# MORPHOLOGICAL AND QUANTITATIVE CHARACTERISTICS OF THE NORMAL APEXCARDIOGRAM IN CHILDHOOD

I. Daskalov

The apexcardiogram (AGG) is a graphic recording of the movements of the chest wall produced by the apex beat of the heart, and reflects the mechanical and hemodynamical changes mainly in the left half of the heart (6, 7, 10, 12, 16, 19, 25 and others). In the past few years a number of papers dedicated to apexcardiography (ACGP) have been published. Most of the authors point out its great clinical importance for the study both of the systolic and diastolic hemodynamics of heart activity in normal and pathological conditions (24, 15, 16, 20, 33, 10, 6, 1). In this country, Oreshkov (1965) was the first author reporting the results of studies in this field in adults (8, 9), and later on, systematic researches ihto the problem were undertaken by Kaponov (1970) (3, 4, 5).

It is the purpose of this paper 1) to study the morphological peculiarities of the normal ACG in childhood, 2) to submit a detailed quantitative assay of the individual ACG components, 3) to try to establish an eventual correlation between the data concerning the morphological and quantitative characteristics of ACG, and the age and sex of the children under review. We failed to come across similar studies in childhood in the medical literature surveyed.

## Material and method

For the purpose, a series of 100 healthy children, aged 3—14 years, without past history heart disease, were examined. The distribution of the case material according to sex and age is illustrated in Table 1. To eliminate dist

Table

**Number of Investigated Healthy Children, Distributed According to Sex and Age**

| Sex \ Age | 3—6 y. | 7—10 y. | 11—14 y. | Total |
|---|---|---|---|---|
| Boys | 16 | 18 | 16 | 50 |
| Girls | 16 | 17 | 17 | 50 |
| Total | 32 | 35 | 33 | 100 |

crete cardiovascular changes, blood pressure was measured in a ' electrocardiograms (ECG) using standard, unipolar and chest leads, ahotocardiograms (PCG) at 35, 70, 140 and 250 Hz, and carotisphygmograms (CSG) of the right carotid artery were also made.

ACG recordings were made with a three-channel apparatur Multiscriptor «Hellige», at speed of the tape movement 50 and 100 mm/sec, simultaneously with ECG (lead II) and PCG (70 Hz). Records were taken with the children in left semilateral recumbent position, at completed normal expiration and in breath-holding. A special pad with diameter 6 mm (designed by the author), fixed to a condensing «infraton» pulse-microphone, was used; the latter was attached by means of an elastic strap to the zone of maximal apex beat of the heart. The tracings were registered at optimal ACG amplitude ranging from 30 to 35 mm (a deformity of the curve is incurred above 40 mm). To prove the left chamber derivation of the ACG, a chest ECG lead from the site of ACG recording was used. A detailed description of the method and technique of ACGP in childhood was already made in a previous publication (2).

The results obtained were statistically elaborated according to the alternative and variational analysis, with calculation of the reliability intervals at significance level u=1.96 (p=O.05). An «Elka» electron conputor was employed in the statistical processing of data.

## Results and discussion

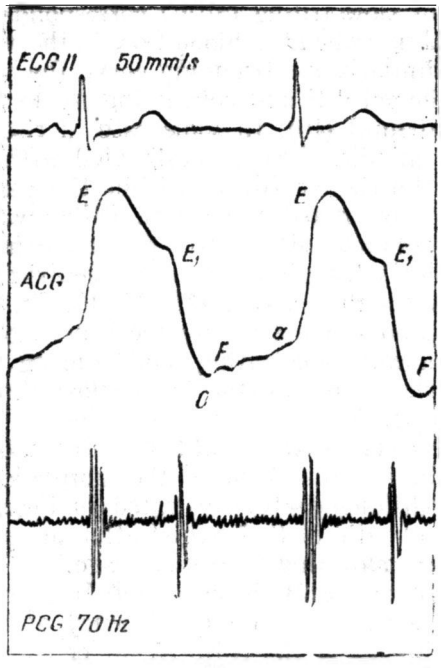
In the morphology of the normal ACG, four basic waves are distinguished — 1 systolic and 3 diastolic (1, 10, 15, 16). The systolic weve (SW) initiates with an abrupt rise and indicates the beginning of the ventricular contraction (point A) (32, 33). The steep curve terminates with an acute (15), or more frequently, rounded peak (27) designated with E (from ejection). It is assumed that the SW peak corresponds to the opening of the semilunar vavles (1, 10, 13, 16, 32, 33 etc). Using CSG and PCG, Oreshko vwas successful in submitting well argumented proofs (7, 28) that the aortic valves are opened shortly before the SW plak (about 30 msec before E); a fact confirmed by other authors to (5, 30, 31). After the peak, the curve usually displays a descending course (11, 15, 16), as an exception — horizontal or ascending (6), and towards the end of the SW a second peak ($E_1$) is formed indicating the end of ejection (11, 15, 26). In some instances, in the depression between the two peaks a small intermediate wave (IW) is registered with an upward convexity (8). After the second peak ($E_1$) the curve initiates its fall and ends in the lowermost point of the ACG — the point O (from opening) — marking the ventricular valves' opening (18, 20, 24, 26). In a number of cases, along the ascending arm of the SW supplementary vibrations ($N_1$), due to the mitral component of tone I, may be seen (11, 20, 24, 33), whereas along the descending arm, vibrations ($N_2$) due to the aortic component of tone II are detectable. The SW morphology thus outlined includes the following phases of the cardiac cycle: phase of isovolumetric contraction, phase of ejection, the protodiastole and the phase of isovolumetric relaxation (1, 3, 7). The ACG systolic wave is produced mainly by the heart motions related to muscle contraction and relaxation (accordingly, pressing of the apical area to the chest wall, stiffening of the myocardium, changes in form and volume of the heart, rotation and the like) (7, 19, 23, 25, 32).

The first diastole wave, called the rapid filling wave (RFW), marks the phase of initial, passive rapid filling of the ventricles subsequent to the opening of the atrioventricular valves. RFW starts from the point O, and following a steep upward rise, ends in the point F (from filling) (17, 20, 32, 34).

