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Targeting Oxidative Stress and Immunomodulation in Metabolic and Endocrine Disorders: Lessons from Benign Prostatic Hyperplasia, Diabetes, and Reproductive Hormone Imbalance

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ABSTRACT

Metabolic and endocrine disorders share a set of conserved pathogenic circuits in which oxidative stress and immune dysregulation are tightly intertwined. Benign prostatic hyperplasia (BPH), diabetes mellitus, and reproductive hormone imbalance provide complementary windows into this biology. Across these conditions, mitochondrial dysfunction, NADPH oxidase activity, advanced glycation end-products, and endoplasmic reticulum stress amplify reactive oxygen and nitrogen species, while innate and adaptive immune programs-Toll-like receptors, NLRP3 inflammasome, macrophage polarization, and T-cell skewing-sustain chronic inflammation and fibrotic remodeling. Hormonal milieus modulate these redox–immune loops: androgens and estrogens shape stromal–epithelial crosstalk in the prostate; insulin and adipokines orchestrate hepato–renal injury in diabetes; and hypoestrogenism, hyperandrogenism, or hypogonadism recalibrate neuroimmune tone and metabolic flux. This review synthesizes mechanistic commonalities and disease-specific features, highlights organ and axis crosstalk (gut–liver–kidney–prostate–brain), and outlines a therapeutic framework combining metabolic control, redox restoration, and immunomodulation. We discuss biomarkers for stratification and monitoring and propose trial designs that test multi-target strategies across indications where shared biology predicts shared benefit.

Keywords: oxidative stress, immunomodulation, benign prostatic hyperplasia, diabetes, reproductive hormones

INTRODUCTION

Metabolic and endocrine disorders rarely operate in isolation. Instead, they propagate through conserved molecular nodes that couple redox imbalance to immune activation [1]. BPH, diabetes, and reproductive hormone imbalance each exemplify this principle. In BPH, age-related shifts in androgen–estrogen balance sensitize prostate stroma and epithelium to oxidative injury and chronic inflammation, driving hyperplasia and fibrosis [2]. In diabetes, hyperglycemia, lipotoxicity, and insulin resistance create a systemic pro-oxidant state that activates innate and adaptive immunity, accelerating hepatotoxicity, nephrotoxicity, vascular disease, and neuropathy [3]. In reproductive hormone imbalance-ranging from hypoestrogenism to hyperandrogenic states such as PCOS-perturbations of the hypothalamic–pituitary–gonadal axis reshapes mitochondrial function, microglial tone, and peripheral immunity, feeding back on metabolism and organ health [4]. A unifying feature across these conditions is bidirectional crosstalk among organs and axes. Gut dysbiosis and barrier dysfunction increase endotoxemia, stimulating TLR signaling and redox stress in the liver, kidney, prostate, and brain [5]. Adipokines, hepatokines, and gonadal hormones circulate as endocrine cues that tune redox set points and immune polarization [6]. Recognizing this shared architecture motivates therapeutic designs that move beyond single-pathway interventions toward coordinated correction of metabolic, oxidative, and immune drivers.

2. Mechanistic Convergence: The Redox–Immune–Endocrine Triangle

Metabolic and endocrine disorders such as benign prostatic hyperplasia (BPH), diabetes, and reproductive hormone imbalance converge mechanistically on a shared triangle of oxidative stress, immunomodulation, and endocrine regulation [7]. These three components are not independent but operate as an interconnected system, where disruption of one rapidly influences the others.

