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Heavy metal content of rice meals sold in a Nigerian market population with a high prevalence of hypertension

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Abstract

Context: Some market populations in Nigeria have been shown to have high prevalence of hypertension. Current evidence includes environmental pollutants such as heavy metals as risk factors for hypertension. **Aim:** To study the heavy metal content of rice meals sold in a market population with a high prevalence of hypertension. **Settings and Design:** This was a descriptive, cross-sectional study conducted in Ogbete market in Enugu, Southeast Nigeria. **Subjects and Methods:** Five different cooked rice meals were obtained from 25 locations of the market. The rice meals included jollof rice, white rice and tomato stew, fried rice, white rice and vegetable sauce, and white rice and palm oil stew (*ofeakwu*). Accompanying protein (meat, fish, and egg) and vegetable salad were excluded. Similar rice meals were homogenized and analyzed in triplicates using spectrophotometric methods for mercury, copper, cadmium, lead, and arsenic determination. **Statistical Analysis Used:** The mean concentrations of the heavy metals were compared using analysis of variance, and $P < 0.05$ was considered statistically significant. **Results:** Twenty-five rice dishes were evaluated, five of each kind. Arsenic content ranged from 503 to 550 mg/kg and was comparable across the five rice dishes ($P = 0.148$). Copper was significantly highest (16767 mg/kg) in the white rice and tomato stew dish ($P < 0.001$), while mercury was significantly highest (33 mg/kg) in white rice and *ofeakwu* ($P < 0.001$). Jollof rice had the highest cadmium content (23 mg/kg), which was statistically significant ($P = 0.021$). Lead was not found in any of the rice dishes. **Conclusions:** Risk factors such as heavy metals may play a role in the high prevalence of hypertension observed in market populations, and rice meals may be a major source of these heavy metals.

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Full Text

Introduction

Hypertension is a medical condition of chronic elevation in blood pressure, which can lead to other cardiovascular diseases and sudden death, hence termed the “silent killer.”[1] There is a high prevalence of hypertension in several community populations in Nigeria. The overall prevalence of hypertension in Nigeria ranges from 8% to 46.4% depending on the study population, type of measurement, and cutoff value used for defining hypertension.[2] It was found that the prevalence was similar among men and women and in the urban and rural settings. The pooled prevalence increased from 8.6% (during the period of 1970–1979) to 22.5% (from 2000 to 2011).[2]

Market populations in Nigeria have been shown to have high prevalence of hypertension. A survey was done in a market population in Enugu that showed a 42.2% prevalence of hypertension.[3] The survey indicated physical inactivity among the population and high salt content of the foods consumed in the market as possible risk factors.[3] A similar Nigerian survey on hypertension in a market population in Lagos documented a prevalence of 34.8%,[4] while another survey by Vincent-Onabajo et al. documented a prevalence of undiagnosed hypertension of 25% among traders in Maiduguri, Northern Nigeria, in 2017.[5]

Traditional risk factors of hypertension include increasing age, male gender, genetic predisposition, excessive salt consumption, significant tobacco use, excessive alcohol consumption, obesity, physical inactivity, diets low in potassium and rich in saturated fats, nonsteroidal anti-inflammatory drugs, and steroids.[6]

Current scientific evidence implicates environmental toxicants such as heavy metals such as arsenic, mercury, lead, and cadmium as risk factors of cardiovascular disease. Their potential to cause cardiovascular toxicity even at low levels that may be considered safe limits has just begun to evolve.[7] A recent systematic review and meta-analysis on environmental toxic metal contaminants and risk of cardiovascular disease observed approximately linear associations between arsenic, lead, and cadmium levels with cardiovascular disease outcomes, indicating the risk of adverse health consequences even at a relatively low exposure of these toxic metals.[8]

Exposure to arsenic has been documented as an independent risk factor for cardiovascular diseases, because it has been linked to production of reactive oxygen species in endothelial cells, lipid peroxidation, upregulation of inflammatory signals, and high blood pressure.[9],[10] The resulting cardiovascular disorders include carotid atherosclerosis, impaired microcirculation, prolonged QT interval and increased QT dispersion in electrocardiography, and clinical outcomes such as hypertension, blackfoot disease (aunique peripheral vascular disease endemic in Southwestern Taiwan), coronary artery disease, and cerebral infarction.[11],[12]

Methylmercury exposure through fish consumption may increase the risk of cardiovascular disease. The heart is one of the target organs of mercury toxicity and can affect heart development in utero, affect cardiac sodium channel, block (Na/K)-ATPase, cause atherosclerosis, and damage lipids in the blood or lipid peroxidation.[13]

