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Gender Disparities, Complications, and Treatment Approaches in Insulin Resistance: Evidence from a Tertiary Care Center

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Abstract
Insulin resistance (IR) is a metabolic condition where the body's response to insulin is impaired, contributing to type 2 diabetes, obesity, and metabolic syndrome. This retrospective study at Al-Bayda Diabetes Center, Libya, included 67 patients diagnosed with IR from January 2023 to September 2024. The sample was predominantly female (90%) with a mean age of 43 years and a mean BMI of 36 kg/m², indicating obesity. Statistical analysis showed moderate positive correlations between HbA1c and HOMA-IR (r = 0.63), and BMI and HOMA-IR (r = 0.41), reflecting the link between glycemic control, adiposity, and insulin resistance severity. About 69% of patients had complications, mainly obesity-related. Treatment mostly involved lifestyle interventions: 44.6% used diet and exercise, and 28.6% took dietary supplements; metformin was less commonly prescribed. The findings highlight the importance of managing obesity and glycemic levels in IR treatment, with lifestyle modification as the primary approach. The predominance of female patients suggests potential gender-related differences in IR prevalence that need further study.
Keywords. Gender Disparities, Complications, Treatment Approaches, Insulin Resistance.

Introduction

Insulin resistance is a condition known as insulin resistance occurs when the body's glycemic reaction to insulin is below normal. Multiple sets of reactions result from the alteration in insulin sensitivity. One set affects the beta cell, causing it to break down more quickly and resulting in diabetes mellitus [1]. Insulin resistance is a metabolic syndrome, which includes type 2 diabetes/glucose intolerance, obesity, dyslipidemia, and hypertension, and is characterized by insulin resistance. The primary indicator of insulin resistance in skeletal muscles is a reduction in insulin-promoted glycogen production due to diminished glucose transport. The development of insulin resistance is significantly influenced by ectopic lipid buildup [2]. A number of factors might increase the likelihood of developing insulin resistance. For example, because of the high percentage of visceral fat, oxidative stress, and mitochondrial dysfunction, aging raises the risk of insulin resistance [3,4]. Additional risk factors for insulin resistance include increasing body fat and abdominal obesity [5,6]. Thus, the development of hepatic insulin resistance and type 2 diabetes is caused by high concentrations of pro-inflammatory cytokines and free fatty acids released into the portal vein of obese people from visceral adipose tissue [7]. Gender is one of the additional risk factors [8-10], and lack of physical activity [11,12]. Managing non-insulin-dependent diabetes requires lowering insulin resistance, which can be achieved, for instance, by quitting smoking, losing weight, and engaging in cardiovascular activity. Moderate alcohol use also helps to lower insulin resistance [13]. The insulin resistance syndrome is improved in a number of ways by metformin. New medications that improve insulin action, such as thiazolidinediones, are being studied [13].

Methodology

Study design and setting

A retrospective and observational approach was used in this investigation, which was carried out at the Al-Bayda Diabetes Center, a specialized tertiary facility located in Al-Bayda, Libya. The center focuses on the management of diabetes mellitus, insulin resistance, and associated metabolic disorders. In addition to medical treatment, it provides individualized nutritional counseling and lifestyle modification programs. Data were collected over a period of three weeks, and the study population consisted of patients who received care at the center between January 1, 2023, and September 30, 2024.

Ethical approval

Before any data was collected, ethical approval was acquired from the institutional review board and the data protection officer at the Al-Bayda Diabetes Center. All procedures were conducted in accordance with the ethical standards outlined in the Declaration of Helsinki. Patient data were anonymized to ensure confidentiality, and no personal identifiers were included in the dataset.

Data collection

A structured literature review was conducted to provide a theoretical foundation for the study. Electronic databases, including PubMed, MEDLINE, Medscape, Google Scholar, and peer-reviewed online journals, were searched for articles related to insulin resistance, nutritional management, and diabetes care.

