



## Study on ECG in the Adolescent

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### Abstract

Normal ECG values in newborns, infants, and children have been collected and published. ECG in the adolescent, however, remains, to be collected and studied. The present study was designed and carried out to establish the normal ECG standards in male and female adolescents. A total of 898 school children and adolescents screened and examined as healthy were divided by age and sex into 6–9, 9–13, and 13–18 years age-groups. A 12 lead conventional ECG was recorded in 10 mm/mV and 25 mm/s, utilizing an automated Fukuda Denshi FCP-4301, MS-DOS/IBM-AT ECG machine. Lead V3R was not taken. Analog-to-digital conversion was performed by Fukuda signal acquisition module at a sampling rate of 500 Hz. The data on 69 ECG parameters were analyzed for the mean, standard deviation, 2nd to 98th percentiles, 95% confidence intervals, and sex difference. Normal values on 69 ECG parameters, sex-specific heart rate, P-QRS-T interval, duration, axis, wave amplitude, and calculated R/S amplitude ratio and ventricular activation time by age-group and sex were established. Male and female difference was noted in 49 (71.0%) parameters, of which 3 (6.1%) began in 6–9 years age-group, 30 (61.2%) began in 9–13 years age-group, and 16 (32.7%) in 13–18 years age-group. No sex difference occurred in 20 (29.0%) parameters. Normal male and female ECG standards on 69 ECG parameters in the adolescent were established. ECG sex difference began to appear the earliest at ages 6–9 years, and it occurred mostly at ages 9–13 years and 13–18 years, reflecting the anatomical and physiological consequences of puberty.

**Keywords** Normal ECG values · Children and adolescents · Puberty · Male and female

### Introduction

Normal ECG standards in newborns, infants, and children have been collected and published [1–7]. Davignon et al. [3], Rijnbeek et al. [4], and our previous study [5] provided the most extensive collection of normal values of ECG parameters. The normal ECG values in the adolescent, however, were limited, lacking in male- and female-specific ECG values and in sex-difference beginning ages. This study was designed and carried out to establish the normal ECG standards in male and female adolescents.

### Materials and Methods

The study population consisted of 898 school children and adolescents, who were screened with a questionnaire, then examined and confirmed, as healthy and of normal weight, height, and appearance, by a pediatrician and a pediatric cardiologist, during the period of 2003–2005, in Taipei, Taiwan. They were divided by age and sex, into 6–9 years ( $N=99$ ), 9–13 year ( $N=289$ ), and 13–18 year ( $N=510$ ) age-groups (Table 1). A 12-lead ECG was recorded on supine position, utilizing a Fukuda Denshi FCP-4301, MS-DOS/IBM-AT, ECG machine, at a paper speed of 25 mm/s and calibration 10 mm/mV. For large amplitude complexes, half-standard (5 mm/mV) was used. Lead V3R was not taken. Analog-to-digital conversion was performed by Fukuda signal acquisition module. The analog potential was digitalized into 5-UV units at a sampling rate of 500 Hz (once every 2 ms) [8, 9]. ECG chest electrodes were placed according to standard procedure [10].

Morphology measurements were made from the median voltages of the identical P-QRS-T cycles representative

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**Table 1** Study population

Age-group	Male (N)	Female (N)	Total (N)
6–9 years	57	42	99
9–13 years	164	125	289
13–18 years	260	250	510
Total	481	417	898

of a normal complex selected by the above-mentioned analysis program. Amplitude measurements were made using the PR segment as reference for the baseline. The onsets and offsets of the P-QRS-T wave were determined by an analysis of the simultaneous slopes in all 12 leads from the earliest onset in any lead to the latest deflection in any lead.

Visual verification using a magnifier and appropriate lighting was systematically performed by a pediatric

cardiologist on all electrocardiograms, with measurements made to the nearest 0.1 mm. In instances of computer wave-recognition error and of more than 10% difference between visual and computer measurements, the visually determined value was substituted in the data file. ECG records discarded due to noises, baseline drifting, bundle branch blocks, WPW, and ECG rhythms other than sinus rhythm were around 54 in total. The data collected were processed and analyzed, for the mean, standard deviation, 2nd to 98th percentiles, 95% confidence intervals of heart rate, P-QRS-T intervals, duration, axis, amplitude and calculated values, such as R/S amplitude ratio and ventricular activation time (VAT). The percentiles were estimated by parametric method with normal distribution. The analysis program had been validated [5]. No transformation was made. The differences of male and female values and of the values from this study and the literature were analyzed using the independent *t* test. *P*

**Table 2** Heart rate, P, QRS, and T interval and duration by age-group and sex

Age-group	6–9 years		9–13 years		13–18 years		
	Sex (N)	M (57)	F (42)	M (164)	F (125)	M (260)	F (250)
<b>Heart rate (beats/min)</b>							
M ± SD		94 ± 14.09	93 ± 15.48	89 ± 13.91	93 ± 13.96	78 ± 14.95	82 ± 13.86
(2–98%)		(66–123)	(61–125)	(60–117)	(65–122)	(48–109)	(54–111)
95% CI of Mean		(90.34, 97.66)	(88.51, 97.87)	(86.74, 91)	(90.82, 95.72)	<b>(76.67, 80.31)</b>	<b>(80.45, 83.89)</b>
<i>P</i> Value		0.665		0.008		0.004	
<b>PR interval (ms)</b>							
M ± SD		132 ± 15.04	130 ± 15.04	134 ± 14.07	135 ± 15.80	140 ± 19.07	141 ± 17.11
(2–98%)		(101–163)	(99–160)	(105–163)	(102–167)	(101–179)	(106–176)
95% CI of Mean		(128.3, 136.11)	(125.05, 134.14)	(131.54, 135.85)	(131.77, 137.31)	(138.01, 142.65)	(138.7, 142.94)
<i>P</i> Value		0.393		0.630		0.760	
<b>QT interval (ms)</b>							
M ± SD		337 ± 24.13	336 ± 23.59	339 ± 21.69	334 ± 21.61	351 ± 23.34	354 ± 28.62
(2–98%)		(287–386)	(287–384)	(295–383)	(290–379)	(299–403)	(295–412)
95% CI of Mean		(330.43, 342.95)	(327.87, 342.13)	(335.79, 342.4)	(330.42, 338)	(348.08, 354.24)	(350.08, 357.18)
<i>P</i> Value		0.822		0.058		0.300	
<b>QTc interval (ms)</b>							
M ± SD		423 ± 21.46	417 ± 17.32	413 ± 19.78	417 ± 18.89	401 ± 24.71	413 ± 20.39
(2–98%)		(379–467)	(382–453)	(373–454)	(379+456)	(350–452)	(371–455)
95% CI of Mean		(417.38, 428.52)	(412.19, 422.67)	(410.24, 416.3)	(414.01, 420.63)	<b>(397.86, 403.86)</b>	<b>(410.79, 415.84)</b>
<i>P</i> Value		0.173		0.080		<0.001	
<b>QRS duration (ms)</b>							
M ± SD		89 ± 14.37	85 ± 7.38	91 ± 8.24	87 ± 8.73	100 ± 9.60	91 ± 8.13
(2–98%)		(59–118)	(70–100)	(74–107)	(69–105)	(80–120)	(74–108)
95% CI of Mean		(85.23, 92.7)	(82.46, 86.92)	<b>(89.29, 91.82)</b>	<b>(85.75, 88.81)</b>	<b>(98.71, 101.04)</b>	<b>(90.1, 92.12)</b>
<i>P</i> Value		0.081		0.001		0.001	
<b>RR interval (ms)</b>							
M ± SD		645 ± 90.96	657 ± 104.2	687 ± 99.94	654 ± 94.13	787 ± 149.9	745 ± 123.15
(2–98%)		(458–832)	(443–871)	(481–892)	(460–847)	(479–1098)	(493–998)
95% CI of Mean		(621.71, 668.53)	(625.7, 688.73)	<b>(671.22, 701.81)</b>	<b>(637.04, 670.05)</b>	<b>(768.91, 805.21)</b>	<b>(730.26, 760.67)</b>
<i>P</i> Value		0.539		0.005		0.001	

Bold values indicate that the 95% confidence intervals of the mean for boys and girls do not overlap

Values of <0.05 and <0.01 were considered as significant and highly significant, respectively.