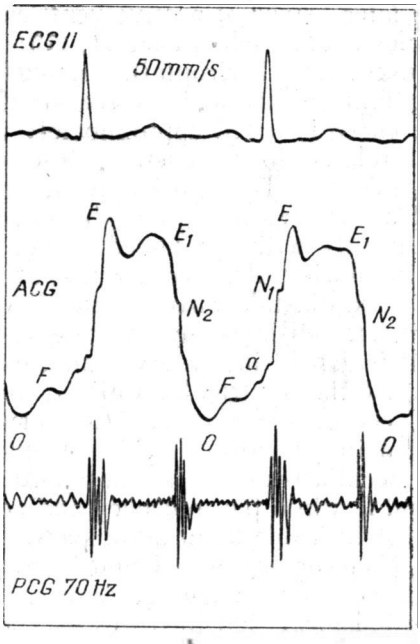
The second diastole wave, or the wave of slow filling (SFW) corresponds to the later stage of passive ventricular filling, when the blood flow in the ventricles is also reduced (8, 11, 20). It is similarly an ascending curve (by way of exception—horizontal), starting from the point F and continuing up to the beginning of the atrial wave «a» (from atrium) (16). In some cases a rise of the curve is noted approximalety in the middle of SFW, designated with F' and related to a somewhat intensified ventricular filling within the mesodiastole (8). The third diastole wave, denominated the active filling wave (AFW) or «a» wave (from atrium), represents a small positive deflection most frequently with a rounded shape. It reflects the phase of active ventricular filling during atrial contraction at the end of the diastole (11, 13, 17, 20, 21, 34). The diastole waves in the ACG are produced mainly by the heart movements, conditioned by the rate and volume of penetrating blood during the ventricular filling interval and, more particularly, by the blood flow thrust against the ventricular wall (7, 16, 20, 32).

The outlined above ACG curve, described by many authors, was established in virtually all children under examination. Some of the morphological peculiarities of the normal ACG in childhood are illustrated in Figures 1 and 2, while the frequency and percentual ratio of their registration are presented in Table 2, in a comparative study according to sex and age.

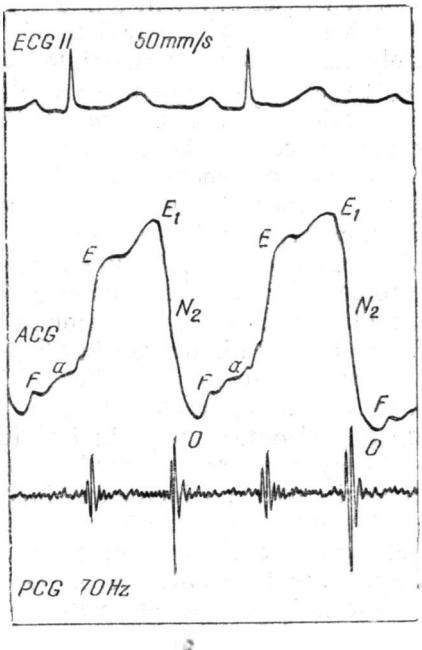
$N_1$ recordings were found in 56 per cent of the ACG performed. In a comparative study of the age groups, it is noteworthy that the frequency of this morphological sign increases parallel to the age of the children under examination, being more pronounced among girls. Acute E was established in 45 per cent, and rounded E — in 55 per cent, with the ratio similarly being variable in the different age groups, and practically manifested in boys and girls. A descending systolic plateau (E—$E_1$) was observed in 91 per cent, while a horizontal and an ascending one — in isolated cases only, in 5 and 4 per cent respectively. The descending systolic plateau was better registered in younger children and in boys. An adequately manifested intermediate systollic wave (IW) was discovered in 46 per cent; the incidence of this morphological sign became higher parallel to the reduction of age, and was better pronounced in the group of girls. Strongly pronounced $N_2$ weve recorded in 66 per cent of the cases, a fact suggesting a similar age dependence — an increase with the reduction of age, and similarly rather strongly pronounced among girls. An acute O was established in 57 per cent, and a flattened one — in 43 per cent. The impression is that the incidence of acute O is substantially increased with the fall of age, and is more readily recorded among girls, whereas the rounded O incidence decreases, and is recorded more frequently in boys. A tapered rapidly filling wave (RFW = F) was discovered in 85 per cent, and a rounded one — in 15 per cent, virtually equally manifested in the various groups of examined children. The ascending wave of slow filling (ASF) was recorded in 95 per cent, and a horizontal one — in isolated cases only (5 per cent), similarly failing to display a clearcul dependence on sex and age. F' wave was observed in 62 per cent, with its incidence increasing parallel to age, and better pronounced among boys. A rounded atriall wave «a» was established in 93 per cent, rather manifested in the younger children, and an acute one — in 7 per cent only, more frequently recorded in older children. The latter morphological characteristics of the «a» wave was equally manifested in boys and girls.




