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CORRECTIONS OF HEART RATE VARIABILITY INDICATORS TO MINIMIZE THE EFFECT OF POSTURAL CHANGE AND CIRCADIAN RHYTHM

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INTRODUCTION

The implementation of heart rate variability analysis (HVA) in industrial production practice is greatly interfered with by the fact that its indicators are influenced by posture and timing of the examination over 24 hours. This necessitates the undertaking of specific investigation for precise quantitative assessment of the correlations involved with the purpose to recalculate values obtained in single examinations through their multiplication by translated coefficients.

Of all factors exerting an effect on the cardiovascular system during body transition from horizontal to vertical position, the alteration of hydrostatic pressure with ensuing blood redistribution is the most important one. As a result of venous stasis, venous pressure at heart and thoracic cage level, stroke volume and systolic blood pressure are decreased. This in turn, necessitates triggering of a number of physiological mechanisms, accomplishing active adaptive hemodynamic reactions of a reflex nature. It is believed that the reflex arch is initiated by the arterial baro- and stretch receptors of the intrathoracic vessels (in aortic arch, carotid sinus, etc.). Moreover, during rather prolonged maintaining of the standing erect posture, certain humoral regulation mechanisms are also included, such as enhanced catecholamine secretion from the adrenal glands, renin-angiotensin system activation as well as enhanced vasopressin and aldosterone release. Simultaneously, the peripheral vessels in striated muscles, skin, kidneys and splanchnic region are contracted, giving rise to a short-term increase of mean arterial pressure. The central blood pressure drops by 3–5 Torr with parallel acceleration of heart rate by 20 per cent of the values for recumbency. The stroke volume and cardiac out-put decrease owing to reduced venous supply, followed by a gradual recovery of the initial values as a result of vascular spasm. Overall peripheral resistance augments parallel to the diminishing blood volume in capacity vessels. The changes in cardiovascular system described, associated with a different postural activity, are likewise mirrored in the heart rhythm indicators which necessitates unification of their concrete values to those of the "supine" posture in each examination. Vybiral et al. /1/ were successful in demonstrating that in +70° passive body tilt, the standard deviation (SD) of the cardiointerval (R–R interval) decreases, as well as the indicator V_1 and the high-frequency component of the frequential FHRS component sugments, as well as the difference between maximal and minimal cardiointerval during deep expiration. Similar data have been reported by Fallen et al. /2/ according to which the spectral energy of FHRS in the range 0.1 Hz shows statistically highly significant difference upon comparison of the supine and standing position of the body. The alteration in pulse variance as the result of postural change was used by Kuroiwa et al. /3/ as an objective criterion to assay autonomic dysfunction, associated with a number of diseases, namely: spinocerebellar degeneration, syndrome of Shy–Drager, parkinsonism, diabetes mellitus, etc. On the other hand, Simpson and Wicks /4/ established that baroreceptor-related heart rate variability in different postures is an indicator strongly affected by the age of the subjects under study. A similar analysis of the phisiological mechanisms of initial heart rate response to postural change is presented by Borst et al. /5/. Unfortunately, the cited work contains no data concerning variability and spectral parameters of the heart rhythm.

An identical problems is the one linked to the necessity of unification in terms of circadian biorhythmic changes in the cardiovascular system. Ninomiya et al. /6/ studied the dynamic pattern of pulse rate, its variance and variation coefficients during 24-hour Holter monitoring. They found a bimodal distribution of the cardiointervals, with their number in nocturnal hours a statistically highly significant lowering. The circadian dependence of heart rhythm was documented by other authors too: Clark et al. /7/, Glagov /8/, Drodsky /9/, etc. According to Stefikova et al. /10/, the circadian rhythm of heart rate variability is largely dependent on the 24-hour curve of body temperature and physical activity of the individual.

In the opinion of Burdick et al. /11/ the heart rate variability is altered not only with respect to sleep and wakefulness, but also depending on the type of sleep. For instance, during REM stage it may reveal heightened values. as compared to wakefulness and fourth stage of sleep.

Our experience similarly shows that heart rhythm indicators are under strong circadian influence /12, 14/. However, in our recent investigations, the examinees were workers, examined during day and night shift work schedules. The obtained data in this group could not be done only in persons abiding to the normal course of transition from sleep to wakefulness, and vice versa.

PURPOSE

It is the purpose of this study to work out translation coefficients for sitting and standing relative to resting supine postures, at single hours throughout the day relative to 0,00 am (morning) for the basic indicators of the heart rate variability analysis, and more particularly for the most frequently used one — the so-called classification indicator (CI).

