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Heart rate variability in healthy children

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Background: *The aim of this study was the evaluation of heart rate variability (HRV) time and frequency domain indices and their correlation with age, gender, mean heart rate and mean RR interval.*

Material and methods: *We examined 372 healthy subjects aged from 4 to 18 years (mean age 11 years), 180 girls and 192 boys. The following HRV components were calculated: mean RR interval (mRR), SDNN, SDANNI, SDNNI, rMSSD and* pNN_{50}*. Spectral domain analysis was performed from short-term 5- and 20-minute periods during the day and at night. The following HRV parameters were calculated: very low frequency power (VLF), low frequency power (LF), high frequency power (HF), total power (TP), balance LF/HF, normalized LF power, and normalized HF power.*

The statistical analysis was performed with the use of package S-Plus 3.4. Pearson's correlation coefficient was calculated between mean heart rate, mRR, age, gender and HRV time domain and frequency domain indices. Using the multivariate analysis of regression the most adequate model for the explanation of the behaviour of time domain parameters was selected.

Results: *We observed a strong positive linear dependence between mRR and all time domain HRV parameters, whereas the linear dependence between mean heart rate and all HRV indices was clearly negative. From among time domain parameters SDNN, SDANNI and SDNNI were significantly dependent on age. This relation is strongest in the case of SDNN and SDNNI and weakest in the case of SDNNI. However rMSSD and* pNN_{50} *are definitely not age-dependent. The most adequate model of regression always indicated mRR as a predictor of time domain parameters. There is a positive linear dependence between age and normalized LF power during the day as well as at night in 5-minute periods. The dependence is weaker at night. There is a negative linear dependence between age and normalized HF power during the day and at night in 5-minute periods. The daily linear dependence is stronger than the night one. There is a positive dependence in LF/HF ratio and age during the day and also at night. For 20-minute periods we found the same characteristics as for 5-minute ones. Model selection procedure using mRR, age and mean heart rate as possible predictors of frequency domain HRV parameter always included age as one of the optimal predictors.*

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Conclusions: *Global sympathetic and time domain HRV parameters, such as SDNN, SDANNI and SDNNI, increased significantly with age. Parasympathetic parameters, such as rMSSD and pNN_{50}, are not age-dependent. Among the studied variables (mRR, age, gender and mean heart rate) it was mRR which was the most significant predictor off all time domain HRV parameters. In our healthy population older than 4 years of life LF values increased significantly with age. In the same cohort HF values decreased significantly with age. In the same cohort HF values decreased significantly with age.* (Folia Cardiol. 2003; 10: 203–211)

heart rate variability, time domain, frequency domain, healthy children, age, gender, mean heart rate

Introduction

Heart rate variability (HRV) is a non-invasive marker of autonomic nervous system influence on sinus node [1]. Heart rate variability characterises all healthy hearts [2]. In 1965 Hon and Lee reported the loss of heart rate variability preceding foetal death [3]. Disturbances between sympathetic and parasympathetic activities were known to have been responsible for sudden infant death syndrome (SIDS) [4]. There is a significant correspondence between depressed heart rate variability and cardiovascular mortality [5] as well as lethal cardiac arrhythmias [6, 7] and progress of heart failure [8, 9] in patients after myocardial infarction. There is also a significant loss of HRV values in diabetic patients [10].

However autonomic nervous system maturation is not very clearly known in children. Papers with controversial results in healthy subjects during childhood [11, 12] have been published. The aim of this study was an evaluation of the time domain and frequency domain HRV indices in healthy children and a their correlation with age, gender and mean heart rate.

Material and methods

Our population consisted of 372 children aged from 4 to 18 years (mean age 11 years), 180 girls and 192 boys. In each case parental permission to perform non-invasive examinations was obtained. All healthy subjects had a normal medical history as well as physical and echocardiographic performances. None used tobacco products or took medications. There were no athletes in the adolescent cohort. The samples was created so that for each 2-year period from 4 to 12 years of life at least 30 subjects were included. However from age 12, in each 2-year period, at least 29 subjects of each gender were considered. Table 1 presents age and gender distribution in the study population.