a

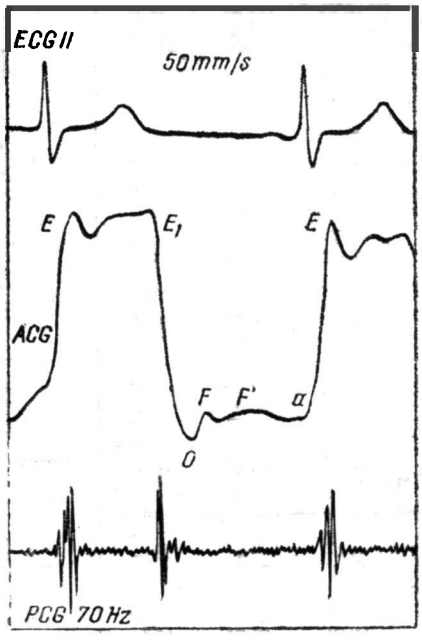



b

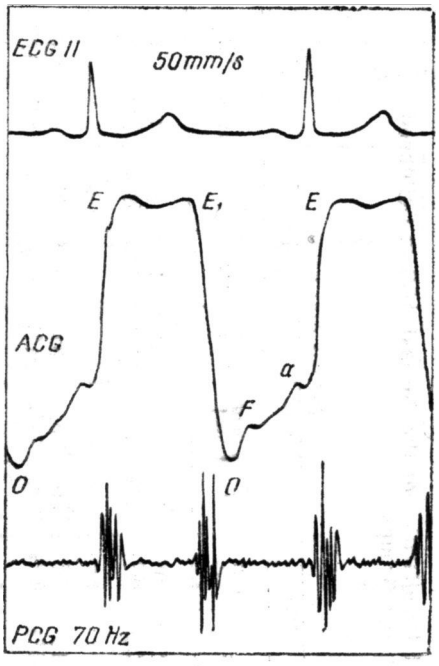



c

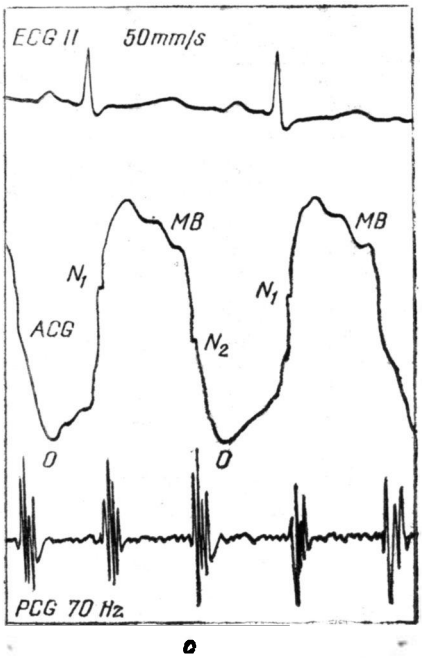
Fig. 1 a, b, ci. Some morphological peculiarities of the normal ACG in childhood: a) ACG recording of H. Zh. H., ♂, aged 7 years. Rounded E; descending systolic plateau E—$E_1$; weakly pronounced and flattened F and a waves; ascending F'wave. b) ACG recording of S.I.B. ♀, aged 4 years. Acute E; systolic depression E—$E_1$, well manifested $N_1$ and $N_2$; rounded F and a waves. c) ACG recording of D.D.Y., ♀, 10 years old. Rounded E; ascending systolic plateau E—$E_1$; well manifested and acute F wave; rounded a wave.




a




b




c

Fig. 2 a, b, c, i. Some morphological peculiarities of the normal ACG in childhood: a) ACG recording of L. I. B., ♂, aged 9 years. Acute E; well pronounced RFW; horizontal SFW. b) ACG recording of I. B. I., ♀, 13 years old. Horizontal systolic plateau E—$E_1$; well pronounced and rounded F and a waves. c) ACG recording of T. B. B., ♀, aged 10 years. Descending systolic plateau E—$E_1$; pronounced intermediate systolic wave IW; well manifested $N_1$ and $N_2$.

Table 2

**Incidence and Percentual Correlation of Some Morphological Peculiarities of the Normal ACG in Childhood, Distributed according to Sex and Age Groups**

| Age groups / Sex | Systolic ACG waves | | | | | | | | Diastolic ACG waves | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $N_1$ | E | | E — $E_1$ | | | IW | $N_2$ | O | | RFW | | SFW | | | a | |
| | | acute | rounded | descend. | horiz | ascend | | | acute | rounded | F | rounded | ascend | horiz | F' | acute | rounded |
| 3—6 y. n=32 | 13 67% | 17 53% | 15 47% | 31 97% | 1 3% | — — | 19* 59% | 23 72% | 23* 72% | 9* 28% | 28 87% | 4 13% | 31 97% | 1 3% | 17 53% | 1 3% | 31 97% |
| 7—10 y. n=35 | 22 63% | 16 46% | 19 54% | 30 86% | 2 6% | 3 8% | 16 46% | 24 69% | 19 54% | 16 46% | 30 86% | 5 14% | 33 94% | 2 6% | 22 63% | 2 6% | 33 94% |
| 11—14 y. n=33 | 21 64% | 12 36% | 21 64% | 30 91% | 2 6% | 1 3% | 11* 33% | 19 58% | 15 46% | 18* 54% | 27 82% | 6 18% | 31 94% | 2 6% | 23 70% | 4 12% | 29 88% |
| Boys n=50 | 26 52% | 22 44% | 28 56% | 48 96% | 1 2% | 1 2% | 20 40% | 31 62% | 26 52% | 24 48% | 44 88% | 6 12% | 48 96% | 2 4% | 34 68% | 2 4% | 48 96% |
| Girls n=50 | 30 60% | 23 46% | 27 54% | 43 86% | 4 8% | 3 6% | 26 52% | 35 70% | 31 62% | 19 38% | 41 82% | 9 18% | 47 94% | 3 6% | 28 56% | 5 10% | 45 90% |
| Total n=100 | 56 56% | 45 45% | 55 55% | 91 91% | 5 5% | 4 4% | 46 46% | 66 66% | 57 57% | 43 43% | 85 85% | 15 15% | 95 95% | 5 5% | 62 62% | 7 7% | 93 93% |

The above data warrant the assumption that the ACG curve morphology is influenced as much by the age, as by the sex of the examined children. Yet, the statistical processing of the results in our series of children (comparative study of the proportional values of the morphological signs by groups)

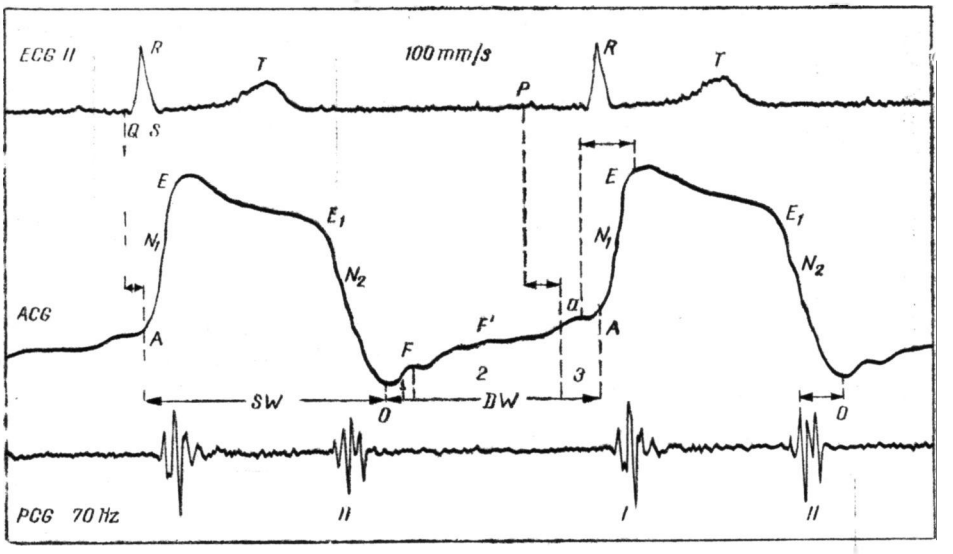



Fig. 3. ACG recording of Z. H. H., ♀, aged 6 years. Methods and markings of the measurement of separate ACG components: SW=systolic wave; DW=diastolic wave: 1. RFW=F=rapid filling wave; 2. SFW=F'=slowly filling wave; 3. AFW=a=active filling wave

shows that there are essential differences ($p<0.05$) only in terms of IW and morphology of the O point between the first and third age group. Hence the inference is reached that age and sex exert certain effect on the morphological peculiarities of the normal ACG, but it is statistically reliable relative to IW and point O only.

