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Reverse Relationship Between Blood Boron Level and Body Mass Index in Humans: Does It Matter for Obesity?

Mustafa Hasbahceci · Gokhan Cipe · Huseyin Kadioglu · Erhan Aysan · Mahmut Muslumanoglu

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Abstract The exact role of boron in humans is not known although its supplementation causes several important metabolic and inflammatory changes. The objective of this study is to evaluate the possibility of an association between blood boron level and obesity in normal, overweight, obese, and morbidly obese subjects. A total number of 80 subjects, categorized into four groups based on their body mass index as normal, overweight, obese, and morbidly obese, were enrolled in this study. Age, sex, body mass index, and blood boron levels were recorded for each subject. Although the distribution of female and male subjects and blood boron levels were similar between groups, the mean age of normal subjects was significantly lower than the others (p=0.002). There was a significant relationship between age and quantitative values of body mass index for each subject (β=0.24; p=0.003). In addition, between blood boron levels and quantitative values of body mass index for each subject, a significant reverse relationship was detected (β=−0.16; p=0.043). Although age seemed to be an important variable for blood boron level and body mass index, blood boron levels were shown to be lower in obese subjects in comparison to non-obese subjects.

Keywords Obesity · Morbid · Body mass index · Trace elements · Boron · Adults

Introduction

It is generally known that humans obtain trace elements from their daily diet, and serum concentrations of trace elements are directly related to dietary intake of individuals [1]. Boron as one of the trace elements does not appear naturally in its elemental form; instead, it is found most notably as boric acid and borax [2, 3]. In biological fluids, boric acid is the only boron species which can be identified after environmental and occupational exposure to boron compounds [4].

Although the exact role of boron has not been known, its supplementation in animal and human nutrition was shown to cause several important metabolic and inflammatory changes [3]. However, there are many conflicting results on the metabolic effects of boron both in humans and animals [5–8]. Short- and long-term weight reduction with boron supplementation has been shown by several animal studies [5, 6]. Although the mechanism of action of several boron compounds including boric acid and other borates on weight reduction has not been explained in these studies, it was claimed that increased thermogenesis and lipolysis with higher catabolism secondary to the hormonal changes might be the causative factors [5]. Therefore, it may be speculated that boron may have some important regulatory effects on body weight.

In humans, oral boron supplementation with regard to its effect on bone mineral metabolism, blood coagulation systems, steroid hormones, and pro-inflammatory cytokines has been studied [8–13]. However, the relationship between boron either supplied by supplementation or chronic environmental exposure and body weight has not been reported yet. In addition, whether blood boron level (BBL) varies in normal and obese subjects is also unknown.

In this study, we aim to evaluate the possibility of an association between BBL and obesity in normal, overweight, obese, and morbidly obese subjects.

Materials and Methods

A prospective observational study was conducted in the Department of General Surgery, Faculty of Medicine,

M. Hasbahceci (✉) · G. Cipe · H. Kadioglu · E. Aysan · M. Muslumanoglu
Department of General Surgery, Faculty of Medicine, Bezmialem Vakif University, Vatan Str, Fatih 34093 Istanbul, Turkey
e-mail: hasbahceci@yahoo.com

Bezmialem Vakif University. The study was approved by the Ethical Committee of Clinical Trials at Bezmialem Vakif University (number B.30.2.BAV.0.05.05-97; date, 28 June 2011). All subjects gave informed consent for inclusion to the study.

Subjects were categorized into four groups based on their body mass index (BMI) which was calculated by dividing weight in kilograms by the square of height in meters: BMI 18.5 to 24.9 kg/m^2 as normal (group I), BMI 25.0 to 29.9 kg/m^2 as overweight (group II), BMI 30.0 to 39.9 kg/m^2 as obese (group III), and >BMI 40.0 kg/m^2 as morbidly obese (group IV). A total number of 80 subjects, 20 in each group, were enrolled consecutively from the list of outpatient clinics during their evaluation of chronic nonspecific abdominal pain. All of them were living in urban areas. Patients receiving vitamin and/or mineral supplementation, and who had history of chronic metabolic, cardiovascular, respiratory, and hepatic disease, were excluded.