Table 1. Distribution of gender and age in study population

Age [years]	Girls (n = 180)	Boys (n = 192)
4–6	15	31
6–8	30	18
8–10	21	24
10–12	19	21
12–14	29	35
14–16	29	33
16–18	37	30

24-hour ECG recording

An 3-channel ECG tape recorder Oxford MR 4500 was used to record continuous ambulatory ECG monitoring. We used recorder tapes TDK AD 60. The electrocardiographic templates were studied and relabelled normal or abnormal as appropriate. Incorrectly labelled segments with artefacts were removed from analysis of successive normal RR intervals. Sinus rhythm was confirmed before entering the protocol. All time domain indices as well as mean heart rate were automatically calculated by the commercially available Oxford Medilog Excel computer program.

Time domain HRV analysis

Six measures were examined in the entire 24-hour ECG recording:

- mRR — mean RR interval during sinus rythm;
- SDNN — standard deviation of all filtered RR (NN) intervals in entire 24-hour ECG recording;
- SDNNI — mean of the standard deviations of all filtered RR (NN) intervals for all 5-minute segments of the analysis;
- SDANNI — standard deviation of the means of all (RR) NN intervals for all 5-minute segments of the entire recording;
- rMSSD — the square root of the mean from the sum the squares of differences between

adjacent filtered RR intervals over the length of the analysis;
- pNN_{50} — percentage of differences between adjacent filtered RR (NN) intervals that are greater than 50 ms for the whole analysis.

Frequency domain HRV analysis

Spectral domain analysis was performed by Medilog Oxford 7.5 application using fast Fourier transformation (FFT) algorithm from short-term 5- and 20-minute periods during the day as well as at night. The following HRV parameters were obtained:
- ULF [ms^2] — power of ultra low frequency spectrum (0–0.0033 Hz);
- VLF [ms^2] — power of very low frequency spectrum (0.0033–0.04 Hz);
- LF [ms^2] — power of low frequency spectrum (0.04–0.15 Hz);
- HF [ms^2] — power of high frequency spectrum (0.15–0.4 Hz);
- TP [ms^2] — total power (0–0.4 Hz);
- LF/HF — ratio of powers LF/HF;
- nLF [NU] — normalized power of low frequency spectrum (NU — normalized units):
  $$nLF = 100 \times LF/(TP - ULF);$$
- nLF [NU] — normalized power of high frequency spectrum:
  $$nHF = 100 \times LF/(TP - VLF);$$

Total power values obtained from the computer were diminished by ULF values determined as artefact in short-term (5- and 20-min) recording.

Statistical analysis

Statistical analysis was performed using statistical package S-Plus 3.4. Pearson's correlation coefficient (r) were computed between time domain HRV indices and age as well as mean heart rate, mRR and gender. The analysis concerned also linear dependence between time domain parameters and mean RR, gender, age and mean heart rate as explanatory variables. The analysis concerned also linear dependence between spectral domain indices, age and gender, as explanatory variables. Beside the best multivariate models also individual models were considered. The level of significance was considered as < 0.05.

Results

Mean heart rate decreases significantly with age. It is negatively linearly dependent with respect to mean heart rate and all time domain HRV parameters. There is positive linear correlation between mRR and all time domain parameters. Dependence analysis of time domain parameters indicates that SDNN, SDANN, SDANNI increase significantly with age. The relation is strongest in the case of SDNN and SDANN, and weakest in the case of SDNNI. However in the case of rMSSD and pNN_{50} there was no significant dependence on age. Time domain values in study population are presented in table 2. The corresponding Pearson's correlation coefficient and significance level values are given in table 3. We also considered dependence between time domain HRV parameters and age for girls and boys separately. Figures 1–3 show the results for SDNN, SDNNI and rMSSD. For SDNN and SDNNI regression lines for boys' population have approximately the same slope as for girls' population but they are shifted upwards. However for SDNNI slope values are consistent with previous results for the whole group, which indicated that dependence between SDNNI and age is weaker than between SDNN and age. When two sub-popu-

