12-13-2013

Fluid and Sodium Intake and the Relationship to Total Body Water in Children with Sickle Cell Anemia

Katelyn Nicole Hart

FLUID AND SODIUM INTAKE AND THE RELATIONSHIP TO TOTAL BODY WATER IN CHILDREN WITH SICKLE CELL ANEMIA

by

Katelyn Nicole Hart

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

Major: Clinical Nutrition

The University of Memphis

December 2013

ABSTRACT

Hart, Katelyn Nicole. MS. The University of Memphis. December 2013. Fluid and Sodium Intake and the Relationship to Total Body Water in Children with Sickle Cell Anemia. Major Professor: Dr.Ruth Williams-Hooker.

Sickle cell anemia (HbSS) is the most common and severe form of sickle cell disease.[1,2] A complication of HbSS is vaso-occlusion pain crisis (VOC) that occurs when the sickled red blood cells become lodged in the blood vessel and causes pain.[5] The purpose of this study was to measure hydration status using bioelectrical impedance analysis (BIA), to measure fluid and sodium intake, and to see if there is an association between oral fluid intake, sodium intake, and hydration status. Ten children between the ages of 5 and 17 who had HbSS were recruited. The BIA measured their total body water (TBW) and their food records were analyzed. The average sodium intake among subjects was 3708 mg/day. This average intake is much higher than the USDA DRI for sodium intake in children. The average fluid intake was 1.29 liters/day, which was less than recommended. There was no correlation found between fluid or sodium intake and TBW content.

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CHAPTER 1

INTRODUCTION

Sickle cell disease (SCD) is one of the most common genetic blood disorders in the world. An estimated 12,500 individuals suffer from SCD in England. [1,2] It is known that over 60 children are born with SCD each year in Canada. One in 10 African Americans in the United States carry the sickle cell trait, and 1 in 400 has SCD. [3]

SCD includes a group of genetic disorders that affect hemoglobin shape and function. Hemoglobin is the molecule of the erythrocytes or red blood cells (RBCs) that is responsible for delivering oxygen throughout the body. Those with SCD have atypical hemoglobin molecules, called hemoglobin S, that alter the shape of the red blood cells into a sickle or crescent shape. (See Figure 1).

Sickle cell disease is an autosomal recessive genetic disorder. In order for the disease to occur, a person must inherit two copies of the sickle cell gene—one from each parent. Those who only receive the gene from one parent become carriers, and can therefore pass the gene along to their children.[2]

Subcategories of sickle cell disease exist based on hemoglobin (Hb) variants.[1]

The four main subclassifications of the disease include sickle cell hemoglobin C disease, sickle cell β thalassemia zero, sickle cell β + thalassemia, and sickle cell anemia (HbSS). [4] The most serious forms are sickle cell anemia (HbSS) and sickle beta zero thalassemia (β Thal 0). β Thal 0 manifests clinically in the same fashion as HbSS since the end result of β Thal 0 is a decreased amount of β-globin chain, thus leading to abnormally-low amounts hemoglobin. [3] Hemoglobin (Hb) is known as the most important protein found in RBCs because of its binding and transporting properties.

Hemoglobin binds with ambiently-supplied oxygen from the alveolar sacs in the lungs and transports it to the left side of the heart and out to the remainder of body tissues via the arterial system. Subsequently, catabolically-produced carbon dioxide from these same tissues is diffused into the venous system, where it binds to any available Hb and is transported back to the right side of the heart and out to the lungs for removal.

A normal RBC has a biconcave shape and is soft and flexible. These normal RBCs maintain shape as they pass through the capillaries and release oxygen to the tissues. Sickle cell disease causes the RBCs to have a sickle shape and become more rigid. These rigid, sickle-shaped RBCs have difficulty flowing through smaller blood vessels to the extent that they may cause an obstruction or blockage (See Figure 1). The resultant attenuated blood flow would concomitantly reduce oxygen delivery to the corresponding tissues, and may precipitate a *pain crisis* characterized by localized intense pain in the legs, back, joints, or chest, ischemia, and tissue damage.[1-3] These adverse conditions appear to be more likely when those with the disease are exposed to extreme temperatures and/or if they become dehydrated.[5] To compound the situation, sickle RBC cells have shortened lifespans, often resulting in reduced overall RBC count to the extent that SCD patients become anemic. It is unclear if excessive hemoconcentration associated with dehydration further contributes to the premature demise of the RBC.