Demographic data including age, sex, and BMI were recorded for each subject. Blood samples were drawn by venipuncture into appropriately coated tubes. Boron testing was performed using coupled plasma mass spectrometry with a flow injection [14].

Statistics

All statistics were performed using SPSS 15.0 for Windows (SPSS, Inc., Chicago, IL, USA). Continuous variables were expressed as mean ± standard deviation (SD). Categorical variables were expressed as frequencies and evaluated by the chi-square test. The Student's t test was used for comparison of continuous variables between female and male subjects. Pearson's correlation tests were performed for correlations between these variables. A one-way analysis of variance was used to compare the differences in age and BBL between the groups based on BMI. Multiple linear regression analysis was used to determine the effect of BBL, age, and sex on BMI. The differences were considered statistically significant if the p value was equal to or less than 0.05.

Results

The study group included consecutive 80 subjects consisting of 59 women and 21 men, with a mean age of 44.13± 13.0 years. In each group, which was categorized according to BMI, there were 20 subjects. Demographic data and BBL of each group were given in Table 1. Distribution of female and male subjects, and BBL, were similar. However, there was a statistically significant difference in age distribution (p=0.002). The mean age of group I was significantly lower than the other three groups.

Although there was no difference in BBL with sex (p=0.933) and no correlation of BBL with quantitative values of BMI for each subject (p=0.403), significant correlations of age with BBL (r=0.401, p=0.001) and with quantitative values of BMI for each subject (r=0.274, p=0.014) were detected (Table 2).

Multiple linear regression analysis (Table 2) showed that there was a significant relationship between age and quantitative values of BMI for each subject (Table 3). A significant negative relationship was also detected between BBL and quantitative values of BMI for each subject (partial regression plot; Fig. 1).

Discussion

It is known that eating habits are important for the development of obesity. There are many studies in which lower or higher intakes of several micronutrients including both vitamins and minerals may be an important pathophysiologic mechanism for obesity [1, 15]. Although the relationship between trace elements and obesity is proved to be a difficult issue, they may cause several biochemical and hormonal changes in mammalians because of their physiological properties.

The inhibitory role of boron in oxidoreductase enzymes of energy substrate metabolism is a well-known subject [4–6]. In several animal and human studies, the positive effect of boron in alleviation of perturbed plasma glucose and triacylglycerol concentrations, and inhibition of glycolytic enzymes, were reported [4, 6]. It was also shown that oral supplementation with boron caused reduction of insulin in adipose tissue and a decrease in sensitivity of adipose tissue to insulin [6]. After oral supplementation of low-dose boric acid, higher levels of cholesterol, low density lipoprotein, lactate dehydrogenase, aspartate aminotransferase, alanine aminotransferase, and amylase and urine urobilinogen were shown in another animal study. Authors hypothesized that these results may be related to an increased catabolism

Table 1 Demographic data and blood boron levels of the subjects

	Group I	Group II	Group III	Group IV	p
Age[a]	36.3±10.0	42.8±10.8	50.7±13.5	46.8±13.6	0.002
Female/male (n)	16/4	14/6	15/5	14/6	0.871
BBL[b]	12.3±13.8	11.3±7.9	18.2±19.5	9.4±8.0	0.180

[a] Year ± SD

[b] Blood boron level, ppb

especially with regard to increased thermogenesis and accelerated lipolysis [5]. With regard to lipid metabolism, the plasma lipid-lowering effect of boron has been shown in an animal study using boron-derived agents [4]. Promoted removal of cholesterol from tissues and decreased lipid accumulation were the underlying mechanisms of boron. Therefore, it can be accepted that even physiologic amounts of boron may modulate both energy substrate utilization and mineral metabolism [5, 6].

In animal studies, conflicting results with regard to the effect of boron on body weight during short- and long-term exposure were found. Some studies revealed that oversupplementation of boron caused weight gain [7, 16]. However, body weight reducing effect of boron supplementation was also reported [5, 6, 17]. In an animal study with different concentrations of orally supplemented boron, it was demonstrated that body weight was not affected by boron supplementation [18]. It is believed that heterogeneity with regard to type and dosage of the boron compound and duration of the exposure may cause such differences.

