Quantification of Some Trace Elements in The Scalp Hair of Patients with Type 2 Diabetes Mellitus in Jeddah, Saudi Arabia

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ABSTRACT

Type 2 diabetes mellitus (DM) is one of the major global health challenges of the 21st century. Owing to their diversified metabolic characteristics and functions, various metals such as zinc (Zn), copper (Cu), chromium (Cr), manganese (Mn), iron (Fe), and magnesium (Mg) are considered to be essential for human health. Deficiency of some essential trace elements may lead to the development of DM. The present study aimed to evaluate the contents of Zn, Cu, Cr, Mn, and Mg in the scalp hair samples of patients with type 2 DM from Jeddah (Saudi Arabia). The hair samples were collected from 55 patients with DM aged 45–65 years. Also, 55 age-matched nondiabetic healthy subjects were selected from the same city for a comparative analysis. Zn, Cr, Mn, and Mg levels in hair were found to be significantly lower ($P < 0.05$) in the group of patients with type 2 DM than in nondiabetic subjects. However, the Cu level in hair was significantly higher ($P < 0.05$) in patients with type 2 DM than in nondiabetic subjects. The results revealed that hair Cu concentrations in patients with DM were positively related to body mass index (BMI), whereas Zn, Cr, Mn, and Mg concentrations were inversely related to BMI. Finally, the concentrations of these trace elements in the scalp hair and serum samples of patients with DM were compared.

Key Words: Atomic absorption spectrometer, diabetes mellitus, scalp hair, trace elements.

INTRODUCTION

Diabetes mellitus (DM) is recognized as one of the leading causes of morbidity and mortality in the world (1). The prevalence of DM in the Saudi population is high; 90% of diabetics suffer from type 2 DM. In Saudi Arabia, almost one Saudi in four beyond the age of 30 years has DM. It is estimated to be 40%–50% in 2020 (2,3). In Saudi Arabia, obesity has become one of the most common health problems affecting people of both sexes and all age groups. DM and obesity have a complex relationship, with type 2 DM strongly associated with obesity. The risk of type 2 DM increases fourfold in obese patients (4). Overweight and obesity affect more than 75% of the total population in Saudi Arabia. The risks of DM, hypertension, and dyslipidemia increase from a body mass index (BMI) of about 21.0 kg/m^2, thereby reducing life expectancy and greatly increasing health and socioeconomic burden. Available data suggest that the trace metal status is altered in obese humans and animals (4,5).

Accumulating evidence indicates that the metabolism of several trace elements is altered in DM. It is important to determine the status of trace elements in biological samples of patients with DM. Blood, scalp hair, and urine may be used as bio-indicators for this purpose. With the development of analytical techniques of high power and sensitivity, the significance of the levels of trace elements in human hair has gained the attention of researchers. Many authors have

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reported that human hair is a good indicator of environmental pollution (6-8). Therefore, instead of hematology analysis, hair analysis was the method preferred in this study.

The main objective of the present study was to investigate and quantify some trace elements profile in the scalp hair of individuals with DM and nondiabetic individuals using atomic absorption spectrometry. The correlation of the measured trace elements to BMI was also explored.

MATERIAL AND METHODS

This study was conducted on 55 male patients with type 2 DM (DM group) and 55 age-matched, nondiabetic male subjects (control group) aged 45–65 years. All of them worked in the King Abdulaziz University. The patients attended the clinic of the University regularly. They were all residents of Jeddah City, Saudi Arabia. The study was conducted during the period from December to May. Before the start of the study, all control subjects and patients with DM were informed about the aim of the study via a distributed questionnaire. All agreed to participate and signed the form. The study protocol was approved by the Research Ethics Committee of the University.

The inclusion and exclusion criteria were the same as those mentioned in previous reports (9,10).

Body weight and height were measured and used to calculate the BMI, which was used as a measure of relative body weight. Following enrollment, both patients and control subjects were instructed not to change their lifestyle or their dietary habits and not to take any dietary supplements. The diet was not monitored.

