Climate change causes changes in biochemical markers of renal disease

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Abstract

Background: Climate change is a significant threat to the health of the Ghanaian people. Evidence abounds in Ghana that temperatures in all the ecological zones are rising, whereas rainfall levels have been generally reducing and patterns are increasingly becoming erratic. The study estimated the impact of climate change on biochemical markers of renal disease.

Methods: This study recruited 50 conveniently sampled apparently health peasant farmers and hawkers at the market place at Wa in the Upper West Region of Ghana. A pre-study screening for hepatitis A and C, diabetes, hypertension, was done. Serum creatinine and urea levels were analyzed to rule out kidney defects. Baseline data was collected by means of analysing blood samples for renal function (i.e. urea, creatinine, sodium, potassium, eGFR) as well as for hemoglobin (Hb) and hematocrit (Hct) concentrations. Anthropometric data such as height, weight and blood pressure were measured. The study participants were closely followed and alerted deep in the dry season for the second data collection as the baseline.

Results: This study recruited more males (58.82%) than females (41.15%) , majority (52.92%) of which were aged 25-29 years with the youngest being 22 years and the elders being 35 years. The study found body mass index (p<0.001), systolic blood pressure (p=0.019), creatinine (p<0.001), urea (p=0.013) and eGFR (p<0.001) to be significantly influenced by climate change. Stage 1 hypertension was predominant among the study participants during the dry season, 8 (15.69%) than was observed during the rainy season, 4 (7.84%) nonetheless the number of participants with normal BMI rose from 49.02% in the rainy season to 62.75% during the dry reason. Additionally, the study observed that the impact of climate change on systolic blood pressure and urea varied based on age and sex.

Conclusion: This study revealed that climatic changes cause variations in various biochemical parameters which could lead to renal disease. Public health education on climatic changes and its implication including precautionary measures should be done among inhabitants of Wa and its environs to reduce its effect. Additionally, appropriate dietary patterns should also be advised to avoid the development of non-communicable diseases such as hypertension and obesity that are known principal causes of CKD.

Introduction

Considering the persistent peril of global warming, physicians in recent times have given much attention to the influence of climate change on human health and health care in general (Fakheri & Goldfarb, 2011). The impacts of human-induced climate alteration are on the upsurge nationwide if not worldwide, threatening human health and the very existence of man by affecting our food and water sources, the air we breathe, the weather we experience, and our interactions with the natural environment (John et al., 2016; USAID, 2017). Studies suggests that whereas a preponderance of these effects are already being experienced, in the absence of climate change restraint or control, their progression will to a very large
extent amplify the existing global health challenges and inequalities so much so that it threatens to undermine principally the social, economic and environmental drivers of health; factors which have contributed largely to human growth and progress (Watts et al., 2018). Signals in Ghana indicates that temperatures in all the ecological zones are intensifying whilst patterns and levels of rainfall generally are plummeting and increasingly becoming erratic (Minia, 2004). A study conducted in Adelaide, a city with temperate climate to investigate the association between temperature and admissions for specific renal diseases thus urolithiasis, UTIs and CKD saw that increases in daily temperature per 1 °C were associated with an increased incidence for all renal disease categories considered for the study except for pyelonephritis (Borg et al., 2017). Similar studies documented an increased admissions for renal disease and acute renal failure during the periods of heat waves compared with non-heat wave periods (Hansen et al., 2008). Meanwhile according to UNDP the average annual temperature has over the last 30 years increased 1 °C (UNEP/UNDP, 2012) elevating the risk of renal pathologies among the Ghanaian people. Worsening the situation however is a predicted average temperature rise of about 0.6 °C, 2.0 °C and 3.9 °C by the year 2020, 2050 and 2080 respectively, in all forest ecological zones coupled with a predicted nose dive of average rainfall of 2.8%, 10.9% and 18.6% by 2020, 2050 and 2080 respectively in all forest ecological zones (Minia, 2004). Richard and colleagues in their work indicated that heat stress duets the risk for developing CKD among those working in hot environments and that despite the fact that involvement of toxins and infections were not entirely ruled out, common risk factors for each of the CKD epidemics observed in India, Sri Lanka, Mexico, and Central America were hot temperatures and recurrent dehydration that can be linked with climate change (Johnson et al., 2016). Little data exist on the effect of climate change on kidney function in Ghana hence the necessity for this study.

