

UPPER LIMITS OF QT INTERVALS IN CHILDREN

1 Davignon and Rautaharju, Pediatric Cardiology, 1980

Normal ECG values in 2,141 white children aged 0 to 16 years divided into 12 age groups. The mean QT duration decreases steadily with increasing heart rate. The mean value of the Bazett rate-corrected QT interval, throughout all ages is 0.40.

In 95% of the subjects, the corrected QT interval is less than 0.45 and in 98% less than 0.48.

Davignon and co-authors do not separate out the gender with respect to the QT interval. They showed that the uncorrected QT interval increases with age.

The QT values are plotted on graphs containing the second, the fifth, 25th, 50th, 75th, 95th and 98th percentiles for each heart rate group (Table 1) and each age group (Table 2)

Table 1: QT duration versus heart rate

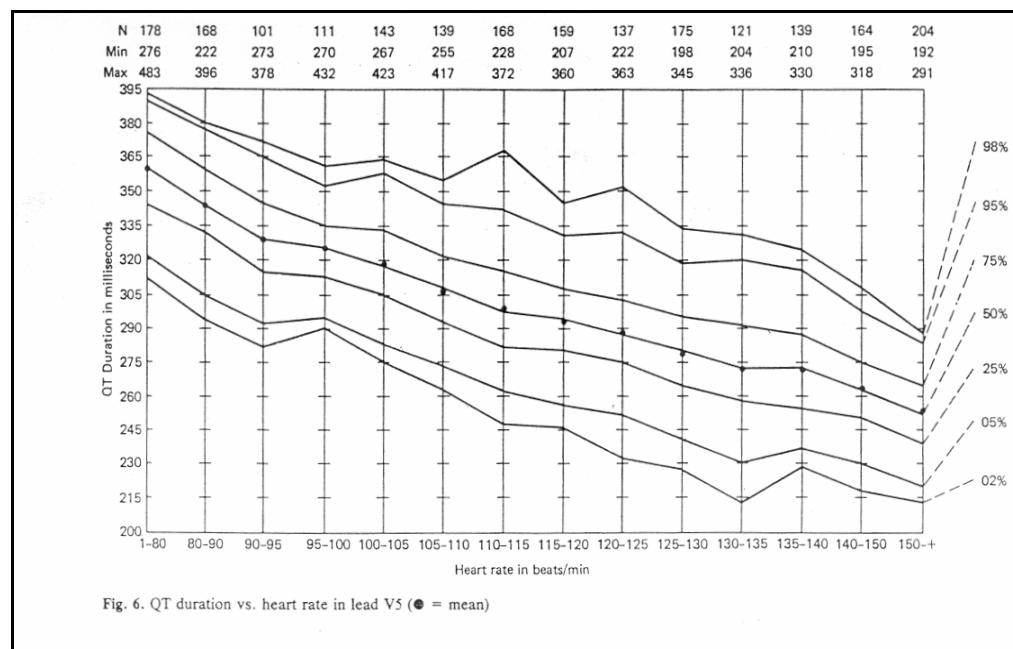
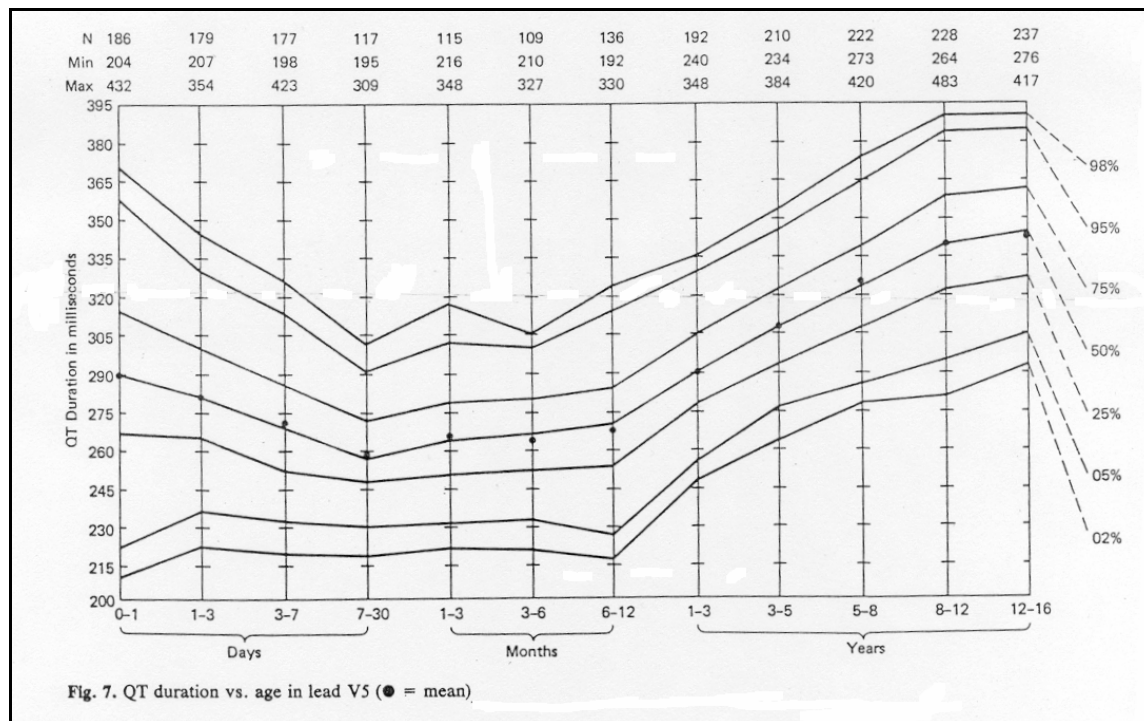


