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ORIGINAL RESEARCH ARTICLE

"Effect of Hyperglycemia on Electrolytes Imbalance"

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ABSTRACT

Electrolytes are the chemicals dissolved in the body fluid. The distribution has important consequences for the ultimate balance of fluids. The balance of the electrolytes in our bodies is essential for normal function of our cells and our organs. In present study a total of 33 hyperglycemic serum samples were analyzed for their electrolytes imbalance from their reference range corresponding to blood sugar value. At blood sugar level 130-190 mg % the percent variation value varied from 7.1 – 39.94 % and 18.25 – 66.28% For Na+ and K+ respectively. The Na+ ions not showed significance fluctuation from their normal range. At 190-250 mg % hyperglycemic range the level of various electrolytes showed significant variation from their reference range. The statistical analysis showed significant percent variation varies from 4 – 98% for Na + whereas 37 to 193% and6.5% - 97 % variation for K+ and Cl- respectively form their reference range. Higher range of sugar concentration (250 – 380 mg %) in blood serum, the Na+ concentration diverge from 10- 65%, K+ level speckled in the range of 14 – 80% and Cl- ions diverse 15-78 % . Sugar concentration in blood showed 54.51, Na+ 41.87, K+ 5.27 and Cl- 52.27 standard deviation respectively from reference range of concentration among all 33 samples. When data were subjected to Pearson Correlation analysis it was found that, There is a significant correlation of serum sodium (r = 0.107, P < 0.552), potassium (r = -0.035, P < 0.848), Chloride (r = 0.087, P < 0.631) with blood sugar. The present study concluded that the hyponatremia and hyperkalemia are more likely to be related to short-term metabolic control as reflected by blood glucose. Diabetes mellitus is associated with disturbances in electrolyte metabolism.

INTRODUCTION

Electrolytes are the chemicals dissolved in the body fluid. The distribution has important consequences for the ultimate balance of fluids. Sodium chloride is found mostly in extra cellular fluid, while potassium and phosphate are the main ions in the intracellular fluid. Chemically, electrolytes are substances that become ions in solution and acquire the capacity to conduct electricity. Electrolytes are present in the human body, and the balance of the electrolytes in our bodies is essential for normal function of our cells and our organs. Common electrolytes that are measured in blood testing include sodium, potassium, chloride, and bicarbonate (WOLF *et al*, 1954). The main fluid in the body is water. Total body water is 60% of body weight. The water is distributed in three main compartments separated from each other by cell membranes. The intracellular compartment is the area within the cell. The extra cellular compartment consists of the interstitial area (between and around cells) and the inside of the blood vessels (plasma). Compartments of Body and Distribution of Water by Weight is Plasma 5% Interstitial 15%, Intracellular 40%, Total 60 % Water, Solids - 40%, fat, protein, carbohydrates and minerals. Electrolytes are electrical conduits. Body fluid, tissue, and blood contain them. They are known as chloride, calcium, magnesium, sodium, and potassium. Healthy muscle, heart and nerve functioning as well as concentration depend upon the vital balance of electrolytes (Gault *et al* 1971).

Electrolytes are dissolved minerals used by the body to conduct electricity. Potassium, sodium and calcium are all important for proper electrolyte balance. Electrolytes are vital for proper electric signals in the heart. Electrolytes are salts that conduct electricity and are found in the body fluid, tissue, and blood. Examples are

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chloride, calcium, magnesium, sodium, and potassium. Sodium (Na+) is concentrated in the extracellular fluid (ECF) and potassium (K+) is concentrated in the intracellular fluid (ICF). Proper balance is essential for muscle coordination, heart function, fluid absorption and excretion, nerve function, and concentration (Perez GO *et al*, 1977).

The kidneys regulate fluid absorption and excretion and maintain a narrow range of electrolyte fluctuation. Normally, sodium and potassium are filtered and excreted in the urine and feces according to the body's needs. Too much or too little sodium or potassium, caused by poor diet, dehydration, medication, and disease, results in an imbalance. Too much sodium is called hypernatremia; too little is called hyponatremia. Too much potassium is called hyperkalemia; too little is called hypokalemia (Makoff *et al*, 1971).

