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Smart Nanocarriers for Modulating Adipose-Pancreatic Axis in Obesity and Diabetes

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ABSTRACT

The interrelationship between obesity and type 2 diabetes (T2D) is largely mediated by dysfunctions in the adipose tissue and pancreas, which are central to regulating metabolism. This dysfunction results in insulin resistance, altered glucose metabolism, and chronic inflammation, driving the pathogenesis of both conditions. Recent advancements in nanotechnology have led to the development of smart nanocarriers that can specifically target the adipose–pancreatic axis, the interconnected network of signaling between adipose tissue and the pancreas, crucial for maintaining metabolic balance. These nanocarriers are designed to enhance the targeted delivery of therapeutic agents, modulate adipose tissue function, and improve pancreatic β-cell activity, thereby addressing the root causes of obesity-related diabetes. This review highlights the role of smart nanocarriers in modulating the adipose–pancreatic axis by delivering anti-inflammatory agents, insulin-sensitizing drugs, and metabolic modulators directly to the affected tissues. Additionally, we examine their potential in restoring insulin sensitivity, reducing adiposity, and improving pancreatic function. The review also discusses the clinical prospects, challenges, and regulatory issues surrounding the use of smart nanocarriers for obesity and diabetes treatment. Ultimately, these smart nanocarriers offer a promising platform for developing more effective, targeted therapies to combat obesity-driven diabetes.

Keywords: Nanocarriers, Adipose Tissue, Pancreas, Obesity, Type 2 Diabetes, Targeted Therapy.

INTRODUCTION

Obesity and type 2 diabetes (T2D) are both significant contributors to the global health crisis, with their prevalence steadily rising due to unhealthy lifestyles, sedentary habits, and poor diets[1–3]. The pathophysiology of these diseases is deeply intertwined, particularly through dysfunctions in the adipose tissue and pancreas, which are central to regulating energy homeostasis and glucose metabolism. In obesity, the excess accumulation of adipose tissue, especially visceral fat, leads to the release of pro-inflammatory cytokines and adipokines, which induce systemic inflammation and insulin resistance[4–6]. This metabolic disturbance severely affects glucose metabolism, contributing to the development of T2D.

At the same time, the pancreas, responsible for secreting insulin, becomes stressed due to the increased demand for insulin in the context of insulin resistance[7–9]. This places undue strain on the pancreatic β-cells, which eventually results in β-cell dysfunction and failure, exacerbating hyperglycemia and the progression to T2D. The dysfunction of the adipose–pancreatic axis, which governs communication between the adipose tissue and pancreas, plays a critical role in this vicious cycle[10, 11]. This axis, regulated by hormones such as leptin, adiponectin, and insulin, influences the functioning of both organs, driving metabolic dysfunction[12].

Nanotechnology has emerged as a powerful tool in addressing these challenges. Smart nanocarriers engineered to deliver therapeutic agents with precision hold promise for modulating the adipose–pancreatic axis[13–15]. By targeting specific molecular pathways involved in inflammation, insulin sensitivity, and β-cell function, these nanocarriers can restore metabolic balance and improve therapeutic outcomes. This review discusses the potential of smart nanocarriers in targeting the adipose–pancreatic axis to manage obesity-driven diabetes, their mechanisms of action, and their clinical implications.

Pathophysiology of Adipose–Pancreatic Crosstalk in Obesity and Diabetes

The adipose tissue and pancreas are key players in regulating glucose homeostasis. In obesity, the excessive accumulation of adipose tissue, particularly visceral fat, results in an altered secretory profile of adipokines[16–18]. Adipokines, such as leptin, resistin, and TNF-α, contribute to inflammation and insulin resistance. Leptin, a hormone secreted by adipocytes, normally helps to regulate energy balance by promoting satiety and

enhancing insulin sensitivity[19, 20]. However, in obesity, the action of leptin becomes impaired due to leptin resistance, leading to overeating, weight gain, and further insulin resistance.

