

The Impact of Geophagia on the Iron Status of Black South African Women

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Abstract—Objectives: To determine the nutritional status and risk factors associated with women practicing geophagia in QwaQwa, South Africa.

Materials and Methods: An observational epidemiological study design was adopted which included an exposed (geophagia) and non-exposed (control) group. A food frequency questionnaire, anthropometric measurements and blood sampling were applied to determine nutritional status of participants. Logistic regression analysis was performed in order to identify factors that were likely to be associated with the practice of geophagia.

Results: The mean total energy intake for the geophagia group (G) and control group (C) were 10324.31 ± 2755.00 kJ and 10763.94 ± 2556.30 kJ respectively. Both groups fell within the overweight category according to the mean Body Mass Index (BMI) of each group ($G= 25.59$ kg/m²; $C= 25.14$ kg/m²). The mean serum iron levels of the geophagia group (6.929 μ mol/l) were significantly lower than that of the control group (13.75 μ mol/l) ($p = 0.000$). Serum transferrin ($G=3.23$ g/l; $C=2.7054$ g/l) and serum transferrin saturation ($G=8.05\%$; $C=18.74\%$) levels also differed significantly between groups ($p=0.00$). Factors that were associated with the practice of geophagia included haemoglobin (Odds ratio (OR):14.50), serum-iron (OR: 9.80), serum-ferritin (OR: 3.75), serum-transferrin (OR: 6.92) and transferrin saturation (OR: 14.50). A significant negative association ($p=0.014$) was found between women who were wage-earners and those who were not wage-earners and the practice of geophagia (OR: 0.143; CI: 0.027; 0.755). These findings seem to indicate that a permanent income may decrease the likelihood of practising geophagia.

Key Findings: Geophagia was confirmed to be a risk factor for iron deficiency in this community. The significantly strong association between geophagia and iron deficiency emphasizes the importance of identifying the practice of geophagia in women, especially during their child bearing years.

Keywords—Anaemia, anthropometry, dietary intake, geophagia, iron deficiency.

I. INTRODUCTION

GEOPHAGIA is the practice of consuming clay, dirt and other parts of the earth's crust, and is practiced

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worldwide [1]. Geophagia is the most common type of pica practiced in Southern Africa and South Africa [2].

The practice of geophagia varies in different cultures according to the local soil types and cultural motivation for the behaviour [3]. The dominant reasons for practicing geophagia are related to medical reasons, cultural and religious purposes [4], [5] and because of mental illness [6]. The compulsive ingestion of soil is linked to numerous psychological abnormalities [7]. Young urban women that practice geophagia in South Africa believe that clay improves ones natural beauty [8] and pregnant women in Nairobi, Kenya, choose soft stone because they believe it is safer and makes the baby and mother stronger during labour [9].

The type of soil a geophagist chooses to consume determines the possibility of nutrient-release in the gastrointestinal tract [10]. Adsorptive clays are more likely to bind iron or zinc [11] and are more likely to contain kaolinite and micas (illite and muscovite) enter the stomach with a pH of 7-10 [12]. Nutrient-ions retention is increased which can result in a higher incidence of nutrient deficiency. A number of cross-sectional studies have reported that iron deficiency and/or anaemia are associated with pica [13].

Iron deficiency is the most prevalent single deficiency documented worldwide and is present in both developing and developed populations [14]. Anaemia is an indicator of iron deficiency, which can contribute to behavioural and cognitive dysfunction [15].

II. METHODS AND TECHNIQUES

A. Study Design

The study design comprised an observational epidemiological study which included an exposed (geophagia) and non-exposed (control) group. Logistic regression analysis was performed in order to identify factors that were likely to be associated with the practice of geophagia. The sample consisted of 69 participants, of whom 42 were in the geophagic group (G) and 27 in the control group (C).

