Original Article

The association between intracellular electrolytes and obesity indices

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Abstract

Background: Obesity with a rapid grow in developed and developing countries has a close association with higher disposition to related diseases such as hypertension. Intracellular functions of sodium, potassium, calcium, phosphate, and iron have been an interested subject in obese patients since their dysregulations are linked to a higher risk of hypertension and other metabolic disorders. **Materials and Methods:** In this study, the circulating levels of sodium, potassium, calcium, phosphate, and iron were determined in the serum of obese patients compared to normal-weight people. Moreover, we examined the correlation of such electrolytes with the well-known indices of obesity such as body mass index (BMI), waist circumference (WC), hip, triglycerides (TG), cholesterol and other characterizations. **Results**: The mean levels of sodium, potassium, calcium, phosphate, and iron were significantly different ($p < 0.05$) in obese patients compared to normal-weight subjects. We observed a positive partial correlation between the levels of these electrolytes and obesity indices such as BMI, WC, hip, and cholesterol. **Conclusion**: Collectively, the present study suggests the positive correlation between obesity and the indices of metabolic disorders such as hypertension and renal failure according to the observed imbalances in the concentration of electrolytes. Moreover, efforts for diet modification may be helpful in the programs aimed at decreasing the burden of obesity and related disorders.

Keywords*:* Obesity, electrolytes, body mass index, waist circumference.

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Introduction

Based on World Health Organization (WHO), obesity is growing rapidly worldwide with a prevalence of more than thirteen percent among adults. Moreover, it has a close association with higher disposition to related diseases such as type two diabetes, dyslipidaemia, atherosclerosis, and hypertension (1, 2). This epidemic raises higher concerns with a serious deterioration in quality of life. In addition to genetic bases, obesity may be connected to an inability to alter the life manners and health behaviors due to a low control over stress factors and dietary habits in the patient's life (3). This is attributed more to the compositions of diet which are not only energy-dense but also rich in supplies such as sodium without an adequate amount of potassium. Moreover, another study reported the association of sodium, potassium, calcium, phosphate, and iron with blood pressure, cardiovascular events and other diseases. Therefore, the level of these electrolytes usually indicates a patient's dietary intake and nutritional status and with increasing such diet among people all over the world particularly in Iran, the ratio of sodium to potassium and dysregulation in electrolytes level would be increased over the time with worse outcomes in involved patients (4, 5).

Intracellular functions of sodium and potassium has been an interested subject in patients with overweight since their dysregulations increase the risk of hypertension (6, 7). However, the dysregulations of intracellular electrolytes could only be examined in those obese patients suffering from hypertension or presenting its familial disposition . It means that some obese patients with or without familial disposition to hypertension may have normotension with normal concentrations of electrolytes (8, 9). Moreover, changed renal activity may cause to an impaired renal excretion of electrolytes such as sodium, potassium, calcium, phosphate, and iron and then result in their accumulation in the body (50).

There are several studies indicating the higher concentrations of intracellular electrolytes only in obese people with a high intake of food rich in such electrolytes or a familial disposition to hypertension. However, other evidences propose that dysregulation in electrolytes level is linked to obesity, independent of energy or food compositions. Nevertheless, results from a few studies report that lower potassium, a electrolyte positively related to healthfulness of diet (18), and a higher ratio of sodium to potassium are connected to obesity and related hypertension (19). It should be noted that the associations of sodium, potassium, calcium, phosphate, and iron with obesity indices such as body mass index (BMI), waist circumference (WC), hip, triglycerides (TG), cholesterol and other characterizations have been studied in separate studies (10-17). However,to the best of our knowledge, no study has been investigated the association of afore-mentioned electrolyte together. Consequently, in this study, we aimed to evaluate the concentration of common electrolytes such as sodium, potassium, calcium, phosphate, and iron and their correlation with the well-known indices of obesity ,lipid profile and other metabolic features in the context of obesity in Iranian population.

Methods

Study Population. The study was performed on 39 women from who referred to Loqman Hakim, Erfan, and Sina hospitals, Tehran, Iran, aged 20-53 years including 20 obese patients (BMI ≥35 kg/m2), and 19 normal-weight individuals (BMI ≤ 25 Kg/m2). The exclusion criteria were as any diagnosis with type one or two diabetes, cardiovascular disease, autoimmune disease, renal and liver disease, acute and chronic infectious diseases, cancer, or having an operation in last 6 months. The study was approved by Ethics Committee of the Tehran University of Medical Sciences (IR.TUMS.VCR.REC.1397.827). The written informed consents were obtained from studied subjects prior to the study.

