Assessment of basic body measurements during puberty

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Since calendar age does not always correspond to the biological age of the individual, in many cases the assessment of children's and adolescents' physical develompent based solely on their calendar age can be wrong. The aim of this paper is to demonstrate how biological age may affect the basic body measurements in a population of equal calendar age.

The following measures, routinely used in practice, have been considered: height (stature), weight, weight/height ratio, and thoracic circumference. The degree of sexual maturation (onset of puberty in girls and boys, and menarche) has been employed as a criterion of biological age. Each age-group was subdivided into three categories: with early, average and late sexual development. Subject of examination were girls, age 8 to 18 and boys, age 11 to 18.

Appreciable differences, namely earlier physical development, are seen in children with early puberty compared with the remaining children of the same age. These differences exist in girls as early as 8.5 years of age, and in boys - at age 11.5. The mean differences between the two opposite categories (i.e. early and late puberty) reach their peak at age 11.5 - 12.5 in girls, and age 14.5 in boys. The differences are impressive: in stature about 14 cm in girls and 16 cm in boys, in weight - 21 and 22 kg and in thoracic circumference - 10 and 13 cm , respectively. Since pace of growth varies, by the age 14.5 the mean stature of girls of all categories is already equal. The same is observed in 16.5 year old boys. At age 17.5 girls who have experienced late menarche are the tallest and those with early menarche are of the shortest stature.

In contrast to stature absolute and relative weights, and thoracic circumferences remain greater in the early puberty categories of both sexes. The observation is in accordance with the somatotype of the individuals: early puberty occurs usually in endomorphs, late puberty - in ectomorphs.

The described dramatic changes in body measurements during the growth period are clearly related to different stages of sexual maturation. Therefore, to avoid gross errors in the assessment of body development, it is necessary to apply standards which consider not only the calendar, but also the biological age of children and adolescents.

For best results, the hereditary factor and social environment should be considered as well.

Key words: age, puberty, body measurements.

The calendar age of children and adolescents during puberty often does not correspond to their biological age, i.e. to their maturation. For this reason, the assessments of their physical development based solely on normative charts (standards) and accounting only for the individuals' calendar age is rather inaccurate in many cases. Such an assessment is valid only for adolescents whose development is average for their age (when their calendar age coincides with their biological age).

The aim of this paper is to demonstrate the effect of biological age on the basic body measurements in a population of equal calendar age.

The following basic body measures have been considered: height (stature), weight, relative weight, and thoracic circumference. The study is semi-longitudinal and includes boys (ages 8-18) and girls (ages 11-18) from Sofia. Each group comprises 80 - 130 individuals. The degree of sexual maturation (onset of puberty and menarche) has been employed as a criterion of the biological age. Each age-group was subdivided into three categories: with early, average and late sexual development. The younger age groups were divided into two categories: children with early sexual development and children who had not reach puberty. Menarche was the criterion for girls over 15 years of age.

Results and Discussion

Height

Girls between the ages of 8.5 to 12.5 with different onset of puberty demonstrate appreciable differences in height (Table 1, Fig.1). Between the ages of 8.5 and 10.5 those with early puberty were taller than their pre-pubescent peers by an average of 6-7 cm. The mean difference between the two categories (i.e. early and late puberty) reaches its peak at the age of 11.5 years-14 cm, while at the age of 12.5 it is 11 cm. The differences at the age of 13.5 years are already small. The stature curves cross between the ages of 13.5 and 14.5. After the age of 14.5 the girls who have experi-

T a b l e 1. Height of girls with different onset of puberty

Age, years	Category	Height, cm
8.5	Early	137.2
	Pre-Pubescent	131.0
9.5	Early	143.9
	Pre-Pubescent	137.2
10.5	Early	146.7
	Pre-Pubescent	140.7
11.5	Early	158.0
	Average	151.8
	Late	143.9
12.5	Early	160.2
	Average	156.2
	Late	149.5
13.5	Early	159.6
	Average	158.0
	Late	157.2
4.5	Early	160.3
	Average	160.1
	Late	160.1
15.5	Early	159.4
	Average	161.3
	Late	161.8
16.5	Early	160.1
	Average	162.3
	Late	163.1
17.5	Early	160.7
	Average	162.5
	Late	164.4

T a b l e 2. Height of boys with different onset of puberty

Age, years	Category	Height, cm
11.5	Early	155.0
	Pre-Pubescent	147.1
12.5	Early	162.3
	Pre-Pubescent	150.4
13.5	Early	170.1
	Average	161.5
	Late	154.8
14.5	Early	175.9
	Average	166.9
	Late	160.2
15.5	Early	176.6
	Average	174.2
	Late	170.0
16.5	Early	177.4
	Average	176.1
	Late	176.9
17.5	Early	177.7
	Average	177.1
	Late	176.9

enced a late menarche are the tallest and those with early menarche are with the shortest stature. At the age of 17.5 the mean difference in stature between the two opposite categories is approximately 4 cm. Keeping in mind the pace of development in the different categories of girls, it can be expected that the difference between their definitive statures will increase in the following years.