Adipose tissue dysfunction is closely linked to pancreatic dysfunction. Insulin resistance in peripheral tissues, caused by dysregulated adipokine secretion, increases the demand for insulin production. This heightened demand stresses the pancreatic β-cells, leading to β-cell dysfunction and impaired insulin secretion. In turn, this exacerbates the hyperglycemia that characterizes T2D[16, 21, 22]. In addition to insulin resistance, obesity-induced inflammation plays a central role in both adipose and pancreatic dysfunctions. Inflammatory cytokines such as IL-6 and TNF-α disrupt insulin signaling pathways and interfere with insulin action in both the adipose tissue and liver. Moreover, increased circulating free fatty acids (FFAs) contribute to ectopic fat deposition in non-adipose tissues, further impairing insulin sensitivity and promoting the progression of metabolic disorders[23, 24]. The adipose–pancreatic axis involves complex signaling pathways that modulate insulin sensitivity, glucose metabolism, and inflammation. Targeting these pathways using precision nanomedicine holds great potential for restoring normal metabolic function and reversing the effects of obesity-driven T2D.

Smart Nanocarriers: Design and Mechanisms of Action

Smart nanocarriers are engineered nanoparticles designed to deliver therapeutic agents with high precision and specificity. Their design typically incorporates features that allow for enhanced drug encapsulation, targeted delivery, controlled release, and minimal side effects[25–28]. The key features of smart nanocarriers include their small size (typically 1-100 nm), large surface area, ability to carry both hydrophobic and hydrophilic drugs, and potential for functionalization with targeting ligands such as peptides, antibodies, or small molecules[29, 30].

One of the most significant advantages of smart nanocarriers is their ability to enhance the bioavailability and stability of therapeutic agents, which are often poorly soluble or unstable in the bloodstream[31, 32]. Additionally, these nanocarriers can be engineered to release their therapeutic cargo in a controlled manner, either in response to specific environmental conditions such as pH or temperature, or in response to biological cues such as enzymes or receptors. This controlled release ensures that drugs are delivered directly to the target tissues, improving therapeutic efficacy and reducing off-target effects[33, 34].

In the context of obesity and T2D, smart nanocarriers can be used to deliver a variety of therapeutic agents, including anti-inflammatory drugs, insulin-sensitizing agents, glucagon-like peptide-1 (GLP-1) agonists, and molecules that regulate adipogenesis[35, 36]. These nanocarriers can be targeted to adipose tissue or the pancreas, where they can modulate key metabolic pathways, restore insulin sensitivity, reduce inflammation, and improve β-cell function.

For example, nanoparticles functionalized with ligands specific to insulin-resistant adipocytes or pancreatic β-cells can ensure that drugs are delivered precisely where they are needed most. Furthermore, nanocarriers can be designed to bypass systemic circulation and target areas with high metabolic activity, such as the pancreas and adipose tissue, thereby maximizing therapeutic outcomes[37–39].

Modulating the Adipose–Pancreatic Axis with Smart Nanocarriers

The use of smart nanocarriers for modulating the adipose–pancreatic axis offers a novel approach for addressing the metabolic dysfunction in obesity and T2D. By targeting both adipose tissue and pancreatic β-cells, nanocarriers can help restore normal signaling and metabolic function, thereby improving insulin sensitivity and glucose homeostasis.

Targeting Inflammation in Adipose Tissue: Chronic inflammation in adipose tissue plays a crucial role in the development of insulin resistance and the progression of T2D[8, 40]. Smart nanocarriers can be designed to deliver anti-inflammatory agents directly to inflamed adipose tissue. For example, nanoparticles can encapsulate cytokine inhibitors, such as TNF-α blockers, IL-6 inhibitors, or NF-κB inhibitors, and target these agents to the adipose tissue where inflammation is most prominent[41]. This targeted delivery reduces systemic inflammation, improves insulin sensitivity, and restores normal adipokine secretion, which in turn alleviates insulin resistance.

Restoring Insulin Sensitivity: Insulin resistance in peripheral tissues, including the liver, muscle, and adipose tissue, is a key feature of obesity and T2D. Nanocarriers can be used to deliver insulin-sensitizing agents, such as metformin or thiazolidinediones (TZDs), directly to insulin-resistant tissues[42–44]. This localized delivery increases the bioavailability of these agents, ensuring that they reach their target tissues in optimal concentrations. Furthermore, nanoparticles can be designed to release these agents in a controlled manner, ensuring prolonged therapeutic effects and minimizing the need for frequent administration.