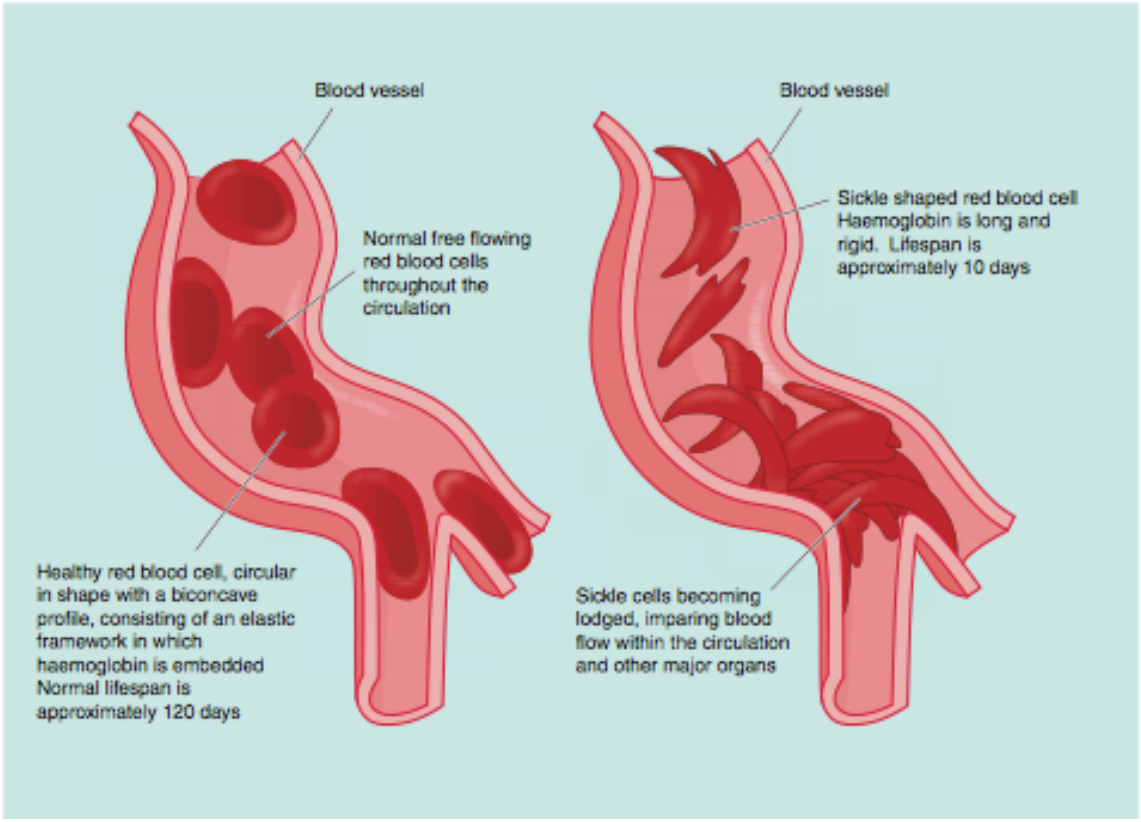

Figure 1. Diagram reflecting a normal red blood cell and a sickle shaped red blood cell.[11]

A pilot study conducted at University of Memphis and St. Jude Children's Research Hospital examined the feasibility of monitoring hydration status with bioelectrical impedance.[6] In addition, sodium and fluid intake were measured. The current proposal is a follow-up to that study for the following purposes: 1) to measure hydration status using bioelectrical impedance analysis, 2) to measure fluid and sodium intake, and 3) to see if there is an association between oral fluid intake, sodium intake, and hydration status.

LITERATURE REVIEW

Sickle Cell Anemia

Sickle cell anemia (HbSS) is the most common and severe form of sickle cell disease. It affects 1 in 600 African Americans in the United States. [7] Sickle cell anemia is characterized by the predominance of hemoglobin S rather than the typical hemoglobin A in the erythrocytes or red blood cells (RBC). [8]

The symptoms experienced by those with HbSS vary by each patient. Some report mild symptoms while others are frequently hospitalized for the treatment of more serious complications the disease might cause. Many complications can arise from HbSS; two more common and severe complications are chronic hemolytic anemia and vaso-occlusion. [8]

Hemolytic Anemia. The anemia that occurs with HbSS is due to RBC destruction. Normal RBCs live about 120 days, while sickled RBCs live for only 10-20 days. Unfortunately, the bone marrow cannot produce new RBCs fast enough to replace the sickled RBCs. [9] A low RBC count results in severe anemia. The manifestations of chronic hemolytic anemia include shortness of breath, jaundice, aplastic crisis (abnormal increase of immature RBC or reticulocytes in the body), fatigue, delayed growth, and pigment gallstones. [4]

Vaso-Occlusion. Vaso-occlusion develops in the body when sickled red blood cells are inflexible and become lodged in the blood vessel (See Figure 2). This results in the obstruction of blood and damage to the surrounding tissues and organs. The vaso-occlusion can occur anywhere the blood flows. The manifestations of vaso-occlusion include recurrent acute pain or vaso-occlusive pain crisis (VOC), abnormal spleen

function, acute chest syndrome, stroke, hyposthenuria and enuresis, chronic nephropathy, priapism, avascular necrosis, proliferative retinopathy, renal insufficiency, leg ulcers, and spontaneous abortion. Acute chest syndrome involves a variety of symptoms including fever, cough, or dyspnea. Ischemic strokes occur due to vaso-occlusion in one or more cranial vessels. Hyposthenuria is the concentration of the urine, while enuresis is the inability to control urine. Chronic nephropathy is damage to the kidneys, and priapism is a painful penis erection. Avascular necrosis occurs when the bone tissue dies due to too little blood supply. With proliferative retinopathy, blood vessels begin to grow in the retina of the eyes. The reasons for leg ulcers are unknown, however they are a complication commonly seen in HbSS patients.

