

Metabolic health is commonly defined as the absence of all components of metabolic syndrome (MetS): Central obesity, Hypertension, Hypertriglyceridaemia, low HDL cholesterol, and Impaired fasting glucose.<sup>2</sup> By this standard, fewer than one in eight adults globally are truly metabolically healthy.

India particularly faces a rapid metabolic transition. Urbanisation, reduced physical activity, ultra-processed foods, chronic stress, and changing lifestyles have created a population vulnerable to metabolic dysfunction, often at lower body mass indices than Western populations because of a greater tendency for visceral fat accumulation.<sup>3</sup> This shift represents one of the most important public health challenges of our time.

### Metabolic Ill Health: The Central Public Health Crisis

Metabolic dysfunction underlies a substantial proportion of non-communicable disease (NCD) burden

worldwide. A useful framework is the “insulin resistance tree.” Insulin resistance develops in a biological environment shaped by excess refined carbohydrates, ultra-processed foods, inactivity, poor sleep, and chronic stress. Through glycation, oxidative stress, inflammation, mitochondrial dysfunction, and impaired cellular repair, this disturbance spreads across multiple organ systems.

Consequences extend far beyond diabetes to include cardiovascular disease, hypertension, dyslipidaemia, metabolic dysfunction-associated fatty liver disease, Polycystic Ovarian Disease, erectile dysfunction, stroke, cognitive decline, gout, sleep apnoea, autoimmune conditions, selected cancers, and accelerated ageing.

This perspective challenges a common clinical assumption that controlling blood sugar, cholesterol, and blood pressure is adequate to maintain health. Infact, blood sugar, cholesterol, and blood pressure are often downstream manifestations rather than primary causes of disease. Pharmacological treatment remains essential in many situations, particularly for reducing immediate risk, but long-term disease control requires addressing the metabolic environment that produces these abnormalities.

The economic consequences are equally profound. Obesity-related healthcare expenditure in the United States exceeds USD 170 billion annually, while metabolic syndrome imposes major costs across Europe. For India, where healthcare resources remain

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constrained, prevention through lifestyle intervention is not only medically necessary but economically indispensable.

### Biological Processes Driving Metabolic Disease

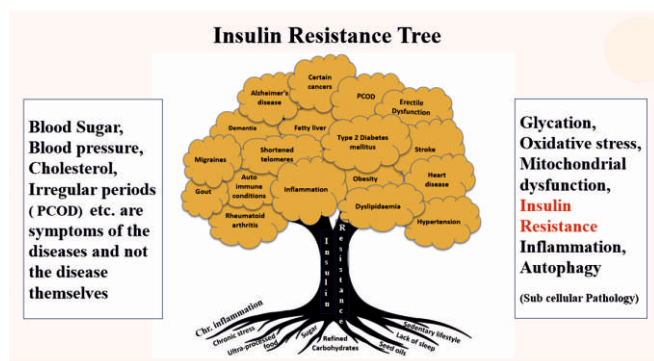
Metabolic dysfunction develops through interconnected biological pathways.

#### Glycation

Persistently elevated glucose binds non-enzymatically to proteins & lipids, generating advanced glycation end-products (AGEs) that impair vascular, neural, renal, and connective tissue function. Glycation begins well before overt diabetes and is strongly influenced by refined carbohydrate intake.<sup>7</sup>

#### Oxidative Stress and Mitochondrial Dysfunction

Excess nutrient exposure increases reactive oxygen species (ROS), damaging DNA, cell membranes, and mitochondria. This activates inflammatory pathways and worsens insulin resistance. Dysfunctional mitochondria reduce fatty acid oxidation and promote intracellular lipid accumulation. Exercise stimulates mitochondrial renewal, explaining why physical activity improves metabolic health even without major weight loss.<sup>8,9</sup>



### Insulin Resistance

The central linking mechanism. When muscle, liver, and adipose tissue become less responsive to insulin, glucose uptake declines and insulin levels rise. The liver overproduces glucose and triglycerides; adipose tissue releases excess free fatty acids; skeletal muscle loses metabolic flexibility.<sup>10</sup> Insulin resistance drives not only diabetes but also hypertension, dyslipidaemia, endothelial dysfunction, and vascular diseases.

### Epigenetic Regulation and Methylation

Diet influences gene expression through epigenetic mechanisms such as DNA methylation. Nutrients including folate, vitamin B12, choline, and betaine alter expression of genes regulating lipid metabolism, inflammation, and mitochondrial function,<sup>11</sup> providing a biological explanation for how dietary habits shape disease risk across generations.