B. Measurements and Techniques

Questionnaires that investigated geophagic habits; extent and practices; demographic and biological data; and medical history of individuals who practiced geophagia; reasons for geophagic practices; soil/clay type (based on traditional knowledge description); general profile and social and personal history of geophagic individuals were completed. Anthropometric measurements included height, weight and waist circumference. These measurements were used to calculate body mass index (BMI) and waist circumference.

For the purpose of this study, dietary intake referred to nutrient intake determined using a food frequency questionnaire validated for black populations, adapted from the one from THUSA (Transition and Health during Urbanisation of South Africans) [16]. The frequency of food consumption was categorized as 'consumes it daily', 'weekly' and 'monthly' or 'does not consume it', according to [17]. The questionnaire concentrated on food items commonly consumed in South Africa.

Full blood counts were performed using the ABX PENTRA 60 which uses current impedance changes, spectrophotometry, and double hydrodynamic sequential system coupled with cytochemistry and measuring of transmitted light, to measure the different parameters of the full blood count [18].

The iron studies were performed on the serum specimens. The total serum-iron and transferrin were analysed on the Beckman Coulter CX9 and the transferrin saturation automatically calculated. The ferritin values were calculated by the Siemens Advia Centaur using a method as described by UCSF Clinical Labs-Chemistry [19]. The FBC were performed using the ABX PENTRA 60 which uses current impedance changes, spectrophotometry; double hydrodynamic sequential system coupled with cytochemistry and measuring transmitted light to measure the different parameters of FBC. The reliability of these tests was scrutinised using

commercially available standards and controls, as well as the recommended tubes and needles for each test.

III. RESULTS

Descriptive statistics, namely frequencies and percentages for categorical data, and means and standard deviations or medians and percentiles for continuous data, were calculated. Comparisons between groups for continuous data were assessed using independent t-tests. For categorical data, the Chi-square test was used. Logistical regression analysis was performed in order to identify those factors measured in this study that can be used to predict whether a person practices geophagia or not in this specific target population. Although not indicated in table format, a short overview of results pertaining to socio-demographic information, anthropometry and dietary intake will briefly be given.

A. Socio-Demographic Information

The majority of participants in both groups (G=77.5%; C=70.4%) were unmarried. Sotho was spoken by more than 90% of participants. A large percentage of participants in both groups had an education level of grade 11-12 (G = 42.9% and C = 51.9%) and were unemployed (G = 90.48% and C = 74.1%). Electricity was used by both groups as the main source of energy for cooking (G = 83.3% and C = 85.2%), followed by paraffin (G = 11.9% and C = 7.4%).

