Correlation of Sex Hormone, Lipid Profile and Serum Electrolytes: A Case of 100 Apparently-healthy Human Subjects in Enugu State, Nigeria

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Abstract: *Background*: Current data on age-associated decline in sex hormone levels in apparently-healthy middle-aged human subjects and the link with the incidence of bone disorders, electrolyte imbalance and other associated risk factors are conflicting. The aim of this study was to assess the levels of sex hormone, lipid profile and electrolyte indices in 100 (65 males and 35 females) apparently-healthy subjects, aged 20-70 years and find any correlation among the parameters. *Methods*: The concentrations of serum testosterone and oestradiol were detected by competitive immunoassay. Lipid profile and serum electrolyte were evaluated by spectrophotometry. *Results*: The results showed an age-dependent significant ($p < 0.05$) decrease in testosterone and oestradiol levels. The testosterone concentrations of male subjects (18.86 ± 2.53 nmol/L) were significantly ($p < 0.05$) higher than female subjects (6.65 ± 2.46 nmol/L). Oestradiol concentrations of female subjects (38.21 ± 1.30 nmol/L) were significantly ($p < 0.05$) higher than male subjects (16.28 ± 1.60 nmol/L). The level of high density lipoprotein (HDL) decreased with increase in age while the total cholesterol (TC), low density lipoprotein (LDL) and triacylglycerol (TAG) concentrations increased non-significantly ($p > 0.05$) with increase in age. Conversely, TC and TAG correlated inversely with testosterone and oestradiol. Serum HDL concentration positively correlated with testosterone and oestradiol. There was no significant ($p > 0.05$) difference among the concentrations of calcium, phosphate and potassium of male and female subjects. Sodium correlated negatively with testosterone. Oestradiol correlated negatively with bicarbonate and positively with sodium. *Conclusion*: The findings of this study suggest that sodium and bicarbonate analyses may be indirect markers of hypogonadism and other steroid dysfunction. Results also showed that there is an association between serum lipid profile and sex hormone status and this could suggest the roles of sex hormones in the development of lipid-related diseases.

Key words: Lipid profile · Sex hormones · Testosterone · Oestradiol · Serum electrolytes

INTRODUCTION

The primary sex hormones are testosterone in males and oestradiol and progesterone in females [1]. Sex steroids are responsible for normal sexual development and the establishment of secondary sexual characteristics of male and female reproductive organs. They also induce sexual dimorphism in a number of other tissues, such as muscle, bone, liver, kidney and brain. Being small, fat-soluble molecules, their effects are far-reached from the site of biosynthesis and actions are under strict regulation at multiple levels [2]. Age-associated decline in sex hormone concentrations in healthy middle-aged individuals is paralleled by an increase in the incidence of cardiovascular diseases and the associated risk factors such as: type 2 diabetes mellitus (T2DM), obesity and dyslipidemia. Sex hormone levels decrease with increase in age, in both males and females [3]. Hypogonadism in men refers to decreased function of the testes, in either testosterone or sperm production. A deficiency of testosterone may be due to primary gonadal failure, or be secondary to hypothalamo-pituitary disease. Indeed, after age 30 years, the average annual decline in serum testosterone in males is about 1% to 2% [4, 5]. Testosterone decline is also associated with numerous comorbidities [5] and reduced survival [6] such as insulin resistance [7], obesity and diabetes [3, 5, 7, 8], metabolic syndrome [5] and cardiovascular disease [7]. In males,

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muscle mass and strength are often described as being associated with testosterone concentrations. This applies to older males as well as to adolescents [9, 10]. However, some studies failed to find any significant association between baseline testosterone levels and the development of cardiovascular diseases (CAD) [11, 12]. Testosterone stimulate proximal reabsorption of sodium and water [13], causing a reduction in the sodium delivery to the macula densa and through tubule-glomerular feedback. This leads to a reduction in afferent resistance that could lead to an increase in glomerular capillary pressure. This ultimately leads to glomerular injury and loss of renal function [14]. Testosterone levels decrease with age, exposing older persons to adverse consequences of cardiovascular-renal disorders [2].

