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Nanotechnology at the Metabolic Interface: Emerging Solutions for Obesity-Driven Diabetes

Winniefred Nankya

Department of Clinical Pharmacy Kampala International University Uganda
Email:winniefred.nankya@studwc.kiu.ac.ug

ABSTRACT

Obesity and type 2 diabetes (T2D) are increasingly prevalent global health issues, often coexisting as part of a metabolic syndrome characterized by insulin resistance and chronic inflammation. Recent advances in nanotechnology offer innovative solutions to address the complex interplay between these two conditions, particularly at the metabolic interface. Nanomedicine presents novel strategies for improving drug delivery, targeting inflammation, regulating metabolic pathways, and enhancing tissue regeneration. This review explores emerging nano-based solutions that aim to break the vicious cycle of obesity-driven diabetes. By leveraging the unique properties of nanomaterials, such as enhanced bioavailability, tissue-specific targeting, and the ability to modulate cellular signaling, these therapeutic approaches hold the potential to transform the management of obesity-induced metabolic disorders. We discuss the role of nanoparticles, nanocarriers, and nanomaterials in modulating key metabolic processes, such as insulin signaling, lipid metabolism, and adipogenesis. The review also considers the clinical prospects and challenges of translating nanotechnology-based treatments into mainstream healthcare for obesity-driven diabetes, emphasizing the importance of safety, efficacy, and regulatory approval. These emerging solutions hold promise for reshaping the treatment landscape of metabolic diseases and improving patient outcomes on a global scale.

Keywords: Nanomedicine, Obesity, Diabetes, Metabolic Disorders, Drug Delivery.

INTRODUCTION

Obesity and type 2 diabetes (T2D) are two major metabolic disorders that have become a global health crisis, with the World Health Organization (WHO) identifying obesity as a leading risk factor for T2D development[1–4]. The relationship between these two conditions is complex and interconnected, often referred to as obesity-driven diabetes. Obesity contributes to insulin resistance through several mechanisms, including the accumulation of visceral fat, chronic inflammation, and alterations in lipid metabolism[1, 5, 6]. Insulin resistance, in turn, leads to hyperglycemia, triggering the onset of diabetes and a cascade of related complications such as cardiovascular disease, neuropathy, and kidney dysfunction[7–10].

The pathophysiology of obesity-driven diabetes involves a multifaceted interplay of genetic, environmental, and metabolic factors[11, 12]. These factors disrupt insulin signaling, impair glucose uptake by peripheral tissues, and promote an inflammatory state within adipose tissue. Despite advancements in traditional therapies such as oral hypoglycemic agents and insulin injections, the growing prevalence of both obesity and T2D necessitates the exploration of novel treatment strategies.

Nanotechnology, the manipulation of materials at the nanoscale, offers a potential solution to overcome the limitations of conventional approaches[13–15]. Nanomedicine, which applies nanotechnology to drug delivery, biomolecular modulation, and tissue engineering, has emerged as a promising field for addressing the metabolic interface between obesity and diabetes. By using nanoparticles and nanomaterials, it is possible to target tissues more precisely, enhance the bioavailability of therapeutic agents, and regulate complex metabolic processes involved in both conditions[16–18]. This review delves into the emerging role of nanotechnology at the metabolic interface, focusing on innovative solutions that target obesity-driven diabetes. It will examine key strategies such as targeted drug delivery, modulation of inflammatory pathways, regulation of lipid metabolism, and promotion of insulin sensitivity, all of which could offer new avenues for treating these interconnected diseases. Additionally, the review will explore the clinical potential of these approaches and highlight the challenges in translating nanomedicine from research to clinical practice.