Oxidative stress is a unifying initiator. In virtually all tissues, mitochondria are the dominant source of reactive oxygen species (ROS), generated when electron leakage occurs during oxidative phosphorylation [8]. NADPH oxidase (NOX) enzymes, cytochrome P450 reactions, and metabolic pathways such as the polyol and protein kinase C (PKC) cascades further elevate ROS production under stress conditions [9]. In diabetes, for example, chronic hyperglycemia accelerates the formation of advanced glycation end-products (AGEs), which activate the receptor for AGEs (RAGE) on endothelial and immune cells [10]. This signaling triggers NF-κB, leading to proinflammatory cytokine release. Concurrently, endoplasmic reticulum (ER) stress and the unfolded protein response intersect with JNK and CHOP pathways, lowering antioxidant defenses and promoting apoptosis [11]. Normally, the transcription factor Nrf2 orchestrates the induction of detoxifying and antioxidant enzymes, but in chronic disease states, Nrf2 activation is impaired, weakening resilience to oxidative injury [12].

Immunomodulation represents the second axis of convergence. Innate immune sensors such as Toll-like receptors (TLR2/4) and the cGAS–STING pathway detect DAMPs from injured cells and microbial ligands derived from dysbiosis or endotoxemia [13]. These signals activate inflammasomes, particularly NLRP3, which drive caspase-1–mediated maturation of IL-1β and IL-18. In parallel, macrophages polarize toward proinflammatory M1 phenotypes or fibrogenic M2-like states depending on cytokine context [13]. Adaptive immunity adds another layer, with T-cell skewing toward Th1 and Th17 phenotypes sustaining inflammation, while inadequate regulatory T-cell (Treg) function fails to restrain excessive responses [14]. Importantly, ROS act both upstream and downstream in these pathways-oxidative stress activates immune signaling, while activated immune cells generate more ROS-creating a self-reinforcing loop.

Endocrine regulation closes the triangle. Hormones such as androgens, estrogens, progesterone, insulin, IGF-1, adiponectin, and leptin directly modulate mitochondrial function, NOX activity, antioxidant tone, and immune polarization [15]. Estrogens generally enhance antioxidant defenses and temper immune activation, while androgens influence mitochondrial bioenergetics and inflammatory responses [16]. Adipokines such as adiponectin suppress inflammation and oxidative stress, whereas leptin promotes immune activation and fibrosis [17]. Endocrine imbalance-whether due to aging, menopause, andropause, or metabolic syndrome-thus recalibrates the redox-immune axis, making tissues more vulnerable to injury and less capable of repair.

Taken together, these three pillars form an interconnected pathogenic circuit. Oxidative stress ignites immune responses, immune activation perpetuates oxidative injury, and endocrine dysregulation shifts the balance toward chronic inflammation and fibrosis.

3. Lessons from Benign Prostatic Hyperplasia

Benign prostatic hyperplasia (BPH) exemplifies how endocrine imbalance, oxidative stress, and immune dysregulation converge to drive disease progression. BPH is fundamentally a disorder of stromal–epithelial interactions within the prostate, tightly regulated by reproductive hormones [18]. Dihydrotestosterone (DHT), produced from testosterone by 5α-reductase, strongly activates androgen receptor signaling in prostate cells, driving proliferation and glandular enlargement [19]. With aging, the estrogen-to-androgen ratio shifts, increasing estrogen receptor-α (ERα) activity, which promotes inflammation and fibrosis [20]. Estrogen receptor-β (ERβ), in contrast, has antiproliferative and pro-apoptotic roles, but its relative influence diminishes over time [21].

Oxidative stress features prominently in BPH pathology. Prostate tissues display increased lipid peroxidation, protein oxidation, and reduced antioxidant enzyme activity [22]. Mitochondrial dysfunction contributes to ROS generation, while infiltrating immune cells amplify oxidative injury through NOX-derived ROS and proinflammatory cytokines [23]. Immune contributors are consistently observed in hyperplastic prostate tissue. T-cells and macrophages infiltrate the stroma, while mast cells secrete mediators that sustain chronic inflammation [24]. Cytokines such as IL-6, IL-8, and TNF-α stimulate stromal proliferation and extracellular matrix deposition [25]. Pattern recognition receptors, including TLRs, detect endogenous ligands released from stressed cells and microbial metabolites derived from gut dysbiosis, bridging local oxidative stress with systemic inflammatory signals [26].