Along with the study of the morphological peculiarities of the ACG curve, we made it our aim to present a detailed quantitative assay of the normal ACG in childhood. Figure 3 shows the method and the designations of measurement of the individual ACG components, while Table 3 illustrates the averaged values of the duration of the intervals (in milliseconds), correlated to the sex and age groups of the children under study. The beginning (point A) of the systolic wave in ACG takes place at $26.30\pm1.49$ msec after the Q tooth in the ECG (Q — A interval), while the end (point O) — at $88.90\pm2.39$ msec following the main vibrations of tone II in the PCG (interval II—O). The SW duration is $416.10\pm8.08$ msec (interval A—O). Measured in this manner, SW includes in addition to the systolic phases, also two diastolic — the protodiastole and the isovolumetric relaxation phase. The duration of the RFW is $44.20\pm1.45$ msec (interval O—F), while the duration of the SFW is $187.40\pm18.48$ msec (interval F—a). The beginning of the atrial «a» wave is recorded within $98.50\pm2.67$ msec from the beginning of the P wave in ACG (interval P—a), and its duration is $45.40\pm2.18$ msec (interval a—A). The overall duration of the three diastolic waves (DW) is

Table 3

**Mean Values (in msec) of the Duration (Period) of the Intervals of the Individual Normal ACG Components in Childhood**

| Age groups / Sex | Statist. indices | Duration of the intervals (in msec) of the individual ACG components | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q—A | H—O | SW | RFW | SFW | P—a | a | a—E | DW | A—A |
| 3—6 y. n=32 | x | 24,69* | 80,00* | 395,00* | 43,75* | 128,75* | 97,50* | 40,63* | 107,50* | 213,13* | 608,13* |
| | s | 6,16 | 8,35 | 34,22 | 5,40 | 60,20 | 12,55 | 11,15 | 12,46 | 71,10 | 53,16 |
| | sx | 1,09 | 1,48 | 6,05 | 0,95 | 10,85 | 2,22 | 1,97 | 2,40 | 12,56 | 9,39 |
| | m | ±2,41 | ±2,90 | ±11,86 | ±1,86 | ±20,85 | ±4,35 | ±3,86 | ±4,31 | ±24,62 | ±18,40 |
| 7—10 y. n=35 | x | 24,57* | 91,43* | 412,86* | 41,43* | 200,29* | 96,00 | 43,14* | 113,14* | 284,86* | 697,71* |
| | s | 7,34 | 10,33 | 23,31 | 6,36 | 85,58 | 13,12 | 8,25 | 8,41 | 89,06 | 99,53 |
| | sx | 1,24 | 1,74 | 3,94 | 1,07 | 14,46 | 2,22 | 1,44 | 1,42 | 15,04 | 16,81 |
| | m | ±2,43 | ±3,41 | ±7,72 | ±2,10 | ±28,34 | ±4,35 | ±2,82 | ±2,78 | ±29,48 | ±32,95 |
| 11—14 y. n=33 | x | 29,70* | 94,85* | 441,82* | 47,58* | 230,61* | 102,12 | 52,42 | 129,09* | 330,61* | 772,42* |
| | s | 8,37 | 13,36 | 23,10 | 9,02 | 102,12 | 21,41 | 10,41 | 21,11 | 109,74 | 125,90 |
| | sx | 1,46 | 2,33 | 4,02 | 1,57 | 17,79 | 3,73 | 1,81 | 3,68 | 19,12 | 21,93 |
| | m | ±2,87 | ±4,57 | ±7,88 | ±3,08 | ±34,87 | ±7,31 | ±3,55 | ±7,21 | ±37,48 | ±42,98 |
| Boys n=50 | x | 25,20 | 87,20 | 417,60 | 44,60 | 204,00 | 98,00 | 47,40 | 117,60 | 296,00 | 713,60 |
| | s | 6,12 | 11,21 | 25,06 | 8,47 | 102,05 | 12,45 | 10,35 | 14,35 | 112,14 | 136,41 |
| | sx | 0,87 | 1,59 | 3,54 | 1,20 | 14,43 | 1,76 | 1,46 | 2,03 | 15,86 | 19,29 |
| | m | ±1,71 | ±3,12 | ±6,91 | ±2,35 | ±28,28 | ±3,45 | ±2,86 | ±3,98 | ±31,09 | ±37,81 |
| Girls n=50 | x | 27,40 | 90,60 | 414,60 | 43,80 | 170,80 | 99,00 | 43,40 | 115,60 | 258,00 | 672,60 |
| | s | 8,72 | 13,01 | 50,60 | 6,27 | 82,60 | 30,03 | 11,23 | 13,21 | 88,92 | 101,36 |
| | sx | 1,23 | 1,84 | 7,16 | 0,89 | 11,68 | 4,25 | 1,59 | 1,87 | 12,58 | 14,34 |
| | m | ±2,41 | ±3,61 | ±14,03 | ±1,47 | ±22,89 | ±8,33 | ±3,12 | ±3,67 | ±24,66 | ±28,11 |
| Total n=100 | x | 26,30 | 88,90 | 416,10 | 44,20 | 187,40 | 98,50 | 45,40 | 116,60 | 277,00 | 693,10 |
| | s | 7,55 | 12,21 | 41,20 | 7,43 | 94,32 | 16,60 | 11,11 | 13,56 | 102,48 | 121,32 |
| | sx | 0,76 | 1,22 | 4,12 | 0,74 | 9,43 | 1,66 | 1,11 | 1,36 | 10,25 | 12,13 |
| | m | ±1,49 | ±2,39 | ±8,08 | ±1,45 | ±18,48 | ±2,67 | ±2,18 | ±2,67 | ±20,09 | ±23,77 |

227.00±20.09 msec (interval O—A), and that of the complete ACG — 693.10± ±23.77 msec (interval A—A). Some authors (12) measure the so-called «a — E» interval (from the peak of the atrial «a» wave to the peak of SW and ACG). The duration of the latter interval in our studies is 116.60±2.67 msec.

All averaged numerical values of the individual ACG-curve components, accordingly correlated with the sex and age of the children under study, show varying degrees of difference. However, the statistical elaboration of the results proves that significant differences ($p<0.05$) are established only in the age groups where all the intervals are consistently lengthened parallel to the increase of the children's age, except for the P—a interval which remains practically unchanged (in Table 3 the statistically reliable differences are indicated with the mark*). The comparative study of the numerical data between boys and girls shows no statistically reliable difference ($p>0.05$). Thus, the inference may be reached that a direct relationship exists between age and duration of the ACG intervals, whereas there