Exposure to lead has been associated with nephropathy and this may lead to hypertension.[14] Lead-induced oxidative stress and inflammation has also been documented and has been linked to atherosclerosis and other cardiovascular diseases.[15],[16],[17]

Cadmium contributes to the burden of cardiovascular disease through atherosclerosis, increased blood pressure,[18] kidney damage,[19] cadmium-related estrogenic activity,[20] and epigenetic changes.[21] The underlying mechanism through which cadmium causes cardiovascular diseases includes increased reactive oxygen species formation and interference with anti-oxidative stress responses by binding metallothionein and acting as a free radical scavenger.[22]

These environmental factors may contribute to the increasing prevalence and inadequate control of hypertension in Nigeria. Given that the market population has a high prevalence of hypertension, and the most commonly consumed food in Nigeria is rice, we propose that the heavy metal composition of the rice meals may be related to the prevalence of hypertension observed in this population. Therefore, we aimed to study the heavy metal content of rice meals sold in a market population with a high prevalence of hypertension, 42.2%.[3]

Subjects and Methods

Study design

This was a descriptive, cross-sectional study of heavy metal content of rice meals, ready for consumption, sold in a Nigerian market population.

Study site

The rice meal samples were obtained from food vendors and restaurants at Ogbete main market in Enugu state, Southeast Nigeria. Ogbete main market is a major market in Enugu city, and one of the largest in Southeast Nigeria. In the market, food sellers stay in shop clusters, some are also scattered at various locations, while others hawk their foods within the market.

Definition of the rice meals

Jollof rice: Rice was cooked in tomato sauce with spicesWhite rice and tomato stew: Tomato sauce was fried with pepper and spices to get a stew and then served with boiled white riceFried rice: Rice was parboiled and then fried with vegetable oil and shredded vegetablesWhite rice and vegetable sauce: Vegetable sauce is prepared without oil and served with boiled white riceWhite rice and palm oil stew (ofeakwu): The oil extracted from palm kernels and added with tomatoes puree and local spices to prepare a stew and then served with boiled white rice.

Procedure for data collection

Five different rice dishes were obtained: Jollof rice, white rice and tomato stew, fried rice, white rice and vegetable sauce, and white rice and palm oil stew (ofeakwu). A sample of each rice dish was obtained at various locations in the market: the food selling clusters, isolated food sellers, and food hawkers. The food vendors were numbered and selected by simple random sampling using a table of random numbers. One pack/plate (a standard serving size) of each of the samples was purchased from each food vendor. Proteins such as meat, fish, and eggs were excluded as well as salad vegetables. Similar samples were combined and ground in an industrial food blender to ensure homogeneity and representativeness of the foods sampled. They were vacuum packed and frozen at −18°C until analysis.

Methods for heavy metal analyses

The homogenized samples were analyzed in triplicate. Spectrophotometric methods were used for the determination of arsenic, copper, mercury, lead, and cadmium concentrations.[23],[24],[25],[26],[27]

Statistical analysis

The data collected were analyzed with SPSS Statistical software version 22 (Chicago, Illinois). They were tested for normality using Shapiro–Wilk test and found to have a normal Gaussian distribution. Thereafter, the mean and standard deviation of the heavy metal concentrations were obtained, and analysis of variance was used to compare the mean values of the samples. $P < 0.05$ was considered statistically significant.

Results

A total of 25 rice dishes were sampled, five of each kind. The mean ± standard deviation concentrations of the heavy metals are shown in [Table 1]. Arsenic content of all the rice dishes ranged from 503 ± 10 mg/kg in white rice and ofeakwu to 550 ± 40 mg/kg in jollof rice and were comparable across the five rice dishes ($P = 0.148$). Copper was significantly highest (16767 ± 2580 mg/kg) in the white rice and tomato stew dish ($P < 0.001$) and least in jollof rice. Mercury was significantly highest (33 ± 10 mg/kg) in white rice and ofeakwu ($P < 0.001$), but absent in white rice and vegetable sauce. Jollof rice had the highest cadmium content (23 ± 10 mg/kg), which was statistically significant ($P = 0.021$), while fried rice had the least content (7 ± 10 mg/kg). Lead was not found in any of the rice dishes. In [Table 2], the heavy metal concentrations were much higher than the maximum permissible limit[28] where available, except lead.{Table 1}{Table 2}

Discussion

Rice is a common, staple food in Africa and Asia, which is consumed by all social classes and at any time of the day-breakfast, lunch, and dinner. An average Nigerian consumes 24.8 kg of rice per year, representing 9% of annual calorie intake.[29] Although there is the choice of local (unpolished) or imported rice (polished), majority of Nigerians (55.4%) eat a combination of both depending on the income and educational status of the head of the household.[30]