Enhancing Pancreatic β-Cell Function: The β-cell dysfunction that occurs in obesity-driven T2D is a significant challenge in managing the disease. Smart nanocarriers can be used to deliver agents that promote β-cell survival, proliferation, and insulin secretion. For example, nanoparticles can encapsulate GLP-1 agonists, which stimulate insulin secretion from pancreatic β-cells and enhance insulin sensitivity in peripheral tissues[28, 31]. By targeting the pancreas specifically, these nanocarriers can help restore normal β-cell function and reduce the insulin production burden caused by insulin resistance.

Clinical Prospects and Challenges in Smart Nanocarriers for Obesity and Diabetes

Smart nanocarriers have emerged as a promising therapeutic platform for the management of obesity and type 2 diabetes (T2D) by enabling targeted modulation of metabolic pathways, including those governing adipose tissue function, inflammation, and insulin sensitivity[45]. Despite encouraging preclinical outcomes, the successful clinical translation of these nanotechnologies faces several critical challenges that must be systematically addressed.

One of the foremost concerns is safety and biocompatibility. Due to their nanoscale size and high surface reactivity, nanoparticles can interact extensively with biological systems, leading to unintended biodistribution and accumulation in organs such as the liver, kidneys, spleen, and lungs[46]. Chronic exposure raises concerns about long-term toxicity, immunogenicity, oxidative stress, and potential interference with normal cellular functions. Moreover, some nanomaterials may undergo slow biodegradation or persist in tissues, exacerbating cumulative toxicity risks[46]. Comprehensive toxicological assessments, including long-term and dose-escalation studies, are therefore essential to establish acceptable safety profiles, particularly for metabolic diseases that require prolonged or lifelong treatment.

Another major challenge lies in interindividual variability in therapeutic response. Obesity and T2D are heterogeneous disorders influenced by genetic predisposition, disease severity, metabolic phenotype, lifestyle factors, and the presence of comorbidities such as cardiovascular disease or non-alcoholic fatty liver disease[47]. These factors can significantly affect nanoparticle biodistribution, cellular uptake, and therapeutic efficacy. As a result, a "one-size-fits-all" nanomedicine approach may be inadequate. The integration of patient stratification and biomarker-driven design may be necessary to optimize clinical outcomes[48].

Manufacturing scalability and reproducibility further complicate clinical translation. Many smart nanocarriers involve complex architectures, multi-component formulations, or stimuli-responsive elements that are difficult to reproduce consistently at an industrial scale[49]. Batch-to-batch variability in particle size, surface charge, drug loading, and release kinetics can significantly influence therapeutic performance and safety. The development of standardized, scalable manufacturing processes that comply with Good Manufacturing Practice (GMP) guidelines remains a critical bottleneck[49].

Additionally, the regulatory landscape for nanomedicines is still evolving. Regulatory agencies require robust characterization of physicochemical properties, pharmacokinetics, biodistribution, and toxicity profiles, often beyond what is needed for conventional small-molecule drugs[50]. The absence of universally accepted regulatory frameworks for nanocarriers can prolong approval timelines and increase development costs[50].

Despite these challenges, the clinical prospects of smart nanocarriers remain highly encouraging. Early-phase clinical trials of nanoparticle-based drug delivery systems in related metabolic and inflammatory disorders have demonstrated feasibility, supporting the notion that with rigorous optimization, smart nanocarriers could become a transformative therapeutic modality for obesity and diabetes.

The Future of Smart Nanocarriers in Obesity and Diabetes Management

The future of smart nanocarriers in obesity and diabetes management is poised to be shaped by rapid advancements in nanotechnology, molecular biology, and precision medicine. By enabling targeted, controlled, and responsive drug delivery, smart nanocarriers offer the potential to overcome many limitations associated with conventional pharmacotherapy, including poor bioavailability, off-target effects, and systemic toxicity.

One of the most promising directions is the development of next-generation nanocarriers with enhanced targeting specificity[51]. Advances in ligand engineering and surface functionalization are expected to improve selective delivery to metabolically active tissues such as adipose depots, pancreatic β-cells, liver, and skeletal muscle[51]. Targeting moieties based on peptides, antibodies, aptamers, or cell-penetrating ligands could facilitate precise modulation of the adipose–pancreatic axis, thereby improving insulin sensitivity and metabolic homeostasis while minimizing adverse effects.

Stimuli-responsive and intelligent delivery systems are also likely to play a central role in future therapeutic strategies[25, 52]. Nanocarriers capable of responding to glucose levels, inflammatory signals, oxidative stress, or enzymatic activity could enable on-demand drug release, mimicking physiological feedback mechanisms. Such systems may be particularly beneficial for glycemic control in diabetes, where dynamic and tightly regulated drug release is crucial.