The cyclic hormonal changes can affect a variety of physiological and biochemical in females [15]. Oestrogens have essential roles, together with other hormones, in the development of the female sex organs and secondary sex characteristics, the regulation of the menstrual cycle and reproduction. Thus, it has been proposed that the effect of many established reproductive risk factors for breast cancer are mediated by hormonal mechanisms, for the most part involving oestrogens [16]. Apparently, increased concentrations of endogenous oestrogens are strongly associated with increased risk for breast cancer in postmenopausal women [17]. Trials have shown that the anti-oestrogens (tamoxifen and raloxifene) reduce the incidence of breast cancer [18]. The link between oestrogen levels and cancer can be traced to the effects of oestrogen on inhibiting immune cells apoptosis and increasing cell proliferation. Some studies demonstrated the anti-apoptotic effects of oestrogen, hence it can be considered to have pro-inflammatory effects [19]. It has been reported that oestrogen induces hypercalcemia through the action of the parathyroid gland [20]. Withdrawal of estrogen was reported to cause a significant loss of bone calcium [21]. It was observed that an increase in the basal metabolic rate and oxygen consumption during the luteal phase was associated with increased carbohydrate utilization requiring magnesium ions and oxidative enzymes which were found to be increased significantly during the luteal phase [22]. These evidences suggest possibly that ovarian hormones influence calcium, magnesium, sodium and potassium metabolism during different phases of menstrual cycle [20]. Normally, there is loss of bone mass with ageing, perhaps 0.7% per year in adults and is greater in women past menopause than in men of the same age [23]. Bone in older persons is not as efficient as bone in younger persons at maintaining itself; there is decreased activity

of osteoblasts and decreased production of growth factors and bone matrix [24]. Rise in plasma sodium concentration at menopause results in a rise in blood pressure and higher diastolic blood pressure as seen in post-menopausal than in pre-menopausal women results from low oestrogen levels at menopausal and post-menopausal age [25]. The present study determined the association of serum electrolytes, lipid profile and sex hormone status of apparently-healthy human subjects.

MATERIALS AND METHODS

Study Subjects and Ethical Approval: This study recruited a total of 100 human subjects (65 male and 35 female subjects) between August and October 2015. The subjects were residents of Enugu State, South-Eastern Nigeria and are mainly civil servants, traders, farmers and students. Apparent-health in this study was defined as a condition with no identified chronic health challenge and not on medication for the past sixty days. To determine the link across different age ranges, middle age in this study was defined as age between 20-70 years. Pregnant and lactating female subjects were excluded because of the established influence of progesterone and prolactin respectively on other sex hormones. The ethical clearance for this study was got from the Institutional Ethical Review Board of Faculty of Biological Science, University of Nigeria, Nsukka with the certification number UNN/FBS/IRB/2015_012 prior to commencement of the study. Written informed consent was obtained from all the subjects prior to the study. The subjects were assigned into five groups based on their age differences:

Group 1 = subjects within the age range of 20-30 years,
Group 2 = subjects within the age range of 31-40 years,
Group 3 = subjects within the age range of 41-50 years,
Group 4 = subjects within the age range of 51-60 years and
Group 5 = subjects within the age range of 61-70 years.

The subjects were also divided into two groups (A and B- male and female subjects respectively) based on sex differences.

Study Procedures: Full understanding of the research protocols by the subjects was ensured prior to blood collection. This was to ensure for comfort and voluntary participation. Blood sample (5 ml) was drawn from each of the subjects after at least a 6-hour fast (about 89% of subjects' blood samples were drawn after an overnight fast by venipuncture using vacutainer system). The blood samples were allowed to clot for about 15 minutes at room

temperature and thereafter centrifuged at 4000 rpm for 10 minutes; serum derived was used for biochemical analysis.

Determination of Biochemical Parameters: Serum eostradiol (E2) concentration was determined by competitive immunoassay method of Abraham [26] as described in Biocheck Inc. commercial test kits. Serum testosterone concentration was determined by radioimmunoassay method as described by Tietz [27] in AccuBind Inc. commercial test kits. Serum total cholesterol concentration [28] and serum high density lipoprotein (HDL) concentration and serum triacylglycerol concentration [29] and cardiac risk ratio (CRR) was determined by the method of Emokpae *et al.* [30]. Serum calcium ion concentration (Ca^{2+}) was determined using the colorimetric method as described by Faulker and Meites [31]. Serum sodium concentration (Na) was estimated using colorimetric method based on modified Maruna and Trinders method as described by Trinder [32]. Serum potassium concentration (K) was determined using the turbidometric method as described by Henry *et al.* [33]. Serum bicarbonate concentration (HCO_3^-) was determined using enzyme spectrophotometric procedures as described by Forrrester *et al.* [34]. Serum inorganic phosphate concentration (Pi) was determined using the method as described by Ochei and Kolhatkar [35].

