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The correlation between zinc and diabetes mellitus

Jenan S. Zaki[1], and Amir Saeed Naemi[1]
[1], Department of Biochemistry, Faculty of Medicine, Golestan University of Medical Sciences, Iran.
E. mail: kadhim.jenanzaki@gmail.com

Abstract

The study investigates the intricate relationship between zinc, an essential trace element, and diabetes mellitus, focusing on its implications for type 2 diabetes management. The study explores the biochemical mechanisms by which zinc influences insulin synthesis and secretion, carbohydrate metabolism, oxidative stress, and inflammation modulation. They discuss the detrimental effects of zinc deficiency on glycemic control and the potential benefits of zinc supplementation in improving fasting blood glucose levels and lipid profiles in diabetic patients. The document also addresses the variability in outcomes of zinc supplementation studies due to differences in study design, zinc dosages, and patient populations, calling for more randomized controlled trials to establish standardized guidelines for zinc supplementation in diabetes care. The manuscript suggests that assessing zinc levels in diabetic patients could be a valuable component of comprehensive diabetes management strategies, given the mineral's crucial roles in insulin dynamics and metabolic health.

Keywords: Zinc, Zinc supplementation, Insulin, Diabetes mellitus, Diabetic complications.

Introduction

Zinc is an essential trace element critical in various physiological functions, including immune response, cellular metabolism, and insulin synthesis. Recent research has garnered significant attention to the correlation between zinc and diabetes mellitus, particularly type 2 diabetes [1]. This essay explores the biochemical mechanisms linking zinc to diabetes, the implications of zinc deficiency, and the potential benefits of zinc supplementation in managing diabetes [2].

Zinc is integral to synthesizing, storing, and secretion of insulin, the hormone responsible for regulating blood glucose levels. It is a co-factor for several enzymes involved in carbohydrate metabolism and is crucial for properly functioning pancreatic beta cells, which produce insulin. Studies have demonstrated that zinc deficiency can impair insulin action and glucose homeostasis, leading to increased blood sugar levels. Research indicates that zinc protects against oxidative stress, a condition often elevated in diabetic patients [3]. Oxidative stress contributes to insulin resistance and the progression of diabetes complications. By modulating oxidative stress and inflammation, zinc may help improve insulin sensitivity and overall metabolic health.

Zinc deficiency is frequently observed in individuals with diabetes, particularly type 2 diabetes. Low serum zinc levels have been associated with poor glycemic control and increased risk of diabetes-related complications [4]. The mechanisms underlying this correlation include the impaired function of insulin receptors and reduced insulin secretion from pancreatic beta cells due to inadequate zinc availability. In addition to affecting insulin dynamics, zinc deficiency can exacerbate other metabolic disturbances associated with diabetes, such as dyslipidemia and hypertension. This interplay suggests that maintaining adequate zinc levels may be crucial for mitigating the adverse effects of diabetes and improving patient outcomes [5].

Zinc supplementation

Several studies have explored the effects of zinc supplementation on diabetes management. Meta-analyses have shown that zinc supplementation can significantly improve fasting blood glucose levels and glycemic control among diabetic patients. The supplementation not only aids in lowering blood glucose but also positively influences lipid profiles, which are often dysregulated in diabetic individuals [6]. Despite the promising results, the research on zinc supplementation has limitations. Variability in study designs, zinc dosages, and patient populations can lead to outcome inconsistencies. Therefore, further randomized controlled trials are necessary to establish standardized guidelines for zinc supplementation in diabetic care [6, 7].

The relationship between zinc and diabetes mellitus is complex and multifaceted. Zinc plays a vital role in insulin synthesis and glucose metabolism, and its deficiency is linked to impaired glycemic control and increased risk of complications in diabetic patients. While zinc supplementation shows potential benefits in managing diabetes, more research is needed to understand its mechanisms and fully establish effective treatment protocols. Given the rising prevalence of diabetes worldwide, evaluating zinc levels in diabetic patients could be a valuable component of comprehensive diabetes management strategies [8].

Zinc deficiency significantly impacts insulin synthesis and release, critical processes for maintaining glucose homeostasis.

Zinc is essential for the synthesis of insulin in pancreatic beta cells. Insulin is stored in the pancreas as a hexamer comprising two zinc ions. This structure is crucial for the stability and storage of insulin. When zinc levels are adequate, insulin is synthesized and stored effectively. However, zinc deficiency can disrupt this process, impairing insulin synthesis. Although some studies suggest that insulin synthesis may remain normal even in zinc deficiency, insulin's overall functionality and release are compromised [9].