The integration of omics technologies and artificial intelligence is expected to accelerate the transition toward personalized nanomedicine. Genomic, transcriptomic, and metabolomic profiling could be used to identify patient-specific metabolic signatures, guiding the selection of nanocarrier design, payload, and dosing regimens[53]. Machine learning–based predictive models may further optimize nanocarrier performance by correlating physicochemical properties with biological outcomes.

Another emerging frontier is the combination of therapeutic and diagnostic capabilities, leading to theranostic nanocarriers[29, 54]. These platforms could enable real-time monitoring of drug distribution, metabolic responses, and treatment efficacy, facilitating adaptive therapeutic strategies. In obesity and diabetes, theranostics may allow early detection of treatment resistance or disease progression.

Furthermore, advances in biodegradable and bioinspired nanomaterials, including lipid-based, polymeric, and exosome-mimetic systems, are expected to enhance safety and regulatory acceptance. Such materials may reduce long-term toxicity concerns and improve patient compliance[55–57]. In sum, while significant challenges

remain, the continued convergence of nanotechnology, metabolic biology, and precision medicine is likely to position smart nanocarriers as a cornerstone of future obesity and diabetes management. With sustained interdisciplinary research and thoughtful regulatory development, these platforms hold the potential to deliver safer, more effective, and individualized therapeutic solutions.

CONCLUSION

Smart nanocarriers represent a promising frontier in the treatment of obesity and type 2 diabetes by offering a precision-driven approach to modulating the adipose–pancreatic axis. By delivering therapeutic agents directly to the adipose tissue and pancreas, these nanocarriers can improve insulin sensitivity, reduce inflammation, and restore pancreatic function. While challenges related to safety, patient variability, and regulatory approval remain, the continued advancement of nanotechnology offers hope for more effective, targeted treatments for obesity-driven diabetes. The future of nanomedicine lies in its ability to address the root causes of metabolic dysfunction, leading to improved patient outcomes and a reduction in the global burden of metabolic diseases.