Statistical Analysis: The results were expressed as mean±standard deviation (SD) and test of statistical significance was carried out using one-way analysis of variance (ANOVA) in IBM Statistical Product and service solutions (SPSS), version 18. Student T-test was used to compare mean values based on sex differences. Mean values are considered statistically significant at $p < 0.05$.

RESULTS

Sex Hormone Profiles and Electrolyte Indices in Apparently-healthy Subjects Based on Age Range: The mean concentrations of sodium (mEq/L) down the group were: group 1 (130.42±5.36), group 2 (132.87±15.28), group 3 (136.14±12.30), group 4 (147.17±12.93) and group 5 (149.00±18.62). Mean concentrations of potassium (mEq/L) down the group were: group 1 (3.64±0.14), group 2 (3.26±0.28), group 3 (3.28±0.19), group 4 (3.33±0.12) and group 5 (3.23±0.74). Mean concentrations of calcium (mEq/L) down the group were: group 1 (8.33±0.33), group 2 (8.25±0.82), group 3 (8.95±0.71), group 4 (8.80±0.84) and group 5 (8.50±0.43). Mean concentrations of bicarbonate (mEq/L) down the group were: group 1 (24.28±0.72), group

2 (22.46±2.48), group 3 (24.62±1.04), group 4 (27.45±0.84) and group 5 (8.50±0.43). Mean concentrations of inorganic phosphate (mEq/L) down the group were: group 1 (2.27±0.66), group 2 (3.01±0.29), group 3 (3.36±0.14), group 4 (3.12±0.23) and group 5 (3.07±0.33). The mean concentrations of oestradiol (nmol/L) across the group were: group 1 (25.07±7.21), group 2 (20.53±8.68), group 3 (18.48±5.57), group 4 (12.64±3.58) and group 5 (8.66±1.95) (Table 1). The mean concentrations of testosterone (nmol/L) across the group were: group 1 (11.06±3.07), group 2 (8.33±2.73), group 3 (6.75±1.82), group 4 (4.75±1.09) and group 5 (3.33±1.38). Comparing the trends of mean concentrations of hormonal profile and serum electrolyte parameters down the groups, the mean concentrations of sodium and bicarbonate increased down the group while the mean testosterone and oestradiol concentrations decreased. The inorganic phosphate concentration increased from groups 1 to group 3 while the testosterone and oestradiol concentrations decreased. These signify a negative association between the biochemical parameters.

Lipid Profile and Cardiac Risk Ratio in Apparently-healthy Subjects Based on Age Range: There was a non-significant ($p > 0.05$) increase in total cholesterol (TC) and triacylglycerol (TAG) concentrations in the subjects down the groups. The TC concentrations (mmol/L) in apparently-healthy subjects down the groups from the result of the present study were: group 1 (3.40±0.09), group 2 (3.52±0.26), group 3 (3.97±0.13), group 4 (3.86±0.13) and group 5 (4.22±0.42) respectively. Similarly, the TAG concentrations (mmol/L) in apparently-healthy subjects down the groups from the result of the present study were: group 1 (0.65±0.05), group 2 (0.88±0.14), group 3 (1.10±0.75), group 4 (1.11±0.71) and group 5 (0.83±0.15) respectively. This implies that TC and TAG concentrations increase with increase in age. Conversely, there was a non-significant ($p > 0.05$) decrease in high density lipoprotein (HDL) concentration in the subjects down the group. The HDL concentrations (mmol/L) in apparently-healthy subjects down the groups from the result of the present study were: group 1 (2.37±0.06), group 2 (1.98±0.18), group 3 (1.88±0.24), group 4 (1.85±0.18) and group 5 (1.76±0.69) respectively. Meanwhile, cardiac risk ratio (CRR) in apparently-healthy subjects down the groups from the result of the present study were: group 1 (0.16±0.03), group 2 (0.25±0.06), group 3 (0.32±0.17), group 4 (0.32±0.04) and group 5 (0.38±0.02) respectively. The CRR level increases non-significantly ($p > 0.05$) down the groups, hence, increases with age (Table 2).

