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Puberty and nutritional status in adolescents

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Abstract

Malnutrition is a leading cause of decreased school performance and an array of conditions, including delayed puberty. This study was conducted to assess the nutritional status and the serum testosterone, estradiol and prolactin levels in secondary school students aged 11-16 years. A total of 176 secondary school students within Calabar metropolis participated in this study of which 49.4% were male and 50.6% were female. The pubertal status—puberche, thelarche and menarche of the subjects were documented. Nutritional status was determined using standardized technique for anthropometry and WHO Anthroplus software. Sex hormone levels were assayed using ELISA. Statistical analysis was done using SPSS. Analysis of the results showed that 51% of the boys exhibited some degree of pubarche compared to 47.2% of the females. Thelarche and menarche were exhibited by 73% and 49.4% of girls respectively. A comparison of age, anthropometric indices, prolactin, estradiol and testosterone in male and female subjects in the study showed that girls had significantly higher body mass index ($p = 0.023$), estradiol ($p = 0.0001$) and prolactin ($p=0.007$) but significantly lowered testosterone ($p=0.0001$) compared to their male counterparts. There was however, no statistical significant difference ($p>0.05$) in the mean height and weight of both groups. The nutritional status in the study showed that 3.4% of the adolescents were stunted, 6.8% were wasting, 89.2% were normal, 3.4% were overweight while 0.6% were obese. The boys and girls had comparable frequencies of stunting, thinness/wasting, normal, overweight and obesity. Five adolescent girls and seven adolescent boys showed predisposition to delayed puberty. Poor nutritional status and low sex hormones were found to be predisposing factors for delayed puberty, and more male were so disposed.

Keywords: Puberty; Adolescent; Boys; Hormone; Testosterone

1. Introduction

Puberty is the process of physical change through which a child's body matures into an adult body capable of sexual reproduction. Notable among the morphological changes include changes in size, shape, composition and functioning of the pubertal body. There is also the development of secondary sex characteristics of pubarche, thelarche and menarche [1]. Puberty is described as delayed with exceptions when an individual had passed the usual age of onset of puberty with no physical or hormonal evidence that puberty has begun [2]. Menarche is the first occurrence of menstral bleeding in female humans. It signals the possibility of fertility. Thelarche is the onset of secondary breast development which

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often represents the beginning of puberty. Puberche refers to the first appearance of pubic hair at puberty. Testosterone, estradiol and prolactin, among others, are important hormones produced in humans. They have been implicated in reproduction and development of sexual characteristics including attainment of puberty. The serum levels of prolactin, estradiol, progesterone and testosterone, among others, have been implicated in prompt attainment, precocious puberty and delayed puberty [3].

Adequate food and nutrition are essential for proper growth and physical development. This enhances optimal work capacity, normal reproductive performance, adequate immune response and resistance to infections. Inadequate diet may produce severe forms of malnutrition in children and adolescents [4]. Nutritional status of an adolescent is an important factor in the initiation of puberty. Many conditions of precocious puberty are traceable/related to our nutrition while many conditions of delayed puberty can be extrapolated to under-nutrition.

Anthropometric indices can be a sensitive indicator of health, growth and development in infants, children and adolescents. Anthropometry is the single most universally applicable inexpensive and non-invasive method available to access the size, proportion and composition of human body [6]. Hence, with the aid of WHO Anthroplus software a researcher can monitor children's weight as they grow older (individual assessment module) and also analyse survey data including preschool, school age children and adolescents (Nutritional survey module).Thus, WHO Anthroplus facilitates the detection of thinness, underweight, overweight and obesity in individuals and population from 0-19 years old. This software derives nutritional status in z-scores for the indicators weight-for-age (up to 10 years of age), height-for-age and BMI-for-age (up to 19 years) [6].

2. Subjects, Materials and Methods

2.1. Study population

A cross sectional study design was employed in which a total of one hundred and seventy-six apparently healthy residents of Calabar metropolis aged eleven (11) to sixteen (16) years old, attending various secondary schools in Calabar were enrolled in this study. Both male and female subjects were involved in the study. Informed consent was obtained from both the authorities in the schools attended by the students and the parents/guardians of the students involved. Ethical clearance for the work was obtained from the Cross River State Ethics Committee.

2.2. Sample collection

Five millilitres (5 ml) of blood was aseptically drawn with minimum static from a prominent vein into a plain sample container. The blood samples were allowed to clot, and was centrifuged at 2500 rpm for 5 minutes. The resultant sera were collected into plain bottles. The sera were stored frozen until analysis was performed. Estimation of prolactin, estradiol and testosterone were carried out using the ELISA.

2.3. Estimation of nutritional status

The nutritional status of the subjects was derived by the application of WHO Anthroplus Software, using the anthropometric parameters age, height, weight and BMI.