REFERENCES

1. Allocca, S., Monda, A., Messina, A., Casillo, M., Sapuppo, W., Monda, V., Polito, R., Maio, G.D., Monda, M., Marra, M.L.: Endocrine and Metabolic Mechanisms Linking Obesity to Type 2 Diabetes: Implications for Targeted Therapy. Healthcare. 13, (2025). https://doi.org/10.3390/healthcare13121437
2. Baliou, S., Apetroaei, M.-M., Hatzidaki, E., Kuzmin, S.V., Tzatzarakis, M.N., Arsene, A.L., Tsatsakis, A., Ioannou, P.: The Interplay Between Obesity and Type 2 Diabetes: Common Pathophysiological Mechanisms Contributing to Telomere Shortening. Life. 15, (2025). https://doi.org/10.3390/life15060873
3. Ejemot-Nwadiaro, R.I., Betiang, P.A., Basajja, M., Uti, D.E.: Obesity and Climate Change: A Two-way Street with Global Health Implications. Obes. Med. 100623 (2025). https://doi.org/10.1016/j.obmed.2025.100623
4. Uti, D.E., Atangwho, I.J., Omang, W.A., Alum, E.U., Obeten, U.N., Udeozor, P.A., Agada, S.A., Bawa, I., Ogbu, C.O.: Cytokines as key players in obesity low grade inflammation and related complications. Obes. Med. 54, 100585 (2025). https://doi.org/10.1016/j.obmed.2025.100585
5. Ruze, R., Liu, T., Zou, X., Song, J., Chen, Y., Xu, R., Yin, X., Xu, Q.: Obesity and type 2 diabetes mellitus: connections in epidemiology, pathogenesis, and treatments. Front. Endocrinol. 14, 1161521 (2023). https://doi.org/10.3389/fendo.2023.1161521
6. Izah, S.C., Betiang, P.A., Paul-Chima Ugwu, O., Ainebyoona, C., Uti, D.E., Echegu, D.A.: The Ketogenic Diet in Obesity Management: Friend or Foe? Cell Biochem. Biophys. (2025). https://doi.org/10.1007/s12013-025-01878-0
7. Wondmkun, Y.T.: Obesity, Insulin Resistance, and Type 2 Diabetes: Associations and Therapeutic Implications. Diabetes Metab. Syndr. Obes. Targets Ther. 13, 3611–3616 (2020). https://doi.org/10.2147/DMSO.S275898
8. Roy, P.K., Islam, J., Lalhlenmawia, H.: Prospects of potential adipokines as therapeutic agents in obesity-linked atherogenic dyslipidemia and insulin resistance. Egypt. Heart J. 75, 24 (2023). https://doi.org/10.1186/s43044-023-00352-7
9. Suren Garg, S., Kushwaha, K., Dubey, R., Gupta, J.: Association between obesity, inflammation and insulin resistance: Insights into signaling pathways and therapeutic interventions. Diabetes Res. Clin. Pract. 200, 110691 (2023). https://doi.org/10.1016/j.diabres.2023.110691
10. Durrani, I.A., Bhatti, A., John, P.: The prognostic outcome of 'type 2 diabetes mellitus and breast cancer' association pivots on hypoxia-hyperglycemia axis. Cancer Cell Int. 21, 351 (2021). https://doi.org/10.1186/s12935-021-02040-5
11. Ryu, T.Y., Park, J., Scherer, P.E.: Hyperglycemia as a Risk Factor for Cancer Progression. Diabetes Metab. J. 38, 330–336 (2014). https://doi.org/10.4093/dmj.2014.38.5.330
12. Obasi, D.C., Abba, J.N., Aniokete, U.C., Okoroh, P.N., Akwari, A.Ak.: Evolving Paradigms in Nutrition Therapy for Diabetes: From Carbohydrate Counting to Precision Diets. Obes. Med. 100622 (2025). https://doi.org/10.1016/j.obmed.2025.100622
13. Ly, P.-D., Ly, K.-N., Phan, H.-L., Nguyen, H.H.T., Duong, V.-A., Nguyen, H.V.: Recent advances in surface decoration of nanoparticles in drug delivery. Front. Nanotechnol. 6, (2024). https://doi.org/10.3389/fnano.2024.1456939
14. Mim, J.J., Mamun, A.A., Nayem, M.H., Mahmud, S., Nath, A., Rahman, S.M., Fidal, S.A., Hossain, N.: Machine learning-driven advances in nanotechnology: From materials design to process optimization – A review. Mater. Today Commun. 50, 114485 (2026). https://doi.org/10.1016/j.mtcomm.2025.114485
15. Padmanaban, S., Pully, D., Samrot, A.V., Gosu, V., Sadasivam, N., Park, I.-K., Radhakrishnan, K., Kim, D.-K.: Rising Influence of Nanotechnology in Addressing Oxidative Stress-Related Liver Disorders. Antioxidants. 12, (2023). https://doi.org/10.3390/antiox12071405
16. Alexaki, V.I.: Adipose tissue-derived mediators of systemic inflammation and metabolic control. Curr. Opin. Endocr. Metab. Res. 37, 100560 (2024). https://doi.org/10.1016/j.coemr.2024.100560
17. Auger, C., Kajimura, S.: Adipose Tissue Remodeling in Pathophysiology. Annu. Rev. Pathol. Mech. Dis. 18, 71–93 (2023). https://doi.org/10.1146/annurev-pathol-042220-023633

