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Review article

Impacts of Liraglutide on insulin resistance in patients with obesity without diabetes mellitus: Systematic review

Impactos da liraglutida na resistência insulínica em pacientes com obesidade sem diabetes mellitus: revisão sistemática

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Abstract

Objective: to evaluate the effects of liraglutide on insulin resistance in obese individuals without a diagnosis of diabetes. **Materials and Methods:** a systematic review based on articles available in the PubMed, Scopus, *Web of Science*, Embase, LILACS (Latin American and Caribbean Health Sciences Literature), and Cochrane Library databases. We included randomized clinical trials and meta-analyses that evaluated the effects of liraglutide on insulin resistance, lipid profile, and body composition in non-diabetic obese patients. **Results:** the selected studies demonstrated that liraglutide promotes a significant reduction in insulin resistance, improves the lipid profile, and reduces systemic inflammation. In addition, there was an improvement in body composition with a reduction in visceral fat. However, variability among study protocols and the lack of long-term data limit the generalizability of the results. **Conclusion:** Liraglutide represents an effective alternative for managing insulin resistance in obese patients without diabetes, with the potential to prevent metabolic complications. The clinical indication for liraglutide in obese individuals without diabetes is already well established. Further studies may be needed to confirm its efficacy in reducing insulin resistance in obese individuals without diabetes.

Keywords: Liraglutide; Insulin Resistance; Obesity; GLP-1- Agonists

Resumo

Objetivo: avaliar os efeitos da liraglutida na resistência insulínica em indivíduos com obesidade sem diagnóstico de diabetes. **Materiais e Métodos:** revisão sistemática com base em artigos disponíveis nas bases PubMed, Scopus, *Web of Science*, Embase, LILACS (Literatura Latino-Americana e do Caribe em Ciências da Saúde) e Biblioteca Cochrane. Foram incluídos estudos clínicos, randomizados e metanálises que avaliaram os efeitos da liraglutida sobre resistência insulínica, perfil lipídico e composição corporal em pacientes com obesidade não diabéticos. **Resultados:** os estudos selecionados demonstraram que a liraglutida promove redução significativa da resistência insulínica, melhora o perfil lipídico e reduz a inflamação sistêmica. Além disso, houve melhora na composição corporal com redução da gordura visceral. No entanto, a variabilidade entre os protocolos dos estudos e a escassez de dados a longo prazo limitam a generalização dos resultados. **Conclusão**: a liraglutida representa uma alternativa eficaz no manejo da resistência insulínica em pacientes portadores de obesidade sem diabetes, com potencial para prevenir complicações metabólicas. A indicação clínica da liraglutida em pessoas com obesidade sem diabetes já está bem consolidada. Podem ser necessários mais estudos que comprovem sua eficácia na redução da resistência à insulina em pessoas com obesidade sem diabetes.

Palavras-chave: Liraglutida. Resistência à insulina. Obesidade. Agonistas GLP-1.

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Introduction

Obesity is a chronic, multifactorial, and progressive disease characterized by excessive accumulation of adipose tissue, which compromises health and is associated with various metabolic, cardiovascular, and hormonal complications[1-3]. Among the main disorders associated with obesity, insulin resistance stands out—a condition in which target tissues exhibit a reduced response to the action of insulin, increasing the risk of progression to type 2 diabetes and metabolic syndrome[4].

The treatment of obesity is initially based on nonpharmacological interventions, such as dietary counseling, regular physical activity, and psychological support. Although these strategies are essential, they are not always sufficient to promote sustained weight loss and improvement in the metabolic profile, especially in individuals with class II or III obesity[2,5]. For this reason, pharmacological therapy is indicated as an adjunct to clinical treatment, with the goal of enhancing metabolic benefits and facilitating the achievement of therapeutic goals.

Among the drugs used to treat obesity, glucagon-like peptide-1 (GLP-1) receptor agonists, such as liraglutide, have been gaining prominence. Initially approved for the treatment of type 2 diabetes, liraglutide has demonstrated efficacy in reducing body weight, improving the lipid profile, reducing inflammation, and potentially reversing insulin resistance, even in non-diabetic individuals[6–12].