## Results

### Heart Rate, P, QRS, and T Wave Interval and Duration by Age-Group and Sex

The male- and female-specific mean, standard deviation, and 2nd–98th percentiles values of heart rate, PR interval, QT interval, QTc interval, QRS duration, and RR interval in each age-group are listed in Table 2. Sex difference occurred in heart rate, QTc interval, QRS duration, and RR interval, beginning in the 9–13 years and 13–18 years age-group.

### Frontal Plane P-QRS-T Axis by Age-Group and Sex

The male- and female-specific mean, standard deviation, 2nd–98th percentiles values, and 95% confidence intervals of frontal plain P axis, QRS axis, and T axis in each age-group were obtained as listed in Table 3. A highly significant sex difference of T axis values occurring in the 9–13 and 13–18 years age-groups was noted. No sex difference occurred in P axis and QRS axis.

### P, Q, R, S, and T Wave Amplitude by Age-Group and Sex

The male- and female-specific mean, standard deviation, 2nd–98th percentiles, and 95% confidence intervals of

frontal plain P axis, QRS axis, and T axis in each age-group were obtained as listed in Table 4. Significant sex differences which began to appear in 6–9 years age-group were R V1, S III, and S aVF. Sex differences which began to appear in the 9–13 years age-group were Q III, Q aVL, Q aVF, Q V5, Q V6, R aVR, R V2, R V4, R V5, R V6, S II, S V4, S V5, S V6, T II, T III, T aVR, T aVL, T aVF, T V4, T V5, and T V6. Sex differences which began in 13–18 years age-group were Q II, Q V4, S I, S aVL, S V1, S V2, T V1, and T V2.

### Calculated Values on R/S Wave Amplitude Ratio and Ventricular Activation Time (VAT) by Age-Group and Sex

The male- and female-specific mean, standard deviation, 2nd–98th percentiles, and 95% confidence intervals of R/S ratio and VAT values in each age-group were obtained as listed in Table 5. Sex differences that first occurred in 9–13 years age-group were Sum of R V3 and S V3, Sum of R V6, and S V1 and VAT V1. Sex differences that first occurred in the 13–18 years age-group were R/S V1, Sum of R V6 and S V2, VAT II, VAT aVF, VAT V2, VAT V4, VAT V5, and VAT V6.

## Discussion

Of the 69 ECG parameters we studied, 49 (71.0%) parameters showed a significant male and female difference: 3 (6.1%) parameters beginning in the 6–9 years age-group were R V1, S III, and S aVF; 30 (61.2%) parameters

**Table 3** Frontal plane P-QRS-T axis (degrees) by age-group and sex

Age-group	6–9 years		9–13 years		13–18 years	
	M (57)	F (42)	M (164)	F (125)	M (260)	F (250)
<b>P axis</b>						
M±SD	40±21.71	39±20.13	41±23.73	39±23.20	45±0.32.14	42±24.09
(2–98%)	(–4 to 85)	(–2 to 81)	(–8 to 90)	(–9 to 87)	(–21 to 111)	(–8 to 91)
95% CI of Mean	(34.79, 46.07)	(33.36, 45.54)	(37.4, 44.66)	(34.9, 43.04)	(41, 48.81)	(38.61, 44.58)
P Value	0.819		0.460		0.186	
<b>QRS axis</b>						
M±SD	66±17.89	68±19.65	66±19.81	65±19.66	66±25.98	68±18.42
(2–98%)	(29–103)	(27–108)	(26–107)	(25–106)	(13–120)	(30–106)
95% CI of Mean	(61.42, 70.71)	(61.8, 73.68)	(63.24, 69.3)	(61.83, 68.73)	(63.14, 69.46)	(65.5, 70.07)
P Value	0.660		0.674		0.454	
<b>T axis</b>						
M±SD	37±14.57	32±17.47	43±14.01	34±14.30	44±16.47	32±17.25
(2–98%)	(7–67)	(–3 to 68)	(14–72)	(4–63)	(10–77)	(–3 to 67)
95% CI of Mean	(33.48, 41.04)	(27.19, 37.76)	<b>(40.81, 45.1)</b>	<b>(31.05, 36.06)</b>	<b>(41.62, 45.62)</b>	<b>(29.91, 34.19)</b>
P Value	0.140		<0.001		<0.001	

Bold values indicate that the 95% confidence intervals of the mean for boys and girls do not overlap