**Materials And Methods**

**Study site**

This study was conducted at Wa in the Upper West Region of Ghana. The Upper West Region is located in the north-western part of Ghana and shares borders with the La cote D'Ivoire to the north-west, Burkina Faso to the north, Upper East to the East and Northern Region to the South. Wa Municipality has a projected population of 126,609 people as at September, 2018 according to the Ghana Statistical Service (GSS). The climate of the Wa Municipality is characterized by long, windy and hot dry season followed by the short and stormy wet season. The dry season occurs between November and April. The hot seasons records high temperatures with a peak between 40°C to 45°C in March and April.

**Study Design and Eligibility Criteria**

The study recruited 51 conveniently sampled peasant farmers and hawkers at the market place who were considered “active members of society” based on their occupational activities. A pre-study screening for hepatitis A and C, diabetes, hypertension, was done. Serum creatinine and urea levels were analyzed to rule out kidney defects. Apparently healthy individuals within the ages of 18 to 40 years were recruited for this study. Hypertensive, diabetic, HIV and kidney diseased individuals were however exempted from the
study. The study was a longitudinal cohort study where same participants who passed the eligibility criteria served as the control during the wet (rainy) season and the case during the dry season. Baseline data including participant’s blood as well as age, gender, weight, height and blood pressure were taken and analyzed during the wet season as part of the baseline measurements. The study participants were then followed keenly into the dry season and then alerted at the peak of the season for the second data collection taken into account the variable anthropological parameters.

Data Collection

Participant’s socio-demographic variables including age and sex, anthropometric data including weight and height as well as blood and urine sample were collected for the study.

Demographic and Anthropometric Measurements

Demographic data comprising participant’s age and sex were obtained. Anthropometric data which includes height, weight and hemodynamic data thus blood pressure was determined using specific instrument relating to each parameter. A fully automated blood pressure monitor (Omron Automated Blood Pressure Monitor, HEM-71217, Japan) was used to measure Blood Pressure (BP) after the participants had sat quietly for at least ten minutes. The BP measurement was taken on the left arm in a seated position, with the arm supported at heart level. Multipurpose weight and height scale was used to measure body weight of the participants to the nearest 0.1 kg and height to the nearest 0.1 cm, with participants standing erect, back straight, heels together, barefooted, and in tight clothing.

Blood and urine Collection and Processing

Eight (8) ml of venous blood sample was collected from the participant’s median cubital vein after overnight fasting (12–16 hours) between 7 am to 10 am. Four (4) ml. was dispensed into a serum separator tube and 4 ml into EDTA. The blood collected in the serum separator tubes were centrifuges at 3000 rpm for 5 minutes post clotting. The obtained serum was aliquoted into 2 ml Eppendorf tubes and stored at -20 °C prior to analysis. The EDTA containing blood was run for full blood count (FBC) as at when the samples were taken.

Biochemical Analysis of Blood Samples

The serum was thawed and analyzed for creatinine and urea. Serum creatinine was determined using the Jaffe reaction method (Bartels & Bohmer, 1971), urea by enzymatic – UV – kinetic method using (BT 3000 plus automated chemistry analyzer). Full blood count was carried out on the sample in the EDTA tube with particular attention paid to the Hemoglobin (Hb) and Haematocrit (Hct) using Sysmex xs-500i automated hematology analyzer.

Statistical Analysis

Data collected was entered using Microsoft Excel using designed excel forms to avoid entry errors and analyzed with Statistical Package for Social Sciences (SPSS vs. 22.0). Descriptive statistics were used to
calculate frequencies and proportions of study participants. Student's $t$-test was used to compare the means of biochemical variables. $p$-values less than 0.05 were considered statistically significant.