### Chronic Inflammation and Impaired Autophagy

Visceral fat acts as an inflammatory organ, releasing cytokines such as TNF- $\alpha$  and IL-6 while reducing protective adiponectin. This persistent low-grade inflammation worsens insulin signalling and accelerates vascular injury.<sup>12</sup>

At the same time, chronic caloric excess suppresses autophagy—the cellular recycling process responsible for clearing damaged proteins and organelles. Reduced autophagy contributes to ageing, metabolic disease, and neurodegeneration. Intermittent fasting and caloric restriction may partially restore this process.<sup>13</sup>

### Lifestyle Modification: The Most Powerful Therapeutic Tool

Metabolic disease is largely shaped by daily behaviours. The strongest interventions often exist outside conventional pharmacotherapy. The following Lifestyle modification can correct the Metabolic ill health: Diet Modification, Physical Activity, Stress Management, Adequate Sleep, Intermittent Fasting and Avoiding Ultra processed foods.

**1. Diet:** Diet remains the most effective lever for improving insulin sensitivity.

**Control Carbohydrates:** though glucose is the source of energy for all cells, excess carbohydrate is the main cause of hyperinsulinemia. There is nothing called essential carbohydrates unlike Essential Amino Acids and Essential Fatty Acids. Hence restricting carbohydrates to bare minimum is metabolically healthy.<sup>14</sup> Avoid Refined carbohydrates: (packed & Labelled food) . Eat home made food & least processed carbohydrates, from vegetable and fruits (Eating fruits is fine but drinking fruit juice is not metabolically healthy

as it does not contain fiber. Reduce frequency of eating. Two meals per day or maximum three times per day. (Nothing other than water to be taken, between meals)

**Prioritise Proteins:** for healthy Muscle & Bone mass. Focus on Essential Amino Acids from animal source or proper combination of Plant Source Proteins. Pair proteins with polyphenol rich foods for better digestion and absorption of proteins. Plant sources of proteins like nuts, seeds, and legumes have Fiber & Fats along with Protein. As Protein has a high degree of satiety, the frequency of eating will reduce

**Don't fear fats:** In nature good proteins always come with fats. Fats help digest protein better. Omega 3 fatty acids are deficient in our diet where as Omega 6 are in excess. We need to have proportion of Omega3: Omega 6 ideally 1:1 to 1:4. Our current ratio is 1:25 or more. Omega 6 fatty acids are inflammatory. All refined oils also have been subjected to high temperature for extraction and treated with harmful chemicals. Use Ghee/ Cold pressed groundnut oil / cold pressed coconut oil for cooking.<sup>15</sup>

**2. Intermittent Fasting:** Early time-restricted eating & Fasting improve insulin sensitivity.

### **3. Physical Activity:**

Physical activity in general and Resistance Exercise in particular, improve metabolic health through mechanisms extending beyond weight reduction.

Aerobic activity increases skeletal muscle glucose uptake and insulin sensitivity. Resistance training increases metabolically active lean mass. High-intensity interval training (HIIT) provides comparable benefits in less time.

Current WHO recommendations advise 150–300 minutes of moderate aerobic activity weekly with strength training at least twice weekly.<sup>16</sup>

Lifestyle interventions combining diet and exercise significantly improve blood pressure, triglycerides, fasting glucose, and waist circumference and may double rates of metabolic syndrome resolution compared with standard care.<sup>17</sup>

Movement should therefore be viewed as a therapeutic intervention—not merely a weight management strategy.

### **4. Stress Management**

Chronic stress exerts measurable metabolic effects. Sustained cortisol elevation promotes central adiposity, worsens insulin resistance, increases blood pressure, and alters appetite regulation.<sup>18</sup>

Interventions including walking in a garden, deep breathing, Om chanting, Yoga, Mindfulness, relaxation training, and structured stress reduction have demonstrated improvements in glycaemic control and cardiovascular risk markers.

Stress management is not an optional adjunct—it is part of metabolic treatment.

### **5. Sleep and Circadian Alignment:**

Sleep quality and metabolic health are tightly linked.

Insufficient or disrupted sleep increases insulin resistance, alters appetite hormones, elevates cortisol, and promotes weight gain. Circadian disruption caused by irregular schedules, shift work, and late-night light exposure further impairs glucose regulation.<sup>19</sup>

Practical recommendations include maintaining regular sleep timing, aim for 7–9 hours sleep every day, reduce evening screen exposure, align meals and activity with natural day–night rhythms. These are low-cost interventions with substantial metabolic benefits.

### **6. Intermittent Fasting and Time-Restricted Eating:**

Intermittent fasting has emerged as a promising metabolic intervention. Extending fasting periods lowers insulin exposure, promotes fat oxidation, activates Activated Protein Kinase AMPK, suppresses mTOR signalling, and enhances autophagy.<sup>20</sup>

Time-restricted eating protocols have demonstrated improvements in body weight, insulin levels, blood pressure, and inflammatory markers even without intentional calorie restriction.<sup>2</sup> Early daytime eating patterns may offer additional advantages through circadian alignment.

Fasting is not appropriate for everyone and requires caution in pregnancy, type 1 diabetes, and individuals with eating disorders. However, when individualised appropriately, fasting can become a valuable component of metabolic care.