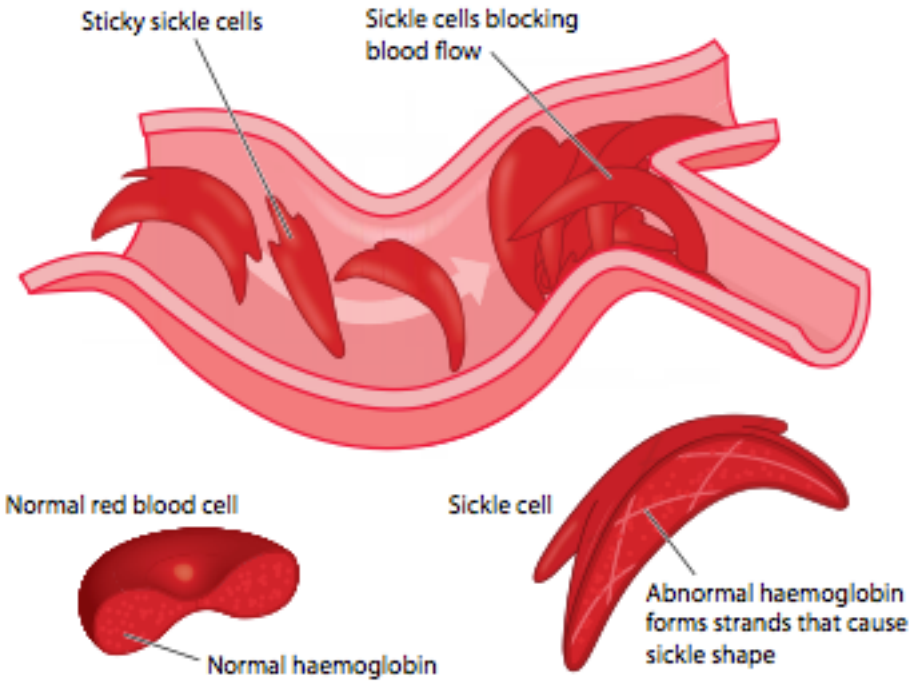

Figure 2. Vaso- occlusion.[1]

Vaso-Occlusive Pain Crisis (VOC)

Vaso-occlusive pain crisis is the primary complaint of patients with sickle cell anemia, accounting for more than 90 percent of all HbSS-related hospital admissions. [10] While the pain associated with VOC is not fatal, it can cause unnecessary suffering and decrease quality of life for the patient, as well as relate to some life-threatening issues such as infections, lung problems, and stroke that singularly or collectively could be fatal.[5]

The frequency and duration of VOC varies from patient to patient, as does the degree of pain. Yale et al. reported that 5.2 percent of patients have a pain crisis 3-10 different times throughout the year, while 34 percent experience one or fewer pain crises a year. [11] Patients with HbSS and relatively high hemoglobin levels are more likely to experience more frequent pain crises than those with lower hemoglobin levels.[6] Crisis duration can persist anywhere from five minutes to several months. The pain patterns most commonly affect the back, knees, legs, arms, chest, and abdomen, and can involve two or more sites.

The crisis can be spontaneous or the result of physiological changes that occur during dehydration, stress, exposure to extreme temperature (such as temperature changes with seasons, jumping in a cold swimming pool, going outside on a hot or cold day), hypoxia, or engaging in strenuous exercise. [1] Several types of pain-crisis episodes have been identified: pain from an area of occlusion with no hematological changes, pain associated with bone marrow hypoplasia, high fever resulting in depressed RBC counts, sudden and massive RBC blockage in the visceral organs especially the spleen, or manifestations of one or more crises at a time. [12]

The management of vaso-occlusive pain is largely supportive, including providing fluid and analgesics and encouraging patients to rest. [8] In order to prevent further crises in

patients with SCD, clinicians recommend that patients consume adequate amounts of fluid to prevent dehydration, avoid exposure to extreme cold, avoid exercising to exhaustion, and avoid alcohol use since it dehydrates the body. [11] These recommendations appear to be based on speculation rather than data.

