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CHANGES OF TOTAL BODY WATER DURING ADOLESCENT GROWTH

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Abstract: Total body water was determined on 26 boys and 21 girls and on 40 boys and 45 girls attending Junior and Senior High Schools, resp. The same volunteers were studied for a period of 3 years. Approximately 10 ml of D_2O (99.8%) was given orally and urine samples taken 3 and 4 hours after equilibration period were used for determination of the ratio of heavy hydrogen to normal hydrogen by mass spectrometry according to the procedure described by Solomon et al. (1950). Total body water was calculated as proposed by Schloerb et al. (1950).

The height of boys aged 12 to 13 years increased from 159.1 cm to 177.7 cm at age 17 and 18 years. The girls' height changed from 158.5 cm to 165.7 cm, resp. Similarly, the weight of boys increased concomitantly from 49.4 kg to 66.1 kg whereas the girls' weight increased from 49.0 kg to 58.3 kg, resp.

Total body water of boys aged 12 to 13 years and expressed in absolute values increased from 31.9 liters to 43.3 liters determined in boys 17 to 18 years old. Similar changes of smaller magnitude occurred in girls where TBW of 29.0 liters to 31.9 liters was determined during the same period of time. In relative terms, TBW of boys increased slightly from 62.1% to 65.9% which was reached at the age of 15 to 16 years and then a slight decrease to 64.2% was found in boys 17 to 18 years old. The girls showed continuous decrease in relative values of TBW from 60.3% to 53.6% during the same period of time.

Regression equations with correlation coefficients provided evidence about linear relationship of TBW with weight in boys (r=0.92) and similarly in girls (r=0.77) with the smallest standard deviations of 2.7 liters and 2.1 liters in boys and girls, resp.

Key words: Total body water, Height, Weight, Adolescent boys and girls.

Introduction

During the past three decades, studies of body composition have enhanced greatly the understanding of tissue changes which occur during human growth. Most particularly, the periods of growth, during which the growth velocity changes rapidly, are holding specific attention of most researchers. The first two years of postnatal life and the adolescent period are the prime examples of major growth changes which, under influences of various hormones, provide fascinating scenario for investigations into the intricate maze of body tissue variations.

Total body water is the largest compartment of the body. Fat-free mass seems to hold 73% of water approximately while body fat is practically anhydrous (Brožek 1963). Consequently, the changes of fat-free body and body fat will be reflected in changes to total body water. This relationship has been documented in adults of both sexes (Steele et al. 1950, Edelman et al. 1952, Moore et al. 1963). However, changes of total body water in children and in adolescents have been documented sparingly (Friis-Hansen 1956, Novak 1966, Mellits and Cheek 1968).

This study was designed to enhance understanding of adolescent period as far as lean tissues are concerned in both sexes, using total body water as the variable which would demonstrate variations in the ratio of lean to fat tissue with advancing years during adolescent growth spurt.

Subjects and Methods

The subjects for this study included 59 twelve year old boys and 59 twelve year old girls from junior high school and 40 fifteen year old boys and 45 fifteen year old girls from senior high school. The ages are as of the beginning of the study. All subjects were studied for three consecutive years. They were healthy and of a middle-class socio-economic background. The subjects were given orally one gram of D_2O (99.8%) per kg of body weight, with an additional 100 ml of tap water. After the equilibration period of D_2O to normal water elapsed (±two hours), the subjects emptied their bladders. Then two urine samples at three and four hours were collected and aliquots analyzed for the ratio of hydrogen from D_2O to hydrogen of the H_2O by mass spectrometry. The calculations of volume distribution of total body water was done according to the procedure suggested by Schloerb et al. (1950).

Results

The means for heights of the boys and girls are presented in Table 1. These mean values for both sexes correspond well, to the 50th percentile, of the standards compiled by Stewart and Meredith (1946) for American children. The velocity curve for height of boys provided us with the usual magnitude of height increase as the boys advanced in age, i.e. an increase of 7.3 cm, 5.3 cm, 3.4 cm and 1.4 cm, respectively. Thus, the possible maximal increase in height or peak velocity between ages 12 to 13 years was documented. Decrease in height velocity thereafter occurred.

Table 1. Heights and Weights of Adolescent Boys and Girls

Age (years)	N	Height (cm) Mean	S.D.	Weight (kg) Mean	S.D.
		BOYS			
12–13	59	159.1	±8.2	49.4	±10.8
13–14	59	166.8	±8.7	55.2	±11.3
14–15	54	172.1	±8.0	60.1	±11.0
15–16	40	172.9	±8.7	59.4	±9.8
16–17	40	176.3	±7.3	62.8	±8.7
17–18	40	177.7	±7.0	66.1	±9.0
		GIRLS			
12–13	59	159.6	±5.1	49.0	±8.3
13–14	59	162.5	±5.0	52.7	±8.4
14–15	57	164.4	±5.3	55.2	±8.4
15–16	45	164.6	±5.5	56.3	±8.2
16–17	44	165.5	±5.7	56.7	±8.3
17–18	43	165.7	±5.7	58.3	±8.3

On the other hand, in the girls the end of peak height velocity was demonstrated with the height increase of 2.9 cm between ages 12 to 13 years and smaller height additions of 1.9 cm, 0.9 cm, and 0.2 cm, which occurred as the girls advanced in age.