Studies show that GLP-1 receptor agonists, such as liraglutide, have positive effects on insulin sensitivity in obese individuals. Studies have reported that approximately 38% of obese patients without a diagnosis of diabetes showed a significant improvement in insulin resistance after using these drugs[1]. This effect was also observed in women with polycystic ovary syndrome, demonstrating the broad range of liraglutide's effects across different clinical contexts[11].

In addition, the combination of liraglutide with behavioral interventions, such as physical exercise, has shown synergistic effects, enhances improvements in insulin sensitivity, and reduces inflammatory markers[5,6]. In a systematic review and meta-analysis, the authors confirmed that liraglutide is effective and safe for the management of obesity, as it provides significant clinical benefits in the short and medium terms[2].

In specific populations, such as older adults with prediabetes, the use of liraglutide has also been associated with preventing the progression of insulin resistance and maintaining body weight[7]. Furthermore, studies show that part of the improvement in insulin action promoted by liraglutide occurs independently of weight loss, suggesting additional mechanisms of action[4].

Insulin resistance is highly prevalent in obese individuals and represents a key factor in the development of serious metabolic complications, such as type 2 diabetes. Identifying effective and

safe pharmacological interventions, especially in patients who have not yet been diagnosed with diabetes, is essential for early prevention strategies. In this context, understanding the effects of liraglutide on insulin resistance can contribute to more informed clinical decisions, enhance treatment outcomes, and promote the rational use of this class of drugs. The scarcity of systematic reviews focused exclusively on non-diabetic obese patients underscores the importance and scientific relevance of this study.

Thus, the aim is to evaluate the effects of liraglutide on insulin resistance in obese patients without a diagnosis of diabetes mellitus through a systematic review, in order to identify the main clinical outcomes related to insulin sensitivity, metabolic profile, and body composition.

Materials and Methods

This study is a systematic literature review aimed at identifying and analyzing the effects of liraglutide on insulin resistance in individuals with obesity but without a diagnosis of diabetes mellitus. The study was conducted in accordance with the guidelines of the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) protocol, to ensure methodological rigor and transparency in the processes of data selection, analysis, and presentation.

The guiding question was: “What are the effects of liraglutide on insulin resistance in obese individuals without a diagnosis of diabetes?” The PICO strategy used considered: a population consisting of obese adults without a diagnosis of diabetes mellitus; an intervention based on the use of liraglutide; a comparison with a placebo or no treatment; and an outcome related to the reduction of insulin resistance.

The search for studies was conducted in the PubMed, Scopus, *Web of Science*, Embase, LILACS (Latin American and Caribbean Health Sciences Literature), and Cochrane Library databases, covering publications from 2010 to 2025. The last search was conducted on May 19, 2025. Controlled and uncontrolled subject headings were used in Portuguese, English, and Spanish, with the following terms and their combinations: obesity, liraglutide, insulin resistance, non-diabetic, and GLP-1 receptor agonist. The Boolean operators AND (*AND*) and OR (*OR*) were used to construct the search queries (Chart 1).

Chart 1. Terms in Portuguese, English and Spanish with Boolean Operators used in the bibliographic search strategy

Portuguese	English	Spanish	Boolean Operator
Obesidade	*Obesity*	*Obesidad*	AND/OR
Liraglutida	*Liraglutide*	*Liraglutida*	AND/OR
Resistência à Insulina	*Insulin Resistance*	*Resistencia a la insulina*	OR
Sem Diabetes	*Non-diabetic*	*Sin diabetes*	OR
Agonista do Receptor GLP-1	*GLP-1 Receptor Agonist*	*Agonista del recptor GLP-1*	OR

The following types of studies were included in the analysis: original articles, randomized or non-randomized clinical trials, observational studies, and articles used in meta-analyses. The inclusion criteria were as follows: a study population composed of adults with obesity and no diagnosis of diabetes mellitus; an intervention involving liraglutide; assessment of insulin resistance as an outcome; publications from 2010 to 2025; articles written in Portuguese, English, or Spanish; and availability of the full text.

Studies were excluded if they: included patients with type 1 or type 2 diabetes; used primary interventions other than liraglutide; were conducted in a pediatric population; did not provide data on insulin resistance; or were abstracts, letters to the editor, opinion pieces, editorials, or study protocols.