EXPERIMENTAL SETUP AND RESULTS

Registration and mathematical assessment of the indicators of heart rate variability analysis (HVA) was done after the method suggested by S. Danev /13/. The study was conducted in two experimental sets:

a) Experimental set one. Forty persons were examined in standing, sitting and supine posture sustained for ten minutes. Values obtained for the differenet postures were averaged. Thus a matrix comprising 40 persons and 3 different postures resulted. In the first 20 subjects apart from CI, the indicators listed in Table 1 were also registered and statistically compared. From the

Table 1

Mean Values of the Indicators Studied in Postural Activity: Standing, Sitting and Supine

Indicators	Standing posture I		Standing posture II		Supine posture III		Test of Student for dependent variables: p =	
	$\bar{X}$	$S\bar{x}$	$\bar{X}$	$S\bar{x}$	$\bar{X}$	$S\bar{x}$	I—II	II—III
X (ms)	658	16,6	844	30,0	922	33,0	0,000	0,088
SD (ms)	42	4,1	57,9	3,2	65,8	5,0	0,003	0,656
AMo (%)	25	1,5	16,8	1,2	16,6	1,5	0,000	0,881
HI (rel. units)	1,2	0,2	0,5	0,1	0,1	0,1	0,000	0,82
Pt (%)	28,8	1,6	21,6	0,8	18,7	0,9	0,021	0,02
Pkn (%)	32,0	1,6	29,0	1,1	24,0	0,8	0,079	0,001
Pp (%)	32,0	1,7	39,0	0,9	48,0	1,3	0,000	0,000
IVO (rel. units)	0,8	0,1	0,5	0,06	0,4	0,03	0,682	0,243
CI (rel. units)	–68,0	7,3	17,0	13,4	41,8	19,0	0,000	0,313
Pleth (mm)	7,9	0,6	12,3	1,1			0,001	
RRs (Torr)	119	2,3	117	2,6	111	2,2	0,655	0,137
RRd (Torr)	78	1,9	76	1,7	74	1,5	0,615	0,613

table it can be seen that with the exception of IVO (basic indicator of the frequential heart rhythm spectrum), systolic and diastolic blood pressure, all remaining indicators exhibited a markedly expressed postural dependence. The great interindividual differences reflected by SD, CI in particular, were impressive. They were explained by the fact that CI calculation implies multiplication of its main components which in turn substantially augments its interpersonality resolution capacity. This is a quality rendering it an excellent tool for diagnosing even the slightest alterations in tension of the mechanisms governing and regulating heart rhythm, but simultaneously it interferes greatly with the obtaining of reliable translation coefficients. For the purpose, the data obtained in forty subjects experimented upon underwent processing by regression analysis, with a rectilinear, exponential and reciprocal regression being done to assay the statistical association of the indicators HI, IVO and CI, measured in sitting and standing position relative to their values in recumbency. Owing to marked variation of the cases around the regression line, low correlation coefficients were obtained, accordingly lowered to zero determination coefficients, as well as a great likelihood (considerably higher than 0.05, as calculated by Fisher's criterion for accepting the zero hypothesis, i. e. the regression models tested failed to describe sufficiently well the statistical association seeked).

Verification of the zero hypothesis (using Student's t-criterion) regarding the regression coefficient difference from zero demonstrated that there was sufficient reason to accept the zero hypothesis. Consequently, to secure reliable determination of the translation coefficients in sitting and standing postures relative to recumbency it was necessary to increase the number of persons examined. In Table 2 are presented algebraic coefficients having just an orientation values; they may be used until definitive completion of the study.

b) **Experimental set two.** Twenty-four subjects were investigated with assessment of the HVA indicators over 24 hours. Processing was done of IVO and Ci values for the following examination hours: 9, 11, 13, 15, 17, 19, 21, 23, 1, 3, 5, 7. IVO values exhibited rather poorly manifested circadian rhythm which was consistent with the changes in frequential heart rhythm spectrum, established by Gerruti et al. /15/ during 24-hour Holter monitoring.