Therapeutically, current strategies address only part of this triangle. 5α-reductase inhibitors reduce DHT and limit androgen-driven proliferation, while alpha-blockers relieve smooth muscle-mediated obstruction [27]. Selective estrogen receptor modulators (SERMs) are being explored to shift the ERα/ERβ balance toward protective signaling [28]. Antioxidants and phytotherapeutics such as saw palmetto, lycopene, and curcumin are under investigation as adjuncts, given their ability to dampen oxidative and inflammatory responses [29]. The key lesson from BPH is that correcting hormonal imbalance alone is insufficient. Unless oxidative stress and immune activation are also addressed, the cycle of hyperplasia, inflammation, and fibrosis persists. Integrated approaches targeting the endocrine–redox–immune triangle may therefore represent the future of disease-modifying therapy in BPH.

4. Lessons from Diabetes

Diabetes creates a systemic environment of oxidative overload and immune activation that injures multiple organs. Hyperglycemia elevates mitochondrial ROS and activates NOX enzymes [30]; the polyol pathway depletes

NADPH, undermining glutathione recycling [31]; AGEs engage RAGE to induce NF-κB [32]; ER stress and defective autophagy propagate organelle damage [33]. These redox abnormalities occur in hepatocytes, Kupffer cells, podocytes, mesangial and tubular epithelial cells, endothelium, and peripheral nerves. Innate and adaptive immune mechanisms amplify injury: TLR signaling and NLRP3 activation promote IL-1β and IL-18; macrophages shift toward inflammatory phenotypes; Th1/Th17 polarization and Treg deficiency sustain chronic inflammation [34]. Organ crosstalk is prominent. In the liver, oxidative injury and CYP2E1 induction generate lipid peroxidation and DAMP release, activating stellate cells and fibrosis; hepatokines (fetuin-A, FGF21, ANGPTLs) and bile acid–FXR/TGR5 signaling modulate systemic metabolism and renal inflammation [35]. In the kidney, podocyte loss, GBM thickening, and tubular lipotoxicity progress with chemokine-driven leukocyte recruitment and interstitial fibrosis; reduced Klotho diminishes antioxidant capacity [36]. Adipokine imbalance (low adiponectin, high leptin) and dysbiosis-derived metabolites (LPS, TMAO) further amplify redox–immune stress, closing a hepato–renal–adipose–gut loop [37].

Therapeutic lessons emphasize multi-modal care: intensive metabolic control; SGLT2 inhibitors and GLP-1 receptor agonists with organ-protective effects; RAAS blockade; statins for vascular redox burden; targeted redox therapies (Nrf2 activators, NOX inhibitors, mitochondria-directed antioxidants) and emerging immunomodulators (IL-1 pathway, CCR2/CCR5) [38]. Diabetes demonstrates that addressing metabolism without redox–immune recalibration leaves substantial residual risk.

5. Lessons from Reproductive Hormone Imbalance

Hypoestrogenism (menopause), hypogonadism, and hyperandrogenic states (such as PCOS) reprogram redox and immune tone [39]. Estrogens typically enhance mitochondrial efficiency, upregulate antioxidant defenses, and temper microglial activation; deficiency increases cerebral and systemic oxidative stress, BBB vulnerability, and cytokine production [40]. Androgens modulate hippocampal plasticity and immune polarization; deficiency heightens microglial reactivity and oxidative injury, whereas excess can aggravate excitotoxic and inflammatory signaling [41]. Progesterone supports myelin and dampens neuroinflammation; dysregulation impairs repair and promotes oxidative damage [42]. In PCOS, insulin resistance, adipose inflammation, and hyperandrogenism converge to increase NOX activity, oxidative modification of lipids and proteins, and TLR/NLRP3 signaling [43]. These changes feedback to worsen metabolic control and reproductive outcomes. Therapeutic approaches integrate lifestyle modification, insulin sensitizers, selective hormone receptor modulators, and antioxidant/immunoregulatory adjuncts, with growing interest in microbiota-targeted strategies that restore gut barrier integrity and endocrine–immune homeostasis.

