Standrds for variation range of rr-intervals at rest and in orthostasis in training of racing skiers with different types of regulation

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Abstract

Objective of the study was to identify standards for the variation range of RR-intervals at rest and in orthostasis in training of racing skiers with different types of regulation

Methods and structure of the study. During the study, we conducted 559 dynamic HRV tests at rest and in orthostasis at different stages of the training cycle. Subject to the study were 34 racing skiers aged 17-22 years, having the sports qualifications of I adult category, CMS, and MS. The subjects were tested in the morning after the previous training day before the first training using the Varikard 2.51 hardware-software complex and Varikard MP program (Ryazan, Russia). The predominant type of autonomic regulation was defined by the classification proposed by N.I. Shlyk. Prior to each HRV test, the racing skiers were interviewed about the physical loads performed on the previous training day, their load tolerance, quality of sleep, well-being, and participation in competitions.

Results and conclusion. The study found that the predominant type of regulation at rest in each athlete defines the bounds of the MxDMn range, divisions of the autonomic nervous system, and level of the body's functioning as a whole. Therefore, racing skiers with different MxDMn values and vegetative balances should be subjected to different training loads, which would help timely prevent overstrain and overtraining.

The lack of clarity over the bounds of the optimal MxDMn range, or disregard of this indicator in the HRV analysis of racing skiers cannot provide researchers with true information on the level of tolerance to physical loads.

Keywords: *heart rate variability, variation range of RR-intervals, types of regulation, racing skiers, individual approach.*

Background. When analyzing the heart rate variability (HRV) data, the basic information on the regulatory mechanisms of cardiac activity was taken from the duration and range of RR-intervals [1]. The amplitude of the heart rate oscillations and functional features of the sinoatrial node determine the variation range of RR-intervals (MxDMn). Any functional changes in the body are immediately reflected in HRV MxDMn of the heart rate variability [2, 3]. Many researchers who use the HRV analysis are dismissive of MxDMn, which is a serious gap in the sinus node and cardio-regulatory system functionality rating. In a series of studies, the authors have not reached a consensus on the standards for this indicator. Such an approach to the HRV analysis does not give a true picture of the level of functioning of the sinus node and the way each of its regulatory links influences it [3, 4].

Objective of the study was to identify standards for the variation range of RR-intervals at rest and in orthostasis in training of racing skiers with different types of regulation.

Methods and structure of the study. During the study, we conducted 559 dynamic HRV tests at rest and in orthostasis at different stages of the training cycle. Subject to the study were 34 racing skiers aged 17-22 years, having the sports qualifications of I adult category, CMS, and MS. The subjects were tested in the morning after the previous training day before the first training using the Varikard 2.51 hardware-software complex and Varikard MP program (Ryazan, Russia). The predominant type of autonomic regulation was defined by the classification proposed by N.I. Shlyk [3, 4]. Prior to each HRV test, the racing skiers were interviewed about the physical loads performed on the previous training day, their load tolerance, quality of sleep, well-being, and participation in competitions.

Results and discussion. The analysis of the HRV data in the racing skiers during the training cycle revealed 7 MxDMn at rest: <150, 151-250, 251-350, 351-450, 451-550, 551-650, and >650 ms, which correspond to different levels of functioning of the sinus node, type of autonomic regulation, and recovery processes.

The data given in Tables 1 and 3 indicate that the increase in the resting MxDMn values from <150 to >650 ms leads to the increase in the HRV parameters: TP, HF, LF, VLF, ULF, as well as to the decrease in SI. It was found that at the same ranges of the MxDMn values, it is the