**Results**

This study recruited 51 peasant farmers and hawker's whose modal age ranged between 25–29 years representing 52.94%. The lowest age of the participants was 22 and the highest was 35. Among them, 30 (58.82%) were males whereas 21 representing 41.18% were females (Table 1).

| Variable | Frequency | Percentage (%) |
|----------|-----------|----------------|
| Total    | 51        | 100            |
| Age      |           |                |
| 20-24yrs | 6         | 11.76          |
| 25-29yrs | 27        | 52.94          |
| 30-34yrs | 11        | 21.57          |
| 35-39yrs | 7         | 13.73          |
| Sex      |           |                |
| Male     | 30        | 58.82          |
| Female   | 21        | 41.18          |

Table 2: **Mean Seasonal Variations of Various Parameters among Study Participants**

In this study, participant’s BMI and GFR were significantly higher during the wet season than in the dry season. Participant’s systolic blood pressure, creatinine, urea and potassium levels were significantly higher during the dry season than observed in the rainy season. The other parameters vis-à-vis TBW, hemoglobin concentration, hematocrit and sodium levels were statistically similar among the participants during the two seasons (Table 2).
Table 2
Mean Seasonal Variations of Various Parameters among Study Participants

| Variables                        | Rainy Season (Mean ± SD) | Dry Season (Mean ± SD) | P-Value  |
|----------------------------------|--------------------------|------------------------|----------|
| Body Mass Index (kgm⁻²)          | 25.14 ± 2.56             | 24.59 ± 2.69           | <0.0001  |
| Systolic blood pressure (mmHg)   | 120 ± 8.60               | 121.88 ± 7.90          | 0.0194   |
| Total Body Water                 | 42.65 ± 4.86             | 41.86 ± 4.73           | 0.4097   |
| Hemoglobin (g/dL)                | 13.49 ± 1.68             | 13.52 ± 1.68           | 0.7161   |
| Hematocrit                       | 41.14 ± 5.10             | 41.14 ± 5.10           | 0.7611   |
| Creatinine (umol/L)              | 69.78 ± 19.99            | 90.51 ± 19.20          | <0.0001  |
| Urea (mmol/L)                    | 3.56 ± 1.22              | 4.00 ± 1.08            | 0.0126   |
| Sodium (mmol/L)                  | 138.98 ± 2.17            | 139 ± 1.85             | 0.1193   |
| Potassium (mmol/L)               | 3.79 ± 0.25              | 3.85 ± 0.23            | 0.0479   |
| GFR (ml/min/1.73 m² BW)          | 132.94 ± 21.40           | 105.67 ± 18.48         | <0.0001  |

GFR = Glomerular Filtration Rate; BW = Body Weight; P-value less than 0.05 is considered statistically significant

Table 3: Mean seasonal measurement of various study parameters stratified by gender

This study assessed the influence of seasonal variation on some of the study parameters among the gender groups. Findings revealed a significantly higher BMI among both males and females during the season of rains as against the dry season. Similarly, GFR among both males and females during the rainy season was significantly high per findings of this study. Antagonistically significantly elevated creatinine levels among both males and females during the dry season were observed in this study. Differences in blood pressure and urea levels among males were significantly higher during the dry season than were in the rainy season but however statistically comparable among the females. Potassium levels among both males and females during the two seasons were statistically analogous per findings from this study (Table 3).
Table 3
Mean seasonal measurement of various study parameters stratified by gender

| Variables               | Rainy Season (Mean ± SD) | Dry Season (Mean ± SD) | P-Value |
|-------------------------|--------------------------|------------------------|---------|
| Body Mass Index         |                          |                        |         |
| Male                    | 24.69 ± 2.13             | 23.99 ± 2.21           | <0.0001 |
| Female                  | 25.79 ± 2.99             | 25.45 ± 3.11           | 0.0302  |
| Systolic blood pressure |                          |                        |         |
| Male                    | 121.27 ± 7.89            | 123 ± 7.02             | 0.0205  |
| Female                  | 118.19 ± 9.43            | 119.19 ± 8.46          | 0.4187  |
| Creatinine              |                          |                        |         |
| Male                    | 80.13 ± 17.18            | 103.57 ± 11.66         | <0.0001 |
| Female                  | 55 ± 13.44               | 71 ± 10.18             | <0.0001 |
| Urea                    |                          |                        |         |
| Male                    | 4.05 ± 1.05              | 4.56 ± 0.97            | 0.0302  |
| Female                  | 2.87 ± 1.12              | 3.22 ± 0.66            | 0.2121  |
| Potassium               |                          |                        |         |
| Male                    | 3.87 ± 0.18              | 3.92 ± 0.18            | 0.1273  |
| Female                  | 3.68 ± 0.29              | 3.75 ± 0.27            | 0.2107  |
| GFR                     |                          |                        |         |
| Male                    | 128 ± 22.13              | 98.40 ± 15.85          | <0.0001 |
| Female                  | 140 ± 18.59              | 116.05 ± 17.24         | <0.0001 |