TABLE I
 MEAN BLOOD RESULTS

	Normal Value	Geophagia Group (N=42)				Control Group (N=27)				95% Confidence Interval (CI) of Mean Difference	
		Min	Max	Mean	Std. Deviation	Min	Max	Mean	Std. Deviation	Lower	Upper
Na	136 - 147.0 MMOL/L	132.5	142.7	138.8	2.3	114.1	143.9	137.6	5.06	-2.9	0.6
Ca	2.15 - 2.50 MMOL/L	2.2	2.5	2.3	0.07	2.2	2.4	2.3	0.1	-0.02	0.03
K	3.5 - 5.1 MMOL/L	3.4	5.3	4.4	0.5	3.6	5.4	4.6	0.5	-0.01	0.5
BUNm	2.60 - 6.70 MMOL/L	.63	4	2.8	0.8	0.8	5.71	3.0	1.15576	-2.7	0.7
Phosm	.80 - 1.46 MMOL/L	.65	1.50	1.10	0.20	0.72	1.47	1.1	0.2	-0.1	0.1
TPm	65.0 - 80.0 G/L	.8	102.6	80.4	15.1	68.5	91.4	79.2	5.1843	-7.2	4.81
Albm	35 - 52 G/L	29.2	46.2	38.8	4.1	33.6	44.9	40.4	3.05141	-0.2	3.4
AST	13 - 35 IU/L	16.3	36.6	23.2	4.2	15.7	38.1	22.5	4.3339	-2.8	1.3
ALT	10 - 40 IU/L	7.9	28.6	13.1	3.9	8.9	36.7	14.7	5.3765	-0.5	3.9
CHOL	<5.0 MMOL/L	2.3	5.2	3.7	0.8	2.6	6.6	4.0	.9893	-0.1	0.7
Mg	2.3 - 2.6 MMOL/L	.69	1.1	0.8*	0.1	0.75	1.06	0.9*	0.1	-0.0	0.1
Fe	10 - 30 MMOL/L	2.0	23	6.9	4.0	3	22.0	13.8	5.0	4.0	9.3
Ferritin	10.0 - 291.0 MG/L	2.5	31.9	11.9	7.7	6.3	175.5	42.3	39.8	15.6	41.4
Transferrin	2.5 - 3.8 G/L	2.4	4.5	3.2	0.4	1.9	3.3	2.7	0.42	-0.7	-0.3
Transferrin saturation	20.0 - 55.0%	1.7	24.8	8.1	6.0	5.4	29.8	18.8	7.5	6.7	13.3
CRP	<5 MG/L	1.0	19.8	3.02	4.2	1.0	28.6	4.7	6.9	-1.1	4.31
Hb	12-15G/DL	7.2	14.4	11.2*	1.83	9.9	15.9	13.3*	1.20	1.2	2.8
MCV	83-101FL	63	95	80.2*	11.8	67	95	87.8*	6.47	2.61	12.8
MCH	27.0-322.5 PG	19.5	32.4	27.1*	3.7	22.4	32.9	29.5*	3.00	-49.3	24.2
RBC	3.8-4.8X10 ¹² /L	3.7	4.6	4.1*	0.3	4.0	5.2	4.4*	0.3	0.14	0.5
WBC	4.0 - 11.0 X 10 ⁹ /L	2.9	12.8	5.6	2.0	3.6	10.7	5.9	2.01	-0.8	1.2
Platelets	150-410 X 10 ⁹ /L	90	443	286.3	85.4	172	389	273.8	637.0	-52	27.0
ESR	0-12 MM/H	3	126	54.1	41.9	3	127	33.9*	33.52	-39.7	-0.6

* Means with the same symbol differ significantly between groups (p<0.05)

The primary employment status of the group with geophagia was part-time or piece jobs (54.8%), while in the control group a full-time wage earner was present in 48.15% of households. The logistic regression showed that women who were wage earners and those that owned a refrigerator (and thus had a higher socio-economic status), were less likely to practice geophagia.

B. Dietary Intake

The mean total energy intake for the geophagia group and control group were 10324.3 ± 2755.0 kJ and 10763.9 ± 2556.3 kJ respectively. The percentage of total energy from carbohydrate was similar in both groups (G = 54.1%; C = 54.4%), which is within the recommendation of 45–65%. The mean total fat intake in the geophagia group was 93.3g and in the control group 94.5g. The percentage total energy intake from fat was 33.1% for the geophagia group and 31.5% for the control group, which was also within the recommended range of 25–35%. The mean soluble dietary fibre (G = 3.7g; C = 3.6g) did not differ significantly between the groups ($p=0.86$) as well as the insoluble dietary fibre intake ($p=0.89$) with a mean intake of 4.6g in the geophagia group and 4.7g in the control group.

Both groups had intakes that were higher than the estimated average intake (EAR) for the following minerals: total iron (G = 11.6 mg; C = 13.5 mg); selenium (G = 50.4 mg; C = 54.5 mg); magnesium (G = 287.5 mg; C = 314.7 mg) and phosphorus (G = 1057.1 mg; C = 1209.0 mg). Mean intakes of haem iron (G = 0.7mg; C = 1.2mg) and non-haem iron (G = 4.2; C= 5.3) differed significantly between the two groups (0.005; 0.004 respectively). An EAR for potassium, sodium, haem iron and non-haem iron has not been established.