Hyponatremia is the most common electrolyte imbalance. It is associated with kidney disease such as nephrotic syndrome and acute renal failure (ARF). Men and women with healthy kidneys have equal chances of experiencing electrolyte imbalance, and people with eating disorders such as anorexia and bulimia, which most often affect women, are at increased risk. Very young people and old people are affected more often than young adults.

Sodium is the major positive ion (cation) in fluid outside of cells. Many processes in the body, especially in the brain, nervous system, and muscles, require electrical signals for communication. The movement of sodium is critical in generation of these electrical signals. Too much or too little sodium therefore can cause cells to malfunction, and extremes in the blood sodium levels (too much or too little) can be fatal. Increased sodium (hypernatremia) in the blood occurs whenever there is excess sodium in relation to water. Sodium is the major positively charged ion (cation) in the fluid outside of cells of the body. The chemical notation for sodium is Na. When combined with chloride (Cl), the resulting substance is table salt (NaCl). A decreased concentration of sodium (hyponatremia) occurs whenever there is a relative increase in the amount of body water relative to sodium (McNair *et al* 1982). Potassium is the major positive ion (cation) found inside of cells. The chemical notation for potassium is K+. The proper level of potassium is essential for normal cell function. A seriously abnormal increase in potassium (hyperkalemia) or decrease in potassium (hypokalemia) can profoundly affect the nervous system and increases the chance of irregular heartbeats (arrhythmias), which, when extreme, can be fatal (Nicolis *et al* 1981). An abnormally low level of potassium (K+) is called hypokalemia. The adrenal gland makes a hormone (aldosterone) that signals the kidneys to excrete or conserve potassium, based on the body's needs (Tzamaloukas AH, Gardner KD, 1984).

Salts are chemical compounds composed of atoms that carry electrical charges. Dissolved in water, the components in a salt exist as ions. Collectively, these ions are called electrolytes. Electrolytes are dissolved in different compartments of body water including: the serum portion of the blood, inside the cells (intracellular), and out-side the cells (extracellular) (Rosenbaum *et al* 1978). The concentration of these electrolytes varies considerably from one area to the other. However, there is a narrow concentration limit of these electrolytes that the body must maintain within each of these compartments. The body transfers electrolytes intracellularly and extracellularly as required to maintain electrolyte balance (McCurdy *et al* 1970).

Electrolytes have many functions and roles in the body. The concentration of electrolytes must be maintained within a narrow range within the blood, otherwise deleterious physiological effects may occur. Electrolytes play a vital role in maintaining homeostasis within the body. They help to regulate myocardial and neurological function, fluid balance, oxygen delivery, acid-base balance and much more. The most serious electrolyte disturbances involve abnormalities in the levels of sodium, potassium, and/or calcium. Other electrolyte imbalances are less common, and often occur in conjunction with major electrolyte changes. Chronic laxative abuse or severe diarrhea or vomiting can lead to electrolyte disturbances along with dehydration. People suffering from bulimia or anorexia nervosa are at especially high risk for an electrolyte imbalance (Sterns RH *et al*, 1981).

High sodium levels may occur in diabetes insipidus, a disease that causes too much urine to be produced. In this type of diabetes, either the hypothalamusfails to make vasopressin or the kidneys don't respond to vasopressin. In either case, the kidney is able to regulate the body's sodium levels, but can't retain water (Goldfarb *et al* 1976). High sodium levels don't occur in diabetes insipidus if the patient is able to drink enough water to keep up with urinary loss, which