The variables extracted from the studies included: HOMA-IR index (homeostatic model assessment of insulin resistance), fasting insulin levels, insulin sensitivity assessed by hyperinsulinemic-euglycemic clamp, body weight, body mass index, dose and duration of liraglutide administration, adverse effects associated with the intervention, and the method used to measure insulin resistance.

In addition, as evidenced in selected studies in the literature, (1) Insulin sensitivity was also measured using the hyperinsulinemic-euglycemic clamp. considered the gold standard for this purpose[4,6]; (2) abdominal obesity was assessed based on waist circumference and waist-to-hip ratio[5]; (3) the metabolic action of insulin was analyzed using indirect indicators of glucose uptake by tissues, especially skeletal muscle and adipose tissue[6,9]; and (4) vascular inflammation was evaluated through serum inflammatory markers, such as C-reactive protein, interleukin-6, and tumor necrosis factor-alpha, in addition to endothelial markers[5,8].

The methodological quality of the studies was assessed using the Jadad scale for randomized clinical trials and the Newcastle-Ottawa scale for observational studies. The risk of bias was assessed using the Cochrane tool adapted to the study type.

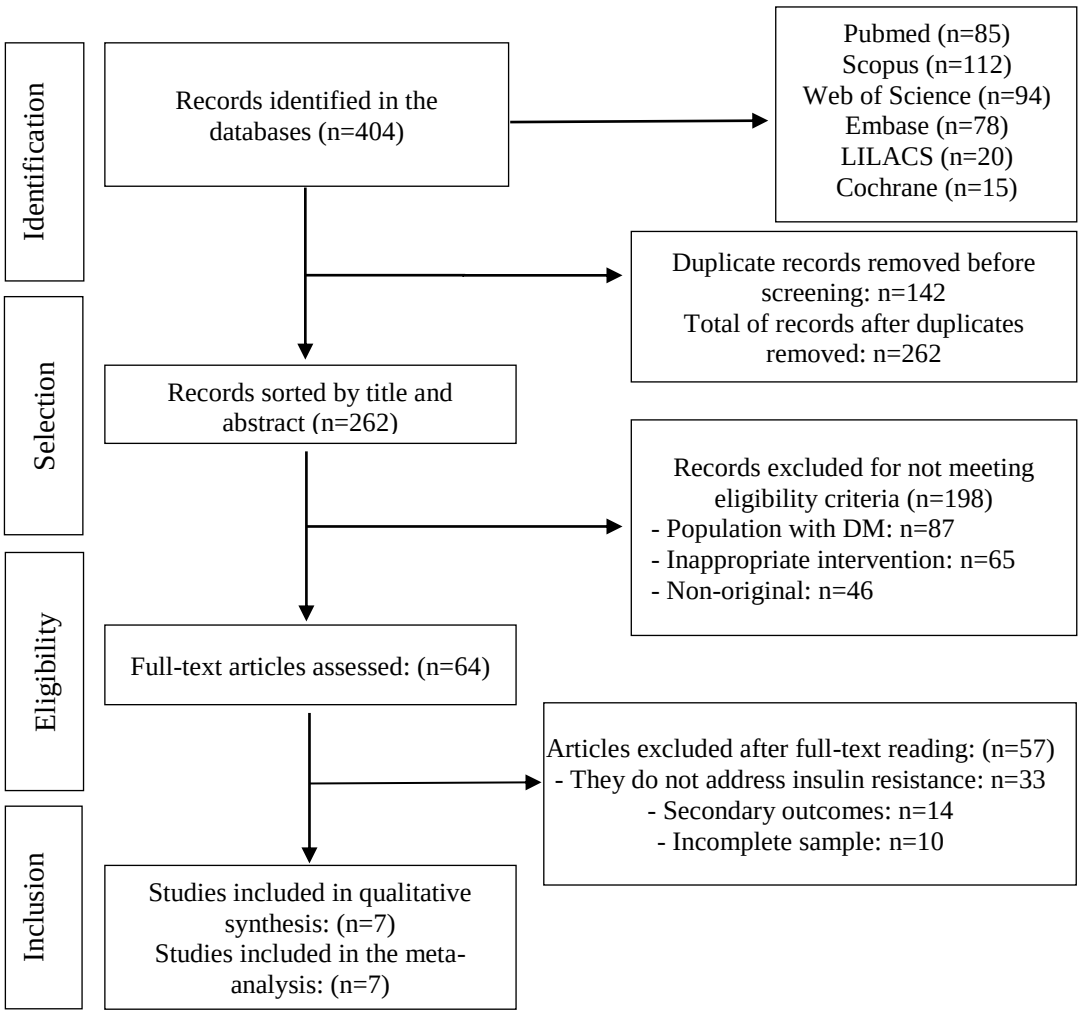
The screening of articles was conducted independently by two reviewers, with the assistance of the Rayyan software, which enabled organization, removal of duplicates, and peer review.