GFR = Glomerular Filtration Rate; P-value less than 0.05 is considered statistically significant

Table 4: Age-Based Seasonal Variation among the Study Participants

With the exception of participants within the age category of 35–39 years, significantly higher BMI was recorded among participants aged 20–24, 25–29 and 30–34 years during the rainy season than that observed during the dry season. Significantly elevated GFR was recorded among all age groups considered in this study in the rainy season as against the dry season. Participant’s creatinine levels compared to the rainy season was significantly higher among all age groups during the dry season. Systolic blood pressure as well urea levels were significantly higher among individuals aged 25–29 years
during the dry season than were during the rainy season. Individuals aged 35–39 years also demonstrated significantly elevated urea concentration as during the dry season than were in the wet season. Potassium levels were statistically comparable among all the age categories during both seasons (Table 4).
Table 4
Age-Based Seasonal Variation among the Study Participants

| Variables          | Rainy Season (Mean ± SD) | Dry Season (Mean ± SD) | P-Value |
|--------------------|--------------------------|------------------------|---------|
| **Body Mass Index**|                          |                        |         |
| 20-24yrs           | 23.23 ± 3.20             | 22.38 ± 3.03           | 0.0134  |
| 25-29yrs           | 24.75 ± 1.91             | 24.20 ± 1.98           | 0.0002  |
| 30-34yrs           | 26.24 ± 2.92             | 25.69 ± 3.04           | 0.0029  |
| 35-39yrs           | 26.57 ± 2.60             | 26.27 ± 3.03           | 0.2973  |
| **Systolic blood pressure** |                    |                        |         |
| 20-24yrs           | 117.5 ± 11.59            | 123 ± 11.24            | 0.1788  |
| 25-29yrs           | 121.67 ± 6.65            | 123.56 ± 5.66          | 0.0361  |
| 30-34yrs           | 119 ± 12.11              | 119.64 ± 11.56         | 0.7627  |
| 35-39yrs           | 117.29 ± 6.24            | 118.00 ± 3.55          | 0.6556  |
| **Creatinine**     |                          |                        |         |
| 20-24yrs           | 72.5 ± 32.47             | 105.17 ± 15.48         | 0.0185  |
| 25-29yrs           | 78.56 ± 14.75            | 99.30 ± 15.28          | < 0.0001|
| 30-34yrs           | 56.91 ± 17.68            | 72.09 ± 11.64          | 0.0045  |
| 35-39yrs           | 53.86 ± 5.76             | 73.00 ± 9.71           | < 0.0001|
| **Urea**           |                          |                        |         |
| 20-24yrs           | 5.33 ± 1.07              | 4.83 ± 0.98            | 0.3404  |
| 25-29yrs           | 3.48 ± 1.04              | 4.30 ± 1.08            | 0.0005  |
| 30-34yrs           | 3.31 ± 1.15              | 3.16 ± 0.74            | 0.7623  |
| 35-39yrs           | 2.76 ± 0.74              | 3.48 ± 0.50            | 0.0021  |
| **Potassium**      |                          |                        |         |
| 20-24yrs           | 3.95 ± 0.15              | 4.05 ± 0.08            | 0.1106  |
| 25-29yrs           | 3.79 ± 0.26              | 3.85 ± 0.21            | 0.1578  |
| 30-34yrs           | 3.71 ± 0.27              | 3.80 ± 0.27            | 0.1669  |