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Keywords included: *insulin resistance*, *HOMA-IR*, *lifestyle intervention*, and *diabetes management*. Articles published within the last 10 years were prioritized to ensure contemporary relevance.
The study population included 67 patients who had been clinically diagnosed with insulin resistance. Documented diagnostic criteria in accordance with recognized guidelines were used to evaluate eligibility (e.g., elevated HOMA-IR, fasting insulin, and HbA1c levels). Patients with incomplete records or comorbid conditions that may confound insulin resistance outcomes (e.g., active cancer, Cushing's syndrome) were excluded.
A standardized data abstraction form was used to extract data from medical records. The following variables were collected: (Demographics: Age and sex, Clinical Information: Reason for referral, method of diagnosis (e.g., HOMA-IR, HbA1c), presence of comorbidities, Management Strategies: Type of treatment (pharmacological, nutritional, combined), medications prescribed, and referral to nutritional services and Complications: Documented health complications attributed to insulin resistance)
The data were collected in two phases: (Retrospective Phase: Archival data from patient records dated 2023 were reviewed and analyzed, and Current Phase: Updated clinical data from 2024 were reviewed for patients still receiving care).
After the extraction of data, patients were divided into subgroups according to: Age, Diagnostic method, Treatment approach, and Complication status (the presence or absence of metabolic complications). This categorization facilitated a comparative analysis of treatment outcomes among different patient subsets

Data Management and Statistical Analysis
All patient data were coded and entered into Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA). Double-entry verification was performed to ensure accuracy and minimize entry errors. Summary statistics (means, standard deviations, frequencies, and percentages) were calculated using built-in Excel functions. The data were then imported into R software (version 4.4.3) for advanced statistical analysis. The relationships between key clinical markers—HOMA-IR, HbA1c, BMI, and treatment modalities.

Results
The study involved 67 participants in total. The gender distribution was markedly unbalanced, with 60 females (90%) and 7 males (10%). To assess whether this distribution significantly deviated from an expected equal proportion of males and females, a chi-square goodness-of-fit test was conducted. The analysis revealed a statistically significant difference in gender distribution (X-squared = 42, df = 1, p-value = 9e-11). This result indicates that the proportion of female participants was significantly higher than what would be expected.
The sample included 67 participants, with recorded ages ranging from 13 to 70 years. The mean age was 43 years, indicating that the study population was predominantly composed of middle-aged individuals. A one-sample t-test was conducted to determine whether the sample's mean age significantly differed from a reference value of zero, as a statistical formality. The results showed a t-value of 24.0 with 66 degrees of freedom, and a p-value less than 0.001, indicating a highly significant difference (t = 24, df = 66, p-value <0.05)**.** The participants' age profile shows a predominance of adults in midlife, a demographic commonly affected by metabolic conditions such as insulin resistance. The wide age range supports the inclusion of both adolescent and elderly individuals, but the concentration around middle age may influence the interpretation of outcomes related to treatment efficacy or risk of complications.
Body Mass Index (BMI) was recorded for 64 participants, with values ranging from 20 to 54 kg/m². The mean BMI was 36 kg/m², indicating that the majority of participants fell into the obese or morbidly obese category, according to WHO classification standards. To assess whether the average BMI in the sample was significantly higher than the normal upper limit (BMI = 25 kg/m²), a one-sample t-test was performed with the null hypothesis that the population mean BMI equals 25. The test yielded a t-statistic of 14, with 63 degrees of freedom, and a p-value < 0.001, indicating a statistically significant difference. The findings clearly demonstrate that the study population is, on average, significantly obese. Given the established role of obesity as one of the main risk factors for type 2 diabetes and insulin resistance, this result emphasizes the need to integrate weight management strategies into the therapeutic plan. These findings also reinforce the relevance of focusing on nutritional interventions and lifestyle modifications in the studied population.

Table 1. Illustrates descriptive statistics, including gender, age, and BMI

parameters	mean	values	statistics	df	P value
Gender	-	Females=60 Males=7	X-squared = 42	1	9e-11
Age	43 years	From 13-70 years	t = 24	66	less than 0.001
BMI	36 kg/m²	from 20 to 54 kg/m	t = 25	63	p-value < 0.001

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A Pearson correlation analysis was conducted to evaluate the strength and direction of the connection between glycated hemoglobin (HbA1c) levels and insulin resistance as measured by the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR).