**Table 4** P, Q, R, S, and T wave amplitude (mV) by age-group and sex

Age-group	6–9 years		9–13 years		13–18 years	
	M (57)	F (42)	M (163)	F (126)	M (260)	F (250)
<b>P II</b>						
M ± SD	0.10 ± 0.04	0.10 ± 0.05	0.09 ± 0.05	0.09 ± 0.04	0.09 ± 0.05	0.09 ± 0.04
(2–98%)	(0.01–0.19)	(0.00–0.19)	(0.00–0.18)	(0.00–0.19)	(0.00–1.90)	(0.00–0.17)
95% CI of Mean	(0.09, 0.11)	(0.08, 0.11)	(0.08, 0.1)	(0.09, 0.1)	(0.08, 0.1)	(0.08, 0.09)
P value	0.809		0.582		0.511	
<b>Q II</b>						
M ± SD	0.04 ± 0.05	0.03 ± 0.06	0.03 ± 0.05	0.03 ± 0.05	0.03 0 ± 0.06	0.02 ± 0.04
(2–98%)	(0.00–0.14)	(0.00–0.16)	(0.00–0.12)	(0.00–0.13)	(0.00–0.15)	(0.00–0.11)
95% CI of Mean	(0.02, 0.05)	(0.02, 0.05)	(0.02, 0.03)	(0.03, 0.04)	(0.03, 0.04)	(0.02, 0.03)
P Value	0.869		0.286		0.007	
<b>Q III</b>						
M ± SD	0.07 ± 0.10	0.09 ± 0.11	0.05 ± 0.08	0.08 ± 0.09	0.05 ± 0.08	0.05 ± 0.07
(2–98%)	(0.00–0.27)	(0.00–0.33)	(0.00–0.21)	(0.00–0.27)	(0.00–0.21)	(0.00–0.20)
95% CI of Mean	(0.04, 0.09)	(0.06, 0.13)	(0.04, 0.06)	(0.06, 0.09)	(0.04, 0.06)	(0.05, 0.06)
P Value	0.238		0.014		0.782	
<b>Q aVL</b>						
M ± SD	0.06 ± 0.11	0.04 ± 0.08	0.08 ± 0.14	0.03 ± 0.07	0.07 ± 0.14	0.04 ± 0.09
(2–98%)	(0.00–0.28)	(0.00–0.21)	(0.00–0.36)	(0.00–0.18)	(0.00–0.35)	(0.00–0.23)
95% CI of Mean	(0.03, 0.09)	(0.01, 0.06)	<b>(0.06, 0.1)</b>	<b>(0.02, 0.05)</b>	(0.05, 0.09)	(0.03, 0.05)
P Value	0.300		<0.001		0.007	
<b>Q aVF</b>						
M ± SD	0.04 ± 0.06	0.05 ± 0.08	0.03 ± 0.05	0.05 ± 0.06	0.04 ± 0.06	0.03 ± 0.05
(2–98%)	(0.00–0.17)	(0.00–0.21)	(0.00–0.14)	(0.00–0.17)	(0.00–0.16)	(0.00–0.13)
95% CI of Mean	(0.03, 0.06)	(0.03, 0.08)	(0.03, 0.04)	(0.04, 0.06)	(0.03, 0.04)	(0.02, 0.04)
P Value	0.508		0.041		0.137	
<b>Q V4</b>						
M ± SD	0.04 ± 0.09	0.02 ± 0.06	0.02 ± 0.04	0.01 ± 0.03	0.02 ± 0.06	0.01 ± 0.03
(2–98%)	(0.00–0.21)	(0.00–0.14)	(0.00–0.10)	(0.00–0.08)	(0.00–0.13)	(0.00–0.07)
95% CI of Mean	(0.02, 0.07)	(0, 0.04)	(0.01, 0.02)	(0.01, 0.02)	<b>(0.02, 0.03)</b>	<b>(0, 0.01)</b>
P Value	0.116		0.240		<0.001	
<b>Q V5</b>						
M ± SD	0.08 ± 0.10	0.06 ± 0.08	0.05 ± 0.06	0.03 ± 0.05	0.05 ± 0.07	0.02 ± 0.05
(2–98%)	(0.00–5.64)	(0.00–0.23)	(0.00–0.18)	(0.00–0.14)	(0.00–2.00)	(0.00–0.11)
95% CI of Mean	(0.05, 0.11)	(0.03, 0.08)	<b>(0.04, 0.06)</b>	<b>(0.02, 0.04)</b>	<b>(0.04, 0.06)</b>	<b>(0.01, 0.03)</b>
P Value	0.410		0.003		<0.001	
<b>Q V6</b>						
M ± SD	0.08 ± 0.10	0.06 ± 0.08	0.06 ± 0.06	0.04 ± 0.06	0.05 ± 0.06	0.03 ± 0.05
(2–98%)	(0.00–0.29)	(0.00–0.22)	(0.00–0.18)	(0.00–0.17)	(0.00–0.18)	(0.00–0.13)
95% CI of Mean	(0.05, 0.11)	(0.04, 0.09)	(0.05, 0.07)	(0.03, 0.05)	<b>(0.05, 0.06)</b>	<b>(0.02, 0.04)</b>
P Value	0.272		0.037		<0.001	
<b>R aVR</b>						
M ± SD	0.11 ± 0.09	0.12 ± 0.12	0.12 ± 0.11	0.100 ± 0.09	0.13 ± 0.11	0.10 ± 0.10
(2–98%)	(0.00–0.29)	(0.00–0.36)	(0.00–0.36)	(0.00–0.29)	(0.00–0.36)	(0.00–0.31)
95% CI of Mean	(0.09, 0.14)	(0.08, 0.15)	(0.11, 0.14)	(0.08, 0.11)	<b>(0.12, 0.14)</b>	<b>(0.09, 0.11)</b>
P Value	0.874		0.040		0.004	
<b>R V1</b>						
M ± SD	0.43 ± 0.21	0.33 ± 0.17	0.36 ± 0.19	0.28 ± 0.16	0.37 ± 0.24	0.27 ± 0.17
(2–98%)	(0.00–0.86)	(0.00–0.69)	(0.00–0.75)	(0.00–0.60)	(0.00–0.86)	(0.00–0.62)

**Table 4** (continued)

Age-group	6–9 years		9–13 years		13–18 years	
	M (57)	F (42)	M (163)	F (126)	M (260)	F (250)
95% CI of Mean	(0.37, 0.48)	(0.28, 0.39)	<b>(0.33, 0.39)</b>	<b>(0.25, 0.31)</b>	<b>(0.34, 0.4)</b>	<b>(0.24, 0.29)</b>
P Value	0.018		<0.001		<0.001	
<b>R V2</b>						
M±SD	1.27±0.57	1.20±0.40	1.12±0.46	0.92±0.39	0.92±0.44	0.68±0.32
(2–98%)	(0.11–2.43)	(0.38–2.03)	(0.17–2.07)	(0.13–1.71)	(0.02–1.83)	(0.03–1.34)
95% CI of Mean	(1.12, 1.42)	(1.08, 1.33)	<b>(1.04, 1.19)</b>	<b>(0.85, 0.99)</b>	<b>(0.87, 0.98)</b>	<b>(0.64, 0.72)</b>
P Value	0.509		<0.001		<0.001	
<b>R V4</b>						
M±SD	2.02±0.71	2.14±0.56	2.10±0.69	1.67±0.53	2.15±0.72	1.33±0.44
(2–98%)	(0.57–3.46)	(1.00–3.28)	(0.68–3.51)	(0.57–2.76)	(0.67–3.62)	(0.42–2.23)
95% CI of Mean	(1.84, 2.2)	(1.97, 2.3)	<b>(1.99, 2.2)</b>	<b>(1.57, 1.76)</b>	<b>(2.06, 2.23)</b>	<b>(1.27, 1.38)</b>
P Value	0.360		<0.001		<0.001	
<b>R V5</b>						
M±SD	1.77±0.61	1.88±0.44	1.77±0.50	1.54±0.45	1.67±0.56	1.23±0.37
(2–98%)	(0.53–3.02)	(0.98–2.78)	(0.75–2.80)	(0.62–2.47)	(0.51–2.83)	(0.47–1.98)
95% CI of Mean	(1.61, 1.93)	(1.75, 2.01)	<b>(1.69, 1.85)</b>	<b>(1.47, 1.62)</b>	<b>(1.6, 1.73)</b>	<b>(1.18, 1.27)</b>
P Value	0.336		<0.001		<0.001	
<b>R V6</b>						
M±SD	1.46±0.45	1.54±0.54	1.41±0.42	1.31±0.40	1.24±0.46	1.05±0.33
(2–98%)	(0.53–2.39)	(0.44–2.64)	(0.54–2.28)	(0.48–2.14)	(0.29–2.19)	(0.38–1.72)
95% CI of Mean	(1.34, 1.58)	(1.38, 1.7)	(1.34, 1.47)	(1.24, 1.38)	<b>(1.18, 1.29)</b>	<b>(1.01, 1.09)</b>
P Value	0.425		0.047		<0.001	
<b>S I</b>						
M±SD	0.18±0.15	0.19±0.15	0.15±0.14	0.13±0.14	0.17±0.14	0.13±0.13
(2–98%)	(0.00–0.48)	(0.00–0.50)	(0.00–0.43)	(0.00–0.41)	(0.00–0.46)	(0.00–0.40)
95% CI of Mean	(0.14, 0.22)	(0.14, 0.23)	(0.13, 0.17)	(0.11, 0.15)	(0.15, 0.18)	(0.12, 0.15)
P Value	0.760		0.347		0.009	
<b>S II</b>						
M±SD	0.14±0.11	0.12±0.12	0.17±0.15	0.11±0.12	0.19±0.16	0.12±0.12
(2–98%)	(0.00–0.37)	(0.00–0.36)	(0.00–0.48)	(0.00–0.35)	(0.00–0.53)	(0.00–0.370)
95% CI of Mean	(0.11, 0.17)	(0.08, 0.15)	<b>(0.15, 0.19)</b>	<b>(0.09, 0.13)</b>	<b>(0.17, 0.21)</b>	<b>(0.1, 0.13)</b>
P Value	0.280		<0.001		<0.001	
<b>S III</b>						
M±SD	0.11±0.12	0.06±0.09	0.13±0.14	0.08±0.10	0.14±0.15	0.08±0.10
(2–98%)	(0.00–0.35)	(0.00–0.24)	(0.00–0.42)	(0.00–0.29)	(0.00–0.44)	(0.00–0.29)
95% CI of Mean	(0.08, 0.14)	(0.03, 0.09)	<b>(0.11, 0.15)</b>	<b>(0.06, 0.1)</b>	<b>(0.12, 0.16)</b>	<b>(0.07, 0.1)</b>
P Value	0.038		0.001		<0.001	
<b>S aVL</b>						
M±SD	0.28±0.23	0.32±0.27	0.24±0.24	0.27±0.25	0.30±0.28	0.24±0.22
(2–98%)	(0.00–0.75)	(0.00–0.87)	(0.00–0.74)	(0.00–0.78)	(0.00–0.88)	(0.00–0.69)
95% CI of Mean	(0.22, 0.34)	(0.24, 0.4)	(0.2, 0.28)	(0.23, 0.32)	(0.26, 0.33)	(0.21, 0.27)
P Value	0.451		0.246		0.007	
<b>S aVF</b>						
M±SD	0.10±0.08	0.07±0.07	0.14±0.14	0.08±0.10	0.16±0.15	0.09±0.10
(2–98%)	(0.00–0.27)	(0.00–0.22)	(0.00–0.42)	(0.00–0.28)	(0.00–0.46)	(0.00–0.30)
95% CI of Mean	(0.08, 0.12)	(0.05, 0.09)	<b>(0.12, 0.16)</b>	<b>(0.06, 0.1)</b>	<b>(0.14, 0.17)</b>	<b>(0.08, 0.1)</b>
P Value	0.028		<0.001		<0.001	