Obesity and Diabetes: Metabolic Crosstalk and Pathophysiological Mechanisms

The relationship between obesity and diabetes is bidirectional, with obesity serving as a major risk factor for the development of T2D[19]. The pathophysiology of obesity-related diabetes involves multiple interconnected metabolic disturbances that contribute to insulin resistance and impaired glucose metabolism[3, 20, 21]. Visceral fat, particularly around the abdomen, plays a crucial role in this process. Adipocytes, or fat cells, secrete various bioactive molecules known as adipokines, which include inflammatory cytokines like TNF-α, IL-6, and resistin[12, 22–24]. These cytokines promote chronic low-grade inflammation in adipose tissue, which, in turn, affects insulin signaling and impairs glucose uptake by peripheral tissues, including skeletal muscle and the liver[24, 25].

In addition to inflammation, obesity leads to dyslipidemia, characterized by elevated levels of free fatty acids (FFAs) in the bloodstream[24, 26, 27]. FFAs interfere with insulin signaling pathways, further exacerbating insulin resistance. Additionally, the accumulation of ectopic fat in non-adipose tissues, such as the liver and muscle, worsens insulin sensitivity. The result is hyperglycemia, which contributes to the development of T2D[28].

The pancreas plays a central role in maintaining glucose homeostasis through the secretion of insulin. In the context of obesity, the increased demand for insulin due to insulin resistance places stress on pancreatic β-cells, ultimately leading to β-cell dysfunction and failure. This progression contributes to the development of T2D and further complicates the management of obesity-related metabolic disorders[29, 30].

Recent studies have also highlighted the role of the gut microbiome in modulating the metabolic crosstalk between obesity and diabetes[21, 31–33]. Dysbiosis, or an imbalance in the gut microbiota, has been implicated in the development of insulin resistance and obesity[34, 35]. Nanotechnology offers the potential to manipulate the gut microbiome by delivering bioactive agents that promote a healthier microbial balance, thereby improving metabolic function. Nanotechnology-based therapies that target inflammation, lipid metabolism, and insulin resistance hold great promise for treating obesity-driven diabetes[36, 37]. By targeting these key pathophysiological mechanisms, nanomedicine can potentially break the cycle of metabolic dysfunction that drives both obesity and diabetes.

3. Nanomedicine for Targeted Drug Delivery in Obesity-Driven Diabetes

One of the most promising applications of nanotechnology in obesity-driven diabetes therapy is targeted drug delivery. Traditional drug delivery systems often fail to provide sufficient therapeutic concentrations at the desired site of action, leading to suboptimal therapeutic outcomes. Nanoparticles, due to their small size and large surface area, can be engineered to enhance the bioavailability of drugs and enable targeted delivery to specific tissues, such as adipose tissue, the pancreas, or the liver[27, 38].

Lipid-based nanoparticles, such as liposomes and solid lipid nanoparticles (SLNs), are commonly used for encapsulating drugs with poor water solubility[27, 37, 39]. These nanoparticles can be functionalized with targeting ligands, such as antibodies or peptides, to enhance their specificity for particular cells or tissues involved in the obesity–diabetes crosstalk. For example, nanoparticles can be designed to target insulin-resistant adipocytes or pancreatic β-cells, ensuring that therapeutic agents are delivered directly to the sites where they are most needed[24]. Polymeric nanoparticles, another type of nanocarrier, can be designed to release their therapeutic cargo in a controlled manner, either in response to specific environmental stimuli (e.g., changes in pH or temperature) or over an extended period. This controlled release can help to maintain therapeutic levels of the drug for longer durations, improving treatment efficacy and reducing the need for frequent administration[40–42].

Additionally, nanocarriers can be used to deliver combination therapies that address multiple aspects of obesity-driven diabetes simultaneously. For instance, a single nanoparticle could carry anti-inflammatory agents, insulin-sensitizing compounds, and adipogenesis inhibitors, offering a multifaceted approach to treating the metabolic dysfunction underlying these diseases.

Modulating Inflammation and Insulin Sensitivity via Nanotechnology

Chronic inflammation is a hallmark of both obesity and diabetes, contributing significantly to insulin resistance and metabolic dysfunction. Nanotechnology offers innovative ways to modulate inflammatory pathways, potentially reversing insulin resistance and improving glucose metabolism[43, 44].