Table 2: QT duration versus age



2 Charles Berul, Am J Cardiol 1994

A group of 1000 normal children from birth to 18 years was analyzed. The QT duration was measured between the QRS onset and the end of the T wave, defined as the point where the T wave return to the isoelectric line. The JT interval was measured from the end of the QRS complex to the end of the T wave. The QTc interval was obtained by applying Bazett’s formula.

The mean JTc interval was 0.32 ± 0.02 second for the entire group and the mean QTc was 0.42 ± 0.02 second. The JT interval increases with age, whereas the JTc interval remains constant. Berul and co-authors did not find gender differences in any ECG measurement.

In this study, Berul found that the JTc interval better identifies Long QT Syndrome patients than the QTc interval. According to the author, the JTc would be a more specific measurement of ventricular repolarization, by eliminating QRS duration variability.

Table 3: Pediatric JT intervals

	Months				Years					All
	<1	1-3	4-6	7-12	1-3	4-6	7-10	11-15	15-18	
Number of patients	100	120	120	100	120	110	110	120	100	1,000
Intervals (s)										
JT	0.21	0.21	0.21	0.22	0.23	0.24	0.27	0.28	0.26	0.23 ± 0.04
JTc	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.31	0.32 ± 0.02
RR	0.41	0.41	0.45	0.48	0.52	0.60	0.72	0.76	0.70	0.60 ± 0.17

s = second.

3 Pearl, Pediatric Cardiology, 1996.

The objective of the study was to determine effects of age, gender and heart rate on corrected QT intervals, in a cohort of 781 healthy children aged 10 to 18 years. The corrected QT interval was calculated by Bazett's formula.

Table 4: Corrected QT intervals for normal boys and girls

Table 1. Corrected QT intervals for normal boys and girls

Age	No.	Boys (n = 341)		Girls (n = 440)		p
		QTc	95th Percentile	QTc	95th Percentile	
10-11	80	0.414 ± 0.020	0.447	0.416 ± 0.015	0.444	0.611
12-13	202	0.411 ± 0.019	0.441	0.411 ± 0.021	0.438	1.000
14-15	251	0.397 ± 0.025	0.436	0.407 ± 0.019	0.441	<0.0005
16-18	248	0.390 ± 0.021	0.426	0.405 ± 0.019	0.436	<0.0005
Total	781	0.400 ± 0.023	0.439	0.408 ± 0.020	0.438	<0.0005

QTc, corrected QT interval, in seconds (mean ± SD).