Whenever possible, data extracted from the studies were subjected to quantitative synthesis (meta-analysis) using RevMan version 5.4, Microsoft Excel®, and, when necessary, Stata or R software for additional statistical analyses.

Results

A total of 404 articles were initially identified; 142 were excluded after checking for duplicates, leaving 262 articles for the next stage. After reviewing the titles and abstracts, an additional 198 articles that did not meet the inclusion criteria were excluded, leaving 64 for full-text review. After the full-text review, 57 were excluded for failing to meet the inclusion criteria, leaving only seven articles for the systematic review (Figure 1).

Figure 1. PRISMA flowchart of the selection of included studies



This systematic review analyzed seven studies published between 2013 and 2024, involving a total of 2,548 participants with obesity who had not been diagnosed with diabetes mellitus. The majority of the reviewed articles were randomized clinical trials, with a predominance of publications from the United States[3,6,7,8], the United Kingdom[3,7], and China[5,11,12], in journals specializing in endocrinology, metabolism, and obesity.

The liraglutide doses used ranged from 1.2 mg to 3.0 mg per day, with the latter being the most commonly used. The duration of treatment ranged from 8 to 56 weeks, with corresponding clinical follow-up. The majority of studies used treatment periods longer than 12 weeks to observe more consistent effects on insulin resistance (Chart 2).

Chart 2. Methodological Characteristics, Liraglutide Dose, Main Results and Adverse Effects of the Included Studies.

Authors	n.	Liraglutide Dose	Main results	Complications presented
Kim *et al.* (2013)	190	3.0 mg/day Average treatment time: 56 weeks (1 year), extending up to 3 years	Improvement in insulin sensitivity associated with weight reduction. Mean of -5.8 +/- 0.6 kg in the liraglutide group, versus -1.2 +/- 0.3 kg in the placebo group (p<0.001)	Nausea (15% to 30%) Diarrhoea (10% to 20%)
Zhang *et al.* (2019)	1,236	1.8–3.0 mg/day Average treatment: 35 to 20 weeks	Improvement in insulin resistance and significant weight reduction, with 88% of liraglutide-treated subjects reducing > 5% of baseline weight, compared to 22% in the placebo group (p<0.001)	Mild nausea (15% to 30%) Headache (5% to 10%)
Hoddy *et al.* (2022)	—	—	Theoretical commentary on persistent insulin resistance	—
Barboza *et al.* (2022)	488	3,0 mg/dia	Improved insulin sensitivity and appetite control. Statistical significance was confirmed (p<0.05).	Nausea (15% to 30%) Vomiting (5% to 15%)
Sandsdal *et al.* (2023)	203	1.2–1.8 mg/day Average treatment: 52 weeks (1 year), after initial diet	Reduction of abdominal obesity and improvement of HOMA-IR from 3.9 +/- 2.4 to 1.7 +/- 1.0 with liraglutide + exercise. (56% reduction p<0.05).	Mild gastrointestinal symptoms
Liu *et al.* (2023)	109	1.8 mg/day Average treatment: 2 weeks in animal model (rats)	Increased metabolic action of insulin and reduced vascular inflammation. (P<0.05).	No relevant complications
Mashayekhi *et al.* (2024)	322	3.0 mg/day Average treatment: 14 weeks	Independent effect of weight loss on insulin sensitivity. (P<0.05).	Dizziness, gastrointestinal discomfort (5% to 10%)

Several tools were used to evaluate insulin resistance in the analyzed studies. The HOMA-IR model was the most commonly used method, allowing for the estimation of insulin sensitivity based on fasting blood glucose and insulin levels (Chart 2)[1,4,5,7,11]. The euglycemic hyperinsulinemic clamp, considered the gold standard for this assessment, was used, enabling direct measurement of insulin's action on glucose metabolism[6]. These tools were essential for quantifying the improvement in insulin sensitivity promoted by the liraglutide intervention, reinforcing its efficacy in managing insulin resistance in obese patients without diabetes.