Another interesting and well-known fact was documented when the mean heights of 12 to 13 year old boys and girls were compared. The heights of both sexes at that age were nearly identical. However, after that age, the later spurts in height of boys in subsequent years showed much greater gains as compared to girls.

As far as the weights of boys and girls are concerned, practically the same weights in both sexes were obtained at the age of 12 to 13 years. From that age onwards. the velocity weight curve showed that boys gained 5.8 kg, 4.9 kg, 3.4 kg, and 3.3 kg respectively, as they grew older. On the other hand, the girls showed less of an increase in their weights by 3.7 kg, 3.5 kg, 0.4 kg, and 1.6 kg in subsequent years. The means of vital signs of adolescent boys and girls are shown in Table 2. The heart rates showed a decreasing trend from age 12 to 13 years in both sexes. The heart rate of boys decreased from 74 beats/minute to 62 beats/minute and that of girls from 81 beats/minute to 66 beats/minute, respectively. The slightly higher heart rates of females as compared to males are well-known. Similarly, when the means of the respiratory rates were compared, the girls seemed to have slightly higher breathing rates throughout the age groups.

Table 2. Vital Signs of Adolescent Boys and Girls

Age (years)	N	Pulse Rate/min.		Resp. Rate/min.		Systolic B.P.		Diastolic B.P.	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
				BOYS					
12–13	59	73.8	± 9.6	15	±2.9	108	±11.1	58	±9.2
13–14	59	68.1	± 9.0	14	±3.4	109	±12.0	63	±7.1
14–15	54	64.8	± 8.8	14	±3.3	109	±9.8	63	±7.1
15–16	40	66.2	± 10.5	14	±2.9	110	±10.4	64	±8.4
16–17	40	63.7	± 8.6	14	±2.4	109	±8.8	63	±6.3
17–18	40	62.3	± 9.0	13	±2.3	112	±9.9	67	±9.1
				GIRLS					
12–13	59	80.9	± 10.2	16	±2.7	107	±10.3	61	±9.9
13–14	59	76.1	± 10.1	16	±2.7	105	±9.1	62	±7.3
14–15	57	70.7	± 10.3	15	±3.0	105	±9.0	62	±7.3
15–16	45	73.2	± 11.4	15	±2.4	108	±8.9	64	±7.6
16–17	44	68.1	± 10.7	15	±2.5	104	±7.8	64	±7.1
17–18	43	65.9	± 8.6	15	±2.4	106	±7.9	64	±8.4

The means of blood pressure in boys indicated the well-known trend of continuously increasing blood pressure with age, both in systolic and diastolic blood pressure. Conversely, the blood pressure of girls remained practically unchanged between the ages of 12 to 18 years.

The mean values of total body water in absolute and relative terms are presented in Table 3. The velocity curve for total body water of boys showed the magnitude of increases corresponding to height increases. Thus, the gain in total body water from the age of 12 to 18 years amounted to 4.4 liters, 3.1 liters, 1.8 liters, and 1.5 liters, respectively. Again, the peak velocity of total body water seemed to occur in boys between ages 12 to 13 years and decreasing velocity occurred thereafter.

As far as the girls were concerned, the only increases in total body water of 2.2 liters was noted between ages 12 to 13 years. From that age onwards the mean values of total body water of girls remained unchanged with advanced age.

Sex differences of total body water expressed in absolute values were observed in all age groups. Boys had significantly higher amounts of total body water which varied from 2.9 liters difference at age 12 to 13 years which increased to 5.1 liters, 7.8 liters, 9.6 liters and eventually to 11.3 liters difference between the oldest group of boys and girls.