GFR = Glomerular Filtration Rate; P-value less than 0.05 is considered statistically significant
Variables | Rainy Season (Mean ± SD) | Dry Season (Mean ± SD) | P-Value
--- | --- | --- | ---
35-39yrs | 3.76 ± 0.24 | 3.77 ± 0.29 | 0.9258
GFR | | | |
20-24yrs | 148.17 ± 8.04 | 119.17 ± 13.91 | 0.0013
25-29yrs | 133 ± 21.33 | 108.04 ± 18.81 | <0.0001
30-34yrs | 119.46 ± 19.60 | 94.91 ± 15.98 | 0.0043
35-39yrs | 140.86 ± 22.63 | 101.86 ± 17.02 | 0.0034

GFR = Glomerular Filtration Rate; P-value less than 0.05 is considered statistically significant

Discussion
To the best of our knowledge, this study is first of its kind to be done in Ghana and especially one of the hottest parts of the country, Wa municipality. The study investigated the impact of climate variations on the renal function among relatively young and healthy individuals in Wa, Upper West region of Ghana. The study ruled out as much as possible, traditional factors including hypertension, diabetes mellitus and therapy with cytotoxic agents including alcohol consumption (Correa-Rotter et al., 2014; Jha et al., 2013; Raju et al., 2014) that could precipitate kidney difficulties among individuals. More males than females were recruited in this study. The preponderance of the participants (52.94%) were aged 25–29 years. This study revealed significantly elevated levels of serum creatinine (p < 0.0001), urea (p < 0.0126) and potassium (p < 0.0479) concentrations during the dry season compared to the rainy (wet) season. Additionally, significantly higher BMI (p < 0.0001), GFR (p < 0.0001) and systolic blood pressure (p < 0.0194) among the study participants during the rainy season than recorded during the dry season was also observed in this study. In the absence of kidney disease, consumption of high electrolyte containing foods and underlying causes of CKD, the discrepancies observed in the urea, creatinine and potassium concentrations despite the fact that these levels are within the normal ranges for a healthy individual could be attributed to the excessive dehydration among the study participants. This is particularly true due to the characteristic of the dry season in the Wa Municipality which is trademarked by intense long, windy and hot dry periods. As a result, significantly reduced GFR among the participants during the dry season was paramount, further explaining the elevated levels of electrolytes observed in this study. Similar findings was observed among Marwari goats where mean serum creatinine was significantly (p ≤ 0.05) higher during hot period than the cold period (Kour et al., 2014) as well as among Mesoamerican sugarcane workers who demonstrated mean increase in serum creatinine of 0.21 mg/dl in Brazil, 0.12 mg/dl in El Salvador and 0.12 mg/dl in Nicaragua after a heavy workday with intense hot weather in focus (Herath et al., 2018). This study recorded no significant changes in participant’s hemoglobin and hematocrit levels as well as total body water in both wet and dry season. In this study, most of the parameters assessed were largely altered among the males than the female group. Except for potassium...
levels, significant drop in BMI and GFR as well as elevated creatinine and urea levels coupled with high systolic blood pressure among males in the dry season was dominant. This phenomenon could be due to the fact that men of Wa and the Northern Region in general are usually exposed to the hot sun during their business activities such as mobile sales of second hand clothing, beads, scrap dealing and the dominating motor cycle business popularly known as the okada business. Other businesses such as rearing of cattle and other animals which requires that the owners take the animals to the field for grazing or bring to the animals feed from the field can also be pinpointed as a cause of the discrepancies observed on the parameters among the males as their frequent exposure to the high temperature renders them dehydrated for longer periods. These activities expose the men to high temperatures which has been established to frequently lead to water scarcity in tropical regions raising the risk of dehydration suspected to have a direct link to CKD (Glaser et al., 2016; Jha et al., 2013; Johnson et al., 2016). Reduced GFR as well as elevated serum creatinine levels across all age groups studied was observed during the dry season in this study. In addition, systolic blood pressure as well urea levels were significantly higher among individuals aged 25–29 years during the dry season than were during the rainy season. The characteristic dehydrative effect and lack of frequent consumption of fluid during these periods of dryness with possible heat waves explains these findings. Meanwhile the age differences could basically be due to the fact that majority of the participants recruited for this study fall within the age bracket of 25–29 years, most of which are males who exposes themselves more to the hot weather than their female counterparts as enumerated above. Though not assessed, owing to the variation in CKD biomarkers assessed in this study, possible initiation of kidney disease such as acute kidney injury (AKI) due to severe dehydration may also account for the observed reduced GFR and elevated serum creatinine levels across all age groups.