Table 4

**Mean Values of Heart Rate and Arterial Blood Pressure of the Children under Investigation, Distributed According to Sex and Groups**

| Age groups / Sex | Statist. indices | Heart rate | Arterial blood pressure | |
|---|---|---|---|---|
| | | | S | D |
| 3—6 y. n=32 | $\bar{x}$ | 99,81* | 105,16* | 70,31* |
| | s | 13,68 | 6,41 | 8,20 |
| | $s_{\bar{x}}$ | 2,42 | 1,13 | 1,45 |
| | m | ±4,47 | ±2,21 | ±2,84 |
| 7—10 y. n=35 | $\bar{x}$ | 85,37* | 109,86* | 74,00* |
| | s | 12,46 | 7,60 | 6,65 |
| | $s_{\bar{x}}$ | 2,10 | 1,28 | 1,12 |
| | m | ±4,12 | ±2,51 | ±2,20 |
| 11—14 y. n=33 | $\bar{x}$ | 77,12* | 115,91* | 81,21* |
| | s | 12,09 | 24,26 | 8,38 |
| | $s_{\bar{x}}$ | 2,11 | 4.30 | 1,46 |
| | m | ±4,14 | ±8,43 | ±2,86 |
| Boys n= | $\bar{x}$ | 84,62 | 112,60* | 76,60 |
| | s | 12,15 | 9,36 | 8,37 |
| | $s_{\bar{x}}$ | 1,72 | 1,32 | 1,18 |
| | m | ±3,37 | ±2,57 | ±2,31 |
| Girls n=50 | $\bar{x}$ | 88,12 | 105,10* | 73,80 |
| | s | 16,18 | 22,34 | 9,34 |
| | $s_{\bar{x}}$ | 2,29 | 3,16 | 1,32 |
| | m | ±4,49 | ±6,19 | ±2,59 |
| Total n=100 | $\bar{x}$ | 87,27 | 110,35 | 75,20 |
| | s | 15,67 | 13,55 | 9,01 |
| | $s_{\bar{x}}$ | 1,57 | 1,36 | 0,90 |
| | m | ±3,08 | ±2,67 | ±1,76 |

* Marking the statisiically significant difference ($p < 0,05$) between the averaged numerical valucs in the comparatively studied groups.

is no such correlation between the sex and the above measurements. The age-related dependence might be explained by the anatomo-physiological characteristic features of the cardiovascular system in children and more particularly, by the heart rate and blood pressure values (both systolic and diastolic) which are different in the compared age groups (Table 4).

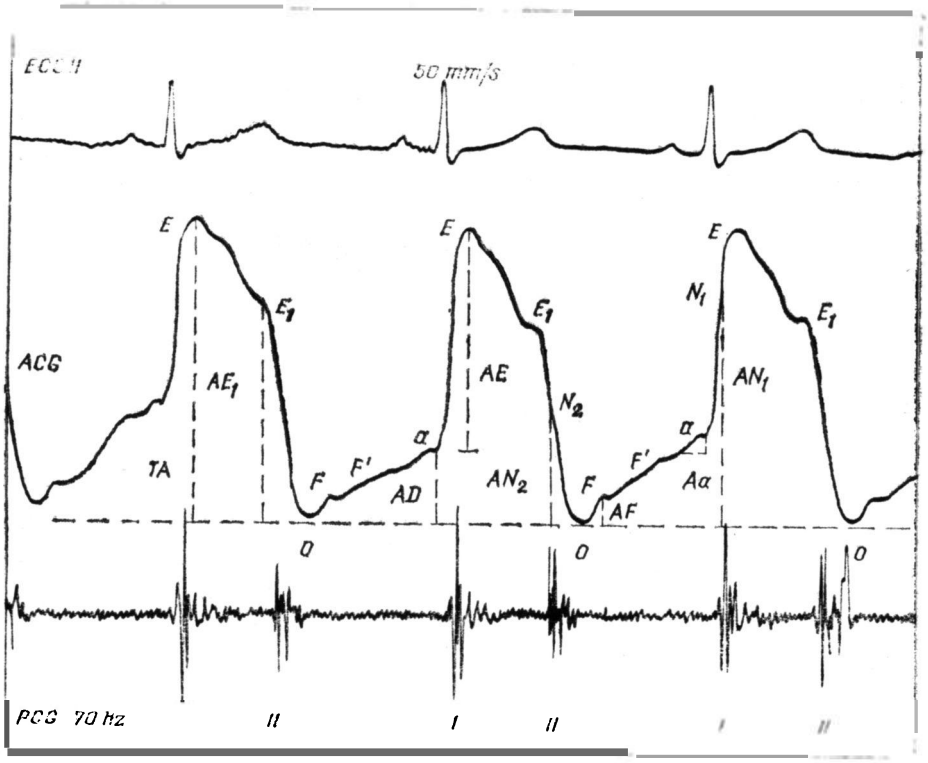



Fig. 4. ACG recording of D. D. M. ♂, aged 9 years. Indications of the amplitudes of the individual ACG waves, according to literature descriptions: TA=total amplitude; AE=amplitude of the systolic wave; AD=diastolic amplitude; $AE_1$=amplitude at the end of the systolic plateau; AF=amplitude of the passive, rapid filling wave; Aa=amplitude of the active diastolic filling wave. Amplitudes suggested by us: $AN_1$=amplitude of mitral valves' closure; $AN_2$=amplitude of aortic valves' closure.

Besides measurements of the intervals, in the quantitative characteristics of the normal ACG, also the amplitude and angles of the individual waves in ACG were studied.

In Figure 4, the amplitudes of the individual ACG waves, already described in the literature (15, 16, 23, 29), are designated as follows: total amplitude (TA) — a vertical vector from the SW peak (E point) to the basement line (BL) of ACG (the horizontal line passing through the O points in the ACG); the systolic wave amplitude (AE) — the vertical line from the point E to the point A level (marking the beginning of SW in ACG); diastolic amplitu-

de (DA) from point A (marking the end of the diastole) to the BL of the ACG; amplitude of the end of the systolic plateau ($AE_1$) — from the point $E_1$ to BL of the ACG; RFW amplitude (AF) — from the point F (marking the end of the rapid ventricular filling) to BL of the ACG; AFW amplitude (Aa) — from the peak of the atrial wave «a» to its starting level (base). Apart from the amplitudes described in the literature, two additional ones are suggested, designated in Fig. 4 as follows: amplitude of closure of the mitral valves ($AN_1$) — the vertical line from point $N_1$ (notch), marking the closure of mitral valves in the ACG, to BL of ACG (in case the indentation $N_1$ is not sufficiently clear, the point $N_1$ may be readily determined by drawing a vertical line from the main vibrations of mitral tone I in the PCG to its intersection with the ascending limb of SW); amplitude of closure of the aortic valves ($AN_2$) — from the point $N_2$ (notch), marking the closure of aortic valves in the ACG, to BL of the ACG (in case the indentation is not sufficiently clear, $N_2$ is determined by raising a vertical line from the main vibrations of aortic tone II in the PCG until its intersection with the descending SW limb). The amplitudes of the individual ACG waves are measured in millimeters. The waves measured in the fashion outlined above are considerably affected by the apparatus amplification which is different in the ACG recordings of individual children. To eliminate the influence of the amplification of the device and to render comparable the amplitudes, their percentual ratio to the total amplitude is calculated (3, 7, 14). The results obtained are illustrated in Table 5. Their mean values, correlated to the sex and age of the examined children, display certain difference which, after statistical elaboration, proves to be insignificant ($p>0.05$). Hence, the assumption is warranted that the children's age and sex by no means exert an essential influence on ACG amplitudes.