Table 1: Sex hormone profiles and electrolyte indices in apparently-healthy subjects

Group (Years)	Electrolyte (mEq/L)					Hormones (nmol/L)	
	Na	K	Ca	HCO$_3$	Pi	T	E2
Group 1 (20-30)	130.42±5.36[a]	3.64±0.14[a]	8.33±0.33[a]	20.28±0.72[a]	2.27±0.66[a]	11.06±3.07[a]	25.07±5.21[a]
Group 2 (31-40)	132.87±15.28[a]	3.26±0.28[a]	8.25±0.82[a]	22.46±2.48[ab]	3.01±0.29[a]	8.33±2.73[b]	20.53±8.68 [b]
Group 3 (41-50)	136.14±12.30[a]	3.28±0.19[a]	8.95±0.71[a]	24.62±1.04[b]	3.36±0.14[a]	6.45±1.82[c]	18.48±5.57[c]
Group 4 (51-60)	147.17±12.93[b]	3.33±0.12[a]	8.80±0.84[a]	27.45±0.84[c]	3.12±0.23[a]	4.75±1.09[d]	12.64±3.58[d]
Group 5 (61-70)	149.00±18.62[b]	3.23±0.74[a]	8.50±0.43[a]	30.10±0.66[d]	3.07±0.33[a]	3.33±1.38[e]	8.66±1.95[e]

Data represent mean±SD (n = 100). Mean values with different superscripts in a column are considered statistically significant (p < 0.05).

Table 2: Lipid profile and cardiac risk ratio of apparently healthy subjects based on age

Groups (Years)	Lipid profile concentrations (mmol/L)			CRR = [TC/HDL]
	TC	HDL	TAG	CRR
Group 1 (20-30)	3.40±0.09 [a]	2.37±0.06[a]	0.65±0.05[a]	1.43±1.50 [a]
Group 2 (31-40)	3.52±0.26[a]	1.98±0.18[a]	0.88±0.14[a]	1.78±1.44[a]
Group 3 (41-50)	3.97±0.13[a]	1.88±0.24[a]	1.10±0.75[a]	2.11±0.54[a]
Group 4 (51-60)	3.86±0.13[a]	1.85±0.18[a]	1.11±0.71[a]	2.09±0.72[a]
Group 5 (61-70)	4.22±0.42[a]	1.76±0.69[a]	0.83±0.15[a]	2.40±0.61[a]

Data represent mean±SD (n = 100). Mean values with different superscripts in a column are considered statistically significant (p < 0.05). n = total number of subjects.

Table 3: Sex hormone profiles, electrolyte indices, lipid profile and cardiac risk ratio

Biochemical parameters	Subjects based on sex differences	
	Male (n= 65)	Female (n= 35)
Testosterone (nmol/L)	18.86±2.53[a]	6.65±2.46[b]
Oestradiol (nmol/L)	16.27±1.59[b]	38.21±1.30[a]
Sodium ion (Na$^+$) (mEq/L)	131.47±5.55[b]	141.24±6.98[a]
Potassium ion (K$^+$) (mEq/L)	3.50±0.12[a]	3.50±0.18[a]
Calcium ion (Ca$^+$) (mEq/L)	9.46±0.35[a]	8.59±0.40[a]
Bicarbonate ion (HCO$_3^-$) (mEq/L)	24.64±0.68[a]	25.41±0.81[a]
Inorganic phosphate (Pi) (mEq/L)	2.52±0.09[a]	2.94±0.13[a]
Total cholesterol (TC) (mmol/L)	3.87±0.08[a]	3.73±0.10[b]
High density lipoprotein (HDL) (mmol/L)	1.50±0.07[a]	1.76±0.13[b]
Triacylglycerol (TAG) (mmol/L)	0.75±0.05[a]	0.96±0.06[b]
CRR = [TC/HDL]	2.58±1.14[a]	2.12±0.77a

Data represent mean±SD. Mean values with different superscripts in a row are considered statistically significant (p < 0.05). n= number of subjects in a group