### Conclusion: Reframing the Future of Public Health

Metabolic ill health is the defining epidemic of modern society. The expanding NCD burden reflects not isolated diseases but a shared metabolic disturbance driven by poor diet, inactivity, stress, inadequate sleep, and disrupted eating patterns. Cholesterol, blood sugar, and blood pressure are important indicators—but they are often visible consequences of deeper dysfunction.

Lifestyle interventions act closer to the biological root of disease. They improve insulin sensitivity, reduce inflammation and oxidative stress, restore mitochondrial function, support autophagy, and alter metabolic trajectories at both individual and population levels.

For preventive medicine, the implication is clear: lifestyle modification must become foundational not supplementary to chronic disease prevention and management. The future of public health will depend less on treating metabolic complications and more on creating environments that make metabolic health possible.

### References:

1. Saklayen MG. The global epidemic of the metabolic syndrome. *Curr Hypertens Rep.* 2018;20(2):12.
2. Rochlani Y, Pothineni NV, Kovelamudi S, Mehta JL. Metabolic syndrome: pathophysiology, management, and modulation by natural compounds. *Ther Adv Cardiovasc Dis.* 2017;11(8):215-25.
3. Islam MS, Wei P, Suzaudulla M, et al. The interplay of factors in metabolic syndrome: understanding its roots and complexity. *Mol Med.* 2024;30(1):279.
4. Kucher SV, Mudra UO, Tkachuk VV, et al. Impact of lifestyle modification interventions on metabolic syndrome and obesity in adults. *Wiad Lek.* 2025;78(9):1857-65.
5. Ward ZJ, Bleich SN, Cradock AL, et al. Association of body mass index with health care expenditures in the United States by age and sex. *PLoS One.* 2021;16(3):e0247307.
6. Scholze J, Alegria E, Ferri C, et al. Epidemiological and economic burden of metabolic syndrome and its consequences in patients with hypertension in Germany, Spain and Italy: a prevalence-based model. *BMC Public Health.* 2010;10:529.
7. Das S, Dasgupta B, Biswas P, Pattanayak A, Mukherjee P. Dietary modification for controlling metabolic disorders. *J Curr Res Food Sci.* 2024;5(1):208-11.
8. Meiliana A, Dewi NM, Wijaya A. Lifestyle modifications and nutraceutical interventions in the prevention and management of metabolic syndrome. *Indones Biomed J.* 2025;17(3):207-32.
9. Bird SR, Hawley JA. Update on the effects of physical activity on insulin sensitivity in humans. *BMJ Open Sport Exerc Med.* 2017;2(1):e000143.
10. DeFronzo RA, Ferrannini E, Groop L, et al. Type 2 diabetes mellitus. *Nat Rev Dis Primers.* 2015;1(1):1-22.
11. Nuotio ML, Pervjakova N, Joensuu A, et al. An epigenome-wide association study of metabolic syndrome and its components. *Sci Rep.* 2020;10:20567.
12. Tilg H, Moschen AR. Inflammatory mechanisms in the regulation of insulin resistance. *Mol Med.* 2008;14(3-4):222-31.
13. Manoogian ENC, Wilkinson MJ, O'Neal M, et al. Time-restricted eating in adults with metabolic syndrome: a randomized controlled trial. *Ann Intern Med.* 2024;177(11):1462-70.
14. Estruch R, Ros E, Salas-Salvado J, et al. Primary prevention of cardiovascular disease with a Mediterranean diet supplemented with extra-virgin olive oil or nuts. *N Engl J Med.* 2018;378(25):e34.
15. Bueno NB, de Melo ISV, de Oliveira SL, da Rocha Ataide T. Very-low-carbohydrate ketogenic diet v. low-fat diet for long-term weight loss: a meta-analysis of randomised controlled trials. *Br J Nutr.* 2013;110(7):1178-87.
16. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organisation 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med.* 2020;54(24):1451-62.
17. Yamaoka K, Tango T. Effects of lifestyle modification on metabolic syndrome: a systematic review and meta-analysis. *BMC Med.* 2012;10:138.
18. Sharma P. Metabolic health: understanding its significance, challenges, and pathways for optimization. *J Diabetes Metab.* 2024;15(12):1193.
19. Meléndez-Fernández OH, Liu JA, Nelson RJ. Circadian rhythms disrupted by light at night and mistimed food intake alter hormonal rhythms and metabolism. *Int J Mol Sci.* 2023;24(4):3392.
20. Park S, Lee J, Seok JW, Park CG, Jun J. Comprehensive lifestyle modification interventions for metabolic syndrome: a systematic review and meta-analysis. *J Nurs Sch.* 2024;56:249-59.
21. Jamshed H, Steger FL, Bryan DR, et al. Effectiveness of early time-restricted eating for weight loss, fat loss, and cardiometabolic health in adults with obesity: a randomized clinical trial. *JAMA Intern Med.* 2022;182(9):953-62.