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Magnesium Deficiency and Its Impact on the Development of Insulin Resistance in Obese Individuals

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Abstract **Original Research Article**

Background: Obesity is a major public health concern, contributing to metabolic disorders such as insulin resistance and type 2 diabetes. In Bangladesh, the rising obesity rates highlight the need for targeted interventions. Magnesium, an essential mineral involved in glucose metabolism and insulin signalling, has been linked to insulin resistance, with deficiency increasing the risk of metabolic disorders. Studies suggest that obese individuals are prone to magnesium depletion due to increased urinary excretion and poor dietary intake. ***Aim of the study:*** The study aims to evaluate the association between magnesium deficiency and insulin resistance in obese individuals. ***Methods:*** This cross-sectional observational study assessed the association between magnesium deficiency and insulin resistance in 100 obese individuals at Department of Medicine, Islami Bank Hospital, Agrabad, Chittagong, Bangladesh, over one year from January to December 2023. Ethical approval and informed consent were obtained. Anthropometric measurements, dietary magnesium intake, and physical activity levels were recorded. Blood samples were analyzed for serum magnesium, fasting glucose, HbA1c, insulin, HOMA-IR, lipid profile, CRP, and vitamin D. Data were analyzed using SPSS (version 26.0), with t-tests, ANOVA, Pearson's correlation, and multiple regression to determine relationships and predictors of insulin resistance. A p-value of <0.05 was considered statistically significant. ***Result:*** This study found a significant association between magnesium deficiency and insulin resistance in 100 obese Bangladeshi individuals. The mean BMI was 29.8 kg/m², with 55% having hypertension and 48% having diabetes. Mean fasting blood glucose was 112.6 mg/dL, HbA1c was 6.1%, and fasting insulin was 15.8 µU/mL. Serum magnesium averaged 1.72 mg/dL, showing a strong negative correlation with fasting glucose ($r = -0.42$, $p = 0.002$), HbA1c ($r = -0.38$, $p = 0.005$), and HOMA-IR ($r = -0.47$, $p = 0.001$). Regression analysis confirmed magnesium deficiency as an independent predictor of insulin resistance. ***Conclusion:*** This study establishes a strong link between magnesium deficiency and insulin resistance in obese individuals. Lower magnesium levels were associated with higher fasting glucose, HbA1c, and HOMA-IR, indicating reduced insulin sensitivity. Addressing magnesium deficiency through diet or supplementation may help mitigate the risk of type 2 diabetes in obese populations.

Keywords: Magnesium Deficiency, Insulin Resistance and Obese Individuals.

INTRODUCTION

Obesity is a major global health concern, significantly contributing to the rising prevalence of metabolic disorders such as insulin resistance, type 2 diabetes mellitus (T2DM), and cardiovascular diseases (CVD) [1]. The increasing obesity rates in Bangladesh pose a critical public health challenge, with a reported 23.7% prevalence of overweight and obesity among adults [2]. Obesity is often accompanied by insulin resistance, a condition where cells fail to respond effectively to insulin, leading to hyperglycemia and an increased risk of T2DM [3]. Emerging evidence suggests that micronutrient imbalances, particularly magnesium deficiency, may play a crucial role in the development and progression of insulin resistance [4]. Magnesium is an essential mineral involved in over 300 enzymatic reactions, including those related to glucose metabolism, insulin signalling, and oxidative stress regulation [5]. Studies indicate that low magnesium levels are associated with impaired glucose homeostasis, insulin resistance, and increased inflammation, which are key

contributors to metabolic disorders [6]. A meta-analysis of 13 studies revealed that individuals with lower serum magnesium levels had a significantly higher risk of developing insulin resistance and T2DM [7]. Magnesium deficiency is particularly relevant in populations with high carbohydrate consumption and low dietary magnesium intake, as seen in many South Asian countries, including Bangladesh [8]. Despite this growing body of evidence, the relationship between magnesium deficiency and insulin resistance remains underexplored in obese individuals in Bangladesh. Obese individuals are more susceptible to magnesium depletion due to increased urinary excretion, chronic inflammation, and poor dietary intake [9]. Insufficient magnesium levels have been linked to elevated fasting glucose, increased HOMA-IR scores, and abnormal lipid profiles [10]. A study conducted in India found that over 50% of obese individuals had suboptimal magnesium levels, with a strong inverse correlation between serum magnesium and HOMA-IR scores [4]. However, limited research has been conducted in Bangladeshi populations to assess this relationship, warranting further investigation. Given the increasing burden of obesity and diabetes in Bangladesh, this study aims to evaluate the association between magnesium deficiency and insulin resistance in obese individuals.