3. Results

A total of 176 school children participated in this study of which 49.4% were male (boys) and 50.6% were female (girls) (Table 1). About 51% of the boys exhibited some degree of pubarche compared to 47.2% of the females. Thelarche and menarche were exhibited by 73% and 49.4% of girls respectively. Table 2 shows a comparison of age, anthropometric indices, prolactin, estradiol, testosterone in male and female adolescents in the study. The boys had significantly higher body mass index ($p=0.023$) and testosterone ($p=0.0001$) but had significantly lower prolactin ($p=0.007$) and estradiol ($p = 0.0001$) when compared to the girls. There was however, no significant difference ($p>0.05$) in the mean height and weight of both groups. The nutritional status of adolescents in the study is shown in Table 3. Only 3.4% of the adolescents were stunted and 10.8% malnourished. The boys and girls had comparable frequencies of stunting, thinness/wasting, normal, overweight, obesity and malnutrition as there were no significant differences in the parameters between the groups as shown in Table 4.

Table 5 shows a comparison of anthropometric indices, prolactin, estradiol, testosterone between boys and girls aged 11-13 years. The girls had significantly higher height ($p=0.022$) and estradiol ($p=0.0001$) but significantly lower testosterone ($p=0.0001$) compared to the boys. While in table 6, the girls aged 14 – 16 years had significantly higher

body mass index (p=0.003), prolactin (p=0.001) and estradiol (p=0.0001) but significantly lower height (p=0.004) and testosterone (p=0.0001) compared to the boys of the same age range.

Table 1 Sex, age and pubertal characteristic distribution of the subjects in the study

Group		n (%)	Pubertal characteristics		
			Pubarche n (%)	Thelarche n (%)	Menarche n (%)
Male Age groups	11	10 (11.4)	0(0.0)	-	-
	12	15 (17.2)	2(2.3)	-	-
	13	15 (17.2)	2(2.3)	-	-
	14	16 (18.3)	12(13.8)	-	-
	15	16(18.3)	13(14.9)	-	-
	16	15 (17.2)	15(17.2)	-	-
Total		87 (100)	44 (50.6)	-	-
Female Age groups	11	13 (14.6)	0(0.0)	3(3.4)	1(1.1)
	12	14 (15.7)	2(2.2)	8(9.0)	0(0.0)
	13	15 (16.9)	5(5.6)	12(13.5)	6(6.7)
	14	14 (15.7)	5(5.6)	11(12.4)	6(6.7)
	15	15 (16.9)	13(14.6)	14(15.7)	14(15.7)
	16	18(20.2)	17(19.1)	17(19.1)	17(19.1)
Total		89 (100)	42 (47.2)	65(73.0)	44(49.4)

Table 2 Comparison of age, anthropometric indices, prolactin, estradiol and testosterone in male and female subjects

Parameters	Boys n =87	Girls n= 89	Calc. t	Crit. T	p-value
Age (years)	13.7±1.64	13.7±1.73	0.059	1.96	0.953
Weight (Kg)	44.1±10.76	45.8±9.91	1.051	1.96	0.295
Height (m)	1.57±0.12	1.56±0.08	0.527	1.96	0.599
Body mass index (Kg/m^2)	17.7±2.32	18.6±2.88	2.291	1.96	0.023
Prolactin (ng/ml)	10.3±10.00	14.6±10.49	2.749	1.96	0.007
Estradiol (pg/ml)	32.1±14.31	61.2±28.56	8.578	1.96	0.0001
Testosterone (ng/ml)	2.9±1.55	0.99±0.65	10.725	1.96	0.0001

Results expressed as Mean ±SD significant at p<0.05

Table 7 shows that there was a significant positive correlation between BMI-for-age z-score and estradiol (r=0.372; p=0.0001) in the boys. Table 8 reveals in the girls' group that, there was a significant positive correlation between BMI-for-age z-score and prolactin (r=0.228; p=0.032) and estradiol (r=0.513; p=0.0001). There were no significant correlations between height-for-age z-score and any of the sex hormones in any of the groups.

Table 9 shows mean age testosterone and nutritional status of male subjects aged 14-16 years with and without pubarche. Seven male subjects (8.0%) were found to be without pubarche. The same subjects had low testosterone and poor nutritional status presentation. These were considered predisposed to delayed puberty. Table 10 shows mean

estradiol and nutritional status of female subjects with and without menarche and thelarche. Five female subjects (5.6%) were found to be without thelarche and menarche. These same subjects had low level of estradiol and poor nutritional status presentation.