Anthropometric and clinical characterization. The anthropometric indices of all participants were measured, including BMI, WC, hip, and blood pressure. BMI was measured according to the ratio of weight in kg divided by height in m2 to evaluate the fatness of participants. WC was measured at the midpoint between the lowest rib and the iliac crest. In addition, hip was calculated at the maximum circumference of the buttocks. For measuring the systolic and diastolic blood pressures, a manual sphygmomanometer was used.

Biochemical and Laboratory Measurements. Serum was separated from blood samples obtained from participants after an overnight fasting. The blood sample was obtained by venipuncture into sterile BD Vacutainer tubes. Then, the collected blood was centrifuged at 800 ×g for 15 min to isolate the serum. The separated serum was stored frozen at -80°C for next experiments. Sodium, potassium, calcium, phosphate, iron, bilirubin, TG, and total cholesterol (TC) were analyzed by auto analyzer using commercial kits (Pars Azmoon, Tehran, Iran). Any other biochemical parameters were measured by enzymatic process using assay kit adapted in hospitals.

Statistical Analysis. SPSS 20 (SPSS, Chicago, IL, USA) was used to analyze the data. Values were presented as median and interquartile range (IQR). Mann–Whitney U test analysis was used for the comparison of data between obese and normal-weight participants. Next, the normality of data was checked by the Shapiro-Wilk test. The correlation analysis was done by Spearman test. P value of <0.05 was considered statistically significant.

Results

The demographic and clinical characteristics of all participants are shown in Table 1.

Table1. Anthropometric and laboratory characteristics of study population.

	Normal-weight subjects	Obese subjects	Total difference p value
Na, mmol/L	141.6 (139.8-146.25)	140.45 (138.12-141.07)	0.027
K, mmol/L	4.09 (3.26-4.57)	4.33 (4.18-4.33)	0.042
Ca, mmol/L	8.3 (7.07-9.28)	9.29 (9-9.58)	0.006
P, mmol/L	2.83 (2.49-3.44)	3.56 (3.27-3.84)	0.000
Fe, mmol/L	54.65 (33.67-91.25)	78.0.5 (57.67-113.82)	0.022
TIBC, -	275 (232.5-345.5)	356 (318-397)	0.000
D-Bil, mmol/L	0.17 (0.12-0.32)	0.16 (0.12-0.21)	0.462
T-Bil, mmol/L	0.43 (0.28-0.55)	0.43 (0.30-0.57)	0.845
BMI, kg/m2	25.85 (24.29-26.98)	41.5 (36.55-45)	0.000
WC , cm	88 (83.75-101)	114 (110.5-119.5)	0.000
Hip, cm	110.5 (90-107.25)	126 (120-136)	0.000
SBP, mmHg	120 (110-120)	120 (110-130)	0.413
DBP, mmHg	80 (70-80)	60 (80-90)	0.814
TG, mg/dL	91.55 (66.42-140.15)	124.9 (90.85-158.32)	0.184
TC, mg/dL	139.5 (115.47-173.12)	175.35 (153.15-200.87)	0.003
LDL-C, mg/dL	86.15 (70.07-110.22)	114.80 (93.85-126.75)	0.007
Urea nitrogen, mg/dL	20.85 (16.32-27.05)	25.60 (23.52-28.22)	0.029
Creatinine, mg/dL	0.57 (0.50-0.68)	0.70 (0.63-0.81)	0.000

*Correlation is significant at .05. Na, sodium; K, potassium ; Ca, calcium; P, phosphate; Fe, iron; TIBC, total iron binding capacity; D-Bil, direct bilirubin; T-Bil, total bilirubin; BMI, body mass index; WC, waist circumference; TG, triglycerides; TC, total cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure; LDL-C, low density lipoprotein-cholesterol.

The mean levels of sodium, potassium, calcium, phosphate, and iron were significantly different ($p < 0.05$) in obese patients compared to normal-weight subjects. Moreover, there was a significant higher total iron binding capacity (TIBC), BMI, WC, and hip circumference in the obese patients compared to the normal-weight subjects (p=0.000). In addition, A significant higher levels of TC, low density lipoprotein-cholesterol (LDL-C), urea, and creatinine was observed in obese group compared to controls (p<0.05). However, TG, bilirubin, systolic blood pressure (SBP), and diastolic blood pressure (DBP) levels were not significantly different between the two groups (p>0.05).

We also analyzed the correlation of sodium, potassium, calcium, phosphate, iron, and TIBC with each other and with anthropometric and laboratory parameters in the whole population (Table 2) and also each studied groups (Table 3 and 4).