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maybe as high as 10 liters per day. Diabetes, also known as diabetes mellitus, is a general term for a variety of different metabolic disorders that affect the ability of the body to process and use sugar properly. Medically, this is referred to as an inability of the body to metabolize glucose effectively. This results in an abnormally high level of glucose in the blood, called hyperglycemia. Hyperglycemia can lead to serious long-term complications (Montoliu and Lethal 1985). Serum glucose concentration and total carbon dioxide content correlated significantly with the presenting serum potassium concentration. The changes in serum glucose concentration and in carbon dioxide content and the serum potassium concentration at hyperglycemia were found to be independent correlates of the decrease in potassium concentration during treatment. Insulin alone resulted in correction of hyperkalemia in all instances. Post treatment hypokalemia was noted in only two instances, each associated with both ketoacidosis and low-normal serum potassium concentration at hyperglycemia (Viberti GC *et al*, 1978). Giving insulin is the only treatment usually needed for the hyperkalemia of hyperglycemia in patients on ongoing dialysis (Legrain M *et al*, 1984).

In the diabetic with ketoacidosis hyperkalemia, in the face of potassium depletion, is attributable to reduced renal function, acidosis and release of potassium from cells due to glycogenolysis, and lack of insulin. Chronic hyperkalemia in diabetics is most often attributable to hyporeninemic hypoaldosteronism but other conditions including urinary tract obstruction may also contribute. A variety of clinical situations (e.g., volume depletion) and drugs (e.g., nonsteroidal antiinflammatory agents, and heparin) may acutely provoke hyperkalemia in susceptible individuals (Jaime Uribarri *et al* 1990). Transmembrane potassium distribution is influenced largely by acid-base equilibrium and hormones including insulin and catecholamines (Rosenstock *et al* 1982). Hence the study was aimed to evaluate the effect of hyperglycemic condition on the electrolytes concentration in blood serum.

Materials and Methods

A total of 33 blood samples were collected from hyperglycemic patients from the district hospital of Mandsaur district MP India. Five milliliters (5ml) venous blood was collected at 09.00hr every morning after overnight fast. The blood was dispensed into plane dry glass test tubes. Serums were isolated by centrifuging in a laboratory centrifuge at 2000g for three minutes immediately after blood clotting and retraction at room temperature. The serums were refrigerated at 4 ^{0} C.

Sample Analyses

Serum potassium (K^+), Sodium (Na^+) and Chloride (Cl^-) were analyzed by Auto Analyzer at the B. R. Nahata College of Pharmacy, Mandsaur MP India. Serum chloride (Cl^-) was estimated by the thiocynate colorimetric method described by coral chloride testing kit. Chloride ions react with mercuric thiocynate to form mercuric per chlorate and thiocynate. Thiocynate form a red complex with ferric ions in the presence of nitric acid (Tietz *et al*, 1964).

Serum potassium (K^+), Sodium (Na^+) were estimated by Elyte 2 and 3 Testing Kit. Sodium is precipitated as a triple salt with Magnesium and uronyl acetate. The excess of uronyl ions are reacted with Ferro cyanide in an acidic medium to develop a brownish color. The intensity of the color produced is inversely proportional to the concentration of sodium in the sample (Schoenfeld *et al* 1964).

The potassium estimating method based on that the potassium reacts with sodium tetraphynyl boron in a specially prepared buffer to form a colloidal suspension. The amount of turbidity produced is directly proportional to the concentration of potassium in the serum sample (Imoruna, 1958). Statistical Analyses was done to determinate the percent variation, standard deviation and Pearson correlation by using statistical methods.

Results and Discussion:-

In present study a total of 33 hyperglycemic serum samples were analyzed for their electrolytes imbalance from their reference range corresponding to blood sugar value. In these samples the blood sugar level selected from 130-380 mg %. All hyperglycemic serum samples were then categorized into 3 major categories indicated as level I, II and III (**Table 1**).