More than 1 g hair of patients with DM and control subjects were cut at the root of the occipital area using stainless-steel scissors and stored in polyethylene bags. A clear solution of the hair sample was needed for analysis using atomic absorption spectrometer. Solid samples of hair were washed, dried, and digested using the procedure available in the literature (6-8). The trace element concentrations of hair samples were measured using Graphite Furnace Atomic Absorption Spectrometer (VARIAN, Model Spectra AA 30P, Australia). The Statistical Package for Social

TABLE 1: Age, BMI, and scalp hair levels of Zn, Cu, Cr, Mn, and Mg in patients with DM and control healthy subjects.

Parameters	DM group	Control group	P value
N	55	55	
Sex	Male	Male	
Age (year)	60.09 ± 6.79	58.92 ± 7.26	NS
Duration of diabetes (year)	5.33 ± 3.26		
BMI (kg/m²)	29.79 ± 1.72	24.37 ± 1.58	<0.05
Zn (µg/g)	162.75 ± 12.82	194.55 ± 8.95	<0.05
Cu (µg/g)	11.55 ± 1.96	8.32 ± 1.42	<0.05
Cr (µg/g)	3.62 ± 1.10	6.16 ± 1.98	<0.05
Mn (µg/g)	2.12 ± 1.20	4.27 ± 1.31	<0. 05
Mg (µg/g)	62.70 ± 4.01	116.72 ± 7.51	<0.05

Mean values are given as mean ± standard deviation.
NS: Not significant.

Sciences Software was used for analyzing results. The results were presented as mean ± standard deviation. The paired t test was used to determine a significant difference between test and control subjects. A P value less than 0.05 was considered statistical significant. The relationships between the investigated parameters were established using Pearson's correlation.

RESULTS

Table 1 shows mean values for age, BMI, and hair zinc (Zn), copper (Cu), chromium (Cr), manganese (Mn), and magnesium (Mg) levels of the nondiabetic subjects and patients with DM in this study. The results of the BMI indicated that patients with DM were overweight. The BMI was significantly higher (P < 0.05) in patients with DM than in nondiabetic healthy control subjects (Table 1).

The mean hair levels of Zn, Cr, Mn, and Mg were significantly (P < 0.05) lower in patients with DM than in control nondiabetic subjects. The mean value of Cu level was significantly (P < 0.05) higher in diabetic patients with DM than in nondiabetic subjects.

The concentrations of trace elements in the serum samples of patients with DM were determined and reported earlier (9,10).

DISCUSSION

Micronutrients form an intricate yet integral part of human body. Analysis of hair, in terms of properties, gives us volumes of information on diseases, metabolic disorders, environmental exposures, and nutritional status. Clinical research suggests that the balance of trace elements and minerals in the body can be disrupted by DM. The most common minerals of concern in patients with DM are Zn, Cu, Cr, and Mg. The hair analysis provides a more permanent record of elemental contents than blood and urine analyses. A previous serum analysis revealed that fasting blood glucose and HbA1c were significantly higher in patients with DM than in nondiabetic subjects. Also, significantly higher Cu levels, lower Zn levels, higher values of Cu/Zn ratio, and also lower Cr, Mn, and Mg levels were found in patients with DM compared with healthy subjects (9,10). The present study found the hair Zn concentrations to be significantly lower in patients with DM than in control healthy subjects, which is consistent with the findings of different authors (6,11,12), who demonstrated low scalp hair Zn concentration in patients with DM; this might be due to the long-term Zn deficiency in the patients. Because of a lack of a specific organ for Zn reserve, its daily intake is needed. Individuals with DM are at risk for Zn deficiency due to increased urinary losses of the mineral, suggesting that Zn supplementation would be of clinical value in this population (13).

The present study indicated that the scalp hair of patients with type 2 DM had significantly lower levels of Cr compared with normal healthy subjects. This result was consistent with the findings of different authors (11,14). Hyperglycemia and high levels of insulin increase Cr excretion; thus, low hair levels of Cr may be seen in patients with DM (14). Insufficient dietary Cr intake has also been implicated as a possible risk factor for the development of DM (15). Individuals with type 2 DM have 20%–40% lower blood Cr levels and 40%–50% lower hair Cr levels compared with healthy controls (16,17). The inclusion of Cr in parenteral nutrition formulas has become standard (18, 19).