Concerning occupational exposure to boron, BBL was found to be between 100 and 150 ppb, and higher than 150 ppb in medium- and high-exposure groups, respectively. Even in high-exposure groups, blood levels of boron are still almost nine times lower than the highest "no observable adverse effect level" with regard to the reproductive toxic effects in rats [2]. BBL was shown to be up to 136 ppb with oral supplementation [9]. BBL of the subjects found in all groups of the present study was also lower than BBL in occupationally exposed subjects. Therefore, boron compounds should not be considered as toxic to reproduction for humans in daily life and can be supplemented in a safe manner [2].

In this study, the subjects were categorized according to their BMI as normal, overweight, obese, and morbidly obese. All groups were similar in terms of gender, but younger subjects were found significantly in group I besides the random inclusion of the subjects into the groups based on their applications to our outpatient clinic. BBL was also similar for all groups based on BMI. However, it was found that there were significant correlations of age with BBL and quantitative values of BMI for each subject. In the US-based Nutrition and Food Board, age was reported as an important factor for the amount of boron intake [19]. A significant reverse relationship between BBL and quantitative values of BMI for each subject was found by multiple linear regression analysis. As a result of these findings, it was shown that BBL of obese subjects was significantly lower than that of normal subjects. Although it cannot be accepted that boron supplementation causes some reduction in BMI of obese subjects in light of our findings, the effect of boron on energy substrate utilization and mineral metabolism in causing reduction in body weight should be regarded as an important step for prevention and medical treatment of obesity.

Another important factor with regard to boron physiology is rapid urinary excretion of orally supplemented boron. It was shown that a 9.0-fold increase in dietary boron caused only a 1.5-fold increase in BBL [10]. In human studies evaluating the degree of boron exposure or boron intake, both blood and urinary levels of boron have been used [2, 4, 14, 20]. However, only the blood level of boron was preferred in this study due to its design to evaluate the relationship between boron and BMI.

Inclusion of the subjects without major health problems instead of totally normal subjects and lack of urinary boron

Table 2 Model summary

Model	R^2	F	p[a]
1	0.126	3.647	0.016

[a] Predictors: sex, BBL, age (constant); BMI (dependent variable)

Table 3 Multiple linear regression analysis showing relationships between constant and dependent variables

Coefficients[a]

Model		Unstandardized coefficients		t	Significance
		B	Standard error		
1	(Constant)	22.399	3.299	6.789	0.000
	Sex	0.674	2.099	0.321	0.749
	BBL	−0.156	0.076	−2.062	0.043[b]
	Age	0.243	0.078	3.120	0.003[b]

[a] BMI (dependent variable)

[b] Statistically significant

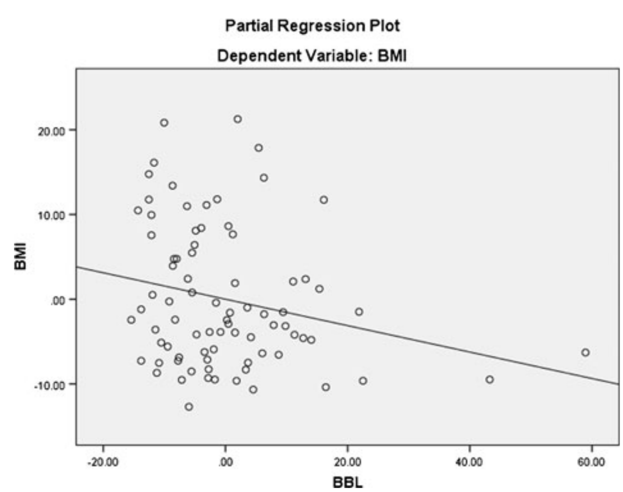

Fig. 1 Partial regression plot of BMI and BBL

levels in addition to BBL may be regarded as examples of the limitations in this study.

Conclusion

This is the first study in which a negative significant relationship between BMI and BBL was shown. BBL was shown to be lower in obese subjects in comparison to non-obese subjects. However, age seems to be important for both BMI and BBL. There should be an explanation for the fact that increasing age causes both an increase in BMI and a decrease in BBL. Therefore, future studies are needed to clarify the physiologic mechanisms between age, BMI, and boron.

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