Factors Affecting VOCs. The triggers for pain crisis appear to include various types of stress: traumatic, physical, psychological, and physiologic. Vichinsky et al. reported that dehydration, extreme weather changes, and low body temperature appeared to be the most common factors leading to a pain crisis. [13] However, research concerning children and these phenomena is limited at this time.

Weather and VOC. During the colder weather, peripheral blood vessels vaso-constrict to conserve body heat. This narrowing of the blood vessels can further impede the movement of sickle shaped RBCs and as a consequence, occlusion may occur. [14] Other weather changes may also lead to VOC, although the reasons for this are not well understood. One possible theory for the influence of the weather on VOC is the equilibrium (acclimatization) that the body must establish with changing climatic conditions.[12] Changes in climate upset the equilibrium and increase the incidence of pain.[6]

Smith et al. reported that from over 400 visits by HbSS patients to the emergency room for complaints of pain, it was found that 5.2 percent of them had pain consistent with VOC, [1] and that the number of pain crises increased with colder temperatures. This relationship between cold weather and pain crisis outbreak was shown to increase in temperatures below 32 °F, but it was not statistically significant when temperatures were >80 °F, indicating that pain crises were not associated with higher temperatures.

However, the average monthly pain score was also higher in humid months. It was reported that there is a significant correlation of VOC with weather conditions, with colder temperature being at the forefront of causes of onset of VOC. [8,15]

Another study has found that 68 percent of chronic pain patients believe that their pain increases with changes in the weather. Cold and damp conditions were ranked the highest influence on pain crises. [16]

Nutritional Factors Affecting VOC. Nutritional factors also appear to affect VOC. Unlike the weather, these nutritional factors can be manipulated, and they can be used to improve a patient's quality of life. Two important nutritional factors related to VOC are hydration and sodium.

Hydration and VOC. For the maintenance of the body's homeostasis, hydration is vital. For an adequately hydrated adult, overall total body water accounts for 55-65 percent of overall body weight. [6] Adequate hydration is needed to maintain optimal physical and mental functioning of an individual and for the sickle cell patient, hydration status may be even more important as a method of pain management. [17]

Dehydration may occur in sickle cell patients for many reasons, including, but not limited to, diarrhea, severe vomiting, excessive sweating, diuresis and/or inadequate fluid intake. [6]

When fluids are reduced, this leads to an increase in plasma viscosity, and a concomitantly more sluggish movement of blood cells. This creates an opportunity for sickle shaped RBCs to stick together, causing an occlusion. [14] When a patient is admitted for VOC, IV fluids to maintain hydration status are provided. Families of sickle cell

patients are counseled to maintain a patient's hydration status as prevention for pain crisis. [18]

Sodium and VOC. Sodium has been linked to pain crises experienced by HbSS patients for a number of years. Some small studies have suggested that proper hydration can aid in the prevention and treatment of sickle cell pain crisis. Further research conducted involving larger groups of patients could help determine if proper hydration may prove to be a simple treatment option, or an adjuvant of other anti-sickling therapies.

Rosa et al. induced a low-sodium or hyponatremia state in three HbSS patients who suffered from severe, frequent pain crises.[19] Hyponatremia was categorized as a serum sodium level of 120 to 125 mmol per liter. These patients were advised to drink 3 to 4 liters of fluid per day and to begin a low sodium diet. After this intervention, VOC occurrence was reduced in each of the three patients during the period of hyponatremia.

Rosa et al. speculated that the decrease in serum sodium levels increased the time required for polymerization of the RBCs. [19]The delay was thought to occur because the HbSS patients' RBCs were able to pass through the capillaries before the process of sickling occurred, therefore reducing the occlusion in the small blood vessels and lowering the frequency and duration of VOCs. Rosa et al. also noted that during a hyponatremia state, the affinity of HbSS for oxygen was increased, and that hydration of sickle cells appears to reduce the inflexibility of irreversibly sickled forms.

Hydration and Sodium Intake Among HbSS Patients. Little information currently exists from controlled studies concerning hydration status and the role both dietary water and sodium in the incidence of VOC in children with sickle cell anemia. Nutrition interventions to limit sodium and enhance hydration while including proper energy and

protein may be created in order to minimize the risk of pain crisis. Appropriate education could benefit this population to potentially reduce the frequency and severity of VOC.

Currently, these nutritional concerns may not be well addressed in HbSS patients. According to research previously conducted at the University of Memphis with St. Jude Children's Research Hospital on patients' nutritional intake, twenty-one patients were found to consume only 88% of fluid requirements, while their sodium intake exceeded recommendations at 150% of upper limit (UL) [5] This study concluded the dietary water intake of pediatric patients with HbSS was suboptimal, and the dietary sodium intake exceeded recommendations. The purpose of the proposed study is to further assess hydration and sodium levels in HbSS patients at St. Jude.