**Table 4** (continued)

Age-group	6–9 years		9–13 years		13–18 years	
	M (57)	F (42)	M (163)	F (126)	M (260)	F (250)
<b>S V1</b>						
M±SD	0.75±0.40	0.62±0.37	0.75±0.36	0.70±0.35	0.90±0.49	0.76±0.36
(2–98%)	(0.00–1.56)	(0.00–0.38)	(0.01–1.49)	(0.00–1.43)	(0.00–1.91)	(0.02–1.50)
95% CI of Mean	(0.65, 0.85)	(0.5, 0.73)	(0.69, 0.81)	(0.64, 0.77)	<b>(0.84, 0.96)</b>	<b>(0.72, 0.81)</b>
P Value	0.099		0.280		<0.001	
<b>S V2</b>						
M±SD	1.30±0.58	1.23±0.57	1.37±0.59	1.25±0.61	1.62±0.69	1.18±0.51
(2–98%)	(0.12–2.49)	(0.06–2.40)	(0.16–2.57)	(0.01–2.49)	(0.21–3.03)	(0.13–2.24)
95% CI of Mean	(1.15, 1.45)	(1.06, 1.41)	(1.28, 1.46)	(1.14, 1.36)	<b>(1.54, 1.7)</b>	<b>(1.12, 1.25)</b>
P Value	0.554		0.100		<0.001	
<b>S V4</b>						
M±SD	0.61±0.39	0.50±0.41	0.65±0.41	0.43±0.35	0.58±0.38	0.37±0.28
(2–98%)	(0.00–1.42)	(0.00–1.34)	(0.00–1.50)	(0.00–1.14)	(0.00–1.36)	(0.00–0.95)
95% CI of Mean	(0.51, 0.71)	(0.37, 0.62)	<b>(0.59, 0.72)</b>	<b>(0.37, 0.49)</b>	<b>(0.53, 0.63)</b>	<b>(0.33, 0.4)</b>
P Value	0.189		<0.001		<0.001	
<b>S V5</b>						
M±SD	0.34±0.25	0.32±0.29	0.33±0.26	0.25±0.22	0.32±0.22	0.25±0.22
(2–98%)	(0.00–0.85)	(0.00–0.91)	(0.00–0.86)	(0.00–0.71)	(0.00–0.77)	(0.00–0.69)
95% CI of Mean	(0.28, 0.4)	(0.23, 0.41)	<b>(0.29, 0.37)</b>	<b>(0.21, 0.29)</b>	<b>(0.29, 0.34)</b>	<b>(0.23, 0.29)</b>
P Value	0.751		0.006		<0.001	
<b>S V6</b>						
M±SD	0.20±0.15	0.20±0.18	0.20±0.18	0.15±0.16	0.20±0.15	0.16±0.16
(2–98%)	(0.00–0.52)	(0.00–0.58)	(0.00–0.56)	(0.00–0.47)	(0.00–0.52)	(0.00–0.48)
95% CI of Mean	(0.16, 0.24)	(0.14, 0.25)	(0.17, 0.22)	(0.12, 0.18)	<b>(0.18, 0.22)</b>	<b>(0.14, 0.18)</b>
P Value	0.979		0.021		0.002	
<b>T I</b>						
M±SD	0.30±0.09	0.27±0.07	0.27±0.08	0.26±0.08	0.24±0.08	0.24±0.08
(2–98%)	(0.12–0.48)	(0.13–0.42)	(0.11–0.43)	(0.11–0.42)	(0.08–0.41)	(0.08–0.40)
95% CI of Mean	(0.28, 0.32)	(0.25, 0.29)	(0.26, 0.28)	(0.25, 0.28)	(0.23, 0.25)	(0.23, 0.25)
P Value	0.253		0.400		0.888	
<b>T II</b>						
M±SD	0.37±0.10	0.32±0.11	0.38±0.12	0.30±0.12	0.35±0.13	0.27±0.11
(2–98%)	(0.16–0.57)	(0.10–0.54)	(0.13–0.62)	(0.06+0.54)	(0.08–0.61)	(0.05–0.49)
95% CI of Mean	(0.34, 0.39)	(0.29, 0.35)	<b>(0.36, 0.39)</b>	<b>(0.28, 0.32)</b>	<b>(0.33, 0.36)</b>	<b>(0.26, 0.28)</b>
P Value	0.124		<0.001		<0.001	
<b>T III</b>						
M±SD	0.06±0.07	0.04±0.09	0.10±0.11	0.03±0.09	0.10±0.12	0.02±0.09
(2–98%)	(–0.09 to 0.21)	(–0.15 to 0.23)	(–0.12 to 0.32)	(–0.15 to 0.22)	(–0.14 to 0.34)	(–0.16 to 0.20)
95% CI of Mean	(0.04, 0.07)	(0.02, 0.07)	<b>(0.08, 0.12)</b>	<b>(0.02, 0.05)</b>	<b>(0.09, 0.11)</b>	<b>(0.01, 0.03)</b>
P Value	0.605		<0.001		<0.001	
<b>T aVR</b>						
M±SD	–0.33±0.09	–0.29±0.08	–0.32±0.09	–0.28±0.09	–0.29±0.09	–0.25±0.08
(2–98%)	(–0.51 to 0.15)	(–0.45 to 0.13)	(–0.50 to 0.14)	(–0.46 to 0.10)	(–0.47 to 0.11)	(–0.41 to 0.09)
95% CI of Mean	(–0.35, –0.31)	(–0.31, –0.27)	<b>(–0.33, –0.31)</b>	<b>(–0.29, –0.26)</b>	<b>(–0.3, –0.28)</b>	<b>(–0.26, –0.24)</b>
P Value	0.125		<0.001		<0.001	
<b>T aVL</b>						
M±SD	0.13±0.07	0.11±0.07	0.09±0.07	0.12±0.06	0.08±0.08	0.11±0.06
(2–98%)	(–0.01 to 0.26)	(–0.03 to 0.25)	(–0.06 to 0.23)	(–0.01 to 0.24)	(–0.08 to 0.23)	(–0.01 to 0.24)