6. Organ and Axis Crosstalk

Metabolic and endocrine disorders rarely remain confined to a single organ. Instead, they propagate through shared mediators that traverse systems and reinforce pathology across multiple axes. Cytokines such as TNF-α, IL-6, and TGF-β, together with chemokines like CCL2, act as common messengers sustaining inflammation, endothelial dysfunction, and fibrotic remodeling in liver, kidney, prostate, and vascular tissues [44]. Extracellular vesicles and microRNAs extend this signaling by shuttling proinflammatory and profibrotic cues between cells and organs, effectively creating a molecular communication network [45]. Adipose and hepatic secretory factors add further complexity. Adipokines such as adiponectin and leptin, and hepatokines including fetuin-A and FGF21, recalibrate systemic insulin sensitivity, metabolic tone, and immune polarization [46]. Disturbances in these mediators often tip the balance toward oxidative stress and chronic inflammation. Bile acids also function as endocrine-like messengers, activating nuclear and membrane receptors such as FXR and TGR5 to fine-tune lipid and glucose metabolism across the liver, kidney, and vasculature [47].

The gut microbiota is another pivotal node. Dysbiosis raises circulating lipopolysaccharide (LPS) levels, which stimulate Toll-like receptors and perpetuate systemic inflammation [48]. At the same time, altered microbial metabolism decreases beneficial short-chain fatty acids (SCFAs) while increasing pro-oxidant metabolites such as trimethylamine N-oxide (TMAO) [49]. These shifts compromise antioxidant capacity and enhance vascular and endocrine dysfunction. Collectively, this circuitry illustrates that correcting one element-such as glycemia-can improve outcomes but rarely normalizes the entire network unless oxidative and immune set points are simultaneously reset.

7. Therapeutic Framework: Combining Metabolic, Redox, and Immune Control

Addressing the intertwined drivers of metabolic and endocrine disorders requires an integrated therapeutic framework. Metabolic correction remains foundational, with control of glucose, lipids, and blood pressure reducing upstream triggers of oxidative stress. Agents such as SGLT2 inhibitors and GLP-1 receptor agonists demonstrate organ-protective effects beyond glycemia, while lifestyle measures like weight loss and exercise enhance mitochondrial efficiency and antioxidant defenses [50]. Redox restoration can be achieved with pharmacological Nrf2 activators, NOX inhibitors, or mitochondria-targeted antioxidants, as well as nutraceuticals like vitamin E, resveratrol, and curcumin [51]. Immunomodulation includes cytokine blockade, TLR antagonism, and strategies to rebalance macrophage and T-cell subsets [52]. In BPH, combining endocrine therapies with antioxidant or anti-inflammatory agents may provide superior control of hyperplasia and fibrosis. Additional strategies focus on the gut microbiota, using prebiotics, probiotics, or dietary interventions to reduce endotoxemia and restore SCFA production [53]. Ultimately, combination design-integrating metabolic, redox, and immune interventions guided by biomarkers offers the most promising path toward durable, multi-organ benefit.

CONCLUSION

Oxidative stress and immunomodulation form the common language of injury across metabolic and endocrine disorders. BPH, diabetes, and reproductive hormone imbalance differ in presentation but converge mechanistically through mitochondrial dysfunction, innate and adaptive immune activation, and fibrotic remodeling. Therapeutic strategies that integrate metabolic control with redox restoration and targeted immunomodulation are poised to deliver cross-organ benefits. Building biomarker-guided, combination trials around this shared biology is the next step toward changing the natural history of these prevalent, intersecting diseases.