Based on our results, there was a significant positive correlation between the levels of potassium and TC (r= 0.346; p= 0.014), and creatinine (r= 0.0444; p= 0.001), the levels of calcium and BMI (r= 0.343; p= 0.015), WC (r= 0.352; p= 0.022), hip (r= 0.406; p= 0.008), TC (r= 0.303; p= 0.032), and creatinine (r= 0.456; p= 0.001), the levels of phosphate and BMI (r= 0.319; p= 0.024), WC (r= 0.332; p= 0.032), hip (r= 0.395; p= 0.011), TC (r= 0.366; p= 0.009), LDL-C (r= 0.387; p= 0.005), urea (r= 0.280; p= 0.049), and creatinine (r= 0.288; p= 0.043), and also the levels of TIBC and BMI (r= 0.415; p= 0.003), WC (r= 0.323; p= 0.037), hip (r= 0.312; p= 0.047), TC (r= 0.315; p= 0.027), LDL-C (r= 0.339; p= 0.017), and creatinine (r= 0.282; p= 0.049) (Table 2).

Moreover, we observed a significant positive correlation between the levels of sodium and SBP (r= 0.464; p= 0.030) in the normal-weight subjects. The significant positive correlation between the levels of potassium and TC (r= 0.628; p= 0.002), LDL-C (r= 0.476; p= 0.025), and creatinine (r= 0.482; p= 0.023) was reported in this group. In contrast, there was a significant negative correlation between the levels of potassium and BMI (r= -0.476; p= 0.025) and and direct bilirubin (r= 0.018; p= -0.498) (Table 3).

Table 2. The correlation of electrolytes with anthropometric characteristics and biochemical data in the whole population.

	Na, mmol/L		**K, mmol/L**		Ca**, mmol/L**		**P, mmol/L**		**Fe, mmol/L**		**TIBC, -**	
	p	**r**	**p**	**r**	**p**	r	p	**r**	**p**	**r**	**p**	**r**
BMI, kg/m2	0.373	-0.129	0.245	0.167	0.015	0.343	0.024	0.319	0.102	0.234	0.003	0.415
WC , cm	0.117	-0.246	0.187	0.207	0.022	0.352	0.032	0.332	0.102	0.256	0.037	0.323
Hips, cm	0.111	-0.252	0.080	0.277	0.008	0.406	0.011	0.395	0.098	0.262	0.047	0.312
SBP, mmHg	0.081	0.254	0.163	-0.205	0.910	0.017	0.535	-0.92	0.344	0.140	0.569	0.085
DBP, mmHg	0.702	0.057	0.061	-0.273	0.313	-0.149	0.378	-0.130	0.668	0.063	0.258	0.168
TG, mg/dL	0.201	-0.184	0.092	0.241	0.063	0.265	0.189	0.189	0.950	0.009	0.973	-0.005
TC, mg/dL	0.139	-0.212	0.014	0.346	0.032	0.303	0.009	0.366	0.182	0.192	0.027	0.315
LDL-C, mg/dL	0.212	-0.180	0.052	0.277	0.099	0.236	0.005	0.387	0.414	0.118	0.017	0.339
Urea nitrogen, mg/dL	0.527	-0.092	0.562	0.084	0.063	0.265	0.049	0.280	0.844	-0.029	0.603	0.076
Creatinine, mg/dL	0.501	-0.097	0.001	0.444	0.001	0.456	0.043	0.288	0.109	0.229	0.049	0.282
Bil-D, mmol/L	0.680	0.060	0.189	--0.189	0.936	0.012	0.738	-0.049	0.579	0.080	0.099	-0.239
Bil-T, mmol/L	0.920	-0.015	0.844	-0.028	0.375	0.128	0.920	0.015	0.069	0.260	0.188	-0.191

*Correlation is significant at .05. Na, sodium; K, potassium ; Ca, calcium; P, phosphate; Fe, iron; TIBC, total iron binding capacity; D-Bil, direct bilirubin; T-Bil, total bilirubin; BMI, body mass index; WC, waist circumference; TG, triglycerides; TC, total cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure; LDL-C, low density lipoprotein-cholesterol.

Table 3. The correlation of electrolytes with anthropometric characteristics and biochemical data in the healthy group.