CHAPTER 2

METHODS

Subjects

Ten children between the ages of 5 and 17 who had sickle cell anemia (HbSS or Hb Sβ0-thalassemia) and were being treated and/or followed by St. Jude Children's Research Hospital were recruited from St. Jude Children's Research Hospital Sickle Cell clinics. The subject's physician or dietitian reviewed the study with the subject and legal guardian to determine whether they were interested in participating. Subjects and/or legal guardians who were interested in participating in the study contacted the study investigator at The University of Memphis to set up an appointment. The patient/caregiver came to the University of Memphis for the analysis.

Informed consent/assent was obtained. All research was conducted at The University of Memphis Human Performance Labs. The Institutional Review Board (IRB) approval was obtained at the University of Memphis. St. Jude Children's Research Hospital was exempt from IRB review.

Inclusion Criteria

- Must be a patient of St. Jude Children's Research Hospital between 5-17 years of age
- Must have the ability to lie still for up to five minutes
- Must have the ability to fast, no food or water, for 12 hours prior to the completion of bioelectrical impedance analysis (BIA)

- Must agree to record details of food and fluid intake over a 72-hour period. The dietitian at St Jude will educate the patient/caregiver on how to properly maintain the food record.

Exclusion Criteria

Subjects were excluded from the study if they did not meet the inclusion criteria, or at any point upon request.

Total Body Water Analysis

Bioelectrical impedance analysis (BIA) was performed on all subjects to assess total body water. Subjects reported in the morning because they had been fasting for the previous 12 hours. While bare-footed, supine, and jewelry free, subjects abducted and held both arms at 30 degrees from the body during data collection. The right hand and foot were cleaned with alcohol before electrodes were positioned. The electrodes were placed at the top of the ankle between two connections of bones, above the toes, and on top of the hand below the fingers and between the bones of the wrist. Subjects were asked to lie still while the analyzer was turned on and the test was conducted, which took about 60 seconds. After completion, the electrodes were removed and disposed. Data were entered into RJL Systems Body Composition Program, Version 2.1.

Nutrient Analysis

The study investigator assessed sodium and fluid intake from a 72-hour food and fluid record. The quantity and time of day the food was consumed, and the name brand of the food if convenience or processed, were obtained. Fluid and sodium amounts were analyzed using the Nutrition Data System for Research (NDSR) 2013 and compared to the United States Department of Agriculture (USDA) Dietary Reference Intake (DRI) for

children ages 5 to 17. Not included in the analysis was sodium added to the food by the subject before consumption.

Compensation

After completion of the BIA, subjects received a snack and $50. The caregiver or legal guardian received a $5 gas card and a free parking decal.

Data Analyses

Statistical analyses were performed using SPSS version 20 for Windows (SPSS Inc., Chicago, IL, USA, 2011). Means, frequencies, and percentages were calculated for all of the variables. Variables included gender, age, total body water, sodium intake, fluid intake. Recommended values of sodium intake (1500 mg), fluid requirements per the Holliday Segar equation, and total body water averages were used for comparisons. A bivariate Pearson Correlation was conducted to see if there was a relationship among average total body water, sodium intake, and fluid intake. A one-group t-test was conducted to compare the participants' average sodium intake with the recommended intake of 1500mg. A dependent t-test was conducted to compare the participants' average fluid intake with the recommended average fluid intake requirements. Lastly, to evaluate the differences in total body water and the recommended value, males and females were selected separately based on difference recommended values. Thus, one-group t-tests were conducted for both males and females to evaluate whether there was a difference in the participants' total body water intake and their recommended values (38.1 and 30.0, respectively). A p-value of less than 0.05 was considered statistically significant for all inferential statistics test.

CHAPTER 3

RESULTS

Patient Demographics

There were 10 subjects that completed the study ranging from 8 to 18 years old with a mean age of 12.9. There were 4 boys and 6 girls all diagnosed with sickle cell anemia (HbSS). None of the subjects had any recent pain crises or painful events that required use of pain medication or hospitalizations within 2 weeks before the BIA study.

Sodium Intake

The average sodium intake among subjects, based on three-day food records, was 3708 mg/day, which did not include salt added to foods during the cooking process or before intake (See Table 1). This average intake is much higher than the USDA Dietary Reference Intake (DRI) of 1500 mg for sodium intake in children. The minimum daily intake of sodium collected was 1294 mg with a maximum daily intake reported of 9210 mg.

The mean sodium intake among males was 3966 mg/day. The mean intake among the females was 3544 mg/day. Both group's sodium intake was significantly higher than the DRI for their age group. Based on the data collected, there is a significant difference found between average sodium intake and the DRI for sodium ($t = 5.226$, $p = 0.001$) (See Table 2). Subjects were consuming a much higher amount of sodium ($M = 3708$; $SD = 1336$) than is recommended for their age.