C. Anthropometric Status

Mean waist circumference of both groups fell under the cutoff point for risk waist circumference in women which is >88 cm (G = 77.5; C = 73.2) [20]. Although the majority of the participants in both the geophagia and control group fell in the normal category for body mass index (BMI) of 18.5 – 24.9 kg/m², the mean BMI fell within the overweight category (G = 25.6 kg/m²; C = 25.1 kg/m²).

D. Biochemistry

The mean values for blood results are summarized in Table I. Participants in both the geophagia and control groups had normal mean blood values for sodium (G = 138.8 mmol/L; C = 137.6 mmol/L), potassium (G = 4.4 mmol/L; C = 4.6 mmol/L) and calcium (G = 2.3 mmol/L; C = 2.3 mmol/L). Both groups had mean serum magnesium values of 0.8 mmol/L and 0.9 mmol/L respectively, which fell below the ideal range of 2.3-2.6 mmol/l. The mean serum iron levels of the geophagia group were significantly lower ($p = 0.000$) than that of the control group (G = 6.9 μ mol/L; C = 13.8 μ mol/L). There was also a significant difference in the serum ferritin levels between the geophagia and control group (G = 11.9 μ g/L; C = 42.3 μ g/L; $p = 0.00$). Serum transferrin and serum transferrin saturation levels also differed significantly between the groups (G = 3.2; 8.1 and C = 2.7; 18.8; $p = 0.00$).

The mean haemoglobin (G=11.2g/dl; C=13.3g/dl) differed significantly while the mean cell haemoglobin (G=27.1pg; C=29.5pg) and the mean cell volume (G=80.2fl; C=87.8fl) were not significantly lower in the geophagia group in comparison to the control group.

The platelet count (G = 286.3; C = 273.8) in both groups were within normal reference range ruling out bleeding. The white blood cell count (WBC) (G = $5.6 \times 10^9/l$; C = $5.9 \times 10^9/l$) and C-reactive protein (CRD) (G=3.0mg/L; C=4.7mg/L) also fell within normal reference range for the geophagia and control groups, while the erythrocyte sedimentation rate (ESR) (G= 54.1mm/h; 33.9mm/h) was higher than the normal reference range in both groups.

E. Risk Factors

Logistic regression analysis with forward selection was performed in order to establish a typical metabolic profile that could be associated with geophagia. It is envisaged that from the variables included in the equation, one could establish whether a given individual practices geophagia or not. Variables included in the equation are presented in Table II.

Risk factors which were significantly associated with the practice of geophagia included: serum iron ($p = 0.00$), haem-iron ($p = 0.009$), non-haem-iron ($p = 0.004$), ferritin ($p = 0.00$), transferrin ($p = 0.000$), transferrin saturation ($p = 0.000$) and haemoglobin ($p=0.000$).

TABLE II
BLOOD VALUES ASSOCIATED WITH GEOPHAGIA

Variable	Score	P-value	Odds ratio	95% Confidence Interval	
				Lower	Upper
Iron (FE)	19.589	0.000*	9.80	2.99	32.11
Ferritin	15.434	0.000*	3.750	1.312	10.721
Transferrin	17.481	0.000*	6.923	2.243	27.929
Haemoglobin	18.425	0.000*	14.50	4.066	51.709
Haem-iron	6.888	0.009*	3.508	1.244	9.893
Non-haem-iron	8.134	0.004*	4.673	1.613	13.538
Transferrin saturation	23.697	0.000*	14.50	4.066	51.709

* Statistically significant $p \leq 0.05$

IV. DISCUSSION

The mean age of participants was similar at 25 years in the geophagia group and 26 years in the control group. This age group was also very comparable to that of participants in a study by [21] at an antenatal clinic in Kenya, where 57.3% of 279 women between the ages of 20 and 39 practiced pica. This age group represents a women's reproductive years which is important since geophagia is strongly associated with pregnancy [22]-[26]. Although participants in this study were not pregnant at the time of the survey, more than half (53.7%) reported that they had practiced geophagia during pregnancy.