	Na, mmol/L		**K, mmol/L**		Ca**, mmol/L**		**P, mmol/L**		**Fe, mmol/L**		**TIBC, -**	
	p	**r**	**p**	**r**	**p**	r	p	**r**	**p**	**r**	**p**	**r**
BMI, kg/m2	0.216	0.275	0.025	-0.476	0.008	-0.551	0.106	-0.354	0.938	0.018	0.753	-0.071
WC , cm	0.851	0.043	0.408	-0.186	0.117	-0.344	0.077	-0.385	0.727	0.079	0.553	-0.134
Hips, cm	0.765	0.067	0.306	-0.228	0.415	-0.183	0.170	-0.304	0.524	0.144	0.846	-0.044
SBP, mmHg	0.030	0.464	0.189	-0.291	0.626	-0.110	0.409	-0.185	0.630	0.109	0.657	0.100
DBP, mmHg	0.204	0.282	0.848	-0.043	0.554	-0.133	0.423	-0.180	0.876	0.035	0.266	0.248
TG, mg/dL	0.300	-0.232	0.190	0.290	0.740	0.075	0.700	0.087	0.824	-0.050	0.530	-0.141
TC, mg/dL	0.109	-0.351	0.002	0.628	0.055	0.415	0.037	0.447	0.562	0.131	0.538	0.126
LDL-C, mg/dL	0.318	-0.223	0.025	0.476	0.132	0.331	0.030	0.463	0.883	0.033	0.469	0.163
Urea nitrogen, mg/dL	0.482	-0.158	0.863	0.039	0.112	0.348	0.348	0.210	0.449	-0.170	0.774	0.065
Creatinine, mg/dL	0.883	-0.033	0.023	0.482	0.008	0.549	0.696	0.088	0.025	0.447	0.282	0.240
Bil-D, mmol/L	0.970	0.009	0.018	-0.498	0.493	-0.154	0.580	0.125	0.782	-0.063	0.602	-0.118
Bil-T, mmol/L	0.747	-0.073	0.265	-0.248	0.932	0.019	0.972	-0.008	0.483	0.158	0.549	-0.135

*Correlation is significant at .05. Na, sodium; K, potassium ; Ca, calcium; P, phosphate; Fe, iron; TIBC, total iron binding capacity; D-Bil, direct bilirubin; T-Bil, total bilirubin; BMI, body mass index; WC, waist circumference; TG, triglycerides; TC, total cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure; LDL-C, low density lipoprotein-cholesterol.

Table 4. The correlation of electrolytes with anthropometric characteristics and biochemical data in the obese group.

	Na, mmol/L		**K, mmol/L**		Ca, **mmol/L**		**P, mmol/L**		**Fe, mmol/L**		**TIBC, -**	
	p	**r**	**p**	**r**	**p**	r	p	**r**	**p**	**r**	**p**	**r**
BMI, kg/m2	0.061	0.358	0.441	0.152	0.002	0.567	0.140	-0.286	0.310	-0.199	0.576	-0.113
WC , cm	0.829	0.052	0.914	-0.026	0.004	0.612	0.670	-0.102	0.610	-0.122	0.044	-0.455
Hips, cm	0.886	-0.035	0.097	0.392	0.009	0.585	0.448	0.185	0.542	-0.149	0.101	-0.387
SBP, mmHg	0.272	0.224	0.115	-0.317	0.592	-0.110	0.448	-0.156	0.588	0.111	0.831	0.045
DBP, mmHg	0.757	-0.064	0.006	-0.527	0.246	-0.236	0.552	-0.122	0.739	0.069	0.331	0.203
TG, mg/dL	0.898	0.025	0.661	-0.087	0.139	0.287	0.344	0.186	0.824	-0.050	0.530	-0.141
TC, mg/dL	0.830	0.042	0.977	0.006	0.959	0.010	0.883	-0.029	0.359	0.180	0.473	0.144
LDL-C, mg/dL	0.837	0.041	0.932	-0.017	0.927	-0.018	0.822	0.045	0.855	0.036	0.403	0.168
Urea nitrogen, mg/dL	0.714	0.072	0.736	-0.067	0.868	0.033	0.613	0.100	0.961	0.010	0.136	-0.295
Creatinine, mg/dL	0.382	0.172	0.018	0.445	0.098	0.320	0.728	-0.069	0.161	-0.272	0.671	0.086
Bil-D, mmol/L	0.767	0.059	0.325	0.193	0.162	0.272	0.470	0.142	0.136	0.289	0.159	-0.279
Bil-T, mmol/L	0.798	0.051	0.481	0.139	0.212	0.243	0.842	0.039	0.143	0.284	0.116	-0.310

*Correlation is significant at .05. Na, sodium; K, potassium ; Ca, calcium; P, phosphate; Fe, iron; TIBC, total iron binding capacity; D-Bil, direct bilirubin; T-Bil, total bilirubin; BMI, body mass index; WC, waist circumference; TG, triglycerides; TC, total cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure; LDL-C, low density lipoprotein-cholesterol.