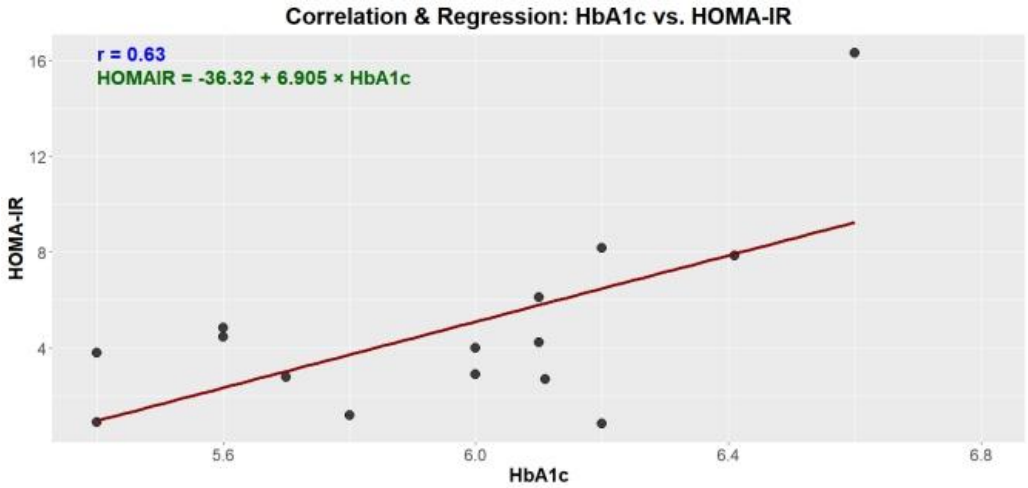

Figure 1. Scatter plot showing the relationship between HbA1c (%) and HOMA-IR levels. The red line represents the linear regression model (HOMA-IR = -36.32 + 6.905 × HbA1c). The Pearson correlation coefficient was r = 0.63, indicating a moderate positive correlation between the two variables.

The analysis revealed a moderate positive correlation between HbA1c and HOMA-IR; r = 0.63, indicating that increases in HbA1c are moderately associated with increases in HOMA-IR. To further explore this relationship, a simple linear regression was carried out, with HOMA-IR as the dependent variable and HbA1c as the independent predictor. The resulting regression equation (HOMA-IR = -36.32 + 6.905 * HbA1c)**.** This model suggests that for every 1% increase in HbA1c, HOMA-IR increases by approximately 6.91 units. The linear model was visually plotted (Figure 1), showing a positive linear trend with scattered data points and a fitted regression line.

A Pearson correlation analysis was performed to evaluate the relationship between body mass index (BMI) and insulin resistance, as measured by HOMA-IR. The analysis revealed a moderate positive correlation between the two variables r = 0.409, indicating a moderate direct association between BMI and HOMA-IR levels.

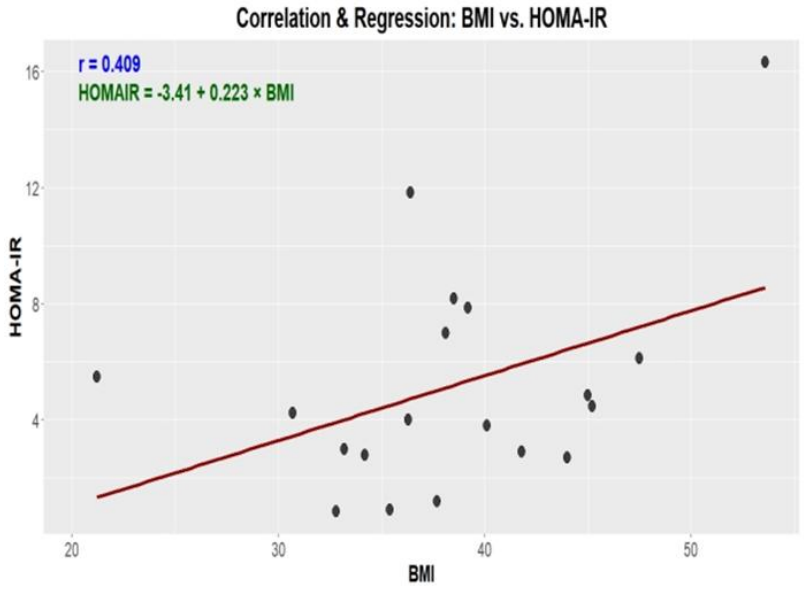

Figure 2. Scatter plot displaying the relationship between BMI (kg/m²) and HOMA-IR. A moderate positive correlation was observed (r = 0.409). The linear regression model is represented by the red line and follows the equation: HOMA-IR = -3.41 + 0.223 × B

A simple linear regression was conducted to further model the relationship, with HOMA-IR as the dependent variable and BMI as the independent variable. The resulting regression equation (HOMA-IR = -3.41 + 0.223 * BMI). This indicates that for every 1-unit increase in BMI, HOMA-IR increases by approximately 0.223 units. While the association is statistically moderate, the direction and slope of the

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relationship support the hypothesis that increased body mass is associated with increased insulin resistance. The fitted regression line and correlation coefficient are shown in the Figure, illustrating the linear trend and the dispersion of data points across the BMI spectrum.