Table 3 Nutritional status and the percentage distribution of the subjects based on WHO Anthroplus

Nutritional Status	Percentage distribution (N=176)n (%)
Stunting	6 (3.4)
Thinness/wasting	12 (6.8)
Normal	157 (89.2)
Overweight	6 (3.4)
Obesity	1 (0.6)
Malnutrition (BMI- for -age)	19 (10.8)

Table 4 Comparison of nutritional status of adolescents in the study based on WHO Anthroplus

Nutritional Status	Percentage distributionn (%)		χ^2	p-value
	Boysn=87	Girlsn=89		
Stunting	4(4.6)	2(2.2)	0.770	0.380
Thinness/wasting	7(8.0)	5(5.6)	0.398	0.528
Normal	76 (87.4)	81(91.0)	0.589	0.443
Overweight	3(3.4)	3(3.4)	0.000	1.000
Obesity	1 (1.1)	0 (0)	0.979	0.323
Malnutrition (BMI-for-age)	11(12.6)	8(5.0)	0.459	0.498

Significant at $p<0.05$

Table 5 Comparison of age, anthropometric indices, prolactin, estradiol, testosterone between boys and girls aged 11-13 years

Parameters	Boys 11-13 yearsn =40	Girls 11-13 yearsn= 42	Calc. t	Crit. T	p-value
Weight (Kg)	36.8±6.65	39.7±8.87	1.661	1.96	0.101
Height (m)	1.49±0.08	1.53±0.09	2.341	1.96	0.022*
Body mass index (Kg/m^2)	16.7±1.95	16.9±2.33	0.518	1.96	0.606
Prolactin (ng/ml)	10.7±13.69	13.4±11.6	0.973	1.96	0.333
Estradiol (pg/ml)	22.1±8.75	40.4±16.88	6.193	1.96	0.0001*
Testosterone (ng/ml)	1.7±0.90	0.7±0.44	6.512	1.96	0.0001*

Results expressed as Mean ±SD; *significant at $p<0.05$

Table 6 Comparison of age, anthropometric indices, prolactin, estradiol, testosterone between boys and girls aged 14-16 years

Parameters	Boys 14-16 yearsn =47	Girls 14-16 yearsn= 47	Calc. t	Crit. T	p-value
Weight (Kg)	50.4±9.62	51.2±7.31	0.483	1.96	0.630
Height (m)	1.65±0.10	1.60±0.05	2.972	1.96	0.004*
Body mass index (Kg/m^2)	18.5±2.28	20.1±2.49	3.109	1.96	0.003*
Prolactin (ng/ml)	10.1±5.30	15.7±9.37	3.567	1.96	0.001*
Estradiol (pg/ml)	40.5±12.62	79.7±23.65	10.033	1.96	0.0001*
Testosterone (ng/ml)	3.9±1.24	1.2±0.72	12.849	1.96	0.0001*

Results expressed as Mean ±SD; *significant at p<0.05

Table 7 Correlation of nutritional z-scores with sex hormones in boys

ParameterN=87	Index	r-value	p-value
BMI-for-age z-score	Prolactin	-0.157	0.147
	Estradiol	0.372	0.0001*
	Testosterone	0.095	0.382
Height-for-age z-score	Prolactin	-0.194	0.072
	Estradiol	-0.060	0.578
	Testosterone	0.192	0.074

*Significant at p<0.05

Table 8 Correlation of nutritional z-scores with sex hormones in girls

Parameter	Index	r-value	p-value
BMI-for-age z-score	Prolactin	0.228	0.032*
	Estradiol	0.513	0.0001*
	Testosterone	0.175	0.101
Height-for-age z-score	Prolactin	0.051	0.637
	Estradiol	-0.074	0.488
	Testosterone	0.112	0.295

*Significant at p<0.05

Table 9 Mean age, testosterone and nutritional status of male subjects aged 14 – 16 years with and without puberche

Parameters	Puberchen =47	No Puberchen= 7	Calc. t	Crit. T	p-value
Age	15.1±1.92	14.4±1.41	0.783	1.96	0.830
Testosterone	4.0±1.25	2.1±1.03	2.972	1.96	0.004*
Thinnes	0	4	14.033	1.96	0.0001*
Normal	40	3	92.849	1.96	0.0001*

Note: 7 (8.0%) of the male subjects predisposed to delayed puberty; *Significant at p<0.05

Table 10 Mean age, estradiol and nutritional status of female subjects age 14 - 16 years with and without thelarche and menarche

Parameters	Thelarche, Menarche n =47	No Thelarche and Menarche n= 5	Calc. t	Crit. T	p-value
Age	15.1±1.98	14.6±1.42	0.687	1.96	0.630
Estradiol (pg/ml)	80.2±23.78	45.07±23.65	2.972	1.96	0.004*
Thinness	1	4	10.033	1.96	0.0001*
Normal	41	1	112.849	1.96	0.0001*

Note: 5 (5.6%) of the female subjects predisposed to delayed puberty; *Significant at p<0.05

4. Discussion

The serum level of sex hormones and the presence or absence of pubertal characteristics of menarche, thelarche and pubarche are important indicators of puberty. Low serum level of sex hormones, as well as absence of pubertal characteristics by age 14 is usually associated with delayed puberty.