18. Alum, E.U.: Metabolic memory in obesity: Can early-life interventions reverse lifelong risks? Obes. Med. 55, 100610 (2025). https://doi.org/10.1016/j.obmed.2025.100610
19. Ormazabal, P., Bastías-Pérez, M., Inestrosa, N.C., Cisternas, P.: Adipokines at the Metabolic–Brain Interface: Therapeutic Modulation by Antidiabetic Agents and Natural Compounds in Alzheimer's Disease. Pharmaceuticals. 18, (2025). https://doi.org/10.3390/ph18101527
20. Roy, P.K., Islam, J., Lalhlenmawia, H.: Prospects of potential adipokines as therapeutic agents in obesity-linked atherogenic dyslipidemia and insulin resistance. Egypt. Heart J. 75, 24 (2023). https://doi.org/10.1186/s43044-023-00352-7
21. Nnolum-Orji, N.F., Kumar, P., Ngema, L.M., Choonara, Y.E.: Adipose tissue NLRP3 inflammasome: a therapeutic target in obesity and type 2 diabetes mellitus. Drug Discov. Today. 30, 104456 (2025). https://doi.org/10.1016/j.drudis.2025.104456
22. Orji, U.O., Ibiam, Udu Ama, Awoke, Joshua Nonso, Atoki ,Ayomide Victor, Eze ,Ejike Daniel, Obasi ,Otuomasiri Divine, Ogbu ,Celestine, Ezeani ,Nkiru Nwamaka, Aloke ,Chinyere, and Aja, P.M.: Ethanolic extract of Cnidoscolus aconitifolius leaves alleviates insulin resistance by modulating oxidative stress and inflammation in albino rats exposed to heavy metal mixture. Nat. Prod. Res. 0, 1–14. https://doi.org/10.1080/14786419.2025.2478654
23. Venkatesan, K., Paulsamy, P., Alqahtani, S., Asiri, Y.I., Alqahtani, T., Alqahtani, A., Sivadasan, D., Ahmed, R., Elfadil, H., Asseri, K.A., Qureshi, A.A., Velraj, M., Krishnaraju, K.: An update on the role of inflammation in insulin resistance and islet β cell failure- A crosstalk between immune cells, adipose tissue, cytokines, and oxidative stress. Lett. Drug Des. Discov. 22, 100023 (2025). https://doi.org/10.1016/j.lddd.2025.100023
24. Aloh, H.E., Obasi, D.C., Okoroh, P.N., Aniokete, U.C., Emeruwa, A.P.: Maternal Nutrition, Toxicants, and Epigenetic Programming of Obesity Across Generations. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy, 18*, 4873–4911. https://doi.org/10.2147/DMSO.S579409
25. Emadi, R., Amiri, Z., Moghadam, F.M., Raoufi, S., Moradi, M.Z., Asadi, S., Cho, W.C., Hee Park, J., Voosough, A., Farani, M.R., Hwang, S.-K., Suk Huh, Y.: Self-assembling nanocomposites for smart drug delivery: towards personalized and stimuli-responsive therapeutics. (2026). https://doi.org/10.1039/D5RA07117H
26. Ma, J., Zhao, C.F., Liu, X.: Advances in targeted therapeutics and smart delivery systems based on precision nano-oncology. Int. Immunopharmacol. 169, 115946 (2026). https://doi.org/10.1016/j.intimp.2025.115946
27. Mistry, A., Bhattacharya, A., Mondal, M., Bhattacharjee, S., Bhattacharya, A., Ghosh, S.B., Kabsh, M.A., Alharbi, M.T., Majrashi, M.A.A., Nagshabandi, M.K., Tarabulsi, M.K., El-Demerdash, F.M., Abdel-Daim, M.M., Dhara, B., Uti, D.E.: Calcineurin Inhibitors: Current Role, Toxicity Management, and Future Frontiers in Immunosuppression. Mol. Neurobiol. 63, 275 (2025). https://doi.org/10.1007/s12035-025-05549-2
28. Zhao, C., Rehman, F.U., Shaikh, S., Qazi, R. e M., Sajid, Z., Mian, A.A., He, N.: Metallic nanoscale-knife application in cancer theranostics. Smart Mater. Med. 4, 313–336 (2023). https://doi.org/10.1016/j.smaim.2022.11.006
29. Omang, W.A., Bawa, I., Idowu, A.O., Atangwho, I.J., Egbung, G.E.: Theranostic Nanoparticles in Prostate Cancer: Disrupting Hypoxia-Induced Glycolysis by Targeting Hypoxia-Inducible Factor-1 Alpha and Downstream Metabolites. Cancer Med. 15, e71519 (2026). https://doi.org/10.1002/cam4.71519
30. Atangwho, I.J., Ugwu, O.P.-C., Egbung, G.E., Aja, P.M.: Lipid-based nano-carriers for the delivery of anti-obesity natural compounds: advances in targeted delivery and precision therapeutics. J. Nanobiotechnology. 23, 336 (2025). https://doi.org/10.1186/s12951-025-03412-z
31. Nunziata, G., Pollonio, D., Lacroce, E., Rossi, F.: Smart pH-Responsive polymers in biomedical Applications: Nanoparticles, hydrogels, and emerging hybrid platforms. Mater. Today Chem. 49, 103063 (2025). https://doi.org/10.1016/j.mtchem.2025.103063
32. Younas, A., Wang, S., Asad, M., Al Mamun, A., Majeed, S., Sharif, A., Zhou, Q., Liu, Y., Geng, P., Shao, C., Xiao, J.: Recent advances in cancer nanomedicine: From smart targeting to personalized therapeutics - pioneering a new era in precision oncology. Mater. Today Bio. 36, 102660 (2026). https://doi.org/10.1016/j.mtbio.2025.102660
33. Sun, L., Liu, H., Ye, Y., Lei, Y., Islam, R., Tan, S., Tong, R., Miao, Y.-B., Cai, L.: Smart nanoparticles for cancer therapy. Signal Transduct. Target. Ther. 8, 418 (2023). https://doi.org/10.1038/s41392-023-01642-x
34. Nwuruku, O.A., Edwin, N.: Harnessing nature: plant-derived nanocarriers for targeted drug delivery in cancer therapy. Phytomedicine Plus. 5, 100828 (2025). https://doi.org/10.1016/j.phyplu.2025.100828
35. Iqbal, N., Ambery, P., Logue, J., Mallappa, A., Sjöström, C.D.: Perspectives in weight control in diabetes – SGLT2 inhibitors and GLP-1–glucagon dual agonism. Diabetes Res. Clin. Pract. 199, 110669 (2023). https://doi.org/10.1016/j.diabres.2023.110669