At blood sugar level I (130-190 mg %) the variation among electrolytes concentration were analyzed. Out of 33 hyperglycemic serum samples, 15 samples were found in this category. Out of these 8 samples were in the normal range indicated no variation from its reference range. The percent variation value varied from 7.1 – 39.94 % and 18.25 – 66.28% For Na+ and K+ respectively. When study data were analyzed for Cl- ions concentration it was found that, out of total 15 only 2 samples were found in their

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reference range whereas 13 serum samples showed variation from their reference value. The percent variation for Cl- was found between 2.74 – 71.75%. The analysis showed that at hyperglycemic level K+ ions showed maximum variation from their reference range as compare to Na+ and Cl- ions. The Na+ ions not showed significance fluctuation from their normal range (**Fig 1**).

When data analyzed for from 190-250 mg % hyperglycemic range the level of various electrolytes showed significant variation from their reference range. Out of total serum samples, 13 samples were showed electrolyte concentration variation from their normal range. The statistical analysis showed significant percent variation varies from 4 – 98% for Na + whereas 37 to 193% and6.5% - 97 % variation for K+ and Cl- respectively form their reference range. In this category Na+ concentration variation found minimum as compare to K+ and Cl- from their normal reference range (**Fig 2**).

Out of 33 serum samples 5 samples were identified for highest hyperglycemic range. The study data indicated that when electrolytes variation observed for higher range of sugar concentration (250 – 380 mg %) in blood serum, the Na+ concentration diverge from 10- 65%, K+ level speckled in the range of 14 – 80% and Cl- ions diverse 15-78 % from their normal reference range. Study showed that at very high rage of blood sugar Na+ and Cl- ions concentration variation found very high as compare to other two categories (**Fig 3**).

The overall analysis reveals that the among all electrolyte which were analyzed Na+ level showed minimum variation as compare to K+ an Cl - .Whereas K+ showed maximum deviation from their normal range, when it correlate with blood sugar as compare to others (**Fig 4**). When descriptive analysis performed it was found that Sugar concentration in blood showed 54.51, Na+ 41.87, K+ 5.27 and Cl- 52.27 standard deviation respectively from reference range of concentration among all 33 samples (**Table 2**).

Tzamaloukas *et al,* also found Severe hyperkalemia (serum potassium level >6 mmol per liter [mEq per liter]), often with electrocardiography disturbances, was noted at presentation in 30% of 73 hyperglycemic episodes (serum glucose concentration >25 mmol per liter [455 mg per dl]) observed in 15 in-hospital patients with insulin-dependent diabetes mellitus. Serum glucose concentration and total carbon dioxide content correlated significantly with the presenting serum potassium concentration. Treatment with parenteral insulin alone resulted in a decrease of the serum glucose value from 41 ± 14 (standard deviation) to 11 ± 5 mmol per liter ($P < .001$) and of serum potassium level from 5.2 ± 1.2 to 4.0 ± 0.6 mmol per liter ($P < .001$). The changes in serum glucose concentration and in carbon dioxide content and the serum potassium concentration at hyperglycemia were found to be independent correlates of the decrease in potassium concentration during treatment.

When data were subjected to Pearson Correlation analysis it was found that, There is a significant correlation of serum sodium ($r = 0.107$, $P < 0.552$), potassium ($r = -0.035$, $P < 0.848$), Chloride ($r = 0.087$, $P < 0.631$) with blood sugar. Thus, in patients with high blood glucose, sodium and chloride tend to be lower while potassium is higher. Among the three parameters, all studied serum electrolytes significantly correlate with the level of blood sugar (Table 3). Ugwuja *et al* in 2007 studied and found that the mean serum levels of some electrolytes were significantly lower in diabetics and HIV/AIDS patients than in controls, but were much lower in diabetics than in HIV/AIDS patients ($p < 0.05$). The greater disturbances in serum electrolytes in diabetics improved with glycaemic control. In addition to restoring electrolyte status, HAART use in HIV/AIDS patients significantly improved serum total protein. They draw the conclusion that diabetic patients exhibit greater electrolyte disturbances than people living with HIV/AIDS.