There were no differences in socio-economic status, for type of house owned, income and the owning of appliances such as a microwave and/or stove between the two groups. However, the control group did have more access to a refrigerator compared to the geophagia group ($p=0.02$), with the probability of practicing geophagia being lower in the group with a refrigerator (OR: 1.54; CI: 0.056; 0.849).

A global nutrition transition has been reported with developing populations tending to increase their intake of energy dense foods [27], [28]. Although a nutrition transition has been reported to be more prevalent in urban areas of South Africa than rural areas [29]-[31], rural areas are also becoming more westernised. Although the macronutrient intake in this study did not point to a confirmed nutrition transition, the tendency towards a high dietary fat intake might be an indication that it is in the process of developing. This hypothesis is strengthened by the results related to the anthropometry and physical activity levels of participants. The mean BMI of participants in both groups of the current study fell within the overweight category of 25-30kg/m² [32], [33]. This finding mirrors the female population of South Africa. The recent SANHANES study reported a mean BMI of 28.9kg/m² for women aged 25-34 years [34]. According to the International Obesity Task Force: Global Burden of Disease Analyses 2002 the mean BMI of South African women between the ages of 15-29 and 30-44 were 24.4 kg/m² and 28.5 kg/m² respectively [35]. These findings seem to indicate that the problem of overweight has not changed in the last ten years in South Africa and suggest that a nutrition transition has developed in South Africa over an extended period of time. There were no significant differences in BMI and weight circumference between the geophagia- and control groups. Women with and without pica in Argentina also had similar BMI [36]. In contrast, non-anaemic women in an urban community area in Pakistan had a higher BMI than anaemic women who practiced pica [37].

A strong association between geophagia and iron deficiency was identified in non-pregnant women in this study. This association has been confirmed in other studies [38], [39]. Similar results have also been reported in 79 women from European and non-European countries of which 44% practiced pica [40]. Fifty six percent of pregnant women attending antenatal clinics in Coastal Kenya with geophagia also had low iron levels [41]. In pregnant women of Eastern Sudan soil eating was significantly associated with anaemia [42]. Similar results have been reported in Tanzania [43], [44]. In another study in the Eastern Cape, South Africa, undertaken amongst pregnant women from three primary health care antenatal clinics, the prevalence of anaemia was significant higher in pregnant women practicing geophagia when compared to the group of pregnant women not practicing geophagia [38].

In the current study low serum ferritin levels, an increase in serum transferrin levels and serum transferrin saturation less than 16% in the geophagia group confirmed the presence of iron deficiency. In a sub-sample (17) of this study low haemoglobin, transferrin saturation, ferritin and transferrin levels in the geophagia group (n=12) was also found [45]. From this, it is evident the practice of geophagia affects not only one single blood parameter, but rather a cluster of parameters, that collectively and comprehensively represent individual iron status (Table III).

Significant predictors of pica were identified in another study namely mean corpuscular volume (MCV), platelet count and red blood cell distribution width (RDW) [46]. In the

current study additional significant predictors were associated with geophagia and iron deficiency, but whether iron deficiency develops because of geophagia or iron deficiency causes women to start practicing geophagia is still unclear. In this study the effect of geophagia on a cluster of blood parameters, indicates the significant effect of soil eating on iron homeostasis. Risk factors associated with iron deficiency are thus also linked to the likelihood of practicing geophagia.

V. CONCLUSION & RECOMMENDATIONS

In Table III a significant association was found between earning a wage and the practice of geophagia, with women that were wage earners being less likely to practice geophagia. In addition women who owned a refrigerator were also less likely to practice geophagia. These findings seem to suggest that socio-economic status might be a predictor of the practice of geophagia and that it is more likely for someone from a low socio-economic status to practice geophagia.