REFERENCES

1. Li B, Ming H, Qin S, Nice EC, Dong J, Du Z, et al. Redox regulation: mechanisms, biology and therapeutic targets in diseases. Signal Transduction and Targeted Therapy. 2025;10(1). doi:10.1038/s41392-024-02095-6
2. Uroko Robert Ikechukwu., Agbafor Amarachi, Uchenna Oluomachi Nancy, Achi Ngozi Kalu, Egba Simeon Ikechukwu**,** Nweje-Anyalowu Paul Chukwuemaka and Ngwu Ogochukwu Rita. Evaluation of Antioxidant Activity of Aqueous Extracts of Palm Friuts *(Elaeis guineensis)* Asian Journal of Biochemistry, 2017; 12: 49-57
3. Ochulor Okechukwu C., Njoku Obioma U., Uroko Robert I and Egba Simeon I**.** Nutritional composition of *Jatropha tanjorensis* leaves and effects of its aqueous extract on carbon tetrachloride induced oxidative stress in male Wistar albino rats. Biomedical Research 2018; 29(19): 3569-3576
4. Emanuel RHK, Roberts J, Docherty PD, Lunt H, Campbell RE, Möller K. A review of the hormones involved in the endocrine dysfunctions of polycystic ovary syndrome and their interactions. Frontiers in Endocrinology. 2022;13. doi:10.3389/fendo.2022.1017468
5. Rosendo-Silva D, Viana S, Carvalho E, Reis F, Matafome P. Are gut dysbiosis, barrier disruption, and endotoxemia related to adipose tissue dysfunction in metabolic disorders? Overview of the mechanisms involved. Internal and Emergency Medicine. 2023;18(5):1287–302. doi:10.1007/s11739-023-03262-3
6. Ren Y, Zhao H, Yin C, Lan X, Wu L, Du X, et al. Adipokines, hepatokines and myokines: Focus on their role and molecular mechanisms in adipose tissue inflammation. Frontiers in Endocrinology. 2022;13. doi:10.3389/fendo.2022.873699
7. Ibiam UA, Uti DE, Ejeogo CC, Orji OU, Aja PM, Ezeaani NN, et al. In Vivo and in Silico Assessment of Ameliorative Effects of Xylopia aethiopica on Testosterone Propionate-Induced Benign Prostatic Hyperplasia. *Pharmaceut Fronts.* 2023;5: e64–e76. DOI:10.1055/s-0043-1768477
8. Kausar S, Wang F, Cui H. The role of mitochondria in reactive oxygen species generation and its implications for neurodegenerative diseases. Cells. 2018;7(12):274. doi:10.3390/cells7120274
9. Offor CE, Uti DE, Alum EU. Redox Signaling Disruption and Antioxidants in Toxicology: From Precision Therapy to Potential Hazards. *Cell Biochem Biophys* (2025). https://doi.org/10.1007/s12013-025-01846-8
10. Ikpozu EN, Offor CE, Igwenyi, I.O, Ibiam, U.A., Alum EU, Obaroh, I.O. et al. RNA-based diagnostic innovations: A new frontier in diabetes diagnosis and management. Diabetes & Vascular Disease Research. 2025;22(2). doi:10.1177/14791641251334726
11. Wang L, Liu Y, Zhang X, Ye Y, Xiong X, Zhang S, et al. Endoplasmic reticulum stress and the unfolded protein response in cerebral Ischemia/Reperfusion injury. Frontiers in Cellular Neuroscience. 2022;16. doi:10.3389/fncel.2022.864426
12. Ruiz S, Pergola PE, Zager RA, Vaziri ND. Targeting the transcription factor Nrf2 to ameliorate oxidative stress and inflammation in chronic kidney disease. Kidney International. 2013;83(6):1029–41. doi:10.1038/ki.2012.439
13. Chen L, Zhang L, Hua H, Liu L, Mao Y, Wang R. Interactions between toll-like receptors signaling pathway and gut microbiota in host homeostasis. Immunity Inflammation and Disease. 2024;12(7). doi:10.1002/iid3.1356
14. Zhou T, Hu Z, Yang S, Sun L, Yu Z, Wang G. Role of adaptive and innate immunity in Type 2 diabetes mellitus. Journal of Diabetes Research. 2018;2018:1–9. doi:10.1155/2018/7457269
15. Bocian-Jastrzębska A, Malczewska-Herman A, Kos-Kudła B. Role of leptin and adiponectin in carcinogenesis. Cancers. 2023;15(17):4250. doi:10.3390/cancers15174250
16. Klinge CM. Estrogenic control of mitochondrial function. Redox Biology. 2020;31:101435. doi:10.1016/j.redox.2020.101435