Two of the included studies were sponsored by pharmaceutical companies, with funding from Novo Nordisk and support from the pharmaceutical industry associated with GLP-1 agonists[7,11].

Analysis of the studies demonstrated significant positive effects of liraglutide on insulin resistance in patients with obesity, even in the absence of a diagnosis of diabetes. Studies confirmed improvements in HOMA-IR and insulin sensitivity with therapeutic safety[1,2]. The persistence of insulin resistance in metabolically healthy obese patients was highlighted, justifying pharmacological interventions[3]. The effects of liraglutide occur independently of weight loss; synergistic benefits are observed when the drug is combined with physical exercise[1–6]. Efficacy in older adults has been demonstrated, and other complementary studies reinforce the applicability of liraglutide in various contexts related to obesity and insulin resistance (Chart 2)[7,9–12].

Complications associated with the use of liraglutide were generally mild and transient. Nausea was reported in 15% to 30% of patients and was the most common adverse effect[1,2,7]. Diarrhea and vomiting occurred in 10% to 20% and 5% to 15% of cases, respectively[1,2,7]. Headaches and dizziness were less common, affecting between 5% and 10% of participants[1,4]. These symptoms were generally self-limiting and did not result in a significant number of patients discontinuing treatment, supporting the safety profile of liraglutide for the treatment of insulin resistance in obese patients without diabetes (Charts 2, 3, and 4).

Chart 3. Methodological quality assessment of the studies, according to adapted criteria from the Cochrane RoB 2.0 tool.

Authors	Methodological clarity	Randomization	Blinding	Clear outcomes	Overall quality
Kim *et al*. (2013)	Yes	Yes	Yes	Yes	High
Zhang *et al*. (2019)	Yes	Yes	Parcial	Yes	High
Hoddy *et al*. (2022)	Not applicable	—	—	—	Not applicable
Barboza *et al*. (2022)	Yes	Yes	Yes	Yes	High
Sandsdal *et al*. (2023)	Yes	Yes	Yes	Yes	High
Liu *et al*. (2023)	Yes	Yes	Yes	Yes	High
Mashayekhi *et al*. (2024)	Yes	Yes	Yes	Yes	High

Chart 4. Risk of Bias Assessment (RoB 2 Tool)

Authors	Biases					
	Selection	**Performance**	**Appreciation**	**Follow-up**	**Report**	**Global Risk**
Kim *et al*. (2013)	Low	Low	Moderate	Low	Low	Moderate
Zhang *et al*. (2019)	Low	Moderate	Low	Low	Low	Moderate
Hoddy *et al*. (2022)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Barboza *et al*. (2022)	Low	Low	Low	Low	Low	Low
Sandsdal *et al*. (2023)	Low	Low	Low	Low	Low	Low
Liu *et al*. (2023)	Low	Low	Low	Low	Low	Low
Mashayekhi *et al*. (2024)	Low	Low	Low	Low	Low	Low

Discussion

Liraglutide is a glucagon-like peptide-1 (GLP-1) receptor agonist with a structure similar to that of endogenous GLP-1, but with a modification that prolongs its half-life, allowing for daily subcutaneous administration. Its pharmacological action occurs primarily through stimulation of this receptor, promoting an increase in glucose-dependent insulin secretion, inhibition of glucagon, delayed gastric emptying, and increased satiety. These mechanisms contribute to glycemic control and, even in individuals without diabetes, promote the modulation of energy metabolism and a reduction in insulin resistance[1,10].

This drug has a significant effect on inducing weight loss in patients with obesity, with or without diabetes[2,7]. Reduced appetite and increased satiety, combined with delayed gastric emptying, result in lower caloric intake and consequent weight loss, associated with important metabolic benefits[2,7]. Furthermore, it has been confirmed that this effect extends to older individuals with prediabetes, reinforcing its usefulness in preventing progression to type 2 diabetes[7].