**Table 4** (continued)

Age-group	6–9 years		9–13 years		13–18 years	
	M (57)	F (42)	M (163)	F (126)	M (260)	F (250)
95% CI of Mean	(0.11, 0.14)	(0.09, 0.13)	<b>(0.08, 0.1)</b>	<b>(0.11, 0.13)</b>	<b>(0.07, 0.09)</b>	<b>(0.11, 0.12)</b>
P Value	0.494		<0.001		<0.001	
<b>T aVF</b>						
M±SD	0.21±0.07	0.18±0.09	0.24±0.11	0.17±0.09	0.23±0.11	0.15±0.09
(2–98%)	(0.06–0.36)	(–0.02 to 0.37)	(0.02–0.46)	(–0.02 to 0.36)	(–0.01 to 0.46)	(–0.03 to 0.33)
95% CI of Mean	(0.19, 0.23)	(0.15, 0.2)	<b>(0.22, 0.26)</b>	<b>(0.16, 0.19)</b>	<b>(0.21, 0.24)</b>	<b>(0.14, 0.16)</b>
P Value	0.163		<0.001		<0.001	
<b>T V1</b>						
M±SD	–0.30±0.11	–0.25±0.10	–0.22±0.14	–0.20±0.10	–0.07±0.19	–0.14±0.13
(2–98%)	(–0.53 to 0.06)	(–0.46 to 0.04)	(–0.51 to 0.08)	(–0.41 to 0.01)	(–0.45 to 0.31)	(–0.40 to 0.12)
95% CI of Mean	(–0.33, –0.27)	(–0.28, –0.22)	(–0.24, –0.19)	(–0.22, –0.18)	<b>(–0.09, –0.05)</b>	<b>(–0.16, –0.13)</b>
P Value	0.175		0.383		<0.001	
<b>T V2</b>						
M±SD	0.30±0.33	0.24±0.22	0.33±0.26	0.27±0.22	0.45±0.27	0.22±0.19
(2–98%)	(–0.37 to 0.97)	(–0.20 to 0.69)	(–0.20 to 0.86)	(–1.70 to 0.72)	(–0.12 to 1.01)	(–0.17 to 0.61)
95% CI of Mean	(0.21, 0.38)	(0.18, 0.31)	(0.29, 0.37)	(0.24, 0.31)	<b>(0.41, 0.48)</b>	<b>(0.2, 0.24)</b>
P Value	0.520		0.061		<0.001	
<b>T V4</b>						
M±SD	0.61±0.25	0.52±0.11	0.65±0.22	0.46±0.20	0.72±0.25	0.38±0.18
(2–98%)	(0.10–1.13)	(0.29–0.75)	(0.20–1.10)	(0.04–0.87)	(0.20–1.23)	(0.01–0.75)
95% CI of Mean	(0.55, 0.68)	(0.49, 0.56)	<b>(0.62, 0.68)</b>	<b>(0.42, 0.49)</b>	<b>(0.69, 0.75)</b>	<b>(0.36, 0.4)</b>
P Value	0.146		<0.001		<0.001	
<b>T V5</b>						
M±SD	0.61±0.23	0.50±0.10	0.56±0.17	0.44±0.16	0.54±0.19	0.38±0.14
(2–98%)	(0.14–1.08)	(0.29–0.71)	(0.22–0.90)	(0.12–0.77)	(0.16–0.92)	(0.09–0.66)
95% CI of Mean	<b>(0.55, 0.67)</b>	<b>(0.47, 0.53)</b>	<b>(0.54, 0.59)</b>	<b>(0.42, 0.47)</b>	<b>(0.52, 0.57)</b>	<b>(0.36, 0.39)</b>
P Value	<0.001		<0.001		<0.001	
<b>T V6</b>						
M±SD	0.55±0.20	0.45±0.10	0.46±0.15	0.38±0.14	0.41±0.16	0.32±0.12
(2–98%)	(0.13–0.96)	(0.24–0.65)	(0.15–0.76)	(0.10–0.66)	(0.08–0.73)	(0.08–0.57)
95% CI of Mean	<b>(0.49, 0.6)</b>	<b>(0.42, 0.48)</b>	<b>(0.43, 0.48)</b>	<b>(0.36, 0.41)</b>	<b>(0.39, 0.42)</b>	<b>(0.31, 0.34)</b>
P Value	<0.001		<0.001		<0.001	

Bold values indicate that the 95% confidence intervals of the mean for boys and girls do not overlap

beginning in the 9–13 years age-group were heart rate, QRS duration, RR interval, T axis, Q III, Q aVL, Q aVF, Q V5, Q V6, R aVR, R V2, R V4, R V5, R V6, S II, S V4, S V5, S V6, T II, T III, T aVR, T aVL, T aVF, T V4, T V5, T V6, Sum of R V3 and S V3, Sum of R V6 and S V1 and VAT V1; and 16 parameters (23.2%) beginning in the 13–18 years age-group were QTc interval, Q II, Q V4, S I, S aVL, S V1, S V2, T V1, T V2, R/S V1, S V2, VAT II, VAT aVF, VAT V2, VAT V4, VAT V5, and VAT V6. Sex difference did not occur in 20 (29.0%) parameters: PR interval, QT interval, P axis, and QRS axis; P wave amplitude in II and T wave in ; R/S ratio in I, II, III, aVR, aVL, aVF, V2, V3, V4, V5, V6; and VAT in I, III, and aVR.

ECG gender difference once occurred, it continued to occur along with the age growth, with only two exceptions in Q III and Q aVF wave amplitudes, which occurred in 6–9 age-group, as an isolated or non-sequential sex difference.

Normal ECG values established in this study were compared with those published in the literature [3, 4, 6]. A total of 14 male- and female-specific normal ECG values were collected from Davignon et al. [3] in a 12–15 years age-group, and Rijnbeek et al. [4] and Semizel et al. [6] in a 12–16 years age-group, as listed in Table 6. The male-specific R V1 values (#1) of this study were compared with those of Davignon et al. [3] which provided mean, standard deviation, and ranges, yielding no statistical difference ( $p=0.867$ ). Female-specific R V1 values (#2) showed also