TABLE III
 SOCIO-DEMOGRAPHIC FACTORS THAT WERE SIGNIFICANTLY ASSOCIATED WITH THE PRACTICE OF GEOPHAGIA

Variable	Score	P-value	Odds ratio	95% Confidence Interval	
				Lower	Upper
Full-time wage earners	6.43	0.014	0.14	0.027	0.755
Not having a refrigerator	1.53	0.028	1.54	0.056	0.849

* Statistically significant p≤0.05

A major finding of this study was the difference in iron status of participants practicing geophagia and the control group, with women that practiced geophagia being more likely to suffer from iron deficiency and iron deficiency anaemia. A cluster of variables including haemoglobin, ferritin, transferrin and transferrin saturation are all affected by the practice of geophagia. Significantly lower haemoglobin and ferritin levels with elevated transferrin levels were prevalent in the group with geophagia compared to the control group. These results implicate that geophagia is a risk factor for iron deficiency and iron deficiency anaemia, confirmed by the aforementioned cluster of metabolic indicators. The precise mechanism that leads to this association requires clarification and further investigation.

To conclude the results of this study showed that an interaction of factors, including social, nutritional, cultural and physiological may influence the iron status of women with geophagia. All of these need to be taken into account when planning interventions to address the risk factors associated with geophagia. Further research to establish whether the practice of geophagia is a cause of iron-deficiency, or it is the consequence thereof, would give a clearer view on how to recognise and treat the condition.