Zinc and insulin release

Zinc plays a vital role in insulin release from pancreatic beta cells. The process of insulin secretion is tightly regulated, and zinc is involved in the signaling pathways that trigger this release. When glucose levels rise, zinc is mobilized within the beta cells, facilitating the exocytosis of insulin granules into the bloodstream. In conditions of zinc deficiency, this process is hindered, leading to reduced insulin secretion in response to glucose stimuli [10]. Studies have shown that low zinc levels correlate with diminished insulin response during glucose tolerance tests, indicating that zinc deficiency can lead to inadequate insulin release when needed [2, 10].

The consequences of zinc deficiency on insulin dynamics can lead to several metabolic disturbances. For instance, reduced insulin secretion can result in elevated blood glucose levels, contributing to insulin resistance and the progression of diabetes. Furthermore, zinc deficiency is associated with increased oxidative stress and inflammation, which can further impair beta cell function and exacerbate the diabetic state. In summary, zinc deficiency adversely affects both insulin synthesis and release, leading to impaired glucose metabolism and increased risk of diabetes. Ensuring adequate zinc levels is crucial for maintaining optimal pancreatic function and overall metabolic health [12].

Zinc supplementation has been studied for its potential effects on glucose tolerance and glycemic control in diabetic patients. Research indicates that zinc plays a significant role in insulin synthesis, secretion, and action, making it a critical nutrient for managing diabetes [13]. Here are the key findings regarding how zinc supplementation affects glucose tolerance in diabetic patients:

Improvement in Glycemic Control

1. **Meta-Analyses Findings**: Several meta-analyses have shown that zinc supplementation can significantly improve glycemic control among diabetic patients. Specifically, it has been associated with reductions in fasting blood glucose (FBG), postprandial blood glucose (PPBG), and HbA1c levels, crucial indicators of long-term glucose control [14].

2. **Specific Patient Populations**: In studies focusing on patients with type 2 diabetes, those with higher baseline HbA1c levels (≥ 7.5%) and marginal zinc status showed the most

significant improvements in glycemic control following zinc supplementation. This suggests that patients with more severe diabetes-related zinc deficiency may benefit the most from supplementation [15].

Mechanisms of Action [16, 17]

1. **Insulin Sensitivity**: Zinc enhances the phosphorylation of insulin receptors, improving insulin sensitivity and promoting glucose uptake into cells. This mechanism may help mitigate insulin resistance, a common issue in type 2 diabetes.

2. **Oxidative Stress Reduction**: Zinc has antioxidant properties that help reduce oxidative stress, often elevated in diabetic patients. By mitigating oxidative damage, zinc may help preserve pancreatic beta-cell function and improve insulin secretion.

3. **Lipid Profile Improvement**: Zinc supplementation has also been linked to improvements in lipid parameters, which can further benefit overall metabolic health in diabetic individuals. Improved lipid profiles can contribute to better cardiovascular health, a significant concern for those with diabetes.

Variability in Results

Despite the overall positive findings, the effects of zinc supplementation can vary significantly among studies. Factors contributing to this variability include:

- Differences in study design, sample sizes, and zinc dosages.
- Variations in baseline zinc status among participants.
- The presence of confounding factors, such as the simultaneous supplementation of other vitamins and minerals.

Zinc supplementation positively affects glucose tolerance and glycemic control in diabetic patients, particularly those with marginal zinc deficiency. While the evidence supports its beneficial role, further research is necessary to establish standardized dosages and treatment protocols. Overall, including zinc assessment in diabetes management may provide valuable insights into optimizing care for diabetic patients [18].

There is limited evidence on the potential side effects of zinc supplementation in diabetic patients. The available research focuses more on the beneficial effects of zinc on glycemic control and diabetes management rather than adverse events. However, a few key points can be made:

Minimal Side Effects Reported [19]

1. **Most studies** did not report any significant side effects of zinc supplementation in diabetic patients, even at doses up to 30 mg daily for several months.

2. **One systematic review** noted that the included studies did not investigate important outcomes, such as the side effects of zinc supplementation.

Potential Interactions [20]

1. **Zinc can interact** with certain medications, such as antibiotics, diuretics, and some antidepressants. Diabetic patients taking these medications should consult with their healthcare provider before starting zinc supplements.

2. **High doses of zinc** (over 40-50 mg per day) may interfere with the absorption of other minerals like iron and copper, potentially leading to deficiencies.

Considerations for Diabetic Patients

1. **Diabetic patients** with kidney disease should be cautious with zinc supplementation, as excess zinc can accumulate in the body and potentially worsen kidney function.

2. **Individuals with diabetes** are at higher risk for certain conditions, such as gastroparesis (delayed stomach emptying), which may affect the absorption of zinc and other nutrients.