Table 2. Time domain heart rate variability indices in study population

Age [years]	Mean heart rate [min^{-1}]	mRR [ms]	SDNN [ms]	SDNNI [ms]	SDANNI [ms]	rMSSD [ms]	pNN_{50}
4–6	91 ± 6	652 ± 48	135 ± 27	75 ± 21	110 ± 23	70 ± 28	23% ± 11%
6–8	91 ± 4	653 ± 44	131 ± 30	69 ± 21	109 ± 26	61 ± 31	20% ± 11%
8–10	87 ± 9	689 ± 74	138 ± 36	72 ± 21	117 ± 34	59 ± 18	22% ± 10%
10–12	85 ± 8	706 ± 67	141 ± 34	71 ± 19	118 ± 27	58 ± 24	23% ± 13%
12–14 Girls	84 ± 6	718 ± 60	147 ± 32	75 ± 17	121 ± 29	59 ± 20	22% ± 12%
12- 14 Boys	81 ± 7	738 ± 57	162 ± 32	81 ± 19	134 ± 29	65 ± 22	25% ± 11%
14–16 Girls	82 ± 5	722 ± 44	153 ± 43	71 ± 20	130 ± 28	49 ± 21	29% ± 10%
14–16 Boys	77 ± 7	788 ± 76	180 ± 32	88 ± 21	154 ± 20	66 ± 22	26% ± 12%
16–18 Girls	79 ± 7	754 ± 62	170 ± 37	77 ± 24	153 ± 35	58 ± 30	21% ± 12%
16–18 Boys	78 ± 7	776 ± 80	238 ± 39	81 ± 19	159 ± 35	61 ± 20	23% ± 9%

Table 3. Relationship assessment between analysed variables. Pearson's correlation coefficient (r) and its significance level

	mRR	SDNN	SDNNI	SDANNI	rMSSD	pNN_{50}
Age	r = 0.52 p < 0.0001	r = 0.40 p < 0.0001	r = 0.13 p = 0.013	r = 0.45 p < 0.0001	r = 0.08 p > 0.1	r = 0.038 p > 0.1
mRR		r = 0.72 p < 0.0001	r = 0.67 p < 0.0001	r = 0.65 p < 0.0001	r = 0.48 p < 0.0001	r = 0.67 p < 0.0001
HR	r = –0.95 p < 0.0001	r = –0.68 p < 0.0001	r = –0.63 p < 0.0001	r = –0.62 p < 0.0001	r = –0.44 p < 0.0001	r = –0.63 p < 0.0001

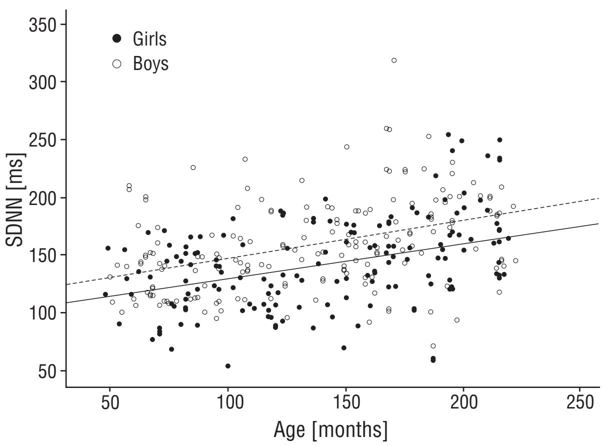

Figure 1. Relationship between SDNN and age for boys' and girls' population. Pertaining regression lines are shown with solid and dashed line respectively

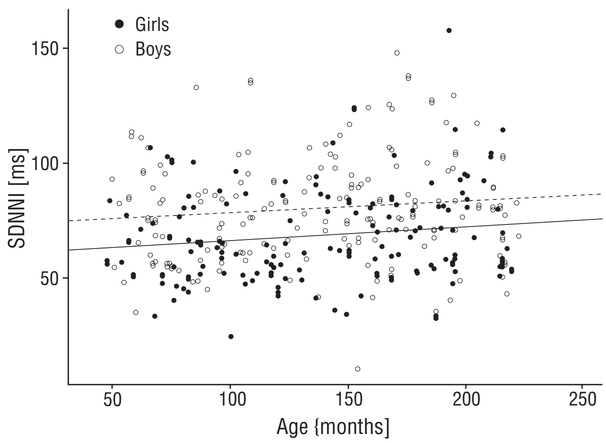

Figure 2. Relationship between SDNNI and age for boys and girls in study population

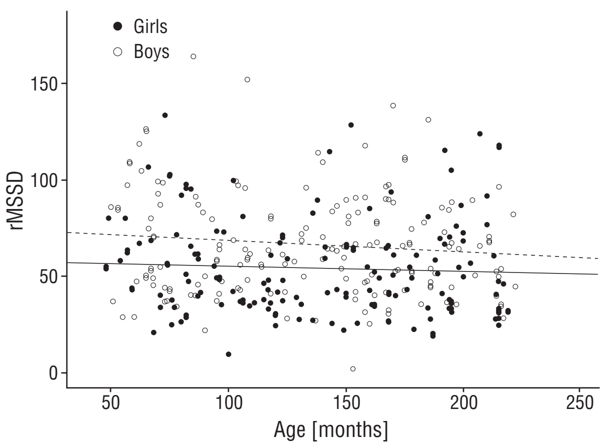

Figure 3. Relationship between rMSSD and age for boys and girls in study population