Evidence indicated that Mn might play a role in the pathogenesis of DM. The results showed a significant difference between hair Mn levels in patients with DM and control subjects, which is consistent with the findings of different investigators (8,11,16). DM, being a degenerative disease, may be initiated as a result of peroxidation caused by free radicals. Since Zn, Cr, and Mn possess antioxidant properties, deficiency of these may increase susceptibility to the disease. It may therefore be critical to suggest the inclusion of dietary supplementation of these minerals in the management of DM in the study area.

In the studied population, the level of Mg was also significantly lower in the scalp hair samples of patients with DM compared with control healthy subjects ($P < 0.05$). Similar results have been reported by other studies (11,16,20). Epidemiological studies showed a high prevalence of hypomagnesemia and lower intracellular Mg concentration in patients with DM (21). The reasons for decreased Mg concentration in type 2 DM are not clear but it may be due to higher urinary losses or impaired absorption of Mg compared with healthy subjects. The decrease in Mg concentration may also be due to Mg depletion caused by osmotic diuresis, and because of indirect hormonal effects (22). Mg depletion provoked a deleterious effect on glucose metabolism due to an impairment of both insulin secretion and action. Deficiencies of Mg in diet and serum have been associated with an increased risk of developing glucose intolerance and DM, whereas increased Mg intake is associated with a significant decline in the incidence of type 2 DM (23, 24). Thus, foods rich in Mg (such as nuts, green vegetables, soya beans, and whole grains) may provide protection against this chronic disease.

The present study clearly demonstrated significantly higher Cu levels in the hair samples of patients with DM compared with nondiabetic subjects. The available literature reports higher Cu values in hair of patients with DM compared with normal subjects (6,25). The increase in the Cu levels in patients with type 2 DM might be attributed to hyperglycemia, stimulating glycation, which results in the formation of highly reactive oxidants that can lead to tissue damage (26, 27).

A comparison of the previous results for trace elements in serum samples of type 2 DM patients (9,10) with the present results showed that the scalp hair samples were better biological samples for trace element analysis, especially in case of Zn and Mg due to the high accumulation of these elements in hair, which caused a better detection.

Many previous prospective studies have shown that obesity or being overweight is related to the risk of DM (28, 29). Available data suggest that the trace metal status of obese humans and animals is altered (4,5,28). The present study enrolled a smaller sample population with a narrow age range; 62% of the patients with type 2 DM were in the overweight group, and 30% were in the obese group. The results revealed that the mean Cu levels increased whereas the mean levels of Zn, Cr, Mn, and Mg decreased in overweight and obese individuals compared with the control group. The group with BMI >30 was found to have the lowest hair Zn, Cr, Mn, and Mg concentrations, but the highest hair Cu concentrations. Furthermore, a comparison of Zn, Cr, Mn, and Mg concentrations in hair between the groups with BMI <25 and BMI >30 showed significant differences, with P less than 0.05 at least. The present results corroborate with those in previous studies (30–32).

DM and obesity have a complex relationship, with type 2 DM strongly associated with obesity. The risk of type 2 DM increased fourfold in obese patients. Epidemiological and interventional studies suggest that weight loss is the main driving force to reduce the risk for DM. Landmark clinical trials on lifestyle changes in subjects with prediabetes have shown that diet and exercise leading to weight loss consistently reduce the incidence of DM. Reducing excess weight and obesity is the key factor in managing DM more efficiently so that the overall health and general sense of well-being can be improved (32–34).

In general, dietary supplements are inexpensive and easily accessible to the public. Because of this, they are frequently used inappropriately as "alternative therapeutics" in the treatment of DM. The most frequent origin of micronutrient deficiencies is inadequate diet. Persons with DM should receive appropriate nutritional counseling to consume an adequate quantity of foods rich in essential micronutrients for meeting their daily requirements. The advantage of this diet over pharmacological supplements is the combined action of the several micronutrients that an appropriate diet contains.