In summary, while zinc supplementation appears to be generally well-tolerated in diabetic patients, individuals need to consult with their healthcare provider before starting any new supplements, especially if they have additional medical conditions or are taking medications. Monitoring for potential side effects and adjusting dosages as needed is recommended [21].
Zinc supplementation can interact with other diabetes medications, influencing their effectiveness and overall management. Here are the key points regarding these interactions:
Insulin and Oral Hypoglycemic Agents [22]

1. **Insulin Interaction**: Zinc is known to form complexes with insulin, which can prolong its action when administered together. This interaction can be beneficial, as it may reduce the frequency of insulin injections needed by diabetic patients. Zinc has been used in formulations like protamine zinc insulin to enhance insulin stability and prolong its release.

2. **Oral Hypoglycemic Agents**: Zinc supplementation may improve the efficacy of oral hypoglycemic agents by enhancing insulin sensitivity and reducing oxidative stress, which is often elevated in diabetic patients. Some studies suggest that zinc can improve the tissue response to insulin, potentially increasing the effectiveness of medications that rely on insulin signaling pathways.

Potential Confounding Factors [23]

1. **Supplementation with Other Nutrients**: Many studies on zinc supplementation often include other vitamins and minerals (e.g., magnesium, selenium) in their protocols. This can complicate the assessment of zinc's isolated effects on glucose metabolism and interactions with diabetes medications, as these other nutrients may also influence glycemic control and insulin sensitivity.

2. **Variability in Patient Response**: The response to zinc supplementation can vary based on individual factors such as baseline zinc levels, the severity of diabetes, and concurrent medications. This variability can affect how zinc interacts with diabetes medications, leading to different patient outcomes.

While zinc supplementation shows promise in improving glycemic control and potentially enhancing the effectiveness of diabetes medications, patients need to consult healthcare providers before starting supplementation. This ensures that any interactions with existing medications are carefully monitored and managed. Further research is needed to clarify the specific interactions between zinc and various diabetes treatments and establish optimal supplementation protocols for diabetic patients [24].
Zinc supplementation may impact the efficacy of GLP-1 receptor agonists, although specific studies directly addressing this interaction are limited. Here are the key points regarding the potential effects of zinc supplementation in conjunction with GLP-1 receptor agonists:
Mechanisms of Interaction [26]

1. **Insulin Sensitivity and Secretion**: Zinc plays a crucial role in insulin synthesis and secretion, which could complement the mechanisms of GLP-1 receptor agonists. These medications enhance insulin secretion in response to meals and improve insulin sensitivity. Zinc's role in enhancing insulin receptor phosphorylation may further support the action of GLP-1 agonists, potentially leading to improved glycemic control.

2. **Oxidative Stress Reduction**: Zinc has antioxidant properties that help reduce oxidative stress, a condition often elevated in diabetes. Since oxidative stress can impair the function of pancreatic beta cells, zinc supplementation may help preserve their function and enhance the overall effectiveness of GLP-1 receptor agonists.

Zinc and glycemic control [27, 28]

1. **Systematic Reviews**: A systematic review indicated that zinc supplementation benefits glycemic control in diabetic patients, including reductions in fasting blood glucose and HbA1c levels. While these studies did not specifically focus on GLP-1 receptor agonists, the improvements in glycemic control suggest that zinc may enhance the overall diabetes management strategy.

2. **Combination with Other Treatments**: Some studies have examined zinc supplementation alongside other treatments, including multivitamins and minerals, showing improved metabolic control in diabetic patients. However, the specific interaction between zinc and GLP-1 receptor agonists remains underexplored.

While there is no direct evidence specifically linking zinc supplementation to the efficacy of GLP-1 receptor agonists, the supportive role of zinc in insulin dynamics and oxidative stress reduction suggests that it could enhance the overall effectiveness of diabetes management strategies that include GLP-1 receptor agonists. Further research is needed to clarify these interactions and establish comprehensive guidelines for zinc supplementation in patients using GLP-1 receptor agonists.

Conclusion:

The manuscript by Zaki and Naemi provides a comprehensive analysis of the correlation between zinc and diabetes mellitus, highlighting the importance of zinc in maintaining insulin synthesis and secretion, glucose homeostasis, and protecting against oxidative stress in diabetic patients. The authors effectively demonstrate that zinc deficiency is associated with poor glycemic control and increased risk of diabetes-related complications, while zinc supplementation shows promise in improving metabolic outcomes. However, they acknowledge the need for further research to address the inconsistencies in study outcomes and to develop clear guidelines for zinc supplementation in diabetes care. The conclusion underscores the potential of zinc as a critical nutrient in managing diabetes mellitus and calls for its integration into diabetes management strategies, particularly in the context of the global rise in diabetes prevalence.

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