One approach involves using nanoparticles to deliver anti-inflammatory agents directly to inflamed adipose tissue. Nanoparticles can be designed to encapsulate small molecules, peptides, or RNA-based therapeutics that target key inflammatory cytokines or signaling pathways, such as TNF-α, IL-6, or NF-κB. By selectively targeting these inflammatory pathways, nanomedicine can help reduce the systemic inflammation that contributes to insulin resistance[45].

Nanoparticles can also be used to regulate insulin sensitivity by delivering insulin-sensitizing agents, such as metformin or thiazolidinediones (TZDs), to specific tissues. For example, polymeric nanoparticles can be engineered to release these agents in the liver or muscle, where they can improve insulin signaling and glucose uptake[45–47]. By enhancing the sensitivity of target tissues to insulin, nanotechnology could help restore normal glucose metabolism and reduce the risk of T2D.

Additionally, nanotechnology can be used to modulate key metabolic regulators, such as AMP-activated protein kinase (AMPK) and peroxisome proliferator-activated receptor gamma (PPAR-γ), which play crucial roles in

regulating insulin sensitivity and glucose homeostasis[48, 49]. Nanoparticles can deliver small molecules that activate or inhibit these pathways, offering a powerful tool for improving insulin action.

Nanotechnology for Regulating Lipid Metabolism and Adipogenesis

Dysregulation of lipid metabolism and adipogenesis (the formation of new adipocytes) is a key feature of obesity and diabetes. Nanotechnology can play a pivotal role in regulating these processes by targeting the molecular pathways involved in fat cell formation, lipid accumulation, and fatty acid oxidation[50, 51].

Nanoparticles can be used to deliver small molecules or RNA-based therapeutics that inhibit adipogenesis[52], thus reducing the accumulation of excess fat in adipose tissue. For example, small molecules that inhibit key transcription factors, such as PPAR-γ or C/EBP-α, can be delivered using nanocarriers to prevent the differentiation of pre-adipocytes into mature adipocytes. This could help reduce the overall adiposity and mitigate the inflammatory response associated with obesity[52].

Nanotechnology also offers the potential to regulate lipid metabolism by modulating enzymes involved in fatty acid oxidation and lipogenesis[53]. For example, nanoparticles can be used to deliver agents that activate AMP-activated protein kinase (AMPK), a key regulator of fatty acid oxidation, or inhibit acetyl-CoA carboxylase (ACC), which plays a role in lipid synthesis. By modulating these enzymes, nanomedicine could help restore normal lipid metabolism and prevent the accumulation of harmful lipids in tissues[53].

Clinical Prospects and Challenges in Nanotechnology for Obesity-Driven Diabetes

While the potential of nanotechnology to treat obesity-driven diabetes is immense, several challenges remain in translating these therapies from the laboratory to clinical practice. One of the major concerns is the safety and biocompatibility of nanomaterials[54]. As nanoparticles accumulate in the body over time, there is a risk of toxicity, particularly in organs such as the liver, kidneys, and spleen. Thorough toxicological evaluations and long-term safety studies are essential to ensure that nanomedicines do not cause adverse effects[54].

Additionally, the complexity of obesity-driven diabetes necessitates the development of multifunctional nanoparticles that can simultaneously target multiple pathways involved in these diseases[55]. This requires careful design and optimization of nanomaterials to ensure that they can effectively modulate the different metabolic processes without causing unintended effects[55].

Regulatory approval is another significant challenge. As nanomedicine is still a relatively new field, regulatory agencies such as the FDA are working to establish guidelines for the approval of nanomedicines. The regulatory pathway for nanotechnology-based therapies must be carefully navigated to ensure that these treatments meet safety and efficacy standards.

Despite these challenges, the future of nanotechnology in obesity-driven diabetes therapy is promising. Continued research and clinical trials are expected to yield valuable insights into the potential of nanomedicine to improve patient outcomes and revolutionize the treatment of metabolic disorders.