According to this study, about two-thirds of patients (69%) confirmed the presence of complications of the disease, the most common complication was obesity, followed by obesity and other problems. The less commonly recorded complication was polycystic ovarian syndrome.

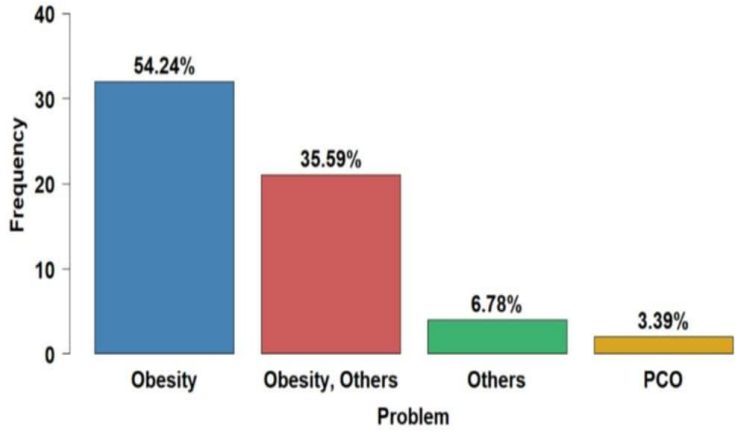

Figure 3. Illustrates a Bar chart showing the distribution of health-related problems among participants. The most common issue was Obesity (n ≈ 32), followed by combined cases of Obesity and Other problems (n ≈ 21). Less frequent issues included Others (n ≈ 4) and PCO (Polycystic Ovary) (n ≈ 3). The chart highlights obesity as the predominant concern in the study population.

According to this study, the most common treatment used for insulin resistance is diet and exercise (44.64%), and another high proportion was recorded for dietary supplements (28.57%). On the other hand, the least treatment used was metformin, then a combination of metformin, dietary supplements then mix of diet and dietary supplements, with diet 12.50%, 10.71% and 3.57% respectively**.**

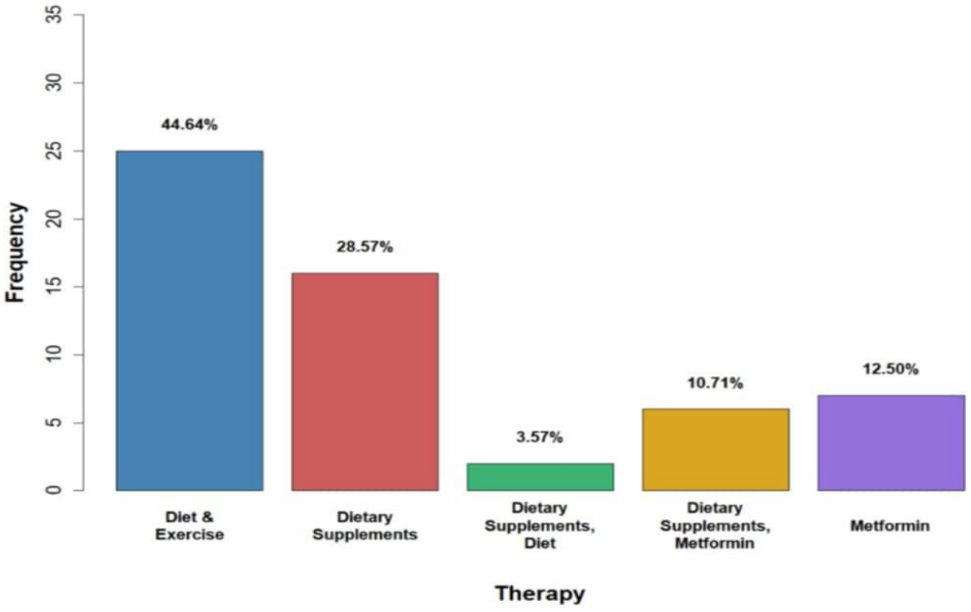

Figure 4. Illustrates Bar chart illustrating the frequency of different therapy approaches among participants. The most common intervention was Diet & Exercise (n ≈ 25), followed by Dietary Supplements (n ≈ 15). Less common therapies included Metformin, Dietary Supplements with Metformin, and Dietary Supplements with Diet. This suggests a preference for lifestyle-based interventions over pharmacological treatments.

