Abnormalities of Magnesium Homeostasis in Obesity

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***Abstract* – Obesity is one of the most important modifiable risk factors for the non-communicable diseases (cardiovascular disease, cancer and diabetes), and is often associated with magnesium (*Mg*) deficiency. In this study we have analysed the characteristics of the anthropometric measures, blood pressure and glucose level, according to the cut off of serum *Mg* < 0.8 *mmol/L* (median of the sample) separately in male and female individuals. In this representative sample of obese, mostly middle aged adults, we have observed different pattern of analysed variables associated with classes of obesity and lower *Mg* levels.**

***Keywords* – obesity, micronutrients, magnesium, glucose abnormalities.**

1. Introduction

According to the World Health Organization (WHO) definition, obesity represent abnormal or excessive fat accumulation that may impair health and promote the development of a number of complications. Obesity prevalence nearly tripled between 1980 and 2016 in the most countries of the European Region [1]. Currently, obesity is one of the most important modifiable risk factors for the non-communicable diseases (cardiovascular disease, cancer and diabetes), and is often associated with micronutrient deficiencies, most notably magnesium (*Mg*) deficiency (up to 40%) [2, 3].

Magnesium is the second most important (after potassium) intracellular cation. Of the body's magnesium (adults: 24 *g*), 60% is deposited in bones, 20% in the skeletal musculature, 19% in soft tissues, and only 1% is in the extracellular compartment [4]. In addition to its important role in maintaining the metabolic homeostasis of carbohydrates, proteins, lipids, magnesium participates as a cofactor in oxidative phosphorylation, intracellular signaling, cellular membrane permeability, and therefore contributes to normal cardiovascular and neuromuscular functions [5]. The *Mg* homeostasis is tightly controlled by the interaction of dynamic processes, food and water intake, gastrointestinal tract absorption (ileum and colon absorption) and kidney excretion (in physiological conditions, 96% of the magnesium is reabsorbed in renal tubules).

In obesity, the increased intake of low nutritional-quality foods (excess of saturated fats), lack of antioxidants due to inadequate fruit and vegetable consumption, may affect the homeostasis of *Mg* [6, 7]. Hence the aim of the study was to analyse the cardiometabolic risk factors (anthropometric characteristics, blood pressure and glucose levels) according to *Mg* serum concentration, in the representative sample of the middle-aged and older obese adults.

2. Measurements

This cross sectional study was performed at the Clinical Center of Vojvodina (CCV). The study was conducted according to Declaration of Helsinki and approved by the Ethical Committees of the CCV. Informed consent was obtained from every participant of the study. Participants were consecutively recruited from the Department of Endocrinology, Diabetes and Metabolic Disorders, of the CCV. A total of 104 obese individuals (body mass index (*BMI*) above 30 kg/m^2) were evaluated. In order to evaluate the effect of obesity on *Mg* status

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we divided the study group according to *BMI* value: class 1 obesity (*BMI* from 30.0 to 34.9 kg/m^2), class 2 obesity (*BMI* form 35.0 to 39.9 kg/m^2) and class 3 obesity (*BMI* higher than 40.0 kg/m^2).

Body height was measured using Harpenden anthropometer with the precision of 0.1 *cm* and the body mass was measured using balanced beam scale with the precision of 0.1 *kg*. Body mass index (*BMI*) is calculated as the ration of body mass and the square of body height. Waist circumference (*WC*) was measured using flexible tape with precision 0.1 *cm*, at the level of middle distance between the lowest point on the costal arch and the highest point on the iliac crest. Systolic blood pressure (*SBP*) and diastolic blood pressure (*DBP*) were measured in the morning hours, after 10–15 minutes of rest, by standard procedure and using sphygmomanometer after Riva-Rocci. Fasting glucose levels (*FG*) were determined by Dialab glucose GOD-PAP method. Total serum *Mg* concentration was measured by photometric method (ADVIA 1800) with xylidyl blue metallochromic indicator, reference value for *Mg* were from 0.59 to 0.97 *mmol*/*L*.

Table 1. Characteristics of dataset

	Minimum	Average	Maximum
AGE	24	44.08	74
BMI	30.03	36.98	56
WC	92	121.34	163
SBP	110	138.58	220
DBP	70	86.78	127
FG	3.7	6.48	19.7
MG	0.59	0.81	0.97

3. Results

In Table 2 are given the obtained results for males with the *BMI* between 30 and 35 kg/m^2.

Table 2. Results for males with 30≤BMI<35

	Minimum	Average	Maximum
Mg<0.8			
AGE	36	55.68	72
BMI	30.03	32.15	34.72
WC	97	111.55	130
SBP	124	152.91	208
DBP	79	94.86	118
FG	5.7	8.47	19.7
Mg≥0.8			
AGE	36	44.55	64
BMI	31.21	32.96	34.61
WC	95	112.48	128
SBP	115	138.64	205
DBP	75	90.73	127
FG	4.24	5.63	6.9

Table 3 presents the results for males with the *BMI* between 35 and 40 kg/m^2.

Table 3. Results for males with 35≤BMI<40

	Minimum	Average	Maximum
Mg<0.8			
AGE	34	46.78	61
BMI	35.19	37.56	39.45
WC	102	125.22	138
SBP	122	146.78	170
DBP	70	93.44	120
FG	4.18	7.43	14.4
Mg≥0.8			
AGE	28	41.63	74
BMI	35	36.76	39.4
WC	104	123.25	135
SBP	120	144.5	220
DBP	77	86.5	114
FG	3.7	5.39	9.5

In Table 4 are presented the results for males with the *BMI* above 40 kg/m^2.