Ages are in years at last birthday.

The QT intervals are similar for boys and girls 10-13 years of age. Both the mean and the 95th percentile corrected QT intervals are significantly greater for girls than for boys in the 14-18-year age range.

4 Tutar, Heart 1998

The study was carried out on 372 local school children (200 male and 172 females) aged 7 to 18 years. The end of the T wave was defined as the point of return to the isoelectric line.

Tutar confirms the findings of Pearl: QTc intervals are significantly greater for girls than for in the 14-18 year age range.

Table 5: QT and QTc intervals for normal boys and girls

Table 1 Heart rate, RR, QT, and QTc intervals, and QT, QTc, and RR dispersion parameters for normal boys and girls

	<i>Boys (n = 200) mean age 12.3 (2.1) years</i>		<i>Girls (n = 172) mean age 12.5 (2.3) years</i>		<i>p</i>	<i>Whole group (n = 372) mean age 12.4 (2.6) years</i>	
	<i>Mean (SD)</i>	<i>95th Centile</i>	<i>Mean (SD)</i>	<i>95th Centile</i>		<i>Mean (SD)</i>	<i>95th Centile</i>
HR (beats/min)	89.1 (13.7)	114	89.7 (13.3)	115	0.66	89.4 (13.6)	114
Mean RR (ms)	680.3 (116.1)	896.1	671.9 (104.3)	838.6	0.47	676.9 (111.4)	877.7
Mean QT (ms)	324.3 (22.6)	360.9	328.4 (26.1)	366.1	0.10	325.9 (24.1)	363.7
Mean QTc (ms)	396.1 (20.2)	432.2	402.6 (18.2)	432.8	0.001	398.7 (19.7)	432.4
QT max (ms)	339.2 (23.2)	380	343.4 (27.7)	390	0.11	340.8 (25.2)	380
QTc max (ms)	420.7 (23.4)	453.5	425.8 (18.8)	462	0.026	422.7 (21.8)	457.6
QTD (ms)	29.8 (9.8)	50	30.0 (10.9)	50	0.90	29.9 (10.2)	50
QTcD (ms)	47.9 (16.9)	80.4	46.5 (16.2)	75	0.42	47.3 (16.6)	79.7
QT-SD (ms)	9.7 (3.1)	15.5	10.0 (3.3)	16.3	0.41	9.8 (3.2)	15.6
QTc-SD (ms)	15.5 (5.6)	27.0	15.4 (5.5)	26.4	0.93	15.5 (5.5)	26.9
RRD (ms)	96.9 (70.3)	274	89.8 (64.4)	320	0.32	94.1 (68.0)	250
RR-SD (ms)	39.8 (29.4)	107.4	36.8 (26.5)	93.7	0.31	38.6 (28.3)	101.5

HR, heart rate.

5 Eberle, Journal of Electrocardiology 1998

In this study, 373 subjects were investigated, aged 5.2 to 16.5 years (185 girls and 188 boys). The end of the T wave was defined according to Lepschkin and Surawicz, i.e the crossing point between the isoelectric line and the tangent of the steepest slope of the descending part of the T wave. Bazett's formula was not used for rate correction, but alternatively Eberle used prediction equations based on multiple regression analysis. Age, body height, and RR intervals were entered in the model.

Eberle confirms that there is no influence of gender to the QT interval from birth to puberty. At the time of puberty, sex hormones probably contribute to the differences of QTc between males and females.