**Table 5** Calculated values on R/S amplitude ratio and ventricular activation time by age-group and sex

Age-group	6–9 years		9–13 years		13–18 years	
Sex (N)	M (57)	F (42)	M (164)	F (125)	M (260)	F (250)
<b>R/S I</b>						
M ± SD	5.61 ± 10.40	6.44 ± 12.15	6.63 ± 12.99	4.49 ± 6.46	6.63 ± 13.27	7.36 ± 14.89
(2–98%)	(0.00–26.97)	(0.00–31.39)	(0.00–33.30)	(0.00–17.75)	(0.00–33.90)	(0.00–17.90)
95% CI of Mean	(2.91, 8.31)	(2.77, 10.11)	(4.64, 8.62)	(3.36, 5.62)	(5.02, 8.24)	(5.51, 9.21)
P Value	0.714		0.093		0.557	
<b>R/S II</b>						
M ± SD	11.70 ± 27.81	14.69 ± 27.37	12.69 ± 24.97	11.64 ± 23.27	12.56 ± 27.07	10.61 ± 16.66
(2–98%)	(–45.42 to 68.83)	(–41.54 to 70.91)	(38.60–63.98)	(–36.15 to 59.43)	(–43.04 to 68.17)	(–23.61 to 44.82)
95% CI of Mean	(10.48, 24.92)	(6.41, 22.97)	(8.86, 16.52)	(7.58, 15.7)	(9.27, 15.85)	(8.53, 12.69)
P Value	0.597		0.717		0.323	
<b>R/S III</b>						
M ± SD	9.42 ± 20.57	12.49 ± 25.85	7.41 ± 15.92	7.96 ± 18.9	10.19 ± 22.73	10.53 ± 20.84
(2–98%)	(–32.87 to 51.68)	(–40.60 to 65.58)	(–25.29 to 40.11)	(–30.87 to 46.78)	(–36.50 to 56.89)	(–32.29 to 53.34)
95% CI of Mean	(4.08, 14.76)	(4.67, 20.31)	(4.97, 9.85)	(4.65, 11.25)	(7.43, 12.95)	(7.95, 13.11)
P Value	0.513		0.790		0.864	
<b>R/S aVR</b>						
M ± SD	0.88 ± 2.51	0.65 ± 1.07	1.19 ± 5.01	0.88 ± 3.86	1.51 ± 4.18	1.20 ± 3.70
(2–98%)	(–4.27 to 6.03)	(–1.55 to 2.85)	(–9.10 to 11.49)	(–7.06 to 8.81)	(–7.07 to 10.09)	(–6.39 to 8.80)
95% CI of Mean	(0.23, 1.53)	(0.09, 1.21)	(0.42, 1.96)	(0.2, 1.54)	(1, 2.02)	(0.74, 1.66)
P Value	0.613		0.558		0.379	
<b>R/S aVL</b>						
M ± SD	2.82 ± 8.78	1.07 ± 1.69	1.09 ± 3.07	0.96 ± 2.21	1.31 ± 4.51	2.09 ± 6.78
(2–98%)	(–15.20 to 20.85)	(–2.39 to 4.53)	(5.22–7.40)	(–3.59 to 5.51)	(–7.96 to 10.59)	(–11.83 to 16.03)
95% CI of Mean	(0.54, 5.1)	(0.56, 1.58)	(0.62, 1.56)	(0.57, 1.35)	(0.76, 1.86)	(1.25, 2.93)
P Value	0.206		0.684		0.126	
<b>R/S aVF</b>						
M ± SD	15.20 ± 29.58	12.49 ± 20.57	11.27 ± 23.45	8.41 ± 13.43	10.52 ± 23.28	12.78 ± 23.14
(2–98%)	(0.00–75.96)	(0.00–54.74)	(0.00–59.44)	(0.00–36.00)	(0.00–58.33)	(0.00–60.32)
95% CI of Mean	(7.52, 22.88)	(6.27, 18.71)	(7.67, 14.87)	(6.06, 10.76)	(7.69, 13.35)	(9.91, 15.65)
P Value	0.612		0.192		0.270	
<b>R/S V1</b>						
M ± SD	0.85 ± 1.21	0.66 ± 0.46	0.6 ± 0.61	0.60 ± 0.73	0.49 ± 0.44	0.41 ± 0.38
(2–98%)	(0.00–3.34)	(0.00–1.60)	(0.00–1.85)	(0.00–2.10)	(0.00–1.39)	(0.00–1.19)
95% CI of Mean	(0.54, 1.16)	(0.52, 0.8)	(0.53, 0.89)	(0.21, 1.65)	(0.44, 0.54)	(0.36, 0.46)
P Value	0.353		0.519		0.028	
<b>R/S V2</b>						
M ± SD	1.23 ± 1.04	1.42 ± 1.76	1.15 ± 1.27	1.09 ± 1.71	0.88 ± 2.28	0.78 ± 1.03
(2–98%)	(0.00–3.3)	(0.00–5.03)	(0.00–3.75)	(0.00–4.60)	(0.00–5.57)	(0.00–2.90)
95% CI of Mean	(0.96, 1.5)	(0.89, 1.95)	(0.96, 1.34)	(0.79, 1.39)	(0.6, 1.16)	(0.65, 0.91)
P Value	0.517		0.730		0.517	
<b>R/S V3</b>						
M ± SD	13.78 ± 51.72	11.51 ± 37.81	3.67 ± 6.4	3.98 ± 14.72	1.76 ± 4.95	1.49 ± 3.06
(2–98%)	(–92.45 to 120.0)	(–66.15 to 89.16)	(–9.49 to 16.82)	(–26.26 to 34.23)	(–8.40 to 11.93)	(–4.79 to 7.77)
95% CI of Mean	(0.35, 27.21)	(0.07, 22.95)	(2.69, 4.65)	(1.41, 6.55)	(1.16, 2.36)	(1.11, 1.87)
P Value	0.810		0.808		0.464	
<b>R/S V4</b>						
M ± SD	6.48 ± 10.39	9.96 ± 19.49	8.40 ± 21.67	5.81 ± 10.45	9.05 ± 25.68	8.47 ± 20.99
(2–98%)	(0.00–27.82)	(0.00–49.99)	(0.00–52.91)	(0.00–27.28)	(0.00–61.80)	(0.00–51.59)



**Table 5** (continued)

Age-group	6–9 years		9–13 years		13–18 years	
	M (57)	F (42)	M (164)	F (125)	M (260)	F (250)
95% CI of Mean	(3.78, 9.18)	(4.07, 15.85)	(5.07, 11.73)	(3.99, 7.63)	(5.93, 12.17)	(5.87, 11.07)
P Value	0.255		0.219		0.781	
<b>R/S V5</b>						
M±SD	9.81±13.1	10.19±13.24	13.70±28.81	11.94±28.55	13.06±31.10	11.36±21.76
(2–98%)	(0.00–36.71)	(0.00–37.39)	(0.00–72.88)	(0.00–70.58)	(0.00–76.95)	(0.00–56.05)
95% CI of Mean	(6.41, 13.21)	(6.19, 14.19)	(9.28, 18.12)	(6.95, 16.93)	(9.28, 16.84)	(8.66, 14.06)
P Value	0.885		0.605		0.474	
<b>R/S V6</b>						
M±SD	15.08±19.17	11.75±22.74	12.77±16.8	18.11±28.9	16.01±36.38	14.45±24.19
(2–98%)	(–24.30 to 54.45)	(–34.96 to 58.45)	(–27.80 to 56.19)	(–20.35 to 38.77)	(–58.72 to 90.75)	(–35.24 to 64.14)
95% CI of Mean	(10.1, 20.06)	(4.87, 18.63)	(10.20, 15.34)	(13.04, 23.18)	(11.59, 20.43)	(11.45, 17.45)
P Value	0.432		0.066		0.568	
<b>Sum RV3+SV3</b>						
M±SD	2.80±0.70	2.56±0.69	2.15±1.14	1.79±1.00	1.82±0.91	1.34±0.62
(2–98%)	(1.36–4.21)	(1.16–3.97)	(0.00–4.49)	(0.00–3.84)	(0.00–3.68)	(0.07–2.61)
95% CI of Mean	(2.38, 2.74)	(2.01, 2.41)	<b>(1.64, 1.94)</b>	<b>(2.09, 2.29)</b>	<b>(1.26, 1.42)</b>	<b>(2.05, 2.23)</b>
P Value	0.096		0.005		<0.001	
<b>Sum RV6+SV1</b>						
M±SD	2.21±0.67	2.15±0.67	2.19±0.58	1.98±0.48	2.14±0.70	1.81±0.51
(2–98%)	(0.82–3.50)	(0.77–3.54)	(1.00–3.37)	(1.00–2.96)	(0.70–3.58)	(0.76–2.86)
95% CI of Mean	(2.04, 2.38)	(1.95, 2.35)	<b>(2.1, 2.28)</b>	<b>(1.9, 2.06)</b>	<b>(2.05, 2.23)</b>	<b>(1.75, 1.87)</b>
P Value	0.707		0.005		<0.001	
<b>Sum RV6+SV2</b>						
M±SD	2.76±0.73	2.77±0.73	2.75±0.75	2.59±0.68	2.85±0.84	2.23±0.60
(2–98%)	(1.25–4.27)	(1.28–4.26)	(1.22–4.28)	(1.20–3.98)	(1.13–4.58)	(1.00–3.46)
95% CI of Mean	(2.57, 2.95)	(2.55, 2.99)	(2.63, 2.87)	(2.47, 2.71)	<b>(2.75, 2.95)</b>	<b>(2.16, 2.3)</b>
P Value	0.944		0.071		<0.001	
<b>VAT I</b>						
M±SD	26±10.08	24±5.21	27±8.02	27±6.61	29±8.85	28±7.65
(2–98%)	(5–47)	(13–35)	(10–43)	(13–40)	(11–47)	(12–44)
95% CI of Mean	(23.51, 28.7)	(22.33, 25.48)	(25.51, 27.97)	(25.44, 27.75)	(27.78, 29.93)	(27.13, 29.03)
P Value	0.205		0.864		0.511	
<b>VAT II</b>						
M±SD	31±8.93	30±5.14	31±5.70	32±6.58	34±7.20	32±6.84
(2–98%)	(13–49)	(19–40)	(20–43)	(18–45)	(20–49)	(18–46)
95% CI of Mean	(28.6, 33.19)	(28.07, 31.17)	(30.56, 32.31)	(30.64, 32.94)	<b>(33.44, 35.19)</b>	<b>(31.22, 32.91)</b>
P Value	0.428		0.626		<0.001	
<b>VAT III</b>						
M±SD	31±9.27	31±8.54	32±8.50	32±9.11	34±10.42	34±10.07
(2–98%)	(12–50)	(13–48)	(15–50)	(13–50)	(13–55)	(13–54)
95% CI of Mean	(28.34, 33.11)	(27.94, 33.11)	(30.89, 33.5)	(30.15, 33.34)	(32.76, 35.3)	(32.55, 35.04)
P Value	0.922		0.665		0.793	
<b>VAT aVR</b>						
M±SD	33±20.17	32±23.03	34±22.42	30±23.32	37±24.69	34±24.59
(2–98%)	(0–74)	(0–79)	(0–80)	(0–78)	(0–88)	(0–85)
95% CI of Mean	(27.81, 38.19)	(24.8, 38.73)	(30.36, 37.25)	(25.86, 34.01)	(33.93, 39.93)	(31.34, 37.44)
P Value	0.811		0.154		0.243	