Similarly also found K. K. Pun and P.W.M. Ho in 1989 studied 68 patients with insulin-requiring diabetes mellitus followed up in the Home Monitoring Clinic in order to assess the relationship between electrolyte disturbances and severity of diabetes. There is a significant correlation of serum sodium ($r = -0.323$, $P < 0.01$), potassium ($r = 0.416$, $P < 0.001$), magnesium ($r = -0.292$, $P < 0.02$) with fasting glucose.

On the basis of data analysis and the sugar concentrations in serum reflect and affect the electrolytes concentration. Study showed that at very high sugar level the electrolytes concentration not showed more variation. The present study concluded that the hyponatremia and hyperkalemia are more likely to be related to short-term metabolic control as reflected by blood glucose. Diabetes mellitus is associated with disturbances in electrolyte metabolism. There are many diseases that can cause abnormal salt levels, including diseases of the kidney, pituitary gland, and hypothalamus. This is especially a concern in elderly patients, who have a harder time regulating the concentrations of various nutrients in the bloodstream. There are no actual conditions that can directly cause electrolyte imbalance. A sodium level in the blood that is too low is dangerous and can cause seizures and coma. Very high sodium levels can lead to seizures and death.. Strict monitoring of serum electrolytes in the diabetic conditions is recommended as early detection and treatment of these abnormalities will enhance the quality of life of patients.

Table 1:- Electrolytes Concentration and Blood Sugar Levels

Sample No.	Sugar	% Variation	Sodium (Na^+)	% Variation	Serum potassium (K^+)	% Variation	Serum chloride (Cl^-)	% Variation
	80-120 mg%		135-155 mmol/dl		3.5-5.5 mmol/dl		98 –106 mEq	
Electrolytes Concentration and Blood Sugar Level I (130-190 mg %)								
1	130	8.3	140.50	0.0	3.822	0.0	147.595	39.2
2	130	8.3	138.967	0.0	3.509	0.0	108.952	0.0
3	149	24.1	110.75	17.96	10.98	99.63	90.996	7.14
4	160	33.3	139.248	0.0	2.662	23.94	147.047	38.7
5	160	33.3	82.430	39.94	16.976	208.65	27.680	71.75
6	162	35	163.682	13.99	6.604	20.07	94.082	3.99
7	164	36.6	116.113	7.1	7.341	33.4	139.613	31.7
8	164	36.6	166.945	7.7	3.674	0.0	56.549	42.29
9	170	41.6	149.678	0.0	2.861	18.25	98.358	7.2
10	170	41.6	144.100	0.0	4.348	0.0	89.602	8.56
11	170	41.6	144.27	0.0	4.375	0.0	168.952	59.3
12	175	45.8	137.549	0.0	1.188	66.28	105.972	1
13	180	50	117.609	12.88	19.677	257.63	84.706	13.56
14	180	50	166.945	7.7	5.476	0.0	126.58	19.41
15	180	50	145.799	0.0	15.290	178	65.130	33.54
Electrolytes Concentration and Blood Sugar Level II (190-250 mg %)								
1	200	66.6	61.778	54.23	9.83	78.2	66.772	31.86
2	200	66.6	114.05	15.51	7.976	45	145.390	37
3	205	70.8	131.736	0	13.736	149	69.113	29.47
4	220	83.3	129.436	4.12	12.50	127	150.476	41
5	220	83.3	213.880	37.98	13.546	146	76.319	22.12
6	229	90.8	127.702	17.6	1.435	59	86.828	11.4
7	230	91.6	121.255	21.7	2.858	18.34	68.642	29.95
8	230	91.6	149.38	0	12.087	119	192	81
9	230	91.6	160.840	3.7	16.162	193	21.513	78.04
10	240	100	151.877	0	3.441	37	115.047	6.5
11	245	104	2.174	98.38	.471	86.54	3.151	96.78
12	250	108	141.455	0	9.656	75.5	232.571	119
13	250	108	199.322	28.5	12.87	119	60.441	38.32
Electrolytes Concentration and Blood Sugar Level III (250-380 mg %)								
1	275	129	120.74	10.56	10.36	88	70.56	28
2	280	133	185.729	19.8	2.609	25.45	188.29	77.6
3	280	133	54.01	65.1	7.751	40.9	121.923	77.6
4	300	150	186.051	59.9	1.575	55	184.43	15
5	380	145	173.347	11.83	6.279	14	87.912	10.29