lations for ages less than 12 years and over 12 years of life were considered, SDNN was significantly dependent in both of them but with a higher slope for the older. For SDNNI and rMSSD dependence on age is not significant in both sub-populations. Moreover multiple regression analysis, using mRR, age, gender and mean heart rate as predictors, was performed. It turned out that for all time domain parameters the most significant predictor is mRR. Model selection using backward selection method and Akaike information criterion AIC gave the same results and indicated the following variables as optimal predictors:

— mRR for predicting SDNN;
— mRR andage for predicting SDNNI;
— mRR and age for predicting SDANNI;
— mRR and age for predicting rMSSD;
— mRR, age and mean heart rate for predicting pNN50.

Frequency domain HRV values in 5-minute periods during the day are presented in table 4. The night ones are presented in table 5. In table 6 spectral domain HRV indices in 20-minute periods during the day are presented, in table 7 night ones in the study population. There is a positive linear dependence between age and nLF during the day (fig. 4) as well as at night in 5-minute periods. The dependence is weaker at night. There is a negative linear dependence between age and nHF during the day

Table 4. Frequency domain heart rate variability indices in study population in 5 minute periods during a day

Age [years]	VLF [ms²]	LF [ms²]	nLF [NU]	HF [ms²]	nHF [NU]	TP [ms²]	LF/HF
4–6	998 ± 637	617 ± 413	62 ± 19	620 ± 413	38 ± 17	2238 ± 945	2.6 ± 1.7
6–8	732 ± 366	532 ± 246	61 ± 16	699 ± 334	39 ± 18	4653 ± 3331	2.2 ± 1.6
8–10	1024 ± 560	680 ± 424	64 ± 13	451 ± 264	36 ± 13	4749 ± 2998	2.3 ± 1.2
10–12	1158 ± 590	843 ± 493	62 ± 12	634 ± 474	38 ± 12	5130 ± 3220	2.1 ± 1.0
12–14 Girls	1622 ± 1354	950 ± 750	67 ± 16	654 ± 354	32 ± 13	5291 ± 3664	3.0 ± 1.8
12–14 Boys	1055 ± 522	1034 ± 754	63 ± 17	851 ± 579	36 ± 17	6360 ± 2500	3.0 ± 1.8
14–16 Girls	1055 ± 522	1034 ± 754	63 ± 17	851 ± 579	36 ± 17	6360 ± 2500	2.5 ± 1.4
14–16 Boys	1251 ± 518	870 ± 734	74 ± 7	275 ± 203	25 ± 10	4761 ± 2033	3.9 ± 1.2
16–18 Girls	2135 ± 1149	1142 ± 510	74 ± 10	544 ± 287	25 ± 10	6343 ± 3381	3.9 ± 2.1
16–18 Boys	871 ± 801	852 ± 900	74 ± 10	377 ± 341	25 ± 10	4113 ± 2477	4.5 ± 2.4

Table 5. Frequency domain heart rate variability indices in study population in 5 minute periods at night

Age [years]	VLF [ms²]	LF [ms²]	nLF [NU]	HF [ms²]	nHF [NU]	TP [ms²]	LF/HF
4–6	1325 ± 520	1411 ± 838	29 ± 17	1325 ± 519	71 ± 17	8214 ± 5378	0.5 ± 0.3
6–8	1273 ± 395	1733 ± 663	30 ± 13	5308 ± 2840	86 ± 13	6181 ± 5185	0.6 ± 0.3
8–10	1327 ± 640	1142 ± 966	40 ± 15	1840 ± 1409	60 ± 15	4368 ± 2843	0.8 ± 0.5
10–12	965 ± 385	892 ± 566	33 ± 18	2545 ± 1375	67 ± 18	4407 ± 2387	0.8 ± 0.4
12–14 Girls	683 ± 598	776 ± 255	32 ± 18	1893 ± 1492	69 ± 18	3356 ± 2397	0.6 ± 0.5
12–14 Boys	1134 ± 382	1305 ± 636	37 ± 15	2069 ± 1223	63 ± 15	4515 ± 2321	0.8 ± 0.4
14–16 Girls	372 ± 302	756 ± 632	37 ± 14	1178 ± 688	62 ± 14	2308 ± 1792	0.7 ± 0.4
14–16 Boys	1683 ± 1200	1207 ± 882	44 ± 18	1712 ± 950	55 ± 19	4610 ± 2988	1.1 ± 0.7
16–18 Girls	1040 ± 529	1424 ± 946	44 ± 20	1641 ± 946	56 ± 20	4108 ± 2963	1.2 ± 0.6
16–18 Boys	2937 ± 1840	1629 ± 1257	42 ± 18	2217 ± 1754	58 ± 18	6802 ± 6658	0.9 ± 0.7