The above differences in stature in girls' categories of biological maturation are also seen in boys (Table 2, Fig 2). Moreover, in boys they are even greater: At the ages of 11.5 and 12.5 boys with early puberty are 8 cm taller than their pre-pubescent peers. At the ages of 13.5 and 14.5 the mean difference between boys with early and late puberty reaches its peak - approximately 15-16 cm. The difference decreases sharply during the following year and is approximately 6.5 cm. At the age of 16.5 boys of the three categories have already reached almost the same stature.

The above-mentioned data show that the different onset of puberty in children of the same calendar age leads to significant differences in stature during puberty. For instance, 12.5-year-old girls and 14.5-year-old boys with early puberty correspond to the mean stature of adolescents who are one to two years older. The reverse is also the true: the stature of adolescents with a late onset of puberty is almost the same as that of children who are one year younger. Therefore, during a certain period of time, children with early puberty look, with respect of their stature, about 3 years older than their peers with late puberty. During the following years, due to the different pace of development (Fig. 3), stature of the different categories becomes comparable. Later, the reverse phenomenon has been observed: girls with a late onset of puberty became taller than their peers. No crossing of the stature curves in boys has been observed until 17.5 years of age. However, the above-described phenomena of increased stature among girls with different onset of puberty are also observed among boys, only 2-3 years old. It is logical to assume, therefore, that the final stature of boys with different onset of puberty will follow the pattern set by the girls.

In conclusion, the tallest definitive stature can be expected from adolescents who are tall for their calendar age and have late biological development. The shortest
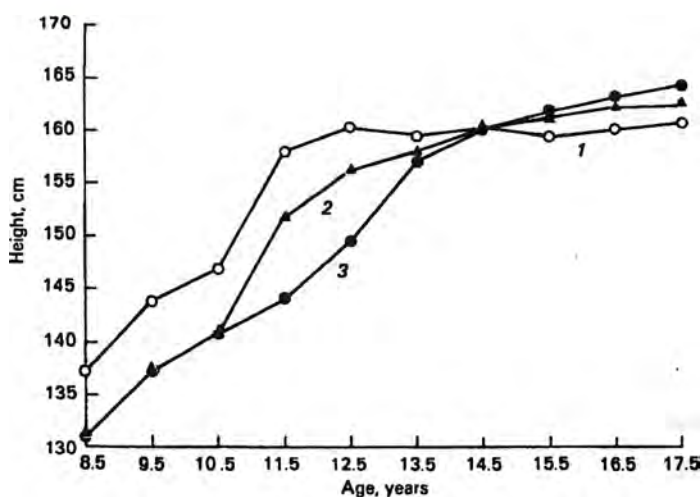

Fig. 1. Height of girls with different onset of puberty
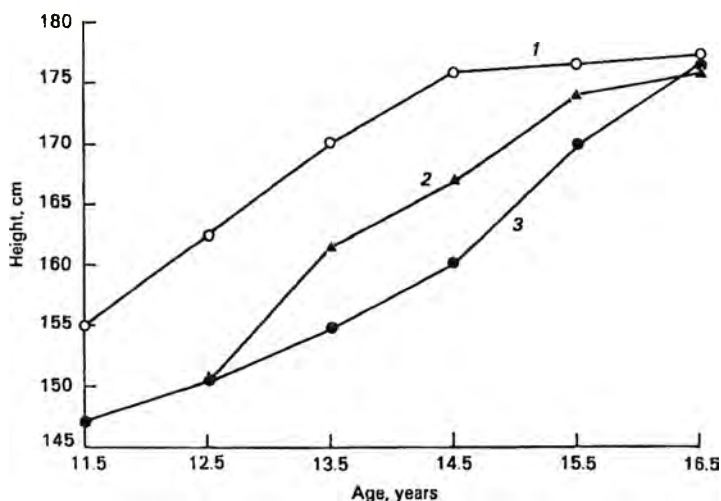*1* — nearly puberty; *2* — average puberty; *3* — late puberty

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Fig. 2. Height of boys with different onset of puberty
Designations as on Fig. 1

definitive stature is to be expected from children with a short stature and advanced physical maturation. Age and stature being equal, children with the latest sexual development will be the tallest because they have the greatest growth potential. This has been proven in our previous longitudinal studies (Angelov, G.: PRAXIS, 61, 27, Bern, Suisse, 1972).