**Table 5** (continued)

Age-group	6–9 years		9–13 years		13–18 years	
	M (57)	F (42)	M (164)	F (125)	M (260)	F (250)
<b>VAT aVF</b>						
M±SD	31±8.35	31±5.40	32±6.24	32±6.83	35±7.20	33±7.26
(2–98%)	(14–48)	(20–42)	(19–45)	(18–46)	(20–50)	(18–48)
95% CI of Mean	(28.99, 33.29)	(29.46, 32.73)	(31.35, 33.26)	(30.68, 33.06)	<b>(34.06, 35.81)</b>	<b>(31.9, 33.7)</b>
P Value	0.891		0.575		0.001	
<b>VAT V1</b>						
M±SD	20±7.80	19±5.65	20±5.57	18±4.49	21±8.70	18±5.13
(2–98%)	(4–36)	(7–30)	(9–32)	(8–27)	(4–39)	(7–28)
95% CI of Mean	(18.13, 22.15)	(17.29, 20.71)	<b>(19.29, 21)</b>	<b>(16.8, 18.37)</b>	<b>(20.33, 22.45)</b>	<b>(17.16, 18.43)</b>
P Value	0.290		<0.001		<0.001	
<b>VAT V2</b>						
M±SD	25±7.65	24±5.26	25±5.68	24±5.69	24±5.03	23±5.08
(2–98%)	(10–41)	(14–35)	(13–36)	(12–36)	(14–35)	(12–33)
95% CI of Mean	(23.31, 27.24)	(22.89, 26.07)	(23.94, 25.69)	(22.99, 24.98)	<b>(23.88, 25.1)</b>	<b>(21.89, 23.15)</b>
P Value	0.533		0.218		<0.001	
<b>VAT V4</b>						
M±SD	30±6.00	31±4.95	32±4.64	32±5.58	35±6.41	33±5.38
(2–98%)	(18–43)	(21–41)	(22–41)	(20–43)	(22–48)	(22–44)
95% CI of Mean	(28.46, 31.54)	(29.17, 32.16)	(30.79, 32.21)	(30.93, 32.88)	<b>(34.43, 35.99)</b>	<b>(32.74, 34.07)</b>
P Value	0.853		0.502		0.001	
<b>VAT V5</b>						
M±SD	30±6.52	31±5.23	32±6.27	31±5.83	35±6.53	32±5.61
(2–98%)	(17–41)	(20–42)	(19–44)	(19–43)	(21–48)	(20–43)
95% CI of Mean	(28.32, 31.68)	(29.47, 32.63)	(30.56, 32.49)	(29.51, 31.55)	<b>(33.88, 35.47)</b>	<b>(31.17, 32.56)</b>
P Value	0.650		0.169		<0.001	
<b>VAT V6</b>						
M±SD	32±8.59	30±8.26	32±6.74	32±6.16	35±7.45	32±6.19
(2–98%)	(15–50)	(13–47)	(19–45)	(19–44)	(20–50)	(20–45)
95% CI of Mean	(30.17, 34.59)	(27.88, 32.88)	(31.42, 33.49)	(30.45, 32.59)	<b>(33.98, 35.79)</b>	<b>(31.56, 33.09)</b>
P Value	0.290		0.228		<0.001	

Bold values indicate that the 95% confidence intervals of the mean for boys and girls do not overlap

no difference ( $p=0.742$ ). R V6 values (#3 and #4) were also compared showing similar results ( $p=0.661$  and  $p=0.719$ ), indirectly confirming that the normal ECG values collected in this study were accurate and credible.

Typical male ECG could be differentiated from typical female ECG in five characteristic features: Higher takeoff of the ST segment, shorter period between J point and onset of T wave, steeper slope of ST segment, steeper ascent of T wave, and higher T wave amplitude [11, 12]. Surawicz et al. [12], Bidoggia et al. [13], and Vicente et al. [14] reported that male sex hormones or autonomic innervations played an important role in modulating the cardiac repolarization. Sex ECG amplitude difference was more prominent in the precordial leads than in extremity leads [15].

Adolescence is a transitional period from puberty to adulthood. Sex difference in the adolescent conveys the

anatomical and physiological consequences of puberty [12]. Before puberty, sex does not appear to influence the ECG significantly [16, 17]. Girls begin puberty usually around ages 10–11 years, and boys around 11–12 years, but puberty may start 1–2 or more years earlier due to social, dietary, environmental, and many other factors [17–20].

Puberty begins, when sex hormone levels rise and secondary sex characteristics, such as pubic hair, enlarged breasts, and facial hair appear. The most obvious difference between male and female includes muscle mass, height, and hair distribution. Men have a heavier heart weight and larger volume than women [21, 22]. Females have a significantly higher heart rate, shorter conduction times, decreased P, Q, and T amplitudes, and longer repolarization time, and decreased P, Q, and T amplitudes [15, 21, 23, 24]. QTc interval begins to decrease in men at the time of puberty when

**Table 6** A comparison of 14 normal sex-specific ECG values collected in this study with those published in the literature