Sex Hormone, Electrolyte Indices, Lipid Profile and Cardiac Risk Ratio of the Subjects Based on Sex Differences: The mean concentration of testosterone (nmol/l) based on sex differences was 18.86±2.53 for male subjects and 6.65±2.46 for female subjects while oestradiol (nmol/l) was 16.27±1.59 for male subjects and 38.21±1.30 for female subjects. Comparing the trends of mean concentrations of hormonal profile and serum electrolyte parameters across sex differences, the mean testosterone level in male subjects was significantly (p < 0.05) higher than that in female subjects while the mean oestradiol level of female subjects was significantly (p < 0.05) higher

in female subjects than male subjects (Table 3). The mean concentrations of sodium and inorganic phosphate in female subjects were significantly (p < 0.05) higher than that of male subjects while the mean calcium concentrations in male subjects were significantly (p < 0.05) higher than that of female subjects. There was no significant (p > 0.05) difference between the mean concentration of potassium and bicarbonate across the rows (Table 3). The total cholesterol concentration (mmol/L) in male subjects (3.87±0.08) was significantly (p < 0.05) higher than that in female subjects (3.73±0.10). On the other hand, the TAG concentration (mmol/L) in female subjects (0.96±0.06) was significantly (p < 0.05) higher than that in male subjects (0.75±0.05) and the HDL concentration (mmol/L) in female subjects (1.76±0.13) was significantly (p < 0.05) higher than that in male subjects (1.50±0.07). The cardiac risk ratio (CRR) of male subjects (2.58±1.14) was non-significantly (p > 0.05) higher than that in female subjects (2.12±0.77).

Correlation Coefficients among the Studied Parameters: The correlation coefficients of the studied parameters are shown in Table 4. There was a non-significant (p > 0.05) positive correlation between HDL and total testosterone concentrations (r= 0.184) and between HDL concentration and oestradiol (r= 0.042). There was a significant (p < 0.05) negative correlation between total cholesterol and total testosterone concentrations (r= -0.219) and a non-significant (p > 0.05) negative correlation between total cholesterol concentration and oestradiol (r= -0.052).

Table 4: Correlation coefficients among the parameters studied

	Testosterone	Oestradiol
Sodium ion	-0.730	0.094
Potassium ion	0.233	-0.281
Calcium ion	-0.-89	-0.020
Bicarbonate	-0.313	-0.023
Inorganic phosphate	-0.089	0.058
Total cholesterol	-0.219	-0.052
High density lipoprotein (HDL)	0.180	0.042
Triacylglycerol (TAG)	-0.083	-0.033
Cardiac risk ratio (CRR)	-0.542	-0.328

Values are correlation coefficient (r) between the two parameters correlated.

There was a non-significant ($p > 0.05$) negative correlation between TAG concentration and testosterone ($r = -0.083$) and between TAG concentration and oestradiol ($r = -0.033$) (Table 4). The results revealed that bicarbonate, sodium, calcium and inorganic phosphate correlated positively with age, while potassium correlated negatively with age. Similarly, there were significant negative correlation among sodium, calcium, inorganic phosphate and bicarbonate and testosterone whereas, potassium correlated positively with testosterone. The result also showed that oestradiol correlated positively with sodium and bicarbonate whereas it correlated negatively with potassium, calcium and inorganic phosphate.

DISCUSION

This study was conducted to determine the relationship between sex hormone status, lipid profile and electrolyte indices in apparently-healthy middle-aged subjects in Enugu State, Nigeria. Results from the present study revealed that the mean testosterone concentration (nmol/L) of male subjects (18.86±2.53) was significantly higher than that of the female subjects (6.65±4.46). The study also found a decrease in total testosterone with increase in age. This result is similar to the findings of Salvatore *et al*. [36] who reported that testosterone decreases as one age. Decrease in testosterone level with age is associated with an increase in risk of cardiovascular disease, erectile dysfunction, depression, mood changes, low bone density, diabetes and obesity [37]. Testosterone is a hormone that plays a key role in modulating sexual drive, carbohydrate, fat and protein metabolism and has major influence on body fat composition and muscle mass in males. Thus, a decrease in testosterone with age as observed in this present study can be linked to high risk of type 2 diabetes, hypogonadism, erectile dysfunction and metabolic syndrome factors such as increased fat mass, reduced insulin sensitivity, impaired glucose tolerance and dyslipidaemia contributing to cardiovascular risk common to older persons [38, 39].