36. Zeng, J., Tang, X., Qin, D., Yu, L., Zhou, X., Feng, C., Mi, J., Pan, H., Wu, J., Huang, B., Wu, A.: Engineered GLP-1R-targeting nanoplatforms: multimodal therapeutics in human diseases. J. Nanobiotechnology. 23, 682 (2025). https://doi.org/10.1186/s12951-025-03677-4
37. Alshammari, E.M.: Curcumin-based biocompatible nanocarriers: a contemporary perspective in functional foods and biomedical applications. Discov. Nano. 20, 226 (2025). https://doi.org/10.1186/s11671-025-04379-4
38. Bera, R., Pathak, S., Srivastava, P., Ghosh, M., Sharma, A., Ahmed, N.Z., Karwasra, R., Akram, U., Kumar, P., Sharma, B., Sharma, N.: Biomimetic nanocarriers for the therapy and management of intestinal inflammations. Int. J. Pharm. X. 10, 100377 (2025). https://doi.org/10.1016/j.ijpx.2025.100377
39. Daoud, E., Abdulsahib, W.K., Ismael, S.H., Roopashree, R., Ray, S., Nellore, J., Mukherjee, G., Chauhan, A.S., Kholiyeva, M.: Nanomedicine and nutraceutical-based nanocarriers for specific delivery to cancer stem cells: targeted drug delivery at the STEM frontier. Discov. Oncol. 16, 2286 (2025). https://doi.org/10.1007/s12672-025-04057-y
40. Bensussen, A., Torres-Magallanes, J.A., Roces De Álvarez-Buylla, E.: Molecular tracking of insulin resistance and inflammation development on visceral adipose tissue. Front. Immunol. 14, 1014778 (2023). https://doi.org/10.3389/fimmu.2023.1014778
41. Lee, Y.S., Kim, J., Osborne, O., Oh, D.Y., Sasik, R., Schenk, S., Chen, A., Chung, H., Murphy, A., Watkins, S.M., Quehenberger, O., Johnson, R.S., Olefsky, J.M.: Increased Adipocyte O2 Consumption Triggers HIF-1α Causing Inflammation and Insulin Resistance in Obesity. Cell. 157, 1339–1352 (2014). https://doi.org/10.1016/j.cell.2014.05.012
42. Lee, B.-C., Lee, J.: Cellular and molecular players in adipose tissue inflammation in the development of obesity-induced insulin resistance. Biochim. Biophys. Acta BBA - Mol. Basis Dis. 1842, 446–462 (2014). https://doi.org/10.1016/j.bbadis.2013.05.017
43. Li, M., Chi, X., Wang, Y., Setrerrahmane, S., Xie, W., Xu, H.: Trends in insulin resistance: insights into mechanisms and therapeutic strategy. Signal Transduct. Target. Ther. 7, 216 (2022). https://doi.org/10.1038/s41392-022-01073-0
44. Kang, H.S., Liao, G., DeGraff, L.M., Gerrish, K., Bortner, C.D., Garantziotis, S., Jetten, A.M.: CD44 Plays a Critical Role in Regulating Diet-Induced Adipose Inflammation, Hepatic Steatosis, and Insulin Resistance. PLOS ONE. 8, e58417 (2013). https://doi.org/10.1371/journal.pone.0058417
45. Baranwal, A., Bansal, V., Shukla, R.: Emerging Biomarkers and Nanobiosensing Strategies in Diabetes. Biosensors. 15, 639 (2025). https://doi.org/10.3390/bios15100639
46. Elmowafy, E.M., Tiboni, M., Soliman, M.E.: Biocompatibility, biodegradation and biomedical applications of poly(lactic acid)/poly(lactic-co-glycolic acid) micro and nanoparticles. J. Pharm. Investig. 49, 347–380 (2019). https://doi.org/10.1007/s40005-019-00439-x