Discussion

In this study, females presented a higher prevalence of insulin resistance. Out of 69 patients, 90% were females and 10% were males. This Disagreement is with a study carried out by Sakamota et al., in 2010, that discovered that males experienced a more significant change in their insulin resistance status, a change in percent BMI, than women [14].

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In this research, the highest number of patients was in the age groups 31-40 and 41-50 followed by the age group 51-60 with 14 patients, then there was an equal number in the age groups from 21-30 and 61-70. The lowest number was in the age group from 11 to 20.

This Findings approach to study carried out by Freeman and pennings in 2018 An analysis from 2003 of the National Health and Nutrition Examination Survey (NHANES) data revealed that insulin resistance impacts roughly 22% of adults in the United States (US) who are over 20 years old. A recent examination of NHANES data from 2021 revealed that 40% of adults in the US aged 18 to 44 are insulin-resistant, as indicated by HOMA-IR measurements [15]. These findings disagree with a study carried out by Szosland and Lewinski, in 2016, in this study Assessment of IR was diagnosed by any of the surrogate methods: HOMA, HOMA 2, QUICKI and Matsuda index [16].

Findings with a study carried out by McAuley et al., in 2001, indicated fasting insulin by itself was just as effective at predicting insulin resistance in the normoglycemic population as HOMA, the insulin-to-glucose ratio, and the Bennett index [17].

The results in our research show most patients are obese, with a body mass index of more than 30 (mean of BMI = 36.12), This result is consistent with another study conducted by Luo, Liping, and Meilian Liu. in 2016 indicated adipose tissue dysfunction significantly contributes to the onset of obesity and associated conditions like insulin resistance, cardiovascular disease, diabetes, depression and cancer [18].

Our study reported a moderate positive correlation between HbA1c and HOMA-IR; r = 0.63, indicating that increases in HbA1c are moderately associated with increases in HOMA-IR., this was roughly similar to another study performed by Yin, B. and at el in 2023 on pregnant women where the occurrence of gestational diabetes mellitus rose with higher HbA1c and HOMA-IR levels, and the danger of GDM was notably heightened when both HbA1c and HOMA-IR were increased [19].

Furthermore, in the present study the correlation between HOMA-IR and BMI was a moderate positive correlation, this result is consistent with another study conducted by Boyer and at el in 2016 indicated patients with higher HOMA-IR values showed an association with increased BMI and WC values in euglycemic individuals (A notable moderate correlation existed between HOMA-IR and BMI) [20].

According to our study, about two-thirds of patients (69%) confirmed the presence of complications of the disease, the most common complication was obesity, followed by obesity and other problems. the less commonly recorded complication was polycystic ovarian syndrome. In our study approach was to our study carried out by Al-Beltagi et al., in 2022 IRS is often linked to dyslipidemia, obesity, alterations in skin, atherosclerosis, hypertension, type-II diabetes mellitus, hyperandrogenism, and polycystic ovary syndrome [21].

The results display that the most used treatment for insulin resistance is diet and exercise (44.7%), and another high proportion was recorded for dietary supplements. On the other hand, the treatments used were metformin, then a combination of metformin, dietary supplements then mix of diet and dietary supplements, with 11.9%, 8.9% and 2.9% respectively. These findings agree with a study carried out by Rácz et al., in 2019, the treatment of insulin resistance based on Dietary intervention must incorporate a mix of calorie limitation and a decrease in high glycemic index carbohydrate [22]. This finding disagrees with a study carried out by Perreault and Nicholas in 2022. Metformin is a widely used primary medication for treating insulin resistance and is authorized for use in PCOS [23].

Conclusion

Insulin resistance is a health problem that can lead to very serious complications. Therefore, society must be educated about its risks and how to avoid them.

Conflict of interest. Nil

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