17. Uti DE, Atangwho IJ, Omang WA, Alum EU, Obeten UN, Udeozor PA, et al. Cytokines as key players in obesity low grade inflammation and related complications. Obesity Medicine, Volume 54, 2025,100585. https://doi.org/10.1016/j.obmed.2025.100585.
18. Ejeogo CC, Ibiam UA, Uti DE, Orji OU, Aja PM, Ezeaani NN, et al. Xylopia aethiopica Attenuates Oxidative Stress and Hepatorenal Damage in Testosterone Propionate-Induced Benign Prostatic Hyperplasia in Rats. Journal of Health and Allied Sciences. 2024, 01: 1-148. https://doi.org/10.1055/s-0043-1777836
19. Robert I. Uroko., Charles N. Chukwu., Simeon I. Egba., Fatima A. Adamude andJoy C. Ajuzie Combined ethanol extract of *Funtumia africana* and *Abutilon mauritianium* leaves improves the lipid profile and kidney function indices of benign prostatic hyperplasia in rats. Acta Sci. Pol. Technol. Aliment. 2020; 19(4): 395-404
20. Mbyemeire H, Fasogbon IV, Musyoka AM, Oviosun A, Ojiakor VO, Agunloye MO, et al. (2025). Exploring the use of phytotherapy in benign prostatic hyperplasia [BPH]: a systematic review. F1000Research, 14, 412. https://doi.org/10.12688/f1000research.162045.1
21. Aja, P.M, Agu, P.C., Musyoka, A.M., Ngwueche, W., Odo, J.U., Alum, E.U., et al. Integrative Approaches to Prostate Disease Management: Nutrition, Exercise, and Lifestyle Modifications. *American Journal of Men's Health*. 2025;19(3). doi:10.1177/15579883251344571
22. Edyedu I, Ugwu OP, Ugwu CN, Alum EU, Eze VHU, Basajja M, Ugwu JN, Ogenyi FC, Ejemot-Nwadiaro RI, Okon MB, Egba SI, Uti DE, Aja PM. The role of pharmacological interventions in managing urological complications during pregnancy and childbirth: A review. Medicine (Baltimore). 2025 Feb 14;104(7):e41381. doi: 10.1097/MD.0000000000041381. PMID: 39960970; PMCID: PMC11835077.
23. Bhol NK, Bhanjadeo MM, Singh AK, Dash UC, Ojha RR, Majhi S, et al. The interplay between cytokines, inflammation, and antioxidants: mechanistic insights and therapeutic potentials of various antioxidants and anti-cytokine compounds. Biomedicine & Pharmacotherapy. 2024;178:117177. doi:10.1016/j.biopha.2024.117177
24. Zhao H, Wu L, Yan G, Chen Y, Zhou M, Wu Y, et al. Inflammation and tumor progression: signaling pathways and targeted intervention. Signal Transduction and Targeted Therapy. 2021;6(1). doi:10.1038/s41392-021-00658-5