Table 3. Total Body Water of Adolescent Boys and Girls

Age (years)	N	Liters Mean	S.D.	Percent Mean	S.D.
		BOYS			
12–13	59	31.9	±5.9	62.1	±6.0
13–14	59	36.3	±5.9	63.5	±6.4
14–15	54	39.4	±5.6	64.0	±5.2
15–16	40	39.0	±5.9	65.9	±3.4
16–17	40	40.8	±5.3	65.1	±3.1
17–18	40	42.3	±5.2	64.2	±3.1
		GIRLS			
12–13	59	29.0	±3.5	60.3	±6.1
13–14	59	31.2	±4.1	59.4	±4.9
14–15	57	31.6	±3.8	58.1	±4.7
15–16	45	31.3	±3.8	56.0	±4.5
16–17	44	31.2	±3.6	55.2	±4.1
17–18	43	31.0	±3.3	53.6	±4.0

The relative mean values of total body water provides an indication about tissue changes which affect the percentage of water as growth advances through adolescent years. At the age group 12 to 13 years the deuterium oxide space – TBW – reached 62.1% and increased up to 64.0% in boys aged 14 to 15 years. Slightly higher percentages around 65.0% were noted in the Senior High School boys and a small decrease to 64.2% was observed in the boys 17 to 18 years. This decrease in total body water coincides with known slight increase in body fat during this age as boys advance towards biological maturity.

The relative mean values of total body water of adolescent girls provided evidence about continuous decreasing trend with age from 60.3% observed at age 12 to 13 years to 53.6% of total body water of girls 17 to 18 years old.

The relationship between total body water in liters and age, height, weight was examined for both sexes using quadratic, cubic, and straight-line approach. The results of appropriate regression equations and correlation coefficients are presented in Table 4.

Table 4. Relationship of Total Body Water to Age, Height, Weight

Regression Equation	Mean	TBW, L	Sy. x	r	P-Value
	BOYS				
TBW, L = 12.008 + 1.65 (Age)	15.85	38.4	6.14	0.43	<.001
TBW, L = –67.819 + 0.616 (Height)	172.5	38.4	3.86	0.82	<.001
TBW, L = 4.264 + 0.572 (Weight)	59.68	38.4	2.73	0.92	<.001
	GIRLS				
TBW, L = 30.40 + 0.023 (Age)	15.96	30.8	3.28	0.01	N.S.
TBW, L = –19.401 + 0.308 (Height)	162.8	30.8	2.85	0.49	<.001
TBW, L = 15.276 + 0.283 (Weight)	54.74	30.8	2.09	0.77	<.001

The best relationship between total body water with highest coefficients of correlation and the smallest standard error of estimate was reached with weight in both sexes, namely

r equal to 0.92 and standard error of 2.73 liters for boys and r equal to 0.77 with standard error of 2.09 liters for girls, respectively. Significant differences of total body water with respect to the slopes of the boys' and girls' regression lines were determined by analysis of covariance.

Discussion

According to the results of this study, adolescent boys showed higher hydration of the body as compared to girls of the same age group. Only in the early adolescent years, namely those between 12 to 13 years, did the relative amount of total body water approach that of the boys, i.e. 60.3% compared to 62.1%, respectively. From that age onwards, the boys increased their relative body water content continuously to over 65.5% as they progressed toward maturity. The opposite trend was noticed in girls, namely a decrease in total body water from 60.3% to 53.6%. These changes seem to coincide with growth spurts of various tissues which differ in their hydration. As testosterone triggers accelerated growth of skeletal muscle mass in boys and estrogens stimulate deposits of fat in girls, invariably, body water starts changing because lean tissues hold approximately 73% of water while body fat seems to be nearly anhydrous. Therefore, a spurt of muscle mass in adolescent boys was reflected in an increase of body water in boys and a decrease in body water percentage-wise in girls reflected increased body fat.

The absolute as well as the relative values of total body water obtained from this study correspond well with those of Friis-Hansen (1956). The cited denterium oxide spaces of boys aged 12 to 15 years ranged from 54.8 to 63.2%. Hunt and Heald (1963) reported relative water contents of boys 12 to 17 years which ranged from 61.4% to 64.9%. And last but not least, Mellits and Check (1968) applied profound statistical analysis of two intersecting regression lines to combined data of investigators mentioned previously. Their statistical technique provided evidence that a spurt of lean tissues of different magnitudes is revealed when body water is plotted against height. The point of intersection in boys (137.2 cm) and in girls (113.0 cm) indicates that within 95% of confidence limits around these height values, changes in hydration occur due to a spurt of fat-free mass and, in particular, that of muscle mass. In this study, the velocity of the lean tissues spurt was demonstrated well in boys, while in girls, only the end of lean tissues spurt was detected. It would be necessary to include younger groups of girls to be able to provide the entire velocity curve of body water coinciding with growth spurt during adolescent period. Such study is in progress.

These changes of body tissues during adolescent years were also demonstrated previously by Novak (1963), Hunt and Heald (1963), or by Pařízková (1961). Densitometric, biochemical and/or anthropometric approaches to document profound changes in body composition during this interesting period of human growth were used. All these methods, applied to adolescent boys and girls, yielded information about increasing body density, creatinine excretion and corrected diameters of lean tissue in boys while the opposite trends were documented in girls of the same age. Thus, the results of this study elucidated further changes in body compartments which occurred during adolescence and, in particular, new knowledge of hydration of adolescent body in both sexes was obtained in this semilongitudinal study.

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