Table 1. Average intake of sodium compared to the Dietary Reference Intake of sodium.

Subject	Gender	Age	Average Sodium Intake (mg)	Sodium DRI (mg)	Percentage of Sodium DRI (%)
01	M	13	2966	1500	197
02	M	12	5103	1500	340
03	F	12	2973	1500	198
04	F	18	3165	1500	211
05	F	16	2705	1500	180
06	F	9	4352	1500	290
07	M	15	5885	1500	392
08	F	10	5256	1500	350
09	M	8	1866	1500	124
10	F	16	2814	1500	188

Table 2. T-test comparing average sodium intake to Dietary Reference Intake of 1500mg for sodium.

	Test Value = 1500					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Average Sodium	5.226	9	.001	2208.96667	1252.7413	3165.1920

Fluid Intake

Fluid intake was also collected from subjects through the 3-day food records and the average fluid intake was 1.29 liters/day, which was on average 39% less than recommended. The fluid needs of each subject were calculated using the Holliday Segar equation, (See Table 3) and the fluid needs compared to the average intake of each subject was then compared (See Table 4).

Using a paired samples test, it can be concluded there was a significant difference between average fluid intake and the fluid needs of subjects ($t = -4.38$, $p = .002$) (See

Table 5). The participants had significantly less fluid intake (M = 1.29 liters; SD = 0.4571) than the recommended intake of fluid.

Table 3. The Holliday-Segar Method used to calculate fluid needs.

	Holliday-Segar Method
First 10 kg	100 mL/kg/day
Second 10 kg	50 mL/kg/day
Every kg thereafter	20 mL/kg/day

Table 4. Average fluid intake compared to the fluid needs of subjects.

Subject	Gender	Age	Average Fluid Intake (L)	Fluid Needed (L)	Percentage of Fluid Needed (%)
01	M	13	1.29	1.75	74
02	M	12	1.90	2.22	86
03	F	12	1.42	2.15	66
04	F	18	1.39	3.00	46
05	F	16	0.81	2.22	36
06	F	9	0.86	1.70	51
07	M	15	1.99	2.59	77
08	F	10	1.65	1.66	99
09	M	8	0.72	1.60	45
10	F	16	0.93	3.05	30

Table 5. Paired Samples Test comparing average fluid intake to the fluid needs of subjects.

Paired Differences							
		Std. Error	95% Confidence Interval of the Difference				
Mean	Std. Deviation	Mean	Lower	Upper	T	DF	Sig. (2-tailed)
-.9072	.6548	.2071	-1.3756	-.4388	-4.381	9	.002

Total Body Water

The total body water (TBW) requirements differ based on gender. Males normal TBW is 30 liters, while females normal TBW is 38.1 liters. [20] The average TBW measured from the BIA was 26.4 liters with a minimum of 15.7 liters and a maximum of 40 liters. The average TBW among male subjects was 25.2 liters. The mean TBW of female subjects was 27.2 liters. Both averages among the male and female subjects fell below the recommended TBW content (See Table 6). However, there was not a significant difference between the males average TBW content (M = 25.2; SD = 10.8) and the recommended value of 38.1 liters (t = -2.38; p = .097) (See Table 7). Nor was there was not a significant difference between the females average TBW content (M = 27.2; SD = 7.98) and the recommended value of 30 liters (t = -0.86; p = .429) (See Table 8).

Table 6. Total Body Water (TBW) measured from Bioelectrical Impedance Analysis compared to normal TBW levels among pediatric males and females.

Subject	Gender	Age	TBW (L)	Normal TBW (L)	Percentage of Normal TBW (%)
01	M	13	18.8	38.1	49
02	M	12	26.3	38.1	69
03	F	12	23.3	30.0	78
04	F	18	35.8	30.0	119
05	F	16	29.0	30.0	97
06	F	9	18.6	30.0	62
07	M	15	40.0	38.1	105
08	F	10	19.6	30.0	65
09	M	8	15.7	38.1	41
10	F	16	36.9	30.0	123

Table 7. T-test of males versus recommended test value of 38.1 liters.

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
TBWL	-2.384	3	.097	-12.90000	-30.1230	4.3230

Table 8. T-test of females versus recommended test value of 30 liters.

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
TBWL	-.860	5	.429	-2.80000	-11.1721	5.5721

Results indicated a significant positive correlation between average sodium and average fluid intake (r = .804). However there was no correlation found between average fluid intake and TBWL or average sodium intake and TBWL. This indicates that there is no correlation between fluid or sodium intake and TBW content (See Table 9).

Table 9. Correlation table comparing average fluid and sodium to Total Body Water (TBW).