METHODOLOGY & MATERIALS

This study follows a cross-sectional observational design to assess the association between magnesium deficiency and insulin resistance in obese individuals. The study was conducted on 100 obese patients at the Department of Medicine, Islami Bank Hospital, Agrabad, Chittagong, Bangladesh, over one year from January to December 2023. The study duration was one year from (start) to (end). Ethical approval was obtained from the Institutional Review Board (IRB) and an Informed consent was obtained from all participants.

Inclusion Criteria:

- Adults (aged 18–65 years)
- BMI ≥ 25 kg/m² (overweight/obese)
- There is no history of chronic kidney disease or gastrointestinal disorders affecting magnesium absorption

Exclusion Criteria:

- Individuals on magnesium supplements
- Pregnant or lactating women
- Patients with type 1 diabetes or chronic inflammatory diseases

Data Collection:

Anthropometric measurements, including height, weight, BMI, waist circumference, and waist-to-hip ratio, were obtained using standard protocols. Dietary magnesium intake was assessed through a 24-hour dietary recall, while physical activity levels were categorized as sedentary, moderate, or active based on participant-reported lifestyle patterns.

Laboratory Investigations:

Blood samples were collected after an overnight fast of 8–12 hours for biochemical analysis. Serum magnesium levels were measured to assess deficiency, while fasting blood glucose and HbA1c were evaluated for glucose control and long-term glucose regulation, respectively. Fasting insulin levels and the HOMA-IR index were used to determine insulin resistance. Additionally, a comprehensive lipid profile, including total cholesterol, HDL, LDL, and triglycerides, was analyzed. Inflammatory and metabolic status were assessed through C-reactive protein (CRP) and serum vitamin D levels.

Data Analysis:

Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS, version 26.0) for Windows. Descriptive statistics, including mean, standard deviation, and frequency distribution, were used to summarize the data. Group differences were assessed using t-tests or ANOVA for comparative analysis. Pearson's correlation analysis was performed to evaluate the relationship between serum magnesium and insulin resistance markers. Additionally, multiple linear regression analysis was conducted to identify predictors of insulin resistance. A p-value of <0.05 was considered statistically significant.

RESULT

The study findings reveal significant associations between magnesium deficiency and insulin resistance in 100 obese Bangladeshi individuals. The demographic and clinical characteristics indicate that the participants had a mean BMI of 29.8 kg/m², with 55% diagnosed with hypertension and 48% with diabetes. Laboratory results showed that the mean fasting blood glucose level was 112.6 mg/dL, mean HbA1c was 6.1%, and mean fasting insulin level was 15.8 µU/mL, suggesting a pre-diabetic state in many participants. Serum magnesium levels averaged 1.72 mg/dL, which is on the lower end of the normal range, raising concerns about potential deficiencies. A strong negative correlation was observed between magnesium levels and insulin resistance markers, including fasting glucose ($r = -0.42$, $p = 0.002$), HbA1c ($r = -0.38$, $p = 0.005$), and HOMA-IR ($r = -0.47$, $p = 0.001$), indicating that lower magnesium levels are associated with worsening insulin sensitivity. Furthermore, regression analysis confirmed that magnesium deficiency significantly predicts insulin resistance ($\beta = -0.56$, $p = 0.001$), independent of BMI and age, reinforcing the hypothesis that magnesium plays a critical role in glucose metabolism. These findings suggest that monitoring and correcting magnesium deficiency may be a key strategy for reducing the risk of insulin resistance and type 2 diabetes in obese individuals, particularly in populations with a high prevalence of metabolic disorders.

Table 1: Baseline Characteristics of Study Participants

Variable	Mean ± SD / n (%)
Age (years)	42.5 ± 10.3
Gender (Male/Female)	60/40
BMI (kg/m²)	29.8 ± 4.1
Waist Circumference (cm)	98.4 ± 10.2
Hypertension (Yes/No)	55/45
Diabetes Status (Yes/No)	48/52

Table 2: Metabolic and Biochemical Parameters of Study Participants

Parameter	Mean ± SD
Fasting Blood Glucose (mg/dL)	112.6 ± 18.4
HbA1c (%)	6.1 ± 1.2
Fasting Insulin (µU/mL)	15.8 ± 5.6
HOMA-IR Index	3.9 ± 1.5
Serum Magnesium (mg/dL)	1.72 ± 0.3
Lipid Profile:	
- Total Cholesterol (mg/dL)	195.4 ± 28.3
- HDL (mg/dL)	41.2 ± 7.1
- LDL (mg/dL)	125.8 ± 25.6
- Triglycerides (mg/dL)	178.9 ± 42.3
C-Reactive Protein (CRP) (mg/L)	3.6 ± 1.2
Serum Vitamin D (ng/mL)	22.4 ± 6.8