Findings from this study indicates largely a normal BMI among the participant in both seasons however, overweight status was predominant among participants during the rainy season than observed during the dry season. Despite the insignificant mean difference observed among participants in the two seasons, total body water was higher among participants in the rainy season (42.65 ± 4.86) than observed in the dry season (41.86 ± 4.73). The rainy season is accompanied with high humid conditions which restricts the process of loss of body water via evaporation through cutaneous vasodilation (Raju et al., 2014). This retention of body water could be the contributing factor to the 43.14% overweight status observed among participants during the raining season than the 29.41% observed among the study participants in the dry season as a result of the increase in total body weight of the participant. Prevalence of obesity, 4 (7.84%) was identical among the study participants in both seasons. This could be due to the fact that not all the participants observed in this study were highly active in terms of their business activities. A select few lived sedentary lives such as sitting at one place throughout the day while conducting their businesses and not exposed directly to the high temperatures compared to the others whose business life entails moving from one locality to the other, exposing themselves to varied climate conditions. Such sedentary life habits by this group of individuals in combination with poor dietary behaviors such as consumption of more caloric food could account for their obese status in both seasons. In fact the people of Wa and
the Northern Region of Ghana in general are known to be people whose meal seldom lack either of those animal products such as meat from cattle, sheep, goat, guinea pig among others.

The season-wise stratification of participant’s blood pressure analyzed in this study revealed a pre-hypertensive status among 54.90% of the total participants studied in both seasons. Stage 1 hypertension was diagnosed among 15.69% of the total participants in the dry season more than 7.84% diagnosed among same participants in the wet season. This finding seems to hold a hidden trend of disease progression as pre-hypertension was observed among preponderance of the participants in both seasons and yet stage 1 hypertension was high during the dry season than the wet season. This could mean that, frequent exposure to adverse climatic conditions, vis-à-vis hot temperatures could be a gradual fueling stimulus for the increase in prevalence of hypertension among the people of Wa municipality in the foreseeable future.

**Conclusion**

This study suggests that exposure to hot climatic weather conditions could lead to kidney diseases as significant variations in biomarkers of kidney impairment were observed. Worth noting is that both genders are affected equally when exposed to the warm climatic conditions. High BMI was however not a prerequisite factor to developing renal diseases associated with hot climatic conditions. Possible upsurge in the prevalence of hypertension owing to exposure to high warm climate conditions among study participant in the proximate future is stipulated in this study.

**Limitations**

Factors such as rhabdomyolysis and inflammation that could cause increased serum Creatinine and urea levels were not assessed. Limited sample size was employed in this study which could account for some of the insignificant variations observed in some of the parameters in this study. This study employed non-standardized method of creatinine estimation and that could affect the general outcome of the results obtained in this study.

**Recommendations**

The study recommends public health education on the dangers of the over exposure to the various climatic conditions. This must include educating the public on the need to rehydrate on frequent bases to avert the hostility of the harsh climate when exposure becomes unavoidable. Advice on diet control should also be ensured in order to avoid the development of hypertension and obesity among other diet related noncommunicable diseases that are known principal causes of CKD. Additionally, further studies into the similar but larger population employing standardized method of estimation of the various biochemical methods is advised most especially in the Upper East, Northern, Savanna, and North East regions which have equally hot climatic conditions during the dry season.
Declarations

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Availability of data and materials

The data are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study protocol was reviewed and approved by the Ethical and Protocol Review Committee of the University of Cape Coast. Written permission was also sought from the administrative heads and head of laboratory of the Wa Regional Hospital to use their facility for the study. All participants provided written informed consent and the procedure adopted conformed to the provisions of the Declaration of Helsinki (as revised in Fortaleza, Brazil, October 2013). Moreover, confidentiality was assured for all the information provided and personal identifiers were not included on questionnaire.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests

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**Figures**
Figure 1

Participant's BMI Stratified by the Two Seasons
Figure 2

Participant's Blood Pressure Distribution Stratified by the Two Seasons