25. Zgheib C, Xu J, Liechty KW. Targeting inflammatory cytokines and extracellular matrix composition to promote wound regeneration. Advances in Wound Care. 2013;3(4):344–55. doi:10.1089/wound.2013.0456
26. Chen R, Zou J, Chen J, Zhong X, Kang R, Tang D. Pattern recognition receptors: function, regulation and therapeutic potential. Signal Transduction and Targeted Therapy. 2025;10(1). doi:10.1038/s41392-025-02264-1
27. Salisbury BH, Leslie SW, Tadi P. 5Α-Reductase inhibitors. StatPearls - NCBI Bookshelf. 2024. Available from: https://www.ncbi.nlm.nih.gov/books/NBK555930/
28. Maximov PY, Lee TM, Jordan VC. The discovery and development of Selective Estrogen Receptor Modulators (SERMs) for clinical practice. Current Clinical Pharmacology. 2013;8(2):135–55. doi:10.2174/1574884711308020006
29. Virk TL, Liu Q, Yuan Y, Xu X, Chen F. Curcumin as therapeutic modulator of impaired antioxidant defense system: Implications for Oxidative Stress-Associated Reproductive Dysfunction. Biology. 2025;14(7):750. doi:10.3390/biology14070750
30. Alum EU. Optimizing patient education for sustainable self-management in type 2 diabetes. *Discov Public Health* **22**, 44 (2025). https://doi.org/10.1186/s12982-025-00445-5
31. Krishnamoorthy R, Gatasheh MK, Subbarayan S, Vijayalakshmi P. Protective Role of Jimson Weed in Mitigating Dyslipidemia, Cardiovascular, and Renal Dysfunction in Diabetic Rat Models: In Vivo and in Silico Evidence. Natural Product Communications. 2024;19(12). doi:10.1177/1934578X241299279
32. Burr SD, Stewart JA. Rap1a Overlaps the AGE/RAGE Signaling Cascade to Alter Expression of α-SMA, p-NF-κB, and p-PKC-ζ in Cardiac Fibroblasts Isolated from Type 2 Diabetic Mice. Cells. 2021;10(3):557. doi:10.3390/cells10030557
33. Cai Y, Arikkath J, Yang L, Guo ML, Periyasamy P, Buch S. Interplay of endoplasmic reticulum stress and autophagy in neurodegenerative disorders. Autophagy. 2016;12(2):225–44. doi:10.1080/15548627.2015.1121360
34. Martynova E, Rizvanov A, Urbanowicz RA, Khaiboullina S. Inflammasome contribution to the activation of TH1, TH2, and TH17 immune responses. Frontiers in Microbiology. 2022;13. doi:10.3389/fmicb.2022.851835