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REFERENCES

- [1] Ghorbani H. 2008. Geophagia, a Soil- Environmental Related Disease. *International Meeting on Soil Fertility, Land Management and Agro climatology, Turkey*, 957-967.
- [2] Brand CE, De Jager L and Ekosse GIE 2009. Possible health effects associated with human geophagic practise: an overview. *Medical Technology South Africa*, 23(1): 11-13.
- [3] Sing D and Sing CF. 2010. Impact of Direct Soil Exposures form Airborne Dust and Geophagy on Human Health. *International Journal of Environmental Research and Public Health*, 7(3):1205-1223.
- [4] Reid RM. 1992. Cultural and medical perspective on geophagia, *Medical Anthropology* 13:337-351.
- [5] Vermeer DE and Ferrell RE Jr. 1985. Nigerian geophagical clay: a traditional anti-diarrheal pharmaceutical. *Science*, 227:634-636.
- [6] Hunter J.M. 1973. Geophagy in Africa and the United States: A culture-nutrition hypothesis. *Geographical review*, vol. 63, pp. 170-195.
- [7] Callahan GN. 2003. Eating Dirt. *Emerging Infectious Diseases*, 9(8): 1016-1021.
- [8] Songca SP, Ngole V, Ekosse G, De Jager L. 2010. Demographic characteristics associated with consumption of geophagic clays among ethnic groups in the Free State and Limpopo provinces South Africa. *Indilinga African Journal of Indigenous Knowledge Systems*, 9(1):110-123.
- [9] Ngozi PO. 2008. Pica practices of pregnant women in Nairobi, Kenya. *East African Medical Journal*, 85(2):72-79.
- [10] Aufreiter S, Hancock RGV, Mahaney WC, Stambolic-Robb A, Sanmugadas K. 1997. Geochemistry and mineralogy of soils eaten by humans. *International Journal of Food Science and Nutrition*, 48(5): 293-305.
- [11] Simon SL. 1998. Soil ingestion by humans: a review of history, data and aetiology with application to risk assessment of radioactively contaminated soil. *Soil Physics*, 74:647-672.
- [12] Abrahams PW. 2012. Involuntary soil ingestion and geophagia: A source and sink of minerals, nutrients and potentially harmful elements to consumers of earth materials. *Applied Geochemistry*, 27(5): 954-968.
- [13] Young SL. 2011. Pica in Response to Food Storage. In *Craving Earth, Understanding Pica, the Urge to Eat, Clay, Starch, Ice & Chalk*. New York: Columbia University Press.
- [14] World Health Organization. 2008. World prevalence of anaemia 1993 – 2005. WHO *Global Database on Anaemia*. Geneva. Available from <http://www.who.int/vmnis/publications/en/> Accessed 22 Nov, 2013.
- [15] Yadav D and Chandra, J. 2011. Iron Deficiency: Beyond Anemia. *Indian J Pediatr*, 78:65-72.
- [16] MacIntyre UE, Venter CS, Vorster HH, Steyn HS. 2001a. A combination of statistical methods for the analysis of the relative validation data of the quantitative food frequency questionnaire used in the THUSA study. Transition, Health and Urbanisation in South Africa. *Public Health Nutrition*, 4(1):45-51.
- [17] Nelson M. 2000. Methods and validity of dietary assessment. In *Human Nutrition and Dietetics*. Edited by JS Garrow, WPT James, Ralph A. 10th Ed. Harcourt Publishers, Limited, Edinburgh, UK: 311-331.
- [18] Nakamine A. 2004. ABX Pentra user manual. Product no. RAB080FA. Montpellier, Horiba Group: 2-13.
- [19] UCSF Clinical Labs-Chemistry. Ferritin: Advia Centaur System. 2010. Available from: http://labmed.ucsf.edu/labmanual/db/resource/Centaur_Ferritin.pdf
- [20] Alberti, K.G.M.M., Zimmet, P. and Shaw, J. 2006. Metabolic syndrome – a new world-wide definition. A consensus statement from the International Diabetes Federation. *Diabetetic Medicine*, 23(5): 476.
- [21] Koryo-Dabrah A, Nti CA and Adanu R. 2012. Dietary practices and Nutrient Intakes of Pregnant women in Accra, Ghana. *Current Research Journal Biological Sciences* 4(4): 358-365.
- [22] Young SL. 2010. Pica in pregnancy: new ideas about an old condition. *Annu Rev Nutr*, 30:403-422.
- [23] Nyaruhucha CN. 2009. Food cravings, aversions and pica among pregnant women in Dar es Salaam, Tanzania. *Tanzania Journal of Health Research*, 11(1): 29-34.
- [24] Corbett R, Ryan C & Weinrich S. 2003. Pica in pregnancy: does it affect pregnancy outcomes? *The American Journal of Maternal Child Nursing (MCN)*, 28(3): 190-191.
- [25] Karimi MR, Kadivar R, Yarmohammadi H. 2002. Assessment of the prevalence of iron deficiency anemia, by serum ferritin, in pregnant women of Southern Iran. *Medical Science Monitor*, 8: CR448-492.
- [26] Tayie FAK and Lartey A. 1999. Pica practice among pregnant Ghanaians: Relationship with infant birth weight and maternal haemoglobin level. *Ghana Medical Journal*, 33:67-76.