Table 6: Normal values in male children

Table 2. Calculated QT Interval Normal Values QTP50 and the Individual Upper Limits of Normal QTP95 in Male Children Separated by Age (in Years)

RRI	HR	5-8 Years		9-12 Years		13-16 Years	
		QTP50	QTP95	QTP50	QTP95	QTP50	QTP95
1,200	50	427	477	422	461	421	454
1,090	55	406	451	405	442	406	438
1,000	60	388	430	392	427	394	424
925	65	374	414	380	415	384	414
855	70	360	398	370	404	374	404
800	75	350	387	362	395	367	396
750	80	340	377	354	388	360	389
705	85	331	368	348	381	354	383
665	90	324	360	342	375	349	378
630	95	317	353	336	370	344	373
600	100	311	348	332	366	340	370
570	105	305	342	327	361	336	366
545	110	300	338	324	358	332	363
520	115	295	333	320	354	329	360
500	120	292	330	317	352	326	357
480	125	288	327	314	349	324	355
460	130	284	323	311	346	321	352
445	135	281	321	309	344	319	350
430	140	278	318	307	342	317	349
415	145	275	316	304	340	315	347
400	150	272	313	302	338	313	345

Table 7: normal values in female children

Table 3. Calculated QT Interval Normal Values QTp50 and the Individual Upper Limits of Normal QTp95 in Female Children Separated by Age (in Years)

RRI	HR	5-8 Years		9-12 Years		13-16 Years	
		QTp 50	QTp95	QTp50	QTp95	QTp50	QTp95
1,200	50	433	499	450	489	438	469
1,090	55	411	469	428	464	420	450
1,000	60	393	444	409	443	405	435
925	65	378	425	393	427	393	423
855	70	363	407	379	412	382	411
800	75	352	394	367	400	373	403
750	80	342	382	357	389	365	395
705	85	333	372	348	380	358	387
665	90	325	364	339	372	351	381
630	95	318	357	332	365	345	375
600	100	312	351	326	358	341	371
570	105	306	346	320	352	336	366
545	110	301	341	315	347	332	362
520	115	296	337	309	342	328	358
500	120	292	333	305	338	324	355
480	125	288	330	301	334	321	352
460	130	284	327	297	330	318	349
445	135	281	325	294	328	315	346
430	140	278	322	291	325	313	344
415	145	275	320	288	322	311	342
400	150	272	318	284	319	308	340

6 Macfarlane, Circulation 1998

A group of 1784 neonates, infants and children was examined. The formula of Hodges was used to correct for heart rate

TABLE 2. Overall QT Interval (Corrected for Heart Rate, According to Hodges Formula) Derived From 1784 Children

Age	Mean, ms	SD, ms	96% Range, ms	n
<24 h	419.88	29.0	376–473	43
1 d	422.84	26.2	383–475	138
2 d	411.64	28.3	369–481	120
3–7 d	399.01	31.3	354–486	224
1 wk–1 mo	416.49	32.9	375–486	42
1–3 mo	413.71	24.7	365–467	69
3–6 mo	413.43	22.7	378–460	52
6 mo–1 y	393.57	24.3	357–470	75
1–3 y	387.87	17.8	360–428	116
3–5 y	390.08	16.7	362–424	141
5–7 y	389.99	13.9	365–418	154
7–9 y	392.84	16.0	361–423	142
9–11 y	399.69	14.1	371–428	114
11–13 y	401.71	16.4	373–440	119
13–15 y	402.96	20.5	372–446	142
>15 y	398.35	19.8	364–434	93

Values are milliseconds.