In its turn, stature can be used to predict the onset of puberty and the menarche. One cannot expect, except in rare cases, an early onset of puberty among children with a short stature for their calendar age, or the opposite - late puberty in children with tall stature.

Body Weight

Like stature, body weight is closely related to the individuals biological age. Adolescents with an early onset of puberty have body weight which is very high for their age. For instance, the mean body weight of girls 8.5 years of age with early puberty corresponds to the mean weight of 10.5-year-old pre-pubescent girls (Table 3). Girls with early puberty, at 11.5 and 12.5 years of age weigh as much as those within the average category, age 15.5 and 16.5. respectively. The opposite phenomenon is observed among girls with late puberty: they lag behind by 1.5-2 years compared with the average weight for their age. Thus, from the onset of puberty until the age of 14.5 body weight depends much less on calendar age than on sexual maturation. For instance, it is normal for a 12.5-year-old girl to weigh 58, 48 or 36 kg, depending on whether she has an early, average or late development of puberty. Similar differences exist among boys, but they are less strong: plus or minus 1.5-2 years (Table 4). Differences in weight gradually decrease: in girls after 13 years of age and in boys - after 15 years of age. The reason is the faster increase of stature among adolescents with average or late puberty, which leads to an increase in body weight. And yet, unlike stature, the different categories did not reach equal weight until the end of our study. This is due to the different typologies of the puberty groups: endomorphic and endo-mesomorphic types reach early puberty, while ectomorphic and ecto-mesomorphic children reach late puberty.

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Table 3. Weight and relative weight of girls with different onset of puberty

Age, years	Category	Weight, kg	Relative weight: Height / $\sqrt[3]{\text{Weight}}$
8.5	Early	36.6	41.4
	Pre-Pubesecnt	28.9	42.4
9.5	Early	40.5	42.1
	Pre-Pubescent	32.6	43.0
10.5	Early	42.2	42.5
	Pre-Pubescent	33.9	43.5
11.5	Early	54.9	41.8
	Average	43.0	43.5
	Late	35.2	44.1
12.5	Early	57.8	41.4
	Average	47.8	43.2
	Late	36.4	44.8
13.5	Early	57.4	41.2
	Average	51.4	42.4
	Late	43.9	44.6
14.5	Early	58.7	41.3
	Average	54.7	42.2
	Late	49.5	43.9
15.5	Early	58.8	41.2
	Average	55.2	42.5
	Late	53.9	43.0
16.5	Early	59.5	41.1
	Average	56.9	42.4
	Late	56.1	42.7
17.5	Early	58.4	41.6
	Average	56.3	42.6
	Late	56.8	42.9

Table 4. Weight and relative weigth of boys with different onset of puberty

Age, years	Category	Weight, kg	Relative weight: Height / $\sqrt[3]{\text{Weight}}$
11.5	Early	51.0	42.1
	Pre-Pubescent	40.5	43.1
12.5	Early	54.1	42.7
	Pre-Pubescent	42.1	42.3
13.5	Early	60.7	43.4
	Average	50.8	43.8
	Late	43.3	44.0
14.5	Early	67.5	43.3
	Average	54.9	44.0
	Late	45.7	45.0
15.5	Early	69.7	42.9
	Average	62.1	43.8
	Late	58.0	44.0
16.5	Early	70.5	43.1
	Average	65.6	43.8
	Late	63.8	44.3
17.5	Early	73.5	42.5
	Average	69.9	43.1
	Late	68.0	43.4

Body weight, like stature, can be used to predict the onset of puberty: children whose body weight is low for their age cannot be expected to experience an early sexual development. The opposite is also true: if body weight is high, puberty comes late only in rare cases.

Relative Weight

Sexual maturation correlates not only with absolute stature and weight, but also with the ratio between them. Adolescents with early puberty have normally a high average weight, more rarely - mean average weight, and only as an exception - low average weight. The opposite is observed among children with late puberty. As with body weight, here too, a major role is played by the typology of the different categories. With girls, the correlation is persistent throughout the entire period in observation (Table 3). With boys, the correlation is somewhat more complicated (Table 4). Boys with early puberty have initially higher relative weight than their coevals. This correlation temporarily disappears (around 12.5 - 13.5 years), after which appears again. This can be explained by the fact that boys with an early puberty are the first to increase in their stature. Their subcutaneous tissue, typical of the pre-puberty period, is reduced earlier. During the following years these two phenomena appear in boys with average and late puberty. It is only then,