Table 3: Correlation between Serum Magnesium and Glycemic Markers

Variable	Pearson's Correlation Coefficient (r)	p-value
Magnesium vs. Fasting Blood Glucose	-0.42	0.002
Magnesium vs. HbA1c	-0.38	0.005
Magnesium vs. HOMA-IR	-0.47	0.001
Magnesium vs. Fasting Insulin	-0.44	0.002

Table 4: Multiple Linear Regression Analysis for Predictors of Glycemic Control

Predictor Variable	β Coefficient	p-value
Serum Magnesium (mg/dL)	-0.56	0.001
BMI (kg/m²)	0.42	0.005
Age (years)	0.21	0.03
Physical Activity Level	-0.28	0.01

DISCUSSION

Magnesium plays a critical role in numerous physiological processes, including glucose metabolism, and its deficiency has been linked to the development of insulin resistance, particularly in obese individuals. This study aimed to explore the relationship between magnesium deficiency and insulin resistance in a cohort of 100 obese individuals in Bangladesh. The findings of this research provide significant evidence supporting the hypothesis that low magnesium levels are associated with increased insulin resistance. The study results showed that serum magnesium levels in the participants were on the lower end of the normal range, averaging 1.72 mg/dL. This finding is consistent with previous studies that have reported magnesium deficiency in individuals with obesity and metabolic disorders [11]. Magnesium deficiency has been associated with impaired insulin sensitivity and glucose intolerance, which are key components of the pathophysiology of type 2 diabetes [12]. The current study observed a strong negative correlation between magnesium levels and various insulin resistance markers, including fasting blood glucose, HbA1c, and the HOMA-IR index. These correlations suggest that as magnesium levels decrease, insulin resistance worsens, supporting the fact that magnesium plays a crucial role in maintaining insulin sensitivity. The regression analysis also confirmed that magnesium deficiency was a significant predictor of insulin resistance, independent of other factors such as BMI and age. This finding aligns with previous research showing magnesium supplementation can improve insulin sensitivity and glucose control in individuals with low magnesium levels [13]. Additionally, the negative correlation between magnesium and fasting insulin levels further underscores the importance of magnesium in insulin secretion and function. These results suggest that correcting magnesium deficiency could be an effective strategy to improve insulin sensitivity and reduce the risk of type 2 diabetes in obese individuals. The study's design, including measuring biochemical markers such as fasting blood glucose, HbA1c, and fasting insulin levels, was robust and allowed for a comprehensive evaluation of glucose metabolism.

Including inflammatory markers such as C-reactive protein (CRP) and serum vitamin D levels further enhanced the understanding of the metabolic status of the participants. Magnesium deficiency is often associated with chronic low-grade inflammation, which can exacerbate insulin resistance [14]. In this study, the mean CRP levels were elevated, indicative of an inflammatory state that may contribute to the observed insulin resistance. One of the strengths of this study is its cross-sectional design, which allows for the identification of associations between magnesium levels and insulin resistance. However, it is important to note that this study does not establish causality. Longitudinal studies or randomized controlled trials (RCTs) would be required to determine whether magnesium supplementation can improve insulin resistance in obese individuals. Moreover, while this study excluded individuals with chronic kidney disease or gastrointestinal disorders that could affect magnesium absorption, other factors such as dietary habits, genetic predisposition, and gut microbiota composition may also play a role in magnesium deficiency and insulin resistance [15]. Additionally, while the study provides valuable insights into the role of magnesium in insulin resistance, the sample size of 100 participants may limit the generalizability of the findings. Future studies with larger and more diverse populations must confirm these results and explore the mechanisms underlying the relationship between magnesium and insulin resistance. It is also worth investigating the potential benefits of magnesium supplementation as a preventive or therapeutic approach for obesity-related insulin resistance.

CONCLUSION

This study highlights a significant association between magnesium deficiency and insulin resistance in obese individuals. Lower serum magnesium levels were strongly correlated with higher fasting glucose, HbA1c, and HOMA-IR, indicating worsening insulin sensitivity. Regression analysis confirmed that magnesium deficiency is an independent predictor of insulin resistance. Given the high prevalence of metabolic disorders, addressing magnesium deficiency through dietary interventions or supplementation may help reduce the risk of type 2 diabetes. Further, longitudinal studies and clinical trials are needed to establish causality and explore the therapeutic potential of magnesium in improving insulin sensitivity and metabolic health in obese populations.

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