Figure 5 shows the angles of the normal ACG. The angle closed between BL of ACG and the slanting straight line, connecting point O and the peak of the following SW (point E), is known as the total ACG angle ($\measuredangle T$) (14). The angle formed between BL and the straight line, passing through the points O and A of ACG, is called diastolic angle ($\measuredangle D$) (8). The rapid filling angle ($\measuredangle R$) (14) is located between BL and the straight line connecting points O and F of ACG. The slow filling angle ($\measuredangle S$) (11) is formed between BL and the straight line connecting point F with the end of SFW. The angle closed between the horizontal line, passing through the peak of SW and its descending arm, following the E peak, is called the «alpha» angle ($\measuredangle \alpha$ or angle of rapid ejection) (22). Besides the angles described in the literature, four additional normal ACG angles are suggested: angle of mitral valves'closure ($\measuredangle N_1$), formed between BL and the straight line, joining point O with point $N_1$ (notch) along the ascending limb of SW and ACG; angle of the end of the systolic plateau ($\measuredangle E_1$ situated between BL and the straight line connecting points O and $E_1'$ of ACG; angle of active filling ($\measuredangle a$), formed between BL and the straight line joining point O with the peak of the atrial systolic wave «a», angle of aortic valves' closure ($\measuredangle N_2$), formed between BL and the straight line, starting from point O and passing through the point $N_2$ (notch) along the descending limb of SW in the ACG.

Since the absolute values (in degrees) of the described angles undergo changes dependent on the amplification of the device, speed of tape movement and heart rate (3, 7, 14), it was nesessary to calculate their values relative to

Table 5

**Mean Values of the Percentual Correlations between the Amplitudes of Individual Waves and the Total Amplitude of the Normal ACG in Childhood**

| A C G amplitudes | Statist. indices | Age groups 3—6 n=32 | 7—10 n=35 | 11—14 n=33 | Sex Boys n=50 | Girls n=100 | Total n=100 |
|---|---|---|---|---|---|---|---|
| AE/TA | $\bar{x}$ | 74,35 | 72,17 | 70,34 | 71,28 | 73,24 | 72,26 |
| | S | 8,14 | 7,33 | 8,41 | 7,65 | 8,23 | 8,10 |
| | $S_{\bar{x}}$ | 1,44 | 1,24 | 1,47 | 1,08 | 0,16 | 0,81 |
| | m | ±2,82 | ±2,43 | ±2,88 | ±2,12 | ±2,27 | ±1,59 |
| $AN_1/TA$ | $\bar{x}$ | 67,12 | 63,77 | 65,40 | 66,30 | 64,47 | 65,38 |
| | s | 13,93 | 13,18 | 13,98 | 14,42 | 12,85 | 13,62 |
| | sx | 2,46 | 2,23 | 2,44 | 2,04 | 1,82 | 1,36 |
| | m | ±4,82 | ±4,37 | ±4,78 | ±4,00 | ±3,57 | ±2,67 |
| $AE_1/TA$ | $\bar{x}$ | 66,88 | 71,22 | 69,10 | 65,84 | 72,43 | 69,13 |
| | s | 13,44 | 12,13 | 14,24 | 11,23 | 20,21 | 16,88 |
| | sx | 2,37 | 2,05 | 2,48 | 1,59 | 2,86 | 1,69 |
| | m | ±4,65 | ±4,02 | ±4,86 | ±3,12 | ±5,61 | ±3,31 |
| $AN_2/TA$ | x | 36,93 | 47,60 | 41,63 | 40,55 | 43,88 | 42,22 |
| | s | 15,02 | 14,11 | 13,95 | 16,40 | 13,14 | 14,88 |
| | sx | 2,65 | 2,38 | 2,43 | 2,32 | 1,86 | 3,92 |
| | m | ±5,19 | ±4,66 | ±4,76 | ±4,55 | ±3,67 | ±2,92 |
| AF/TA | x | 9,03 | 8,80 | 9,66 | 9,00 | 9,31 | 9,16 |
| | s | 2,42 | 3,05 | 3,13 | 2,12 | 3,42 | 3,00 |
| | sx | 0,43 | 0,52 | 0,55 | 0,30 | 0,48 | 2,30 |
| | m | ±0,48 | ±1,02 | ±1,08 | ±0,59 | ±0,94 | ±0,59 |
| Aa/TA | x | 5,23 | 5,65 | 5,93 | 5,58 | 5,63 | 5,61 |
| | s | 2,10 | 2,30 | 2,35 | 1,34 | 2,52 | 2,25 |
| | sx | 0,37 | 0,39 | 0,41 | 0,19 | 0,36 | 0,23 |
| | m | ±0,73 | ±0,76 | ±0,80 | ±0,37 | ±0,71 | ±0,45 |
| AD/TA | x | 28,17 | 28,20 | 29,41 | 28,82 | 28,36 | 28,59 |
| | s | 10,04 | 8,15 | 8,43 | 8,36 | 6,36 | 3,51 |
| | sx | 1,77 | 1,38 | 1,47 | 1,18 | 0,90 | 0,35 |
| | m | ±3,47 | ±2,70 | ±2,88 | ±2,31 | ±1,76 | ±0,69 |

the total ACG angle (T/D, T/R, T/S, $T/N_1$, $T/E_1$, T/a and $T/N_2$) for rendering them comparable in the various recordings and groups of studied children. In Table 6, the averaged values of the ratios of the individual ACG angles relative to the total angle, correlated with the age and sex of the children, are presented. It can be seen from the Table that although it is a matter of varying values, the statistical elaboration proves a significant difference ($p<0.05$) only in terms of the $T/N_1$ and $T/E_1$ and partially of the $T/N_1$ ratios. The averaged values of the other measurements did not reveal statistically reliable difference ($p>0.05$) in the comparatively studied age groups. Similarly, no essential difference was established between boys and girls ($p>0.05$).