CONCLUSION

Nanotechnology is rapidly redefining therapeutic strategies at the metabolic interface linking obesity and diabetes, offering precision tools capable of addressing the multifactorial nature of these intertwined disorders. By enabling targeted drug delivery, improved bioavailability, and controlled release of therapeutics, nanoplatforms overcome many limitations of conventional treatments, including poor tissue specificity and systemic side effects. Beyond therapy, nanotechnology-driven biosensors and imaging systems enhance early diagnosis and real-time monitoring of metabolic dysfunction, facilitating personalized and adaptive interventions. Importantly, the integration of nanomaterials with biological systems allows modulation of key pathways involved in insulin resistance, inflammation, adipose tissue remodeling, and pancreatic β-cell preservation. While preclinical advances are highly promising, successful clinical translation will depend on addressing long-term safety, scalability, regulatory harmonization, and cost-effectiveness, particularly for low- and middle-income settings where the burden is greatest. Overall, nanotechnology stands as a transformative bridge between metabolic biology and precision medicine, holding substantial promise for more effective, durable, and individualized management of obesity-driven diabetes.

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. Aloo, S.O., Barathikannan, K., Oh, D.-H.: Polyphenol-rich fermented hempseed ethanol extracts improve obesity, oxidative stress, and neural health in high-glucose diet-induced *Caenorhabditis elegans*. Food Chem. X. 21, 101233 (2024). https://doi.org/10.1016/j.fochx.2024.101233
3. Anand, S., Patel, T.N.: Integrating the metabolic and molecular circuits in diabetes, obesity and cancer: a comprehensive review. Discov. Oncol. 15, 779 (2024). https://doi.org/10.1007/s12672-024-01662-1
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. Arnesen, E.K., Thorisdottir, B., Bärebring, L., Söderlund, F., Nwaru, B.I., Spielau, U., Dierkes, J., Ramel, A., Lamberg-Allardt, C., Åkesson, A.: Nuts and seeds consumption and risk of cardiovascular disease, type

2 diabetes and their risk factors: a systematic review and meta-analysis. Food Nutr. Res. 67, 10.29219/fnr.v67.8961 (2023). https://doi.org/10.29219/fnr.v67.8961