Rice can be contaminated with heavy metals from environmental pollution. A study by Huang et al. showed the concentration of heavy metals detected in rice across several regions in China to be within the following range of values – arsenic: 0.08–0.199 mg/kg, cadmium: 0.14–0.224 mg/kg, mercury: 0.005–0.3 mg/kg, and lead: 0.054–2.042 mg/kg.[31] Other studies conducted in Nigeria have also evaluated heavy metal concentrations in rice.[32],[33]

We studied cooked rice dishes, which comprised cooked rice and their accompanying sauces or vegetables. This differs from other studies on raw rice,[32],[33] as well as from those on plain cooked rice.[34],[35] We considered that it may give a more holistic picture of the quantity of heavy metals consumed in a meal, as there may be extra sources of heavy metals from spices and vegetables, as suggested by Iwegbue et al.[36]

The most prevalent heavy metal in our rice dishes was copper. This is supported by a study on bioavailability of heavy metals in 22 varieties of cooked rice that showed that copper has the third most abundant bioavailability after zinc and iron,[37] but we did not analyze for zinc and iron. Among our samples, the highest concentration of copper was observed in white rice and tomato stew. The tomato stew is typically a blend of tomatoes, red peppers, onions, and other spices. The spices may explain why we have such high values in our study. Gaya and Ikechukwu showed that for all the spices they investigated, copper levels exceeded the risk levels set by regulatory agencies. They documented copper levels of 11.7 mg/kg in red pepper chilli, 12.15 mg/kg in red bell pepper, and 15.3 mg/kg in African nutmeg.[38] These ingredients were used in some of our rice dishes such as the tomato stew, as well as jollof rice.

Our study observed high concentrations of mercury in white rice and ofeakwu and high cadmium levels in jollof rice, but undetectable lead across all the rice dishes. This differs from the study by Otitoju et al. that did not detect mercury nor cadmium, but detected lead concentrations of 1.389 ± 0.293 mg/kg in Adani rice, and 0.548 ± 0.548 mg/kg in Abakaliki rice, both of

which are locally produced rice in southeast Nigeria.[32] Similarly, the average lead concentration detected in local rice from southwest Nigeria was 0.480 ± 0.353 mg/kg; however, arsenic, cadmium, mercury, and chromium were not detected at concentrations <0.001 mg/kg.[33] Our inability to detect any lead in our rice dishes may be because we sampled commercial foods which may be more of the foreign, imported rice due to its esthetics. Our negligible lead results are favorable because lead levels above 0.2 mg/kg results in increased systemic blood pressure by about 3 mmHg in adults.[28]

All our rice dishes had cadmium levels above the maximum permissible limit of 0.4 mg/kg in polished rice as prescribed by FAO/WHO 2015.[28] We recorded the highest cadmium concentration in jollof rice. This may depend on the ingredients peculiar to that dish. Chizzola et al. determined the concentrations of heavy metals in spices, aromatic, and medicinal plants from different Austrian regions and concluded that the tendency to accumulate cadmium was species dependent, while lead uptake occurs by chance.[39]

Our study discovered a high arsenic concentration in the sampled rice dishes compared to the maximum permissible limit, and this is worrisome, given that intoxication can lead to arsenic poisoning. Fortunately, a Malaysian study that assessed the bioaccessibility of heavy metals, found that arsenic was the least bioavailable heavy metal.[40] They concluded from their health risk assessment that any risk was not from a single element exposure, but the synergistic effect of all the heavy metals is paramount.[40] Hazard quotients for heavy metal exposure were estimated for adults and children at 27 and 18, respectively, while the total lifetime cancer risk were put at 0.0049 and 0.0032 for adults and children, respectively.[40]

Cooking process has been suggested to affect the concentration of heavy metals in rice. Naseri et al. demonstrated reduction in cadmium, lead, chromium, nickel, and cobalt concentrations, respectively, between raw rice and two methods of cooking rice.[34] It has been suggested that if rice is washed and cooked with plenty of water, heavy metals such as arsenic will be reduced.[35] Nonetheless, exposure to high concentrations of heavy metals from daily meals such as rice pose a public health concern in mitigating hypertension.

Due to the cross-sectional design of this study, we could not describe a cause and effect relationship between the concentration of heavy metals in rice-based meals and hypertension in this market population, but that was not the intention of this study.

Conclusion

Our study suggests that risk factors such as environmental pollutants such as heavy metals may play a role in the high prevalence of hypertension in our market population, and rice meals may be a major source of these heavy metals. Further studies may be needed to ascertain the sources of these heavy metals as well as their presence in other local meals sold in the market place. This would lead to sensitization of food contamination with heavy metals which can help prevent deleterious health conditions such as hypertension.

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Conflicts of interest

There are no conflicts of interest.

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