Table 6. Frequency domain heart rate variability indices in study population in 20 minute periods during a day

Age [years]	VLF [ms²]	LF [ms²]	nLF [NU]	HF [ms²]	nHF [NU]	TP [ms²]	LF/HF
4–6	1699 ± 751	1051 ± 790	60 ± 17	1167 ± 834	39 ± 17	3927 ± 2248	2.9 ± 1.4
6–8	2421 ± 1696	1212 ± 926	61 ± 16	1001 ± 855	38 ± 16	4653 ± 3331	2.3 ± 1.6
8–10	2616 ± 1934	1174 ± 466	61 ± 11	939 ± 722	38 ± 11	4749 ± 2998	1.9 ± 0.8
10–12	2221.9 ± 1287.3	1189 ± 744	58 ± 11	1061 ± 976	40 ± 13	5130 ± 3220	2.0 ± 0.9
12–14 Girls	2970 ± 1636	1308 ± 805	61 ± 13.8	992 ± 809	38 ± 13	5291 ± 3664	1.9 ± 1.1
12–14 Boys	3483 ± 2398	1636 ± 971	60 ± 14	1217 ± 992	39 ± 14	6360 ± 2500	2.0 ± 1.2
14–16 Girls	2564 ± 1687	1388 ± 856	69 ± 13	796 ± 517	32 ± 12	4761 ± 2033	2.8 ± 1.5
14–16 Boys	3417 ± 2184	1998 ± 1500	71 ± 13	928 ± 855	29 ± 12	6343 ± 3381	3.1 ± 1.6
16–18 Girls	2366 ± 1481	1124 ± 756	72 ± 11	605 ± 251	26 ± 11	4113 ± 2477	3.9 ± 2.5
16–18 Boys	3896 ± 2275	1656 ± 654	73 ± 9	734 ± 271	26 ± 9	6314 ± 3411	3.4 ± 1.5

Table 7. Frequency domain heart rate variability indices in study population in 20 minute periods at night

Age [years]	VLF [ms²]	LF [ms²]	nLF [NU]	HF [ms²]	nHF [NU]	TP [ms²]	LF/HF
4–6	2095 ± 1654	2051 ± 1095	38 ± 13	4051 ± 3526	62 ± 13	8214 ± 5378	0.7 ± 0.4
6–8	1436 ± 1131	1246 ± 653	40 ± 17	5290 ± 3535	60 ± 18	5290 ± 3535	0.9 ± 0.5
8–10	2313 ± 1292	1431 ± 935	39 ± 12	2511 ± 1433	59 ± 13	6330 ± 4879	0.8 ± 0.3
10–12	2262 ± 1441	1203 ± 1063	40 ± 12	1975 ± 1530	60 ± 12	5450 ± 2723	0.8 ± 0.3
12–14 Girls	1866 ± 928	1459 ± 951	31 ± 18	2450 ± 951	59 ± 12	5785 ± 3845	0.8 ± 0.4
12–14 Boys	2979 ± 2113	1656 ± 1060	39 ± 14	3098 ± 1920	61 ± 13	7748 ± 4173	0.7 ± 0.4
14–16 Girls	1583 ± 1059	1291 ± 678	47 ± 14	1492 ± 1302	53 ± 15	4374 ± 3033	1.1 ± 0.6
14–16 Boys	2728 ± 3176	2131 ± 1353	47 ± 11	2425 ± 1233	47 ± 11	7292 ± 6480	1.2 ± 0.4
16–18 Girls	1915 ± 1562	1670 ± 944	48 ± 19	2672 ± 1293	56 ± 20	6266 ± 4926	1.2 ± 0.9
16–18 Boys	2558 ± 1257	2363 ± 1002	47 ± 14	2602 ± 1697	53 ± 15	7531 ± 1981	1.0 ± 0.6