A significant improvement in insulin sensitivity is also observed, regardless of weight loss. This direct effect on insulin resistance stems from the activation of the GLP-1 receptor, which positively influences intracellular signaling pathways, improves the lipid profile, and reduces lipotoxicity. This improvement occurs even in the absence of significant weight loss, suggesting a mechanism of action that extends beyond the control of adipose tissue. This characteristic is essential for patients with obesity and a metabolically healthy phenotype but with persistent insulin resistance[4].

Another important aspect is its anti-inflammatory action. Activation of the receptor reduces the expression of systemic and vascular inflammatory markers and improves endothelial function. When combined with physical exercise, this substance further enhances these beneficial effects by

reducing vascular inflammation and increasing insulin sensitivity. These results are particularly important in the context of obesity, where chronic low-grade inflammation exacerbates metabolic dysfunction[5,6].

In addition to obesity, this medication has been shown to be effective in other conditions associated with insulin resistance, such as polycystic ovary syndrome (PCOS) and nonalcoholic fatty liver disease (NAFLD). Significant clinical and metabolic benefits were observed in women with PCOS, including weight loss and improvement in hyperinsulinism[11]. The role of GLP-1 agonists in improving insulin sensitivity and controlling hepatic metabolism in patients with NAFLD reinforces their clinical applicability in different contexts[11,12].

However, evidence suggests that many of the benefits achieved, such as weight loss and improved insulin resistance, tend to regress after treatment is discontinued. This indicates that continued use or combination with long-term interventions, such as lifestyle changes, is essential for maintaining these results. Although longer-term follow-up studies are needed, current data suggest greater efficacy as part of a long-term therapeutic strategy[8,10].

The most frequently observed adverse effects include nausea, vomiting, diarrhea, and constipation, which are generally mild to moderate in intensity and transient. Compared with other GLP-1 agonists, such as semaglutide or dulaglutide, the safety profile is similar, although the frequency of nausea may be slightly higher in the early stages due to faster dose titration. The 3.0 mg dose is safe for individuals with obesity, even in the absence of diabetes, with a low incidence of serious adverse events[10].

Finally, several limitations should be considered when interpreting the results. The heterogeneity of the studies analyzed—in terms of dosage, duration of treatment, and the profile of the included populations—may limit the generalizability of the findings to different clinical groups. Furthermore, most of the available research addresses only short- and medium-term effects, which limits our understanding of efficacy and safety in long-term treatments. Another important point concerns the potential bias arising from the pharmaceutical industry's funding of some of the studies, which may influence both the conduct and the interpretation of the published results. These issues underscore the need for independent studies with larger sample sizes, long-term follow-up, and rigorous methodologies to validate the effects of liraglutide in different clinical contexts. Another aspect rarely addressed by the studies is the patient's short- and long-term course following discontinuation of the medication.

Conclusion

This systematic review demonstrated that liraglutide has significant effects on improving insulin resistance in obese patients without a prior diagnosis of diabetes. The observed benefits go beyond simple weight loss, highlighting the drug's direct effects on insulin sensitivity, reduced inflammation, and an improved metabolic profile, which reinforces its potential as an effective tool for preventing the development of type 2 diabetes and other metabolic complications associated with obesity.

For future research, it is recommended that randomized clinical trials be conducted with longer follow-up periods and larger, more diverse samples to deepen our understanding of the molecular mechanisms involved in liraglutide's action on insulin resistance. It is also important to conduct comparative studies involving patients taking the medication with and without MEV. Finally, exploring the impact of liraglutide on specific subpopulations, such as the elderly, patients with metabolic comorbidities, and those with conditions like polycystic ovary syndrome, could expand the drug's clinical indications.

Authors contributions

The authors' contributions are structured according to the taxonomy (CRediT) described below: Research conception and design: Marcelo José da Silva de Magalhães. Analysis, data interpretation and writing of the manuscript: Alice Angélica Caldeira Quaresma, Sofia Beatriz de Freitas Cardoso, Marcelo José da Silva de Magalhães. Resource management: Alice Angélica Caldeira Quaresma, Sofia Beatriz de Freitas Cardoso, Marcelo José da Silva de Magalhães. Critical review of the manuscript for intellectual content and final presentation: Marcelo José da Silva de Magalhães. The authors approved the final version of the manuscript and declared themselves responsible for all aspects of the work, including ensuring its accuracy and integrity.