Table 5. Thoracic circumferencee in girls with different onset of puberty

Age, years	Category	Thoracic Circumference, cm
8.5	Early	65.9
	Pre-Pubescent	60.3
9.5	Early	68.6
	Pre-Pubescent	63.3
10.5	Early	69.0
	Pre-Pubescent	63.9
11.5	Early	74.0
	Average	68.0
	Late	64.4
12.5	Early	75.2
	Average	70.6
	Late	64.4
13.5	Early	74.6
	Average	71.6
	Late	67.5
14.5	Early	74.9
	Average	72.6
	Late	69.3
15.5	Early	76.4
	Average	73.2
	Late	73.3
16.5	Early	75.8
	Average	73.4
	Late	73.3
17.5	Early	74.5
	Average	72.7
	Late	73.3

Table 6. Thoracic circumference in boys with different onset of puberty

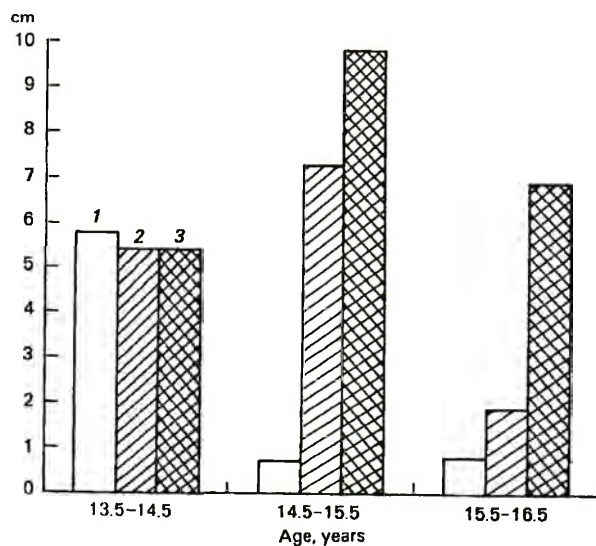| Age, years	Category	Thoracic Circumference, cm
11.5	Early	76.3
	Pre-Pubescent	69.9
12.5	Early	79.0
	Pre-Pubescent	72.1
13.5	Early	82.3
	Average	76.3
	Late	71.9
14.5	Early	84.0
	Average	78.6
	Late	71.3
15.5	Early	87.8
	Average	83.8
	Late	79.9
16.5	Early	88.9
	Average	85.2
	Late	84.2
17.5	Early	89.3
	Average	86.4
	Late	85.3

Fig. 3. Boys: Annual increase of the height (by puberty categories) Designations as on Fig. 1

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after the changes in the latter categories have ended, that the definitive differences between the three categories are established, which correspond to their typologies and are similar to those before the onset of the pubescent period.

Thoracic Circumference (Tables 5 and 6)

Thoracic circumference shows appreciable differences among adolescents with early and late sexual development. Children with early puberty have greater circumference that those with average puberty, while those with late puberty have the smallest circumference. During the first half of the period in question these differences could be explained with both typology of the categories and the differences in stature. The persistence of the same correlation during the second half of the period, when the differences in stature disappear or even change inversely, can be related only to the typologies of the categories. In this respect, thoracic circumference can prove that the category with early puberty consists of endomorphic children, while those with the late puberty consist of ectomorphic children.

Summary and Conclusion

The differences in the onset of puberty among children of the same calendar age are the reason for the existence of appreciable differences in the basic body measurements of adolescents belonging to different categories of puberty. Height, body weight and thoracic circumference, as well as relative weight among children with early puberty, significantly exceed the mean average for the respective age and equal those of children who are 1 to 3 years older. The opposite is observed among children with late sexual development whose measures lag behind by one or more years. It becomes evident that during puberty the degree of biological development is a decisive factor determining the basic body measurements. Adolescents with early development reach very early stature, body weight and thoracic circumference which are close to the definitive ones: around the ages of 12 - 12.5 for girls and 14.5 - 15 for boys.

The results obtained bring about an important conclusion: The use of the same standards for adolescents of the same calendar age does not meet the requirements of the contemporary scientific approach for an assessment of the individuals physical measurements. Each calendar age needs to be assessed according to several standards corresponding to the categories of adolescents with different degrees of physical maturity. The lack of differentiated norms leads to gross errors in the assessment of body development, as well as in the predictions of future development. This applies to all cases when there is a dissociation between the calendar and biological age, especially when this dissociation is significant.

The assessment can be further elaborated if the hereditary factor and social environment are considered.

According to the data reported, the general body measurements can be used to predict the onset of puberty.

The correlation between the morphological type and development during the puberty which was established during previous studies (Angelov, G., 1972) was confirmed in the present investigation. During the first years of the second decade the determination of the morphological type should consider the fact that stature and body weight can lead to errors if they are not interpreted according to the stage of pubertal development.

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