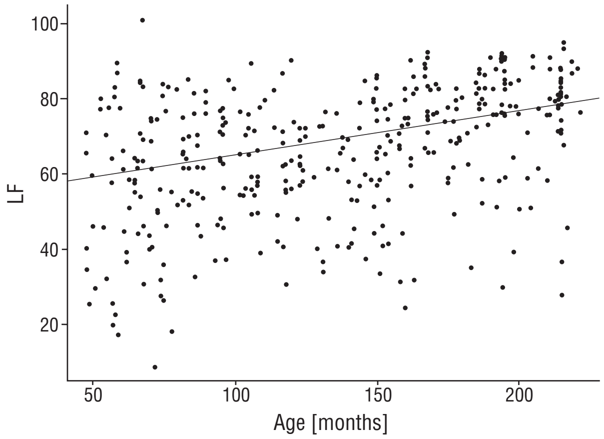

Figure 4. Relationship between normalized power of low frequency HRV spectrum (LF) for 5-minute intervals during the day and age for study population with corresponding least squares regression line

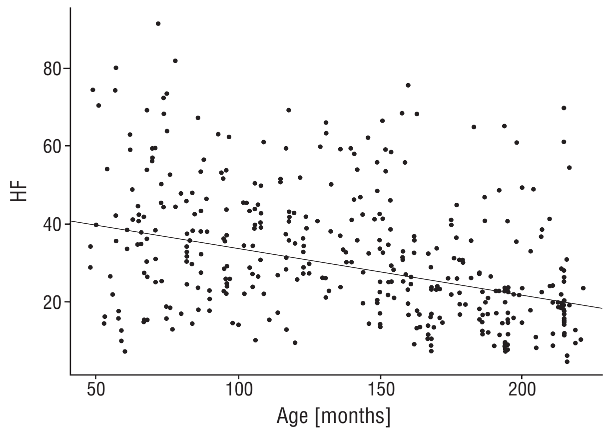

Figure 5. Relationship between normalized power of high frequency HRV spectrum (HF) for 5-minute intervals at night and age for study population with corresponding least squares regression line

as well as at night in 5-minute periods (fig. 5). The daily linear dependence is stronger than the night one. There is a positive dependence in LF/HF ratio and age during the day and also at night, but the latter is weaker than the former. For 20-minute periods we found the same characteristics as for 5-minute ones (fig. 6). The dominance of LF in respect to HF during the day in comparison to the night can be shown best on a scatter-plot of night LF/HF ratio. A position of the point on the plot below the line of agreement (y = x) shows that day LF/HF is larger than night LF/HF ratio. As is seen in figure 6 the majority of the points (330 out of 372) lie below the line of agreement. Our results show that LF increased significantly with age and HF decreased significantly after 4 years of life, but dependence between age and absolute indices of fre-

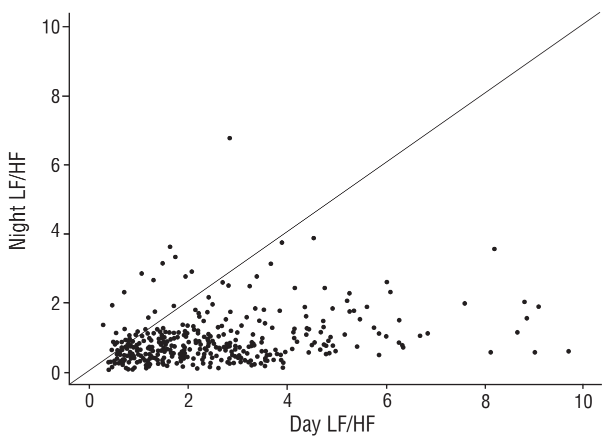

Figure 6. Relationship between LF/HF ratio for 20-minute intervals during the night and the day (line of agreement y = x)

quency domain HRV is weaker than normalized indices (tables 8, 9). There are no significant differences for TP in different age groups in 5- and 20-minute periods during the day as well as at night. VLF values during the day are significantly different for 20-minute periods and with limited significance for 5-minute periods. There is no difference in 5- and 20-minute periods in VLF indices during the night. Analysis of relation between age, gender and frequency domain indices shows the most adequate model always included age, except TP, where gender is the most adequate one. The best models were chosen using the Akaike information criterion and the backward selection method. The results of both procedures were the same.