6. 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
7. Ahmed, B., Sultana, R., Greene, M.W.: Adipose tissue and insulin resistance in obese. Biomed. Pharmacother. 137, 111315 (2021). https://doi.org/10.1016/j.biopha.2021.111315
8. 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 , 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
9. Umoru, G.U., Atangwho, I.J., David-Oku, E., Uti, D.E., De Campos, O.C., Udeozor, P.A., Nfona, S.O., Lawal, B., Alum, E.U.: Modulation of Lipogenesis by Tetracarpidium conophorum Nuts via SREBP-1/ACCA-1/FASN Inhibition in Monosodium-Glutamate-Induced Obesity in Rats. Nat. Prod. Commun. 20, 1934578X251344035 (2025). https://doi.org/10.1177/1934578X251344035
10. David-Oku, E., Agwupuye, E.I., Obeten, U.N., Maitra, S., Subramaniyan, V., Wong, L.S., Aljarba, N.H., Kumarasamy, V.: Tetracarpidium conophorum nuts (African walnuts) up-regulated adiponectin and PPAR-γ expressions with reciprocal suppression of TNF-α gene in obesity. J. Cell. Mol. Med. 28, e70086 (2024). https://doi.org/10.1111/jcmm.70086
11. Omang, W.A., Wokoma, M.A., Oplekwu, R.I., Atangwho, I.J., Egbung, G.E.: Targeting CD44-Hyaluronic Acid Signalling in Obesity Treatment: Insights from Small Molecules and Nanobioconjugates. Nutr. Metab. Insights. 19, 11786388251408961 (2026). https://doi.org/10.1177/11786388251408961
12. 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
13. Ahmad, U., Islam, A., Khan, M.M., Akhtar, J.: Nanotechnology-driven Epigenetic Cancer Therapy: Precision Delivery and Sustained Release of DNA Methylation Modulators. Yale J. Biol. Med. 98, 227–235 (2025). https://doi.org/10.59249/GVNM8843
14. Alghamdi, M.A., Fallica, A.N., Virzì, N., Kesharwani, P., Pittalà, V., Greish, K.: The Promise of Nanotechnology in Personalized Medicine. J. Pers. Med. 12, 673 (2022). https://doi.org/10.3390/jpm12050673
15. Awlqadr, F.H., Majeed, K.R., Altemimi, A.B., Hassan, A.M., Qadir, S.A., Saeed, M.N., Faraj, A.M., Salih, T.H., Abd Al-Manhel, A.J., Najm, M.A.A., Tsakali, E., Van Impe, J.F.M., Abd El-Maksoud, A.A., Abedelmaksoud, T.G.: Nanotechnology-based herbal medicine: Preparation, synthesis, and applications in food and medicine. J. Agric. Food Res. 19, 101661 (2025). https://doi.org/10.1016/j.jafr.2025.101661
16. Al-Thani, A.N., Jan, A.G., Abbas, M., Geetha, M., Sadasivuni, K.K.: Nanoparticles in cancer theragnostic and drug delivery: A comprehensive review. Life Sci. 352, 122899 (2024). https://doi.org/10.1016/j.lfs.2024.122899
17. Barua, S., Mitragotri, S.: Challenges associated with Penetration of Nanoparticles across Cell and Tissue Barriers: A Review of Current Status and Future Prospects. Nano Today. 9, 223–243 (2014). https://doi.org/10.1016/j.nantod.2014.04.008
18. Cheng, T.-M., Chu, H.-Y., Huang, H.-M., Li, Z.-L., Chen, C.-Y., Shih, Y.-J., Whang-Peng, J., Cheng, R.H., Mo, J.-K., Lin, H.-Y., Wang, K.: Toxicologic Concerns with Current Medical Nanoparticles. Int. J. Mol. Sci. 23, (2022). https://doi.org/10.3390/ijms23147597
19. Ejemot-Nwadiaro, R.I., Betiang, P.A., Basajja, M.: 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
20. Wang, L., Wang, Q., Xiong, Y., Shi, W., Qi, X.: Obesity and Its Comorbidities: Current Treatment Options, Emerging Biological Mechanisms, Future Perspectives and Challenges. Diabetes Metab. Syndr. Obes. 18, 3427–3445 (2025). https://doi.org/10.2147/DMSO.S540103
21. Zaky, A., Glastras, S.J., Wong, M.Y.W., Pollock, C.A., Saad, S.: The Role of the Gut Microbiome in Diabetes and Obesity-Related Kidney Disease. Int. J. Mol. Sci. 22, 9641 (2021). https://doi.org/10.3390/ijms22179641
22. Jouy, S.H., Mohan, S., Scichilone, G., Mostafa, A., Mahmoud, A.M.: Adipokines in the Crosstalk between Adipose Tissues and Other Organs: Implications in Cardiometabolic Diseases. Biomedicines. 12, (2024). https://doi.org/10.3390/biomedicines12092129
23. 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
24. 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