		Average Fluid (L)	Average Sodium (mg)	TBWL
Average Fluid (L)	Pearson Correlation	1	.804**	.307
	Sig. (2-tailed)		.005	.388
	N	10	10	10
Average Sodium (mg)	Pearson Correlation	.804**	1	.234
	Sig. (2-tailed)	.005		.516
	N	10	10	10
TBWL	Pearson Correlation	.307	.234	1
	Sig. (2-tailed)	.388	.516	
	N	10	10	10

CHAPTER 4

DISCUSSION

The main complication noted from HbSS is VOC pain crises. There is research supporting adequate fluid status may help in the prevention of increases in blood viscosity, which leads to the obstruction of blood flow leading to VOC pain crises.[6] When total body fluids are reduced, this leads to an increase in plasma viscosity, and a much slower movement of blood cells. This creates an opportunity for sickle shaped RBCs to stick together, causing an occlusion. [14] VOC pain crises are the number one complaint of those with HbSS, and causes suffering among those patients. It also accounts for 90% of all HbSS hospital admissions. [10] When sent home from hospitalization, parents or guardians are sent with the advice of ensuring patient acquires adequate amounts of fluid to prevent future pain crises. This study sought to compare fluid intake and sodium intake with TBW of subjects diagnosed with HbSS in order to seek background of how hydration status could be linked to VOC.

In the current study no correlation was found between TBW and sodium or fluid intake. This supports the findings of Shurley et al and suggests a larger sample size is necessary. [6] It is widely understood that poor hydration status increases the viscosity of the blood and therefore impacts the hemoconcentation of the blood. This results in a higher risk of VOC pain crisis in HbSS patients. From the findings, HbSS patients had a substantially lower fluid intake than recommended, and much lower than their overall needs as calculated by the Holliday-Segar equation. Since hydration status is linked to dietary intake of both fluids and sodium, the dietary intervention to limit sodium and increase patient intake of fluids is necessary.

Not only do HbSS patients have a lower intake of fluids than is necessary, they also have a higher intake of sodium than is necessary. The DRI for daily sodium for all subjects involved in this study is 1500 mg, while the average daily intake of sodium was 3708 mg. This also did not include added sodium or salt added in cooking or before consumption. This patient demographic is primarily eating quick meals such as fast food, which has a high sodium concentration, and processed foods. The processed foods that were eaten primarily included deli meats, hot dogs, bologna, and other ready-to-eat meals patients can easily prepare. According to a study conducted by Sebastian et al, the sources of sodium in the US diet are as follows: sodium added during processing accounts for 77%, sodium already in foods accounts for 12%, salt added at the table accounts for 6%, and salt added in cooking accounts for 5%.[21] This study reveals that the main source of sodium in the US diet is found in processed foods. The study conducted did not take into account sodium added at the table before consumption, however, this shows to be a very miniscule source of sodium in the US diet. This further reveals the necessity of limiting processed foods in the diets of those with HbSS since those patients require an adequate hydration status to avoid pain crises.

From the information collected from this study, sodium intake and fluid intake does not affect TBW of subjects. However, more research needs to be done to investigate this further.

Limitations

The limitations of this study include a small sample size of just 10 subjects involved. This limited sample size may not have provided enough data to evaluate pain crises, use of pain medication or hospitalizations, fluid intake, or sodium intake. Another limitation

involved human error of children and/or guardians not adequately recording intake over a three-day period. There could be some meals, fluid intake, or snacks missed due to the lack of recording by subjects. This study also did not account for sodium added when cooking or before consumption based on the inability to do so using just a recall.

In the future, studies may benefit from a larger sample size, and possibly using a control group as well as the study group to monitor fluid and sodium intake over a three-day period.

Conclusion

Patient demographics appeared to contribute to the findings of the current investigation as subjects consumed much higher quantities of sodium than recommended by the USDA (DRI of 1500 mg per day). Subjects consumed most sodium from processed foods such as deli meats, chips, snack foods, and sodas. While this study did not account for salt added before consumption, studies show that this intake is typically miniscule compared to the overall large consumption of sodium. [21]

Based on the literature, it was thought that the subjects would have a low TBW and a lower intake than recommended of fluid. While their fluid intake was lower than recommended, there was no correlation found between fluid intake and TBW. Overall, this study revealed that sodium and fluid intake both did not affect TBW. This indicates that our HbSS population consumed less than the recommended amount of fluid, and a much higher amount of sodium than recommended. Both of these factors are known to affect hydration status.

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APPENDIX A

Body Composition
2.1
User's Guide

33939 Harper Avenue
Clinton Township, Michigan 48035 USA
Toll-Free: 800-528-4513
Phone: 586-790-0200
Fax: 586-790-0205
Web: http://www.rjlsystems.com/
Manual Revision Date:
September 11, 2009

Indications for Use:
Calculation and Historical Tracking of:
• Actual Impedance
• Actual Phase Angle (PA)
• Estimated Body Fat (FAT)
• Estimated Fat Free Mass (FFM)
• Estimated Total Body Water (TBW)
• Estimated Intra-Cellular Water (ICW)
• Estimated Extra-Cellular Water (ECW)
• Estimated Basal Metabolic Rate (BMR)
• Estimated Daily Energy Expenditure (DEE)
• Actual Body Mass Index (BMI)

Intended Population:
BC is intended only for use on normally healthy adults and adolescents age 3-94. The prediction equations used by the BC software assume that the person being tested has not had either arm or leg amputated.
It is not intended to be used to diagnose, treat, or cure any disease or medical condition.