Table 4. Results for males with BMI≥40

	Minimum	Average	Maximum
Mg<0.8			
AGE	30	42.13	59
BMI	40.40	47.87	56
WC	93	135.13	163
SBP	111	132.5	163
DBP	71	86.63	96
FG	4.4	8.64	17.5
Mg≥0.8			
AGE	33	37.88	44
BMI	40	44.33	52
WC	130	140.25	157
SBP	130	131.25	140
DBP	70	78.75	90
FG	3.9	5.49	9.4

In the Table 5 are given the obtained results for females with the *BMI* between 30 and 35 kg/m^2.

Table 5. Results for females with 30≤BMI<35

	Minimum	Average	Maximum
Mg<0.8			
AGE	37	44.25	51
BMI	30.35	31.72	33.71
WC	92	99	104
SBP	122	145.5	161
DBP	73	86.73	99
FG	5.6	7.58	11.2

Mg≥0.8			
AGE	24	34.8	42
BMI	30.4	32.75	34.3
WC	97.5	114.88	131
SBP	110	122	140
DBP	70	77	90
FG	4.2	4.72	5.2

Table 6 presents the results for females with the *BMI* between 35 and 40 kg/m^2.

Table 6. Results for females with 35≤BMI<40

	Minimum	Average	Maximum
Mg<0.8			
AGE	34	47.6	65
BMI	35.25	36.94	38
WC	102	116.4	135
SBP	120	156	205
DBP	80	90.4	108
FG	5.16	6.45	9
Mg≥0.8			
AGE	25	37.7	43
BMI	35.2	37.38	39
WC	103	125.25	135
SBP	120	125	130
DBP	70	78	85
FG	3.9	4.67	5.5

In Table 7 are presented the results for females with the *BMI* above 40 kg/m^2.

Table 7. Results for males with BMI≥40

	Minimum	Average	Maximum
Mg<0.8			
AGE	28	34.67	40
BMI	41	43.33	47
WC	134	140	147
SBP	115	118.33	120
DBP	75	78.33	80
FG	5	5.43	5.8
Mg≥0.8			
AGE	35	38.5	42
BMI	40.25	43.96	46
WC	130	135.5	152
SBP	120	125	140
DBP	80	83.33	90
FG	3.8	4.91	6

4. Discussion

In this study we have analysed the characteristics of anthropometric measures (*BMI* and *WC*), *SBP* and *DBP* and the glucose level (*FG*), according to the cut off of serum *Mg* < 0.8 *mmol*/*L* (median of the sample) separately in male and female individuals. In this representative sample of obese, mostly middle aged adults, we have observed different pattern of analysed variables associated with classes of obesity. Magnesium in circulation exists in three forms, a plasma protein-related fraction (about 25% for albumin and 8% for globulin), a fraction of *Mg* in the complex with anions (phosphates and sulphates) and the largest fraction in which *Mg* is (60%) ionized, free, physiologically active [8]. In clinical settings, next to total and ionized *Mg* concentration in the serum, it is possible to determine the concentration of *Mg* in the urine. Although many authors believe that the serum *Mg* concentration does not always reflect its total amount in the body (99% is intracellular), serum concentrations of total *Mg* represent the most commonly used parameter for determining the *Mg* status in the body [9].

We have observed higher *SBP*, *DBP* and *FG* in obese male individuals (class 1 obesity) with lower *Mg* serum concentration (< 0.8 *mmol*/*L*). Additionally to the generalised obesity, these subjects had increased *WC*, indicating the high risky abdominal fat enlargement. In individuals with class 2 and class 3 obesity, the higher *FG* was determined in obese males with lower *Mg* serum concentration. Also, obese (class 3) males with lower *Mg* concentrations had higher levels of *DBP*. Previously, it has been reported that *Mg* serum concentration is associated with the non-communicable diseases, mostly cardiometabolic diseases (type II diabetes mellitus and atherosclerotic cardiovascular diseases) [2,5,7,10]. Furthermore, the enlargement of the fat mass in the body composition could be associated with disorders of the levels of calcium, phosphorus and vitamin D, which indirectly can also affect the *Mg* status in obese patients [11]. Also, obesity related changes in the body composition are also associated with an increase in total body water and circulating extracellular volume with a possible effect of volumetric dilution to *Mg* extracellular concentration [12].

In obese female individuals, we have observed the similar trend of *SBP*, *DBP* and *FG* in subjects with lower *Mg* among different classes of obesity. The observed difference was the most prominent for *FG*. Some studies revealed that females have a higher risk of developing *Mg* deficiency than the males [13]. In addition to the influence of the geographical area, it is necessary to take into account the sex differences in *Mg* daily intake. Also, body composition and fat patterning characteristics in women may have an effect on the *Mg* serum concentration, since the period of the middle age is a peak in the fat mass enlargements [14]. Evidence from numerous studies indicate that the disruption of glucose metabolism is

one of the most significant obesity related pathophysiological consequences [4]. On the contrary, *Mg* may have a role in maintaining insulin sensitivity. Experimental studies confirmed the significant involvement of *Mg* as a cofactor of several enzymatic systems involved in the glucose metabolism. Also, since the intracellular concentration of *Mg* is crucial in the phosphorylation of insulin receptor tyrosine kinase, *Mg* deficiency could lead to disruption of enzyme activity and contribute to the development of post-receptor insulin resistance and impaired glucose utilization in the cells [7,15,16].

5. Conclusion

Obese males and females with lower Mg levels have higher values of *SBP*, *DBP* and *FG*. The observed difference in cardiometabolic risk factors between obese individuals was the most prominent for the *FG*.

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