25. Ouchi, N., Parker, J.L., Lugus, J.J., Walsh, K.: Adipokines in inflammation and metabolic disease. Nat. Rev. Immunol. 11, 85–97 (2011). https://doi.org/10.1038/nri2921
26. Bays, H.E., Kirkpatrick, C., Maki, K.C., Toth, P.P., Morgan, R.T., Tondt, J., Christensen, S.M., Dixon, D., Jacobson, T.A.: Obesity, dyslipidemia, and cardiovascular disease: A joint expert review from the Obesity Medicine Association and the National Lipid Association 2024. Obes. Pillars. 10, 100108 (2024). https://doi.org/10.1016/j.obpill.2024.100108
27. Herdiana, Y., Levita, J., Jiranusornkul, S.: Chitosan-Based Nanoparticles Targeted Delivery System: In Treatment Approach for Dyslipidemia. Int. J. Nanomedicine. 20, 6611–6636 (2025). https://doi.org/10.2147/IJN.S517492
28. Alum, E.U., Izah, S.C., Betiang, P.A., Paul-Chima Ugwu, O., Ainebyoona, C., Uti, D.E., Echegu, D.A., Alum, B.N.: The Ketogenic Diet in Obesity Management: Friend or Foe? Cell Biochem. Biophys. (2025). https://doi.org/10.1007/s12013-025-01878-0
29. Tudurí, E., Soriano, S., Almagro, L., Montanya, E., Alonso-Magdalena, P., Nadal, Á., Quesada, I.: The pancreatic β-cell in ageing: Implications in age-related diabetes. Ageing Res. Rev. 80, 101674 (2022). https://doi.org/10.1016/j.arr.2022.101674
30. 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
31. Ugwu, O.P.-C., Edeh, F.O., Ainebyoona, C.: Unveiling the microbial orchestra: exploring the role of microbiota in cancer development and treatment. Discov. Oncol. 16, 646 (2025). https://doi.org/10.1007/s12672-025-02352-2
32. Li, R., Andreu-Sánchez, S., Kuipers, F., Fu, J.: Gut microbiome and bile acids in obesity-related diseases. Best Pract. Res. Clin. Endocrinol. Metab. 35, 101493 (2021). https://doi.org/10.1016/j.beem.2021.101493
33. Pandey, R.P., Dhiman, R., Chang, C.-M.: The potential of nanoencapsulated probiotics in the modulation of the gut microbiome. Nanomed. 20, 335–338. https://doi.org/10.1080/17435889.2025.2452152
34. Patra, D., Banerjee, D., Ramprasad, P., Roy, S., Pal, D., Dasgupta, S.: Recent insights of obesity-induced gut and adipose tissue dysbiosis in type 2 diabetes. Front. Mol. Biosci. 10, 1224982 (2023). https://doi.org/10.3389/fmolb.2023.1224982
35. Zhao, M., Chu, J., Feng, S., Guo, C., Xue, B., He, K., Li, L.: Immunological mechanisms of inflammatory diseases caused by gut microbiota dysbiosis: A review. Biomed. Pharmacother. 164, 114985 (2023). https://doi.org/10.1016/j.biopha.2023.114985
36. 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
37. Atangwho, I.J., 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
38. Ghandforoushan, P., Hanaee, J., Aghazadeh, Z., Samiei, M., Navali, A.M., Khatibi, A., Davaran, S.: Enhancing the function of PLGA-collagen scaffold by incorporating TGF-β1-loaded PLGA-PEG-PLGA nanoparticles for cartilage tissue engineering using human dental pulp stem cells. Drug Deliv. Transl. Res. 12, 2960–2978 (2022). https://doi.org/10.1007/s13346-022-01161-2
39. Nwuruku, O.A., Ugwu, O.P.-C., Uti, D.E., Alum, B.N., 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
40. Eltaib, L.: Polymeric Nanoparticles in Targeted Drug Delivery: Unveiling the Impact of Polymer Characterization and Fabrication. Polymers. 17, (2025). https://doi.org/10.3390/polym17070833
41. Herdiana, Y., Wathoni, N., Shamsuddin, S., Muchtaridi, M.: Scale-up polymeric-based nanoparticles drug delivery systems: Development and challenges. OpenNano. 7, 100048 (2022). https://doi.org/10.1016/j.onano.2022.100048
42. Zhang, H., Chen, H., Hu, X., Muhammad, W., Liu, C., Liu, W.: Inflammation-modulating polymeric nanoparticles: design strategies, mechanisms, and therapeutic applications. eBioMedicine. 118, 105837 (2025). https://doi.org/10.1016/j.ebiom.2025.105837
43. Tsalamandris, S., Antonopoulos, A.S., Oikonomou, E., Papamikroulis, G.-A., Vogiatzi, G., Papaioannou, S., Deftereos, S., Tousoulis, D.: The Role of Inflammation in Diabetes: Current Concepts and Future Perspectives. Eur. Cardiol. Rev. 14, 50–59 (2019). https://doi.org/10.15420/ecr.2018.33.1
44. 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