In this study about 51% of the boys exhibited some degree of pubarche compared to 47.2% of the females. Thelarche and menarche were exhibited by 73% and 49.4% of girls respectively. It is possible to deduce from this study that puberty in a girl roughly follows the order thelarche, menarche and pubarche [2].

The higher level of estradiol and prolactin, in the girls compared to boys, on the one hand, and higher levels of testosterone in boys compared to the girls, on the other, showed that estradiol and prolactin are more specific and related to female pubertal maturity while testosterone is more specific for male pubertal maturity [7].

The difference in hormonal levels between male and female reflects the adolescent range of the hormones within the puberty window [8], and the pre pubertal levels of these hormones are not so discriminatory [3].

Three of the 14 years old female subjects, one of the 15 years old female, and one of the 16 years old female were lacking in thelarche and menarche (Table 1). The same five female subjects also had mean estradiol of about 45 pg/ml compared to 80.2 pg/ml of the females with thelarche and menarche, and they exhibited thinness, which is a measure of degree of malnutrition according to their z – scores in the nutritional survey. These were considered predisposed to delayed puberty, representing 5.6% of the female population (Table 10).

A corresponding assessment of the 14 to 16 years old males showed that there were seven adolescent males without pubarche with mean testosterone value of 2.1 ng/ml compared to 4.0 ng/ml of the male subjects with puberche, and they also exhibited thinness, which is a measure of degree of malnutrition. This represents 8.0% of male subjects. These were considered predisposed to delayed puberty (Table 9).

This finding is consistent with a definition of delayed puberty which is a lack of hormonal and physical signs of puberty by age 14 [2]. More adolescent male than female subjects showed predisposition to delayed puberty.

The nutritional status of the subjects in this study showed that about 10.8% of the adolescents were malnourished. This is lower than what Amuta and Houmsou reported—(50.6%) in school age children 6-17 years in slum parts of Makurdi, Benue state, Nigeria [9, 19]. A related study by Medhi, Barua and Mahanta of school age children (6-14) in Assam-India, a developing country like Nigeria, found 53.9% of the children undernourished [10, 20].

However, the rate of malnutrition in the present study is similar to what Ahmed *et al*. reported in a similar study in Bangladesh among adolescent subjects, where they recorded 16.00% [11]. The lower prevalence of under-nutrition recorded in older children may be due to the fact that these children can pick up food without much parental care.

Most works done on nutritional status were on children under five years of age. According to the Nigerian Demographic and Health Survey, the percentage of stunting in Nigerian children less than five years declined from 41% in 2008 to 37% in 2013 [12]. However, the percentage of children who are wasted increased from 14% in 2008 to 18% in 2013 [12]. This indicates an ongoing nutritional deprivation among Nigerian children. This deprivation, if continued can be extrapolated to poor secondary sexual characteristics development and delayed puberty in the future.

The frequency of stunting, thinness/wasting, normal, overweight, obesity and under-nutrition in this study showed no significant difference between boys and girls. Some studies have found significant difference in the level of under-nutrition between boys and girls [9,11,14].

Another significant finding in this study is the display of growth spurt. During puberty, the female exhibits early growth spurt, attaining heights above their male counterpart. As observed in this study, in the first half of the age range (11-13 years old), females had significant higher height compared to the age-matched boys. But in the later half (14-16 years old), the boys had overtaken the girls in height. Growth spurt is driven by estradiol [13].

The significantly higher BMI in females compared to the males in the latter half of the puberty window also gives credence to the early growth spurt in females as against late onset and long-lasting growth spurt in males [13].

There was a significant positive correlation between BMI-for-age z-score and estradiol in both boys and girls. This reinforces the assertion that it is estradiol that drives the pubertal growth spurt [16].

5. Conclusion

According to WHO, the ultimate intention of nutritional assessment is to improve human health. Malnutrition, which refers to impairment of health either from a deficiency, excess or imbalance of nutrients, is of public health significance among children all over the world [14]. Critical to normal development of puberty in adolescents are proper nutritional and hormonal levels. These control many bodily functions including growth, and development of secondary characteristics associated with puberty [15].

Compliance with ethical standards

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Disclosure of conflict of interest

Authors have declared that no competing interest exists.

Statement of informed consent

Informed consent was obtained from all participants reported in the study.

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