- [27] Prentice A. 2007. Mining the depths: metabolic insights into mineral nutrition. *The Proceedings of the Nutrition Society*, 66(4): 512-521.
- [28] Popkin BM and Gordon-Larsen P. 2004. The nutrition transition: worldwide obesity dynamics and their determinants. *International Journal of Obesity and Related Metabolic Disorders*, Suppl 3: S2-S9.
- [29] Steyn NP, Nel JH, Parker W, Ayah R, Mbithe D. 2012. Urbanisation and the nutrition transition: a comparison of diet and weight status of South African and Kenyan women. *Scandinavian Journal of Public Health*, 40 (3): 229-238.
- [30] MacIntyre UE, Kruger HS, Venter CS, Vorster HH. 2002. Dietary intakes of an African population in different stages of transition in the North West Province, South Africa: The THUSA study. *Nutrition Research*, 22:230-256.
- [31] Vorster HH. 2010. The link between poverty and malnutrition: A South African perspective. *Health SA Gesondheid* 15(1) 1-6. Available from: <http://www.hsag.co.za/index.php/HSAG/article/view/435/482> Accessed: Dec 15, 2014.
- [32] Lysen LK and Israel DA. 2012. Nutrition in Weight management. In *Krause's Food and the Nutrition Care Process*. Edited by LK Mahan, S Escott-Stump and JL Raymond. 13th Ed. Philadelphia: WB Saunders Company: 462-484.
- [33] Thomas B and Bishop J. 2007. General dietetic principles and practices. In *The Manual of Dietetic Practice*. 4th Ed. Wiley-Blackwell.
- [34] Sanhanes-1: Shisana O, Labadarios D, Rehle T, Simbayi L, Zuma K, Dhansay A, Reddy P, Parker W, Hoosain E, Naidoo P, Hongoro C, Mchiza Z, Steyn NP, Dwane N, Makoae M, Maluleke T, Ramlagan S, Zungu N, Evans MG, Jacobs L, Faber M, & Sanhanes-1 Team. 2013. *South African National Health and Nutrition Examination Survey (Sanhanes-1)*. Cape Town: HSRC Press.
- [35] Goedecke JH, Jennings CL, Lambert EV. Obesity in South Africa. 2006. In *Chronic Diseases of Lifestyle in South Africa: 1995-2005*. Edited by K Steyn, J Fourie, N Temple. Medical Research Council, South Africa.
- [36] López LB, de Portela, ML. and Soler CR. 2007. Nutrient intake in women with pagophagia and other forms of pica during the pregnancy. *Nutrition Hospital*, 22(6):641-647.
- [37] Baig-Ansari N, Badruddin SH, Karmaliani R., Harris H, Jehan I, Pasha O, Moss N, McClure EM, Goldenberg RL. 2008. Anemia prevalence and risk factors in pregnant women in an urban area of Pakistan. *Food and Nutrition Bulletin*, 29(2); 132 – 139.
- [38] George G and Abiodun A. 2012. Physiological Effects of Geophagy (Soil Eating) with Reference to Iron Nutritional Status in Pregnant women: - A study in Selected Antenatal Clinics in KSD Municipal Area of the Eastern Cape, South Africa. 3rd International Conference on Biology, Environment and Chemistry. *IPCBE*, 46: 96-98.
- [39] Louw VJ, Du Preez P, Malan A, Van Deventer L, Van Wyk D and Joubert, G. 2007. Pica and food craving in adult patients with iron deficiency in Bloemfontein, South Africa. *South African Medical Journal*, 97(11):1069-1071.
- [40] Kettaneh A, Eclache V, Fain O, Sontag C, Uzan M. et al. 2005. Pica and food craving in patients with iron-deficiency anemia: A case-control study in France. *American Journal of Medicine*, 118:185-188.
- [41] Geissler PW, Shulman CE, Prince RJ, Mutemi W, Mnazi C, Friis H, Lowe B. 1998. Geophagy, Iron Status and anaemia among pregnant women in the coast of Kenya. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 92 (5):793-796.
- [42] Adam I, Khamis AH and Elbashir MI. 2005. Prevalence and risk factors for anaemia in pregnant women of eastern Sudan. *Transaction of the Royal Society of Tropical Medicine and Hygiene*, 99(1): 739-743.
- [43] Young SL, Khalfan SS, Farag TH, Kavle JA, Ali SM, Hajji H, Rasmussen KM, Pelto GH, Tielsch JM, Stolfus RJ. 2010. Association of Pica with Anemia and Gastrointestinal Distress among Pregnant Women in Zanzibar, Tanzania. *American Journal of Tropical Medicine and Hygiene*, 83(1):144-151.
- [44] Kawai K, Saathoff E, Antelmann G, Msamanga G and Fawzi WW. 2009. Geophagy (Soil-eating) in relation to anemia and helminth infection among HIV-infected pregnant women in Tanzania. *American Journal of Tropical Medicine and Hygiene*, 80: 36 – 43.
- [45] Mogongo LF, Brand CE, de Jager L and Ekosse GE. 2011. Hematological Status of QwaQwa women who Ingest Clays. *South Africa Medical Technology*, 25(1):33-37.

- [46] Barton JC, Barton JC, Bertoli LF. 2010. Pica associated with iron deficiency or depletion: clinical and laboratory correlates in 262 non-pregnant adult outpatients. *BMC Blood Disorders*, 10(9):1-11.