Author (Age-group)	This study (13–18 years)		Semizel et al. [6] (12–16 years)		Rijinbeek et al. [4] (12–16 years)		Davignon et al. [3] (12–15 years)	
	M (260)	F (250)	M (151)	F (184)	M (200)	F (166)	M (105)	F (142)
<b>Heart rate (beats/min)</b>								
Mean	78	82	80	87	73*	76*	85	
(2–98%)	(48–109)	(54–111)	(59–100)	(64–110)	(48–99)	(54–107)	(60–119)	
95% CI of Mean	<b>(76.67, 80.31)</b>	<b>(80.45, 83.89)</b>	<b>(78.45, 81.55)</b>	<b>(85.38, 88.62)</b>			(82.94, 87.06)	
P Value	0.004		0.001		0.040		–	
<b>QRS axis (degrees)</b>								
Mean	66	68	60	56	65*	66*	59	
(2–98%)	(13–120)	(30–106)	(14–142)	(35–143)	(–9 to 112)	(5–101)	(11–130)	
95% CI of Mean	(63.14, 69.46)	(65.5, 70.07)	(53.63, 66.37)	(49.88, 62.12)			(54.69, 63.31)	
P Value	0.454		0.946		0.973		–	
<b>PR interval II (ms)</b>								
Mean	140	141	137	133	139*	135*	140	
(2–98%)	(101–179)	(106–176)	(92–184)	(100–174)	(107–178)	(106–176)	(90–180)	
95% CI of Mean	(138.01, 142.65)	(138.7, 142.94)	(133.35, 140.65)	(130.12, 135.88)			(137.57, 142.43)	
P Value	0.760		0.895		0.885		–	
<b>QRS duration (ms)</b>								
Mean	100	91	84	79	91*	87*	70	
(2–98%)	(80–120)	(74–108)	(64–108)	(62–108)	(78–111)	(72–106)	(40–90)	
95% CI of Mean	<b>(98.71, 101.04)</b>	<b>(90.1, 92.12)</b>	<b>(82.14, 85.86)</b>	<b>(76.96, 81.04)</b>			(68.79, 71.21)	
P Value	0.001		0.001		0.050		–	
<b>P II (mV)</b>								
M ± SD	0.09 ± 0.05	0.09 ± 0.04	0.14	0.16	0.13*	0.15*	Birth to 15 years	
(2–98%)	(0.00–1.90)	(0.00–0.17)	(0.29)	(0.28)	(0.24)	(0.26)	Almost unchanged	
95% CI of Mean	(0.08, 0.1)	(0.08, 0.09)	(0.13, 0.15)	(0.15, 0.17)				
P Value	0.511		0.829		0.793		–	
<b>Q III (mV)</b>								
Mean	0.05 ± 0.08	0.05 ± 0.07	0.17	0.14	0.10*	0.10*	0.12	
(98%)	(0.21)	(0.20)	(0.53)	(0.38)	(0.29)	(0.21)	(0.3)	
95% CI of Mean	(0.04, 0.06)	(0.04, 0.06)	(0.14, 0.2)	(0.12, 0.16)				
P Value	0.782		0.883		0.999		–	
<b>Q V6 (mV)</b>								
Mean	0.05	0.08	0.14	0.11	0.11*	0.09*	0.03	
(98%)	(0.18)	(0.13)	(0.55)	(0.22)	(0.43)	(0.23)	(0.3)	
95% CI of Mean	<b>(0.05, 0.06)</b>	<b>(0.02, 0.04)</b>	(0.11, 0.17)	(0.1, 0.12)				
P Value	<0.001		0.060		0.125		–	
<b>R V1 (mV)</b>								
M ± SD	0.37 ± 0.24	0.27 ± 0.17	0.38	0.27	0.48*	0.35*	0.44 ± 0.25	0.37 ± 0.23
(2–98%)	(0.00–0.86) <sup>#1</sup>	(0.00–0.60) <sup>#2</sup>	(1.13)	(0.78)	(1.18)	(1.10)	(0.02–1.03) <sup>#1</sup>	(0.01–0.96) <sup>#2</sup>
95% CI of Mean	<b>(0.34, 0.4)</b>	<b>(0.24, 0.29)</b>	<b>(0.32, 0.44)</b>	<b>(0.23, 0.31)</b>			(0.39, 0.49)	(0.33, 0.41)
P Value	<0.001		0.001		<0.001		<0.001	
<b>S V1 (mV)</b>								
Mean	0.9	0.76	0.95	0.81	1.30*	1.15*	1.1	
(2–98%)	(0.00–1.91)	(0.02–1.50)	(2.45)	(2.16)	(2.44)	(2.05)	(0.01–2.3)	

**Table 6** (continued)

Author (Age-group)	This study (13–18 years)		Semizel et al. [6] (12–16 years)		Rijnbeek et al. [4] (12–16 years)		Davignon et al. [3] (12–15 years)	
	M (260)	F (250)	M (151)	F (184)	M (200)	F (166)	M (105)	F (142)
95% CI of Mean	<b>(0.84, 0.96)</b>	<b>(0.72, 0.81)</b>	(0.83, 1.07)	(0.72, 0.9)			(1.03, 1.17)	
P Value	<0.001		0.065		0.005		–	
R/S V1								
Mean	0.49	0.41	0.5	0.4	0.4*	0.3*	0.5	
(2–98%)	(0–1.39)	(0–1.19)	(2.3)	(0.9)	(0.1–1.1)	(0.1–1.0)	(0–1.7)	
95% CI of Mean	(0.44, 0.54)	(0.36, 0.46)	(0.36, 0.64)	(0.36, 0.44)			(0.43, 0.57)	
P Value	0.028		0.135		0.005		–	
R V6 (mV)								
M±SD	1.24±0.46	1.05±0.33	1.31	1.24	2.02*	1.65*	1.58±0.4	1.23±0.3
(2–98%)	(0.29–2.19) <sup>#3</sup>	(0.38–1.72) <sup>#4</sup>	(2.45)	(1.93)	(3.05)	(2.52)	(0.80–2.41) <sup>#3</sup>	(0.59–1.91) <sup>#4</sup>
95% CI of Mean	<b>(1.18, 1.29)</b>	<b>(1.01, 1.09)</b>	(1.22, 1.4)	(1.19, 1.29)			<b>(1.5, 1.66)</b>	<b>(1.18, 1.28)</b>
P Value	<0.001		0.155		<0.001		<0.001	
S V6 (mV)								
Mean	0.2	0.16	0.22	0.17	0.37*	0.30*	0.1	
(2–98%)	(0–0.52)	(0–0.48)	(0.52)	(0.34)	(0.85)	(0.67)	(0–0.4)	
95% CI of Mean	<b>(0.18, 0.22)</b>	<b>(0.14, 0.18)</b>	(0.2, 0.24)	(0.16, 0.18)			(0.08, 0.12)	
P Value	0.002		0.755		0.818		–	
R/S V6								
M±SD	16.01±36.38	14.45±24.19	6.4	5.1	5.5*	5.4*	14.7	
(2–98%)	(–58.72 to 90.75)	(–35.24 to 64.14)	(28.6)	(22)	(2.0-U)	(1.3-U)	(1.4-U)	
95% CI of Mean	(11.59, 20.43)	(11.45, 17.45)	(4.68, 8.12)	(3.91, 6.29)				
P Value	0.568		0.922		–		–	
VAT V5 (ms)								
Mean	35	32	NA	NA	NA	NA	32	
(2–98%)	(21–48)	(20–43)					(15–45)**	
95% CI of Mean	<b>(33.88, 35.47)</b>	<b>(31.17, 32.56)</b>					(31.21, 32.79)	
P Value	<0.001						–	

#1–#4: This study and Davignon et al. [3] difference studies, *P* values: 0.867, 0.742, 0.661, and 0.719

Bold values indicate that the 95% confidence intervals of the mean for boys and girls do not overlap

*U* undefined, *M* mean, *ms* millisecond, *mV* millivolt

\*Median

\*\*Minimum to maximum

testosterone levels increase affecting effects on calcium current, and begins to increase as men age and testosterone levels decrease [14, 15, 24–26].

### Study Limitations

In this study, lead V3R ECG was not taken, and the number of subjects in 6–9 years age-group was only 99 (male

57, female 42), not over 100, as recommended by Davignon et al. [3].

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## Compliance with Ethical Standards

**Conflict of interest** There is no conflict of interest relevant to this article.

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