7 Rijnbeek et al European Heart Journal 2001

Table 2 Lead-independent ECG measurements for boys (upper row) and girls (lower row): median (2nd percentile, 98th percentile)

Lead	0-1 months	1-3 months	3-6 months	6-12 months	1-3 years	3-5 years	5-8 years	8-12 years	12-16 years
Heart rate (beats . min ⁻¹)	160 (129, 192) 155 (136, 216)	152 (126, 187) 154 (126, 200)	134 (112, 165) 139 (122, 191)	128 (106, 194) 134 (106, 187)	119 (97, 155) 128 (95, 178)	98 (73, 123) 101 (78, 124)	88 (62, 113) 89 (68, 115)	78 (55, 101) 80 (58, 110)	73 (48, 99) 76 (54, 107)
P axis (°)	56 (13, 99) 52 (24, 80)	52 (10, 73) 48 (20, 77)	49 (-5, 70) 51 (16, 80)	49 (9, 87) 50 (14, 69)	48 (-12, 78) 47 (1, 90)	43 (-13, 69) 44 (-6, 90)	41 (-54, 72) 42 (-13, 77)	39 (-17, 76) 42 (-15, 82)	40 (-24, 76) 45 (-18, 77)
P duration (ms)	78 (64, 85) 79 (69, 106)	79 (65, 98) 78 (62, 105)	81 (64, 103) 78 (63, 106)	80 (66, 96) 80 (64, 07)	80 (63, 113) 83 (62, 104)	87 (67, 102) 84 (66, 101)	92 (73, 108) 89 (71, 107)	98 (78, 117) 94 (75, 114)	100 (82, 118) 98 (78, 122)
PR interval (ms)	99 (77, 120) 101 (91, 121)	98 (85, 120) 99 (78, 133)	106 (87, 134) 106 (84, 127)	114 (82, 141) 109 (88, 133)	118 (86, 151) 113 (78, 147)	121 (98, 152) 123 (99, 153)	129 (99, 160) 124 (92, 156)	134 (105, 174) 129 (103, 163)	139 (107, 178) 135 (106, 176)
QRS axis (°)	97 (75, 140) 110 (63, 155)	87 (37, 138) 80 (39, 121)	66 (-6, 107) 70 (17, 108)	68 (14, 122) 67 (1, 102)	64 (-4, 118) 69 (2, 121)	70 (7, 112) 69 (3, 106)	74 (27, 117) 70 (-10, 112)	66 (5, 117) 70 (-21, 114)	66 (5, 101) 65 (-9, 112)
QRS duration (ms)	67 (50, 85) 67 (54, 79)	64 (52, 77) 63 (48, 77)	66 (54, 85) 64 (50, 78)	69 (52, 86) 64 (52, 80)	71 (54, 88) 68 (54, 85)	75 (58, 92) 71 (58, 88)	80 (63, 98) 77 (59, 95)	85 (67, 103) 82 (66, 99)	91 (78, 111) 87 (72, 106)
QTc interval (ms)*	413 (378, 448) 420 (379, 462)	419 (396, 458) 424 (381, 454)	422 (391, 453) 418 (386, 448)	411 (379, 449) 414 (381, 446)	412 (383, 455) 417 (381, 447)	412 (377, 448) 415 (388, 442)	411 (371, 443) 409 (375, 449)	411 (373, 440) 410 (365, 447)	407 (362, 449) 414 (370, 457)

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

*Corrected QT interval, according to Bazett's formula: $QTc = QT \cdot \sqrt{\frac{\text{heart rate}}{60}}$

ECGs from 1912 healthy children (age 11 days to 16 years) were recorded at a sampling rate of 1200 Hz. The digitally stored ECGs were analysed using a well-validated ECG computer program. The normal limits of all clinically relevant ECG measurements were determined for nine age groups.

Rijnbeek PR et al. Eur Heart J 2001 ; 22 : 702-711.

CONCLUSIONS

Age and gender influences have to be taken into consideration. More precisely, before puberty, identical upper limits for both boys and girls can be retained. According to the published data, in normal children before puberty an upper limit of 450 msec seems accurate.

After puberty, it can be suggested to use the same limits as in adults: 450 msec for male teenagers and 470 msec for female subjects.

Pierre Maison- Blanche, MD
Isabelle Denjoy, MD
Lariboisière Hospital
Paris
FRANCE