45. Wang, R., Kubiatowicz, L.J., Zhang, R., Bao, L., Fang, R.H., Zhang, L.: Nanoparticle approaches for manipulating cytokine delivery and neutralization. Front. Immunol. 16, 1592795 (2025). https://doi.org/10.3389/fimmu.2025.1592795
46. Shaban, E.E., Abd El-Aziz, M.E.: Innovative nanotechnological approaches to diabetes treatment: the role of metal oxide nanoparticles. Pharm. Dev. Technol. 30, 1227–1249 (2025). https://doi.org/10.1080/10837450.2025.2566460
47. Wang, Y., Li, H., Rasool, A., Wang, H., Manzoor, R., Zhang, G.: Polymeric nanoparticles (PNPs) for oral delivery of insulin. J. Nanobiotechnology. 22, 1 (2024). https://doi.org/10.1186/s12951-023-02253-y
48. Parvin, N., Aslam, M., Alam, M.N., Mandal, T.K.: Nanotechnology Driven Innovations in Modern Pharmaceutics: Therapeutics, Imaging, and Regeneration. Nanomaterials. 15, 1733 (2025). https://doi.org/10.3390/nano15221733
49. Sukubo, N.G., Bigini, P., Morelli, A.: Nanocarriers and macrophage interaction: from a potential hurdle to an alternative therapeutic strategy. Beilstein J. Nanotechnol. 16, 97–118 (2025). https://doi.org/10.3762/bjnano.16.10
50. Liu, C., Liu, X., Li, H., Kang, Z.: Advances in the regulation of adipogenesis and lipid metabolism by exosomal ncRNAs and their role in related metabolic diseases. Front. Cell Dev. Biol. 11, 1173904 (2023). https://doi.org/10.3389/fcell.2023.1173904
51. Zhou, C., Gui, W., Zhu, W., Zhao, H., Wu, D., Wu, F., Wang, G., Lin, X.: Paradoxical regulation of IGF2 in promoting lipid metabolism in adipose tissues. Commun. Biol. 8, 1026 (2025). https://doi.org/10.1038/s42003-025-08458-1
52. Xie, Y., Ma, Q., Wang, J., Zhu, Z.X., El-Araby, R.E., Tu, M., Li, Z., Xu, X., Tu, Q., Chen, J.: Effects of Modified Messenger RNA of Adiponectin Delivered by Lipid Nanoparticles on Adipogenesis and Bone Metabolism In Vitro and In Vivo. Cells. 14, (2025). https://doi.org/10.3390/cells14120891
53. Li, G., Dai, Z., Guo, J.: Therapeutic Nanomaterials in NAFLD: Current Advances and Potential Applications in Patients with Concurrent HBV Infection. Int. J. Nanomedicine. 20, 3803–3823 (2025). https://doi.org/10.2147/IJN.S510271
54. Kaushal, A., Musafir, A., Sharma, G., Rani, S., Singh, R.K., Kumar, A., Bhadada, S.K., Barnwal, R.P., Singh, G.: Revolutionizing Diabetes Management Through Nanotechnology-Driven Smart Systems. Pharmaceutics. 17, 777 (2025). https://doi.org/10.3390/pharmaceutics17060777
55. Mohaghegh, N., Balajam, N.Z., Hosseinpour, B., Buttles, C., Huang, Q., Huang, Y., Ahari, A., Farhadi, N., Davani, S., Khosravi, S., Mirmashhouri, B., Kouchehbaghi, N.H., Sampath, R., Akbari, M., Jucaud, V., Kang, H., Khademhosseini, A., Pearson, R.M., Najafabadi, A.H.: Immunoengineering strategies using nanoparticles for obesity treatment. Nano Res. 18, 94907707 (2025). https://doi.org/10.26599/NR.2025.94907707

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