Table 8. Relationship assessment of age and frequency domain heart rate variability parameters obtained from short-term (5 min) periods during day and at night in the study population. Pearson's correlation coefficient (r) and its significance level

	Day (5 min)	Night (5 min)
VLF	r = 0.09 p = 0.084	r = 0.046 p > 0.1
LF	r = 0.16 p = 0.002	r = 0.03 p > 0.1
nLF	r = 0.36 p < 0.0001	r = 0.23 p < 0.0001
HF	r = –0.12 p = 0.03	r = –0.11 p = 0.0003
nHF	r = –0.36 p < 0.0001	r = –0.24 p < 0.0001
TP	r = 0.06 p > 0.1	r = 0.08 p > 0.1
LF/HF	r = 0.37 p < 0.0001	r = 0.24 p < 0.0001

Table 9. Relationship assessment of age and frequency domain heart rate variability parameters obtained from short-term (20 min) periods during day and at night in the study population. Pearson's correlation coefficient (r) and its significance level

	Day (20 min)	Night (20 min)
VLF	r = 0.13 p = 0.02	r= 0.04 p > 0.1
LF	r = 0.12 p = 0.03	r = 0.05 p > 0.1
nLF	r = 0.3 p < 0.0001	r = 0.22 p < 0.0001
HF	r = –0.13 p = 0.02	r = –0.11 p =0.03
nHF	r = –0.3 p < 0.0001	r = –0.212 p < 0.0001
TP	r = 0.07 p > 0.1	r = 0.02 p > 0.1
LF/HF	r = 0.3 p = 0.0003	r = 0.2 p = 0.0001

Discussion

In the late 1980s it was confirmed that reduced HRV was associated with higher risk of post-infarction mortality, already reported by Wolf et al. in the 1970s [13]. In the adult population it was shown that different HRV components decreased with increasing age due to the physiological aging process [14]. In childhood postnatal development of the autonomic nervous system is not parallel. In infancy sympathetic components develop faster than parasympathetic ones. In infants who subsequently succumbed to sudden infant death syndrome (SIDS) a delayed or deficient cardiovagal development was demonstrated [4]. Among time domain HRV parameters, SDNN estimates overall HRV, SDANN estimates long-term components of HRV. rMSSD and pNN_{50} estimate short-term component of HRV and might be considered to reflect the averaged extent of vagal modulation of heart rate. In our study mRR, SDNN, SDNNI, SDANNI increased significantly with age. The dependence was strongest in the case of SDNN, SDANNI and weakest in the case of SDNNI. However, the results strongly indicate that parasympathetic parameters, such as rMSSD, pNN_{50}, are not age-dependent. In Reardon et al. [15], a study concerning 56 healthy subjects aged from 40 to 102 years, HRV measures attributable to mean parasympathetic modulation of heart rate did not significantly decline with increasing age. The authors conjectured that the hypothesis of maintaining parasympathetic activity protection in cardiovascular morbidity and also general survival may be plausible. On the other hand, the rMSSD value reported by Reardon et al. was 27 ± 12 ms. In our population we obtained 61 ± 27 ms, which clearly indicates the slow diminishing of this value during the whole life. The same correlation was observed in girls' and boys' population considered separately. However using multiple regression analysis it turned out that for the most significant predictor of all time domain HRV parameters is mRR, as mRR is a natural parameter reflecting the development of autonomic nervous system maturation in contrast to age. This influence on time domain HRV parameters is stronger than the influence of age. The results of our study show that among considered predictors of time domain HRV parameters, gender is the least significant. Previous studies, already reported by Massim et al. [12] and Goto et al. [16], have demonstrated the age dependence in linear analysis of all time domain parameters. However, in our study the most significant predictor factor of time domain HRV parameters in multiple regression analysis was mRR. Age was the second predictor factor of time domain HRV parameters, after mRR, in our study.

Our study concerned a population over 4 years of life. In the study by Finley et al. [11] the authors reported significant diminishing of LF, HF and TP values after 6 years of age. Our results concerning HF were consistent with theirs. In our population of 372 healthy children (with respect to age) we found increasing LF values and decreasing ones in 5- and 20-minute periods during the day as well as at night. We found that this relation was more pronounced for normalized LF and HF indices than for non-normalized ones. This is due to the fact that changes in normalized LF basically correspond to changes in LF/HF ratio and changes in HF correspond to changes in LF/HF ratio. Thus, the positive dependence of LF on age is more strongly shown by normalized LF because of negative dependence of HF on age. This is the case for day LF and HF indices. This also explains why LF during the night for 5-minute intervals was not significantly dependent on age, which was not in the case normalized LF. The reason is the significant negative dependence of HF on age. Dominance of LF over HF during the day in contrast to the night, when HF dominates over LF, is very strongly confirmed. Moreover Goto et al. [16] confirmed diminishing HF values at night after 6 years of life. In TP we have not discovered a diminishing character of changes. Massin et al. [12] dispute the previous finding that LF/HF components decreased after 6 years of age. In particular, figure 6 in this paper shows that LF/HF ratio increases after 4 years of age, which is consistent with our results (tables 8, 9).