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Fig 1:- Percent variation of Electrolytes Concentration with Blood Sugar Level I (130-190 mg %)

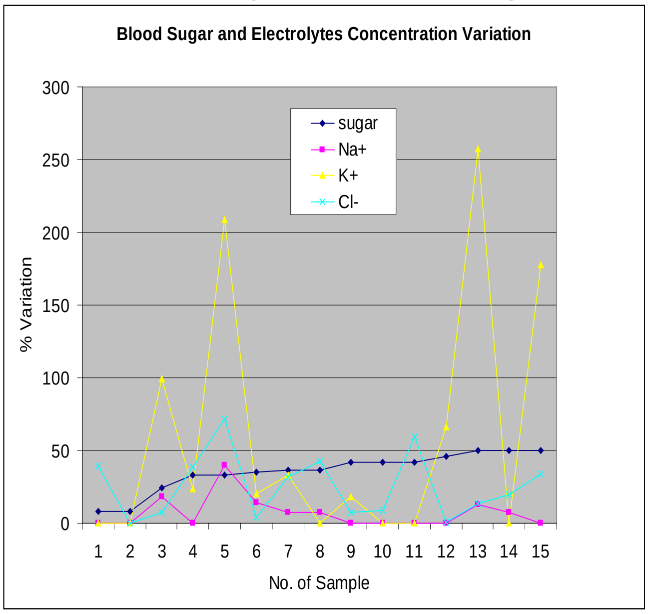

Fig 2:- Percent variation of Electrolytes Concentration with Blood Sugar Level II (190-250 mg %)

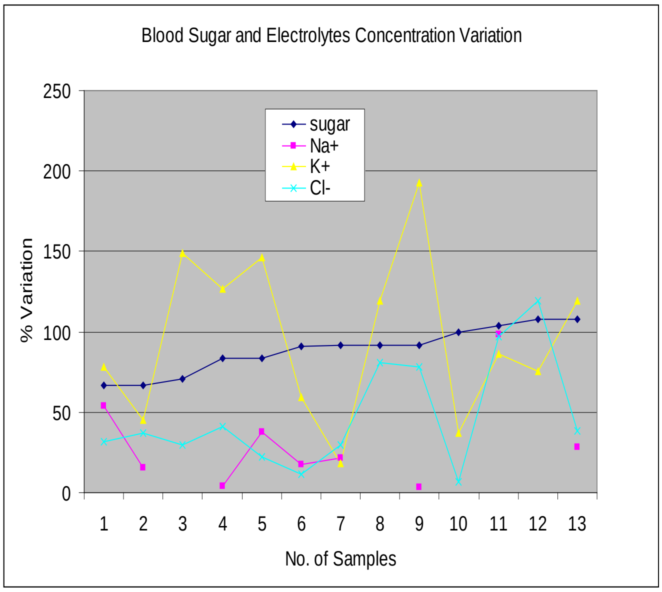

Fig3:Percent variation of Electrolyte Concentration With Blood Sugar level II(250-380 mg%)