The mean oestradiol concentration (nmol/L) in female subjects (38.21±8.30) was significantly ($p<0.05$) higher than that in male subjects (16.28±1.59). Also, the level of oestradiol decreased with increase in age. Similar results were obtained by Feldman *et al*., [40]. Oestradiol decrease in older women has been linked to an increase in sodium concentration and the resultant high blood pressure [25]. Low oestrogen level has been implicated as a risk factor to fragile bones and dysmenorrhea [41], reproductive system disorders like polyps, fibroids, endometriosis and arthritis, type-2 diabetes, obesity and heart disease [42]. Oestradiol is the most potent oestrogen and the predominant form circulating in the body from menarche to menopause; it stimulates regeneration of damaged neurons and production of neurotransmitters [43]. Decrease in level of oetradiol with increase in age as observed in this study affects the hypothalamus, leading to the decrease in serotonin, acetylcholine and dopamine, whereas norepinephrine increases. These events are linked to menopause and andropause status seen in older women and men respectively. Electrolytes conduct an electric current, balance body pH and acid-base levels, facilitates the passage of fluid between and within cells through a process known as osmosis and further plays a role in regulating the function of the neuromuscular, endocrine and excretory systems [44]. The concentration of electrolytes in the body depends on adequate intake of nutrients, proper absorption of nutrients by the intestines, proper kidney and lung functions; hormones also help to control electrolyte concentrations [45]. The results obtained from the electrolyte indices in this study revealed that bicarbonate, sodium, calcium and inorganic phosphate correlated positively with age, while potassium correlated negatively with age. Similarly, there were significant negative correlation among sodium, calcium, inorganic phosphate and bicarbonate and testosterone whereas, potassium correlated positively with testosterone. The result also showed that oestradiol correlated positively with sodium and bicarbonate whereas it correlated negatively with potassium, calcium and inorganic phosphate. These findings agree with the trends reported by Pechere-Bertschi and Burnier [25] which showed that serum concentration of sodium correlated inversely with oestradiol. The effects of testosterone and oestradiol on sodium can be linked with the regulation of sodium concentration, mediated by rennin-angiotensin II system and the regulation of aldosterone activity by oestradiol. Hypernatremia arises when the serum sodium concentration exceeds 145 mmol/l [46]. Serum sodium concentration of subjects above 50

years of age was shown to be higher than 145 mmol/l. The implication of this hypernatremia can be linked to diabetes insipidus, kidney disease, aldosteronism, increased blood volume and blood pressure [46]. Determination of serum concentration of bicarbonate has been used in the diagnosis and treatment of disorders associated with acid-base imbalance in the respiratory and metabolic systems such as diarrhea, renal tubular acidosis, carbonic anhydrase inhibitors, hyperkalemic acidosis, renal failure and ketoacidosis [34]. Recent studies have shown that the decrease in oestradiol leads to the high risk of coronary heart disease, stroke, malignancies, dementia and osteoporosis (also caused by low calcium, low vitamin D and lack of exercise, which affects bone density). Osteopenia and osteoporosis have been linked to the degeneration of ovaries resulting in diminished oestradiol levels [47].

Ferrini and Barrett-Connor [48] earlier reported that serum concentration of testosterone decreases with increase in age, as found in the present study. Testosterone is the primary sex hormone in males that plays a key role in modulating sexual drive, carbohydrate, fat and protein metabolism and has major influence on body fat composition and muscle mass in males [49]. The level of testosterone is generally under the control of hypothalamic-pituitary-gonadal axis. Several factors affect the levels of testosterone in individuals such age, diet, lifestyle (high intake of alcohol and opioids and other drugs) and health status [50]. Decrease in testosterone with age as observed in this present study can be linked to high risk of type 2 diabetes, hypogonadism, erectile dysfunction and metabolic syndrome factors contributing to cardiovascular risk common to older persons [51]. Serum concentration of testosterone in female subjects was lower than that in male subjects. This agrees with the view of Graces *et al.* [52] who stated that sex hormone levels vary with sex (gender). Similarly, the levels of oestradiol were found to decrease with increase in age from the present study. Oestradiol is the most potent oestrogen and the predominant form circulating in the body from menarche to menopause; it stimulates regeneration of damaged neurons and production of neurotransmitters. Decreased level of oetradiol as age increases may affect the hypothalamus leading to the decrease in serotonin, acetylcholine and dopamine, whereas norepinephrine increase; these events are linked to menopause and andropause status seen in older women and men respectively and also a decrease in HDL levels in apparently-healthy persons. Low levels of sex hormones have been attributed to the development of

important diseases primarily as regards to infertility and secondarily to diseases such as type II diabetes, cancers and cardiovascular diseases [53], renal dysfunction and neuropathies of different kinds seen in elderly [54, 55]. Graces *et al.* [52] postulated that sex hormone levels vary with sex (gender). This is in line with the results of the present study which found that the level of total testosterone was significantly ($p < 0.05$) higher in male subjects than in female subjects while the level of oestradiol was significantly ($p < 0.05$) higher in female subjects than in male subjects.