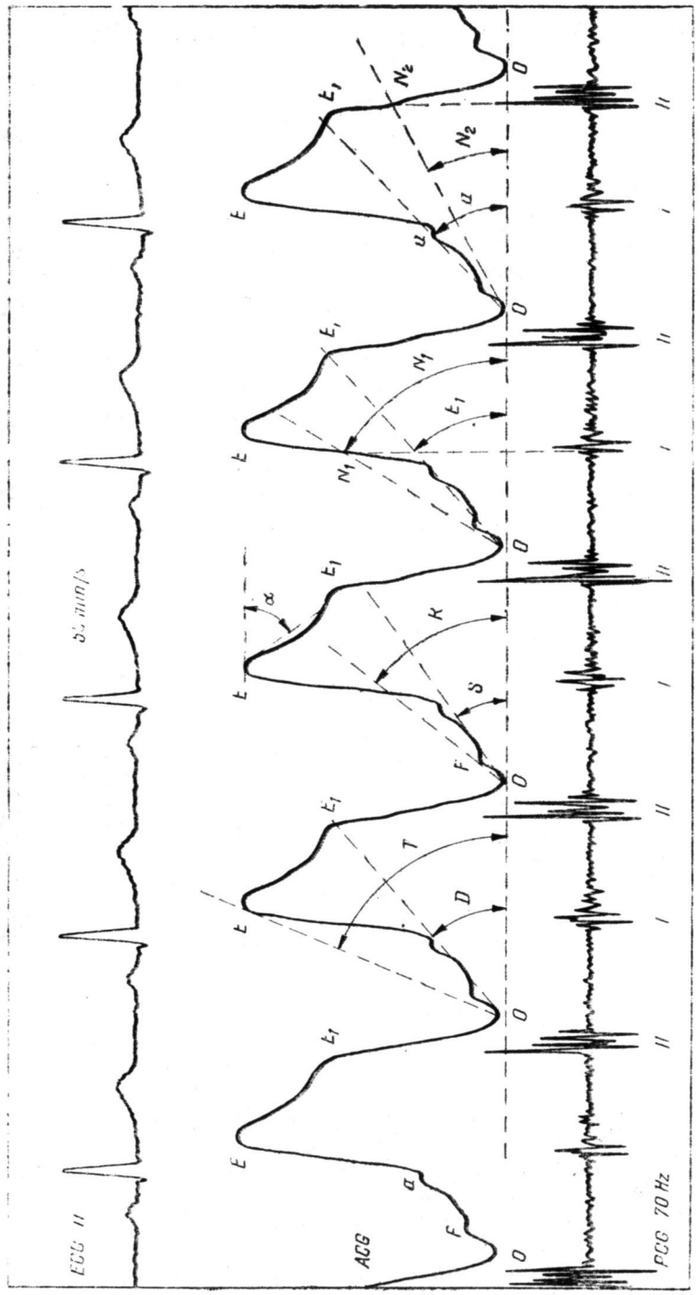



Fig. 5. ACG recording of G. S. G., ♀, aged 8 years. Designations of the normal ACG angles, according to literature descriptions: ∢T=total angle of ACG; ∢D=diastolic angle; ∢R==rapid filling angle; ∢S=slowly filling angle; ∢α=angle of rapid (maximal) ejection. Angles suggested by us: ∢$N_1$=angle of mitral valves' closure; ∢$E_1$=angle at the end of the systolic plateau; ∢a=angle of active diastolic filling; ∢$N_2$=angle of aortic valves' closure.

Table 6

**Mean Values of the Individual Angles Ratios to the Total Angle of the Normal ACG in Childhood**

| ACG angles | Statist. indices | Age groups | | | Sex | | Total |
|---|---|---|---|---|---|---|---|
| | | 3—6 y. n=32 | 7—10 y. n=35 | 11—14 y. n=33 | Boys n=50 | Girls n=50 | n=100 |
| T/N | x | 1,11 | 1,19* | 1,20* | 1,17 | 1,17 | 1,17 |
| | s | 0,10 | 0,17 | 0,17 | 0,14 | 0,17 | 0,14 |
| | sx | 0,02 | 0,03 | 0,03 | 0,02 | 0,02 | 0,01 |
| | m | ±0,04 | ±0,06 | ±0,06 | ±0,04 | ±0,04 | ±0,02 |
| $T/E_1$ | x | 1,59* | 1,60* | 1,70* | 1,69 | 1,57 | 1,63 |
| | s | 0,12 | 0,02 | 0,10 | 0,11 | 0,22 | 0,10 |
| | sx | 0,02 | 0,003 | 0,02 | 0,02 | 0,03 | 0,01 |
| | m | ±0,04 | ±0,006 | ±0,04 | ±0,04 | ±0,06 | ±0,02 |
| $T/N_2$ | x | 3,00* | 2,49 | 2,80 | 2,94 | 2,57 | 2,75 |
| | s | 1,25 | 0,21 | 1,13 | 1,10 | 1,13 | 1,12 |
| | sx | 0,22 | 0,04 | 0,20 | 0,16 | 0,16 | 0,11 |
| | m | ±0,43 | ±0,08 | ±0,39 | ±0,31 | ±0,31 | ±0,22 |
| T/R | x | 1,26 | 1,22 | 1,28 | 1,21 | 1,30 | 1,25 |
| | s | 0,30 | 0,32 | 0,48 | 0,26 | 0,45 | 0,36 |
| | sx | 0,05 | 0,05 | 0,08 | 0,04 | 0,06 | 0,04 |
| | m | ±0,10 | ±0,10 | ±0,16 | ±0,08 | ±0,12 | ±0,08 |
| T/S | x | 2,91 | 2,47 | 2,48 | 2,49 | 2,75 | 2,62 |
| | s | 0,40 | 0,81 | 0,81 | 0,92 | 0,45 | 0,73 |
| | sx | 0,07 | 0,14 | 0,14 | 0,13 | 0,06 | 0,07 |
| | m | ±0,14 | ±0,27 | ±0,27 | ±0,25 | ±0,12 | ±0,14 |
| T/a | x | 1,61 | 1,74 | 1,70 | 1,69 | 1,69 | 1,69 |
| | s | 0,39 | 0,32 | 0,33 | 0,33 | 0,37 | 0,35 |
| | sx | 0,07 | 0,05 | 0,06 | 0,05 | 0,05 | 0,04 |
| | m | ±0,14 | ±0,10 | ±0,12 | ±0,10 | ±0,10 | ±0,08 |
| T/D | x | 1,79 | 1,91 | 1,88 | 1,83 | 1,89 | 1,86 |
| | s | 0,57 | 0,53 | 0,45 | 0,42 | 0,59 | 0,51 |
| | sx | 0,10 | 0,09 | 0,08 | 0,06 | 0,08 | 0,05 |
| | m | ±0,20 | ±0,18 | ±0,16 | ±0,12 | ±0,16 | ±0,10 |

## Conclusions

1. The study of 100 clinically healthy children, aged 3—14 years, shows that apexcardiography is a convenient and readily executed method in childhood. The morphology of the ACG curve, described by various authors, was observed in almost all children under examination.
2. The morphological peculiarities of the normal ACG and their incidence show varying degrees of dependence on the age and sex of the studied children although statistically reliable dependence is established only in terms of the IW and O point morphology in ACG.
3. In addition to the amplitudes and angles for quantitative assessment of ACG, known in the literature, the following ones are also proposed: ampli-

tude and angle of closure of mitral valves, amplitude and angle of closure of aortic valves, angle of the systolic plateau end and angle of active diastolic filling, which complete the quantitative characteristics of the normal ACG in childhood.