Data processing from the 24-hour CI monitoring was done

Table 2

Indicator	Posture standing	Posture supine	Hours round the clock and corresponding group translation coefficients			
	A		B			
X (ms)	1.2827	0.9154	9	1.55	21	0.06
SD (ms)	1.3786	0.8799	10	—2.63	22	0.06
AMo (%)	0.672	1.012	11	—0.57	23	0.05
HI (rel. u.)	0.4167	1.000	12	—0.32	24	—0.05
Pt (%)	0.75	7.155	13	—0.22	01	0.08
Pkh (%)	0.9063	7.2083	14	—0.07	02	0.09
Pp (%)	1.2188	0.8205	15	—0.14	03	0.1
IVO (rel. u.)	0.625	2.000	16	—0.11	04	0.13
CI (rel. u.)	0.250	−1.6585	17	0.09	05	0.15
Pleth. (mm)	1.7571	0.1375	18	0.08	06	0.19
Bl. Pr. (syst.)	0.1579	7.0720	19	0.07	07	0.26
Bl. Pr. (diast.)	0.9744	.0540	20	—0.07	08	0.42

A. Translation algebraic coefficients of HVA indicators for reducing the values in standing and sitting posture to the supine posture.
B. Translation group coefficients for reducing CI values to the ones at 9 am (morning).

using descriptive statistical methods, and for the twelve hour intervals statistical magnitudes were calculated. As shown by the data, there was adequately expressed circadian rhythm; the CI values at 21 and 23 hours were considered as the most unfavourable, and had negative values. At night, especially about 5.00 am, CI values were the highest, pointing to an optimally expressed predominant parasympathetic difference at significance level $p < 0.05$ was disclosed by the values at 13, 15, 17, 19, 21, 23, 01, 05 and 07 hour, calculated by the Student—Fisher criterion, i. e. by rejecting the zero hypothesis. Through modelling by linear regression of the mean CI values in the single hour measurements, a high correlation coefficient was obtained: R = —0.81, respectively determination coefficient 65.9 per cent, with the F criterion corroborating the model feasibility (y = 20.8942 — 2.14848). Based on the latter, levelling of the mean CI values over 24 hours was performed. Using this model it becomes possible to prognosticate a given average group value at intermediate hours uninvestigated by us. An attempt was made (through regression modelling) to work out translation CI coefficients where data on twenty persons, measured at 9 am in the morning, were used as independent variable. A high correlation coefficient (resp. determination coefficient) was obtained only in terms of data measured at 9 and 11 am (correlation coefficient 0.98 and determination coefficient 96.5 per cent). For all remaining hours these coefficients were quite low. A statistically significant difference between the mean CI values, measured at 9 am and all remaining hours, except for 11 am, was present. Because of that the working out of translation coefficients for individual persons for all remaining hours of the day, with the exception of 11 am, was impossible on the ground of the facts so far accumulated. Possibly, on increasing the number of persons examined, the correlation coefficients may also rise. Hence, the assumption is warranted that changes in CI associated with circadian rhythm are characterized by marked interindividual differences leading to increase in variation, and it is quite possible that translation coefficients on the kind will hardly be created at all, or else they may be worked out only in the event of a considerable increase in the number of examinees which in turn, will increase the correlative dependences under study.

Using interpolation procedure group translation coefficients for CI values in the single hours of the day were obtained

(Table 2). Such coefficients are practicable only upon comparison of the average group CI values, when their correlation with respect to circadian biorhythms is required.

The comparatively broad "scope" (ΔCI; difference between the lowest and highest meanings of the indicator in absolute values) confirms on the one hand, its strong dependence on the hour of day, and on the other, compliance with the latter during terrain investigations, usually carried out during different hours of the day.

This is a fact pointing to the utmost methodological importance of the problem, and what is more, not merely in terms of CI, but also in terms of all the other projects contain elements requiring large scale and comprehensive scientific research work.

CONCLUSION

In the experiment described only normal persons in active age participated. Hence it could hardly claim comprehensiveness since most likely, the different postures and time of day will not affect analogically the HVA indicators in patients, children and elderly persons. For this reason algebraic and group translation coefficients found are irrelevant for them. Similar investigations with precisely defined contingents from the mentioned groups will be needed.

The aforementioned facts reiterate the methodological complexity of the task undertaken. The selection of experimental subjects, regimen of nutrition and work, wakefulness-sleep cycle and the like also account for noticeable complications. For instance, to monitor the circadian course of HVA values, we studied university students staying awake till midnight. Some watched TV-programs, others played cards and chess. Owing to that the CI-values were the lowest at 11 pm. However, immediately after falling asleep, these values exhibited a strong increase, and thus an unnatural steep transition resulted. Presumably, in the study of a population with different sleep and wakefulness regimen, the circadian curve will show a "smoother" pattern.

Summarizing, the inference is reached that to obtain reliable coefficients of the indicators evaluated, a considerable increase in the number of examinees will be required which is a task difficult to fulfill in terms of circadian changes.

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