From the result of the present study, the mean total cholesterol concentration increases non-significantly ($p > 0.05$) with increase in age and significantly ($p < 0.05$) higher in male subjects than in female subjects. This finding is consistent with the work of Igweh *et al.* [56] who showed that total cholesterol concentration decreases with age and varies with sex. This may be due to some biochemical changes in the body make up of individuals with age and may hence explain the sex differences in the prevalence metabolic syndrome and cardiovascular diseases [57]. The levels TAG non-significantly ($p > 0.05$) increase with increase in age. The possible significance of this finding is that the risk of cardiovascular diseases, coronary heart disease, diabetes mellitus and obesity increases as individuals advance in age. Also, serum concentration of TAG was observed to vary with sex; the female subjects have higher mean TAG values than the male subjects. These observations followed the same trend proposed by Hongbao [58], who said that TAG concentration vary with age and sex. The serum HDL concentration decreased with increase in age. This is in accordance with the findings of Haring *et al.* [10] which showed that in normal persons, serum HDL concentration decreases with increase in age. Individuals with low concentration of serum HDL are at higher risk of developing of atherosclerosis, hypertension and oxidative stress since HDL has anti-atherosclerotic and anti-oxidative properties [59]. The present study shows that HDL concentration varies with sex; female subjects having higher HDL concentration than the male subjects. A similar result was reported by Page *et al.* [60] who showed that females have higher levels of HDL concentration than men.

Serum TAG concentration from the present study correlated inversely with HDL, oestradiol and testosterone. The result of the present study is in line with the findings of Graces *et al.* [52], which showed that individuals with high serum TAG concentration have higher risk of infertility and other diseases such as

cardiovascular diseases and neuropathies of different kinds. This indicates that individuals with high serum concentration of TAG and low serum concentrations of testosterone, oestradiol and HDL may have higher risk of developing type II diabetes and free radical-induced oxidative damage [61]. Another implication of this finding is that the brain cells of the females may lose neuroprotection and cardioprotection against lipid peroxidation as they age, as well as an increase in risk of developing osteoporosis and diabetic renal disease easily as they advance in age, which could be attributed to the reduction in levels of antioxidant status as oestradiol level decreases. Also, results from the present study showed that HDL concentration decreases with decrease in testosterone concentration, whereas testosterone concentration decreases with increase in mean values of TAG. These findings are in line with Page *et al.* [60] who reported that HDL and testosterone are positively correlated. Morrison *et al.* [62] also showed that as testosterone levels increase between the ages of 10-15 years, serum lipid concentration reduces in normal adult males. Oestradiol was observed to decrease with increasing TAG concentration. This is similar to the findings of Maric and Sullivan [63], who indicated the oestrogen and TAG concentrations are inversely correlated. Both total testosterone and oestradiol correlated negatively with cardiac risk ration, further supporting the earlier hypothesis that decrease in levels of theses sex hormones increase the risk of cardiovascular diseases associated with dyslipidaemia.

CONCLUSIONS

Serum sodium, calcium, inorganic phosphate and bicarbonate ions concentrations correlated negatively with testosterone while potassium ion concentration correlated positively with testosterone. Oestradiol correlated negatively with potassium and calcium ions and inorganic phosphate while it correlated positively with sodium and bicarbonate. The findings of this study suggest that sodium and bicarbonate analyses may be indirect markers of hypogonadism and other steroid dysfunction. Also, it is now evident from the results of this study that sex hormones associate with body lipid profile. Serum HDL concentration positively associates with testosterone and oestradiol. Conversely, total cholesterol and triacylglycerols correlate inversely with testosterone and oestradiol. Therefore, this study provides the link between serum lipid profile and sex hormones and this could suggest the roles of sex hormones in the development of lipid-related diseases.

Limitation of the Study: The major limitation of this study is the relatively small sample size, which might raise questions whether this study was adequately powered for some of the analyses. However, the study has pointed out that there is an association of sex hormone status, lipid profile and electrolyte indices in apparently-healthy middle-aged subjects.

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