4. The statistical elaboration of the results shows a certain degree of directly proportional dependence between the duration of ACG intervals and the age of the investigated children.

5. No essential difference is established in the values of the percentual ratios between individual amplitudes and total ACG amplitude, related to age.

6. No statistically significant relationship is established between the sex of the investigated children and the quantitative signs (intervals, amplitudes and angles) of the normal ACG.

7. The data of the morphological and quantitative characteristics of the normal ACG could be employed as a sound basis of further studies on the mechanical and hemodynamic changes, associated with cardiovascular diseases in childhood.

## REFERENCES

1. Галстян, А. А., Г. А. Арутюнян, Д. Р. Макарян, М. В. Петросян. *Педиатрия,* 1970, 49, 8, 29—32. — 2. Даскалов, Ив. Върху методиката и техниката на апекскардиографията в детската възраст. *Педиатрия,* 1972. — 3. Капонов, Х. Клинично значение на апекскардиографията при артериалната хипертония. Канд. дисертация, Варна, 1970. — 4. Капонов, Х. *Вътр. бол.*, 1970, 9, 2, 72—78. — 5. Капонов, Х. *Вътр. бол.,* 1970, 9, 4, 85—90. — 6. Мирлин, Б. Г. *Кардиология,* 1967, 7, 3, 133—135. — 7. Орешков, В. Върху клиничното значение на апекскардиографията при придобитите митрални вициуми. Канд. дисертация, София, 1966. — 8. Орешков, В. *Вътр. бол.,* 1965, 4, 2, 223—229. — 9. Орешков, В. *Вътр. бол.,* 1965, 4, 5, 391—395. — 10. Слуцкий, М. Е. *Вестн. АМН СССР,* 1965, 20, 2, 80—84. — 11. Якубович, А. А., А. Л. Гребенев. *Клин. мед.,* 1968, 49, 1, 72—73. — 12. Agress, C., S. Wagner, D. Bleifer, A. Lindsey, J. Houten, K. Schroyer, H. Estrin. *Am. J. Cardiol.,* 1964, 13, 3, 226—231. — 13. Ahuja, S., M. Gutierres. Am. J. Gardiol., 1967, 19, 3, 468—473.—14. Benchimol, A., E. Dimond, D. Waxman, Y. Shen. Am. Heart. J., 1960, 60, 3, 417—432. — 15. Benchimol, A., E. Dimond. *Brit. Heart J.,* 1962, 24, 5, 581—594. — 16. Benchimol, A., E. Dimond. *Am. J. Cardiol.,* 1963, 12, 3, 368—382. —17. Benchimol, A., T. Wu, E. Dimond. *Am. J. Cardiol.,* 1966, 17, 1, 63—72. — 18. Benchimol A., J. Ellis. *Am. J. Cardiol.,* 1967, 19, 2, 196—206. — 19. Bodrogi, G. *Magy. belorv. Arch.,* 1966, *19*, 5, 227—236.— 20. Coulshed, N., E. Epstein. Brit. Heart J., 1963, 25, 4, 697—708. — 21. Dimond, E., A. Duenas, A. Benchimol. *Am. Heart J.,* 1966, 72, 1, 124—130.— 22. Dejo, B., M. Alvares, R. Rivada, H. Koga, M. Alzamora, O. Alvardo. *R. Esp. Cardiol.,* 1967, 20, 3, 289—308. — 23. Gleichmann, U. N. Vlachakis, T. Tsilos. *Z. Kreisl.-Forsch.,* 1971, 60, 9, 789—807. — 24. Hartman, H., H. Snellen. The apexcardiogram. Acta tertii europaei de cordis scientia coventus, Romae, 1960, Exc. Med., pars altera B, 711—713. — 25. Jaworsky, V. *Z. Kreisl.-Forsch.,* 1964, 53, 2, 188—205. — 26. Lohr, H., E. Volenhoven, A. A. Rotterdam. *Am. Heart J.,* 1963, 66, 1, 108—127. — 27. Luisada, A. *Cardiology.* New York, McGraw-Hill, 1959, 2, 3—70. — 28. Oreshkov, V. *Jap. Heart J.,* 1968, 9, 4, 332—338.—29. Sherf A., Y. Soad, G. El — Said *Brit Heart J.,* 1969, 31, 3, 357—364. — 30. Spodick, D., S. Kumar. *Am. Heart J,,* 1968, 76, 1, 70—73. — 31. Tavel, M., R. Campbell, F. Steinmetz. *Brit. Heart. J.,* 1965, 27, 6, 829—839. — 32. Tafur, E., L. Cohen, H. Levine. *Circulation,* 1964, 30, 3, 381—391. — 33. Warembourg, H., G. Ducloux. *Arch. Mal. Coeur.,* 1963, 56, 12, 1359—1378. — 34. Wolfe, *A. Brit. Heart J.,* 1966, 28, 2, 179—183.

## МОРФОЛОГИЧЕСКАЯ И КОЛИЧЕСТВЕННАЯ ХАРАКТЕРИСТИКА НОРМАЛЬНОЙ АПЕКСКАРДИОГРАММЫ В ДЕТСКОМ ВОЗРАСТЕ

*Ив. Даскалов*

РЕЗЮМЕ

Проведены апекскардиографические исследования у 100 клинически здоровых детей, в возрасте от 3 до 14 лет. Описываются морфологические особенности нормальной апекскардиограммы (АКГ) в детском возрасте, причем проводится подробная количественная оценка отдельных составных АКГ (интервалов, амплитуд, углов). К описанным в литературе амплитудам и углам предлагается еще включить: амплитуду и угол закрытия двухстворчатого клапана, амплитуду и угол закрытия аортального клапана, угол конца систолического плато и угол активного диастолического наполнения, которые дополняют количественную характеристику нормальной АКГ. Результаты морфологической и количественной оценки АКГ обработаны статистически и сопоставлены с возрастом и полом исследованных детей. Работа иллюстрирована 5 рисунками и 6 таблицами.

В заключение автор подчеркивает, что полученные им данные морфологической и количественной характеристик нормальной АКГ могли бы быть использованы как хорошая база для дальнейших исследований механических и гемодинамических изменений при сердечно-сосудистых заболеваниях в детском возрасте.