Finally, we analyzed such correlations in the obese group. There was a significant negative and positive correlation between the levels of potassium and DBP (r= -0.527; p= 0.006), and creatinine (r= 0.0445; p= 0.018), respectively. Moreover, the significant positive correlation between the levels of calcium and BMI (r= 0.567; p= 0.002), WC (r= 0.612; p= 0.004), and hip (r= 0.585; p= 0.009) was reported in this group. There was a significant negative correlation between TIBC levels and WC (r= -0.455; p= 0.044) too as provided in Table 4.

Discussion

The main finding of this study was the partial correlation between the levels of sodium, potassium, calcium, phosphate, and iron and obesity indices such as BMI, WC, hip, and cholesterol. Hence, this study suggests the relationship between obesity and hypertension and renal failure according to the observed imbalances in the concentration of electrolytes.

The association between obesity disposition and the abnormal concentrations of sodium, potassium, calcium, phosphate, and iron is mostly pertinent and yet underexplored among different populations such as Iran. It is reported that a great number of people in the world suffer from obesity and related conditions such as hypertension or renal failure which is closely related to the intracellular concentrations of electrolytes in these patients (21, 22).

Furthermore, different population have dissimilar dietary habits which among them, Iranian people are one of the most with high caloric food consumption rich in sodium and lacking potassium (23, 24). Hence, realizing how serum electrolytes such as sodium and potassium are associated with obesity outcomes is of great public health interest.

Previous studies performed experiments on the energy intake derived from dietary habits (25-30) which are unavoidably accompanied with errors (31). A few number of studies have examined the electrolytes concentration in association with obesity (32, 33), and to our knowledge, no previous study in Iran has examined the correlation between sodium, potassium, calcium, phosphate, and iron with obesity indices and outcomes. The present study was the first to measure the association between such electrolytes and obesity indices including BMI, WC, hip, TG, TC, and other characterizations in obese subjects compared to normal-weight individuals in Iran.

Several conceivable mechanisms may contribute to the correlation between obesity and the concentrations of electrolytes. First, high level of sodium and low level of potassium may be linked to obesity through augmented energy intake which was indicated by several studies. Consequently, the sodium-obesity association has mostly been recognized to indirect downstream mechanisms linked to augmented energy intake. However, some studies reported the opposite results as the correlation between sodium level and obesity indices was independent of energy (10-17, 34-37). Another mechanism proposed by other studies is that a higher level of sodium may induce the accumulation of fat in adipocyte tissue along with an altered lipid homeostasis in the body. For instance, an increased adipocyte mass was observed in rats fed with a high sodium diet in comparison to controls which had the same nourishment. Another study also reported a higher uptake of glucose and accumulation of lipids within adipocyte tissue in rats with high sodium diet (38, 39).

It should be noted that our study was consistent with the results of others in various populations. For example, a higher risk of obesity was reported along with dysregulation of sodium level in Australian children (40). Remarkably, a revent study on Hispanic and Latino Americans showed the association between sodium and obesity indices such as BMI and WC independent of energy intake. This was similar for the level of potassium and the ratio of sodium to potassium too (42). Moreover, there was no difference between obesity indices and sodium levels among Canadian children (43).

In the present study, we observed a positive correlation between the level of calcium and obesity indices including BMI, WC, and hip in obese people. Interestingly, a decrease in the intracellular calcium level of adipose cells prevents the storage of lipid in these cells by suppressing the lipogenesis and activating the lipolysis. Moreover, phosphate as an essential mineral for cellular signaling, metabolism, and energy homeostasis, was also investigated for its role in conjunction with other electrolytes in obesity, hypertension, and cardiovascular diseases (44-49). It was reported before that a higher intake of phosphate is correlated with higher BMI and WC (50) as was shown in our study too. In addition, another research in line with our study, reported that a higher level of TIBC was observed among which was associated with a greater risk of developing CVD (51).

Conclusion

In conclusion, a higher level of sodium and a lower level of potassium was observed in obese patients with a positive correlation with recognized obesity indices including BMI, WC, and hip compared to normal-weight subjects. Collectively, the present study suggests the positive correlation between obesity and hypertension according to the observed imbalances in the concentration of electrolytes. Moreover, efforts for reducing sodium intake may be helpful in the programs aimed at decreasing the burden of obesity and related disorders. Nevertheless, there is still a need for determining the particular mechanism of the effects of sodium on overweight/obesity risk.

Conflict of Interest

There is no conflict of interest among authors.

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