Jeddah has a hot and humid climate all year-round. Summer (April to November) temperatures are very hot, often breaking the 43°C mark in the afternoon and dropping to 30°C in the evening. In winters, the temperatures are at a comfortable level (between 20°C and 30°C on average), which is during the months of December to March. The present study was conducted during the period from December to May. A possible relationship between Mg deficiency and climate variations was speculated, which contributed to the increase in mortality due to heart disease and DM. High temperatures would increase sweat losses. Consequently, among the minerals, Mg would be most affected because the losses would not be compensated by the diet and water intake, hence increasing the risk for the aforementioned diseases (35 - 37).

A potential limitation of the present study was that it consisted of a sample population not large enough to allow subgroup analyses. To better understand the role of these trace elements in DM and the age-specific relationship between obesity and risk for DM, further clinical studies are required enrolling a large number of male and female patients with a wide age range and using more sophisticated techniques. Besides hair, urine, and nail samples should also be obtained to allow clear conclusions.

Obesity stands out as a risk factor for type 2 DM; however, some lean patients with type 2 DM, probably having latent autoimmune diabetes in adults, are seen. Thus, obesity may be a precursor for type 2 DM, following insulin resistance. Most researchers consider this relationship to be different in different types of obesity and type 2 DM. Further studies are needed to fully understand this.

The causes of obesity are probably different for many types. Genetic disposition is clearly one of them. Different demographic groups based on lifestyle and genetics must be studied in a comprehensive way to understand more of these patterns.

Obesity has become a major cause of concern for Saudi Arabia, with 7 out of 10 Saudis suffering from obesity and 37% of Saudi women facing problems related to overweight (38). Studies show that overweight and obesity are more prevalent among high-income subjects who reside in urban communities. The increase in the prevalence of such conditions among high-income subjects would reflect the perception of fatness as a sign of affluence among those subjects. As the prevalence of obesity increases with age, and considering that the majority of Saudi population comprises people less than 30 years old at the present time, one would expect the magnitude of obesity to be even bigger in the near future. The problem is linked, increasingly, to socioeconomic development and policies in the areas of agriculture, transport, urban planning, environment, food processing, distribution, and marketing, as well as education. It is a social concern and hence demands a population-based multisectoral, multidisciplinary, and culturally relevant approach that can prevent the huge expenses involved in treating this epidemic. This high prevalence of obesity is a cause of concern, since obesity is associated with several complications that increase both morbidity and mortality. Awareness programs must be initiated, and nationwide control and prevention programs should be adopted to decrease the prevalence of obesity in the Saudi population.

To introduce high-quality and safe preventive and curative health care services for individuals at high risk of DM and patients suffering from overweight and obesity, it is mandatory to establish clinical guidelines that will help health care providers to manage these common problems at primary, secondary, and tertiary care levels in Saudi Arabia.

CONCLUSION

This study primarily demonstrated that trace element levels in the scalp hair of patients with type 2 DM significantly deviated from control healthy subjects. The results showed that scalp hair samples were better biological samples for trace element analysis, especially in the case of Zn and Mg due to the high accumulation of these elements in hair, which caused a better detection.

The study showed that patients with diabetes had significantly lower levels of Zn, Cr, Mn, and Mg and significantly elevated levels of Cu in the scalp hair compared with age-matched nondiabetic subjects. Hence, more attention needs to be given to the adequate supply of essential trace elements in the diet of patients with DM. Also, the Cu level in hair increased with BMI for overweight and obese patients. Again, the higher the BMI, the lower the Zn, Cr, Mn, and Mg concentrations observed in hair of patients with type 2 DM. The results obtained in the present study were consistent with those in other studies confirming that trace elements may play a significant role in the development of DM and progression of its metabolic complications.

Based on the results, it is recommended that patients with type 2 DM should consume foods rich in Zn, Cr, Mn, and Mg, but with moderate Cu levels. Health care providers should invest more efforts in diet changes rather than focusing on micronutrient supplementation to achieve the metabolic control of their patients.

Control and prevention of obesity is essential to prevent more serious consequences in Saudi Arabia. Therefore, awareness programs must be formulated to increase the information on obesity, its harmful effects, and measures that should be adopted to prevent it. It is also important that changes must be made to the lifestyle of the Saudi population to reduce the increasing prevalence of overweight and obesity.

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