Contraindications:
No known contraindications exist.

Warnings:
The BC software provides body composition estimates based on the electrical characteristics measured by a
Bioelectrical Impedance Analyzer (BIA). BIAs work by introducing an alternating current (AC) signal into the
body and then measuring how that signal is affected by the body. This device should not be used on subjects with any implantable electronic devices such as pacemakers or implantable cardioverter-defibrillators (ICD)'s.

Pediatric
Most studies that develop body composition equations strictly study adult (and/or teenage) populations.
The equation for estimating FFM (and fat) in this equation set was developed from a population of children
aged 9-14.

What do the Results Mean?
• FAT
Fat is the energy storage of the body. Everybody needs fat in their bodies, but it is important not to have
too much.

• Fat Free Mass (FFM)
This value is, literally, what would be left after all fat was removed from the body. Many people also refer
to FFM as Lean Body Mass (LBM).

• Lean Dry Mass (LDM)
Lean Dry Mass is the non-water portion of Fat-Free Mass, or Lean Mass. It can also be accurately called
"Fat-Free Solids", "Lean Dry Weight", or "Dry Lean". By definition, to calculate LDM, simply subtract
TBW from FFM. I.e.: LDM = FFM – TBW.

Example 1:
To envision what LDM is, picture a T-Bone steak. While the majority of it is meat, (i.e.: muscle) it also
contains fat, the bone, and connective tissues which attach the muscle to the bone. Next, trim the fat from
the imaginary steak. For the sake of argument, let us say that we are able to remove exactly 100% of the
fat. What will be left (the meat, bone, and connective tissues) is the FFM of the steak.
Now, freeze-dry the steak. Depending on the temperature of the freeze-drier, the rate at which the steak is
cooled, and how long it is allowed to freeze-dry, it is possible to extract 100% of the water in the steak. By
doing this, not only is all of the extra-cellular water removed, but all of the intra-cellular water is removed,
as well. This process destroys the cells.
Once the steak has been completely dried, allow it to return to room temperature. It will now be considerably
smaller than it was initially, and completely solid. This is Lean Dry mass.

Example 2:

For another, more human example of what Lean Dry Mass is, look at a mummy from ancient Egypt. During
the embalming and preservation process, the Egyptian priests covered the Pharoah's body in chemicals
which, over time, dissolved all of the fat and extracted all of the water. This was done to prevent the body
from rotting and to prevent insects from consuming it. Because the mummified body contains no fat or water,
the mummy is 100% Lean Dry Mass.

• Total Body Water (TBW)
Literally, the total amount of water in the body. Since fat is essentially 0% water, TBW is entirely contained
within FFM.

• Intra-Cellular Water (ICW)
This is the portion of Total Body Water that is located within the body's cells.

• Extra-Cellular Water (ECW)
This is the portion of Total Body Water that is located outside of the body's cells. Examples of where ECW
is found include, but are not limited to: blood plasma, spinal fluid, joint fluids, and edema.

APPENDIX B

University of Memphis Institutional Review Board Approval

Hello,

The University of Memphis Institutional Review Board, FWA00006815, has reviewed and approved your submission in accordance with all applicable statuses and regulations as well as ethical principles.

PI NAME: Margaret Williams
CO-PI: Karen Smith, and Katelyn Hart
PROJECT TITLE: Fluid Status and Pain Crisis in Children with Sickle Cell Anemia
FACULTY ADVISOR NAME (if applicable): N/A
IRB ID: #2455
APPROVAL DATE: 4/3/2013
EXPIRATION DATE: 4/2/2014
LEVEL OF REVIEW: Full Board

Please Note: Modifications do not extend the expiration of the original approval

Approval of this project is given with the following obligations:

1. If this IRB approval has an expiration date, an approved renewal must be in effect to continue the project prior to that date. If approval is not obtained, the human consent form(s) and recruiting material(s) are no longer valid and any research activities involving human subjects must stop.

2. When the project is finished or terminated, a completion form must be completed and sent to the board.

3. No change may be made in the approved protocol without prior board approval, whether the approved protocol was reviewed at the Exempt, Exedited or Full Board level.

4. Exempt approval are considered to have no expiration date and no further review is necessary unless the protocol needs modification.

Thank you,

Ronnie Priest, PhD

Institutional Review Board Chair

The University of Memphis.