35. Harjumäki R, Pridgeon CS, Ingelman-Sundberg M. CYP2E1 in alcoholic and Non-Alcoholic liver injury. Roles of ROS, reactive intermediates and lipid overload. International Journal of Molecular Sciences. 2021;22(15):8221. doi:10.3390/ijms22158221
36. Guo J, Zheng HJ, Zhang W, Lou W, Xia C, Han XT, et al. Accelerated kidney aging in diabetes mellitus. Oxidative Medicine and Cellular Longevity. 2020;2020:1–24. doi:10.1155/2020/1234059
37. Turpin T, Thouvenot K, Gonthier MP. Adipokines and bacterial metabolites: a pivotal molecular bridge linking obesity and gut microbiota dysbiosis to target. Biomolecules. 2023;13(12):1692. doi:10.3390/biom13121692
38. Luna-Marco C, Iannantuoni F, Hermo-Argibay A, Devos D, Salazar JD, Víctor VM, et al. Cardiovascular benefits of SGLT2 inhibitors and GLP-1 receptor agonists through effects on mitochondrial function and oxidative stress. Free Radical Biology and Medicine. 2024;213:19–35. doi:10.1016/j.freeradbiomed.2024.01.015
39. Rosenfield RL, Ehrmann DA. The Pathogenesis of polycystic ovary Syndrome (PCOS): The hypothesis of PCOS as functional ovarian hyperandrogenism revisited. Endocrine Reviews. 2016;37(5):467–520. doi:10.1210/er.2015-1104
40. Strom JO, Theodorsson A, Theodorsson E. Mechanisms of estrogens' Dose-Dependent neuroprotective and neurodamaging effects in experimental models of cerebral ischemia. International Journal of Molecular Sciences. 2011;12(3):1533–62. doi:10.3390/ijms12031533
41. Atwi S, McMahon D, Scharfman H, MacLusky NJ. Androgen modulation of hippocampal structure and function. The Neuroscientist. 2014;22(1):46–60. doi:10.1177/1073858414558065
42. Webster KM, Wright DK, Sun M, Semple BD, Ozturk E, Stein DG, et al. Progesterone treatment reduces neuroinflammation, oxidative stress and brain damage and improves long-term outcomes in a rat model of repeated mild traumatic brain injury. Journal of Neuroinflammation. 2015;12(1). doi:10.1186/s12974-015-0457-7
43. Liu H, Jin L, Wang X, Shi J, He Y, Sun N, et al. Reactive oxygen species in polycystic ovary syndrome: Mechanistic insights into pathogenesis and therapeutic opportunities. PubMed. 2025;85:103776. Available from: https://pubmed.ncbi.nlm.nih.gov/40694958
44. Zhang C. The role of inflammatory cytokines in endothelial dysfunction. Basic Research in Cardiology. 2008;103(5):398–406. doi:10.1007/s00395-008-0733-0
45. Park MN, Kim M, Lee S, Kang S, Ahn CH, Tallei TE, et al. Targeting Redox Signaling Through Exosomal MicroRNA: Insights into Tumor Microenvironment and Precision Oncology. Antioxidants. 2025;14(5):501. doi:10.3390/antiox14050501
46. De Oliveira Dos Santos AR, De Oliveira Zanuso B, Miola VFB, Barbalho SM, Bueno PCS, Flato UAP, et al. Adipokines, myokines, and hepatokines: crosstalk and metabolic repercussions. International Journal of Molecular Sciences. 2021;22(5):2639. doi:10.3390/ijms22052639
47. Chiang JYL, Ferrell JM. Bile acid receptors FXR and TGR5 signaling in fatty liver diseases and therapy. AJP Gastrointestinal and Liver Physiology. 2020;318(3):G554–73. doi:10.1152/ajpgi.00223.2019
48. Kalyan M, Tousif AH, Sonali S, Vichitra C, Sunanda T, Praveenraj SS, et al. Role of endogenous lipopolysaccharides in neurological disorders. Cells. 2022;11(24):4038. doi:10.3390/cells11244038
49. Trimethylamine N-oxide (TMAO) in human health. EXCLI Journal. 2021;20:301–19. Available from: https://europepmc.org/article/PMC/PMC7975634
50. Guerrero-Mauvecin J, Villar-Gómez N, Miño-Izquierdo L, Povo-Retana A, Ramos AM, Ruiz-Hurtado G, et al. Antioxidant effects of SGLT2 inhibitors on Cardiovascular–Kidney–Metabolic (CKM) Syndrome. Antioxidants. 2025;14(6):701. doi:10.3390/antiox14060701
51. Cort A, Ozben T, Saso L, De Luca C, Korkina L. Redox control of multidrug resistance and its possible modulation by antioxidants. Oxidative Medicine and Cellular Longevity. 2016;2016(1). doi:10.1155/2016/4251912
52. Strzelec M, Detka J, Mieszczak P, Sobocińska MK, Majka M. Immunomodulation-a general review of the current state-of-the-art and new therapeutic strategies for targeting the immune system. Frontiers in Immunology. 2023;14. doi:10.3389/fimmu.2023.1127704
53. Yoo S, Jung SC, Kwak K, Kim JS. The role of prebiotics in modulating gut microbiota: Implications for Human health. International Journal of Molecular Sciences. 2024;25(9):4834. doi:10.3390/ijms25094834

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