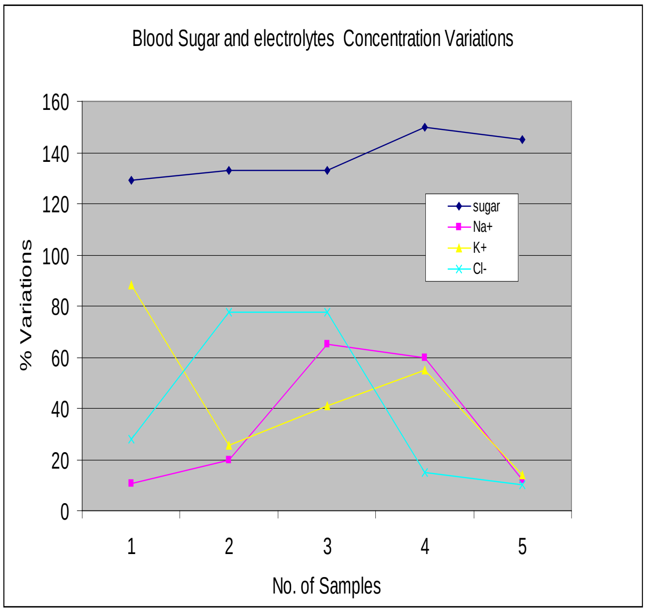

Fig 4:- Total Percent variation of Electrolytes Concentration and Blood Sugar

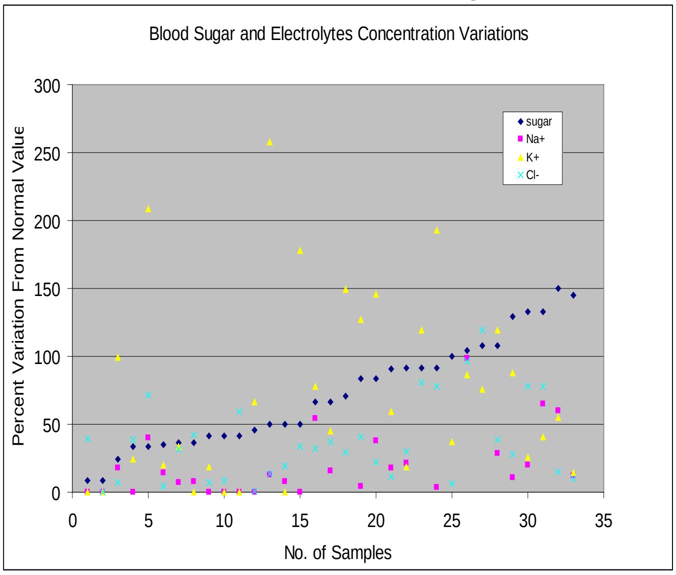

Table 2:- Descriptive Analysis of various parameter

	Mean	Std. Deviation	No. of Samples
Sugar	209.3333	54.51586	33
Sodium	136.0408	41.87413	33
Potassium	7.6947	5.27889	33
Chloride	105.8543	52.27918	33

Table 3:- Pearson Correlation Analysis of various parameter

		Sugar	Sodium	Potassium	Chloride
Sugar	Pearson Correlation	1	.107	-.035	.087
	Sig. (2-tailed)		.552	.848	.631
	Covariance	2971.979	245.334	-9.973	247.543
Sodium	Pearson Correlation	.107	1	.012	.299
	Sig. (2-tailed)	.552		.946	.091
	Covariance	245.334	1753.443	2.720	654.366
Potassium	Pearson Correlation	-.035	.012	1	-.252
	Sig. (2-tailed)	.848	.946		.157
	Covariance	-9.973	2.720	27.867	-69.575
Chloride	Pearson Correlation	.087	.299	-.252	1
	Sig. (2-tailed)	.631	.091	.157	
	Covariance	247.543	654.366	-69.575	2733.113

Conclusion

The present study concluded that the hyponatremia and hyperkalemia are more likely to be related to short-term metabolic control as reflected by blood glucose. Diabetes mellitus is associated with disturbances in electrolyte metabolism. There are many diseases that can cause abnormal salt levels, including diseases of the kidney, pituitary gland, and hypothalamus. This is especially a concern in elderly patients, who have a harder time regulating the concentrations of various nutrients in the bloodstream. There are no actual conditions that can directly cause electrolyte imbalance. A sodium level in the blood that is too low is dangerous and can cause seizures and coma. Very high sodium levels can lead to seizures and death.. Strict monitoring of serum electrolytes in the diabetic conditions is recommended as early detection and treatment of these abnormalities will enhance the quality of life of patients.

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