Conflict of interests

The authors declared no conflicts of interest.

Acknowledgments

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References

1. Zhang P, Liu Y, Ren Y, Bai J, Zhang G, Cui Y. The efficacy and safety of liraglutide in the obese, non-diabetic individuals: a systematic review and meta-analysis. Afr Health Sci. 2019; 19(3):2591–9. https://dx.doi.org/10.4314/ahs.v19i3.35

2. Barboza JJ, Huamán MR, Melgar B, Diaz-Arocutipa C, Valenzuela-Rodriguez G, Hernandez AV. Efficacy of liraglutide in non-diabetic obese adults: a systematic review and meta-analysis of randomized controlled trials**.** J Clin Med. 2022;11(11):2998. https://doi.org/10.3390/jcm11112998

3. Hoddy KK, Axelrod CL, Mey JT, Hari A, Beyl RA, Blair JB, *et al*. Insulin resistance persists despite a metabolically healthy obesity phenotype. Obesity (Silver Spring). 2022;30(1):39–44. Disponível em: https://pmc.ncbi.nlm.nih.gov/articles/PMC9136885/pdf/nihms-1807725.pdf

4. Mashayekhi M, Nian H, Mayfield D, Devin JK, Gamboa JL, Yu C, *et al*. Weight Loss–Independent Effect of liraglutide on insulin sensitivity in individuals with obesity and prediabetes, independent of weight loss. Diabetes. 2023;73(1):38–50. https://doi.org/10.2337/db23-0356

5. Sandsdal RM, Juhl CR, Jensen SBK, Lundgren JR, Janus C, Blond MB, et al. Combination of exercise and GLP-1 receptor agonist treatment reduces severity of metabolic syndrome, abdominal obesity, and inflammation: a randomized controlled trial. Cardiovasc Diabetol. 2023;22(1):41. https://doi.org/10.1186/s12933-023-01765-z

6. Liu J, Aylor KW, Liu Z. Liraglutide and exercise synergistically attenuate vascular inflammation and enhance metabolic insulin action in early diet-induced obesity. Diabetes. 2023;72(7):918–31. https://doi.org/10.2337/db22-0745

7. Kim SH, Abbasi F, Lamendola C, Liu A, Ariel D, Schaaf P, *et al*. Benefits of Liraglutide Treatment in Overweight and Obese Older Individuals With Prediabetes. Diabetes Care. 2013;36(10):3276–82. https://doi.org/10.2337/dc13-0354

8. Marso SP, Daniels GH, Brown-Frandsen K, Kristensen P, Mann JFE, Nauck MA, et al. Liraglutide and cardiovascular outcomes in type 2 diabetes. N Engl J Med. 2016;375(4):311-22. https://doi.org/10.1056/NEJMoa1603827

9. Du M, Yue J, Qi Y, He S, Lu X, Yang M, et al. Effects of liraglutide on abdominal fat distribution and glucose metabolism in Chinese subjects with obesity. Diabetol Metab Syndr. 2024;16:307. https://doi.org/10.1186/s13098-024-01540-4

10. Konwar M, Bose D, Jaiswal SK, Maurya MK, Ravi R. Efficacy and safety of liraglutide 3.0 mg in patients with overweight and obese with or without diabetes: a systematic review and meta-analysis. Int J Clin Pract. 2022;2022:1201977. https://doi.org/10.1155/2022/1201977

11. Ge JJ, Wang DJ, Song W, Shen SM, Ge WH. The effectiveness and safety of liraglutide in treating overweight/obese patients with polycystic ovary syndrome: a meta-analysis. J Endocrinol Invest. 2022;45(2):261–273. https://doi.org/10.1007/s40618-021-01666-6

12. Yan H, Huang C, Shen X, Li J, Zhou S, Li W. GLP-1 RAs and SGLT-2 inhibitors for insulin resistance in nonalcoholic fatty liver disease: systematic review and network meta-analysis. Front Endocrinol (Lausanne). 2022;13:923606. https://doi.org/10.3389/fendo.2022.923606