Conclusions

1. Global sympathetic and time domain HRV parameters, such as SDNN, SDANNI and SDNNI, increased significantly with age.
2. Parasympathetic parameters, such as rMSSD and pNN_{50}, are not age-dependent.
3. Among studied variables (mRR, age, gender and mean heart rate) it was mRR which was the most significant predictor of time domain HRV parameters.
4. In our healthy population older than 4 years of life LF values increased significantly with age.
5. In the same cohort HF values decreased significantly with age.

Streszczenie

Zmienność rytmu serca u zdrowych dzieci

Wstęp: *Celem pracy było ustalenie norm zmienności rytmu serca (HRV) w zależności od wieku, płci, średniej częstości rytmu serca i średniego odstępu RR w populacji dzieci zdrowych.*

Materiał i metody: *Badaniami objęto 372 zdrowych dzieci w wieku 4–18 lat (średnio 11 lat), 180 dziewczynek, 192 chłopców. Zdrowe dzieci podzielono na 10 grup wiekowych: od 4 rż. co 2 lata, od 12 rż. podział dodatkowo uwzględniał płeć. W każdej grupie badano co najmniej 29 dzieci. W analizie czasowej oceniano następujące parametry: mRR, SDNN, SDANN, SDANNI, rMSSD, pNN50, zaś w analizie widmowej — następujące pasma widma: VLF, LF, HF, TP oraz współczynnik LF/HF, w odcinkach 5- i 20-minutowych podczas czuwania oraz snu. Analizę statystyczną przeprowadzono, stosując pakiet S-Plus. Stosując analizę liniową i krokową, wyznaczono normy parametrów czasowych i widmowych, ich wzajemne relacje względem wieku i płci oraz częstości rytmu serca. Przyjęto poziom istotności $p < 0,05$. Metodę wieloczynnikowej analizy regresji zastosowano, by ustalić najlepszy z modeli zmienności do objaśnienia parametrów czasowych.*

Wyniki: *Stwierdzono dodatnią liniową zależność między mRR a wszystkimi parametrami analizy czasowej, zależność między wiekiem a tymi parametrami była liniowo ujemna. SDNN, SDANN, SDANNI istotnie zależały od wieku, w mniejszym zakresie SDNNI. Natomiast* *parametry analizy czasowej rMSSD i pNN50 w tej populacji były nieznamienne. Przy ustalaniu optymalnego modelu zmiennych do objaśniania parametrów czasowych stwierdzono, że najsilniejsza zależność występuje między parametrami czasowymi a mRR. Wiek występuje jako druga zmienna objaśniająca i jest również istotnie zależna od mRR. Wykazano dodatnią zależność między wiekiem a znormalizowaną mocą widma LF w 5-minutowych fragmentach dziennych i nocnych. Zależność nocna była słabsza od dziennej. W 5-minutowych fragmentach dziennych i nocnych zależność znormalizowanej mocy widma HF była liniowo ujemna. Wartości współczynników LF//HF były liniowo ujemnie zależne od wieku, w dziennych i nocnych fragmentach 5- i 20-minutowych. Przy ustalaniu optymalnego modelu zmiennych analizy widmowej najsilniejszą zależność zaobserwowano między ocenianymi parametrami a wiekiem.*

Wnioski: *Parametry SDNN, SDANNI, SDNNI rosną w zależności od wieku. Wartość rMSSD, pNN50 w populacji dzieci powyżej 4 lat nie ulegają istotnym zmianom. Spośród parametrów analizy czasowej przy ustalaniu optymalnego modelu zmienności stwierdzono, że najsilniejsza zależność występuje między parametrami czasowymi a mRR. Wiek stanowi drugą zmienną objaśniającą i silnie koreluje z mRR. W populacji dzieci zdrowych powyżej 4 rż. parametry LF rosły w zależności od wieku, zaś parametry HF znamiennie się obniżały.* (Folia Cardiol. 2003; 10: 203–211)

zmienność rytmu serca, analiza czasowa, analiza widmowa, zdrowe dzieci, średni rytm serca, wiek, płeć

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