47. Pan, Z., Khatry, M.A., Yu, M.-L., Choudhury, A., Sebastiani, G., Alqahtani, S.A., Eslam, M.: MAFLD: an ideal framework for understanding disease phenotype in individuals of normal weight. Ther. Adv. Endocrinol. Metab. 15, 20420188241252543 (2024). https://doi.org/10.1177/20420188241252543
48. Alum, E.U.: 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
49. Parvin, N., Aslam, M., Alam, M.N., Mandal, T.K.: Nanotechnology Driven Innovations in Modern Pharmaceutics: Therapeutics, Imaging, and Regeneration. Nanomaterials. 15, (2025). https://doi.org/10.3390/nano15221733
50. Hertig, J.B., Shah, V.P., Flühmann, B., Mühlebach, S., Stemer, G., Surugue, J., Moss, R., Di Francesco, T.: Tackling the challenges of nanomedicines: are we ready? Am. J. Health. Syst. Pharm. 78, 1047–1056 (2021). https://doi.org/10.1093/ajhp/zxab048
51. Singh, D., Kumar, A.: Next-generation nanocarriers for precision antitumor therapy: from passive targeting to intelligent response. Explor. Target. Anti-Tumor Ther. 6, 1002355 (2025). https://doi.org/10.37349/etat.2025.1002355
52. Hou, J., Xue, Z., Chen, Y., Li, J., Yue, X., Zhang, Y., Gao, J., Hao, Y., Shen, J.: Development of Stimuli-Responsive Polymeric Nanomedicines in Hypoxic Tumors and Their Therapeutic Promise in Oral Cancer. Polymers. 17, (2025). https://doi.org/10.3390/polym17081010
53. Hsu, C.-Y., Askar, S., Alshkarchy, S.S., Nayak, P.P., Attabi, K.A.L., Khan, M.A., Mayan, J.A., Sharma, M.K., Islomov, S., Soleimani Samarkhazan, H.: AI-driven multi-omics integration in precision oncology: bridging the data deluge to clinical decisions. Clin. Exp. Med. 26, 29 (2026). https://doi.org/10.1007/s10238-025-01965-9
54. Calatayud, D.G., Neophytou, S., Nicodemou, E., Giuffrida, S.G., Ge, H., Pascu, S.I.: Nano-Theranostics for the Sensing, Imaging and Therapy of Prostate Cancers. Front. Chem. 10, (2022). https://doi.org/10.3389/fchem.2022.830133
55. Almohaimeed, H.M., Almars, A.I., Tounsi, W.A., Mohammedsaleh, Z.M., Panigrahi, R., Singh, I., Singh, S., Dhara, B., Uti, D.E.: Exosomes in Autoimmunity: Mediators of Autoantigen Presentation and Targets for Therapeutic Intervention in Autoimmune Diseases. J. Clin. Immunol. 46, 3 (2025). https://doi.org/10.1007/s10875-025-01965-0

56. Butreddy, A., Kommineni, N., Dudhipala, N.: Exosomes as Naturally Occurring Vehicles for Delivery of Biopharmaceuticals: Insights from Drug Delivery to Clinical Perspectives. Nanomaterials. 11, 1481 (2021). https://doi.org/10.3390/nano11061481
57. Mukerjee, N., Sarkar, S., Uti, D.E., Sharma, P.K.: Advancements in exosome-based cancer diagnosis: from chipsets to nano vaccine. Cancer Biol. Ther. 26, 2541991 (2025). https://doi.org/10.1080/15384047.2025.2541991

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https://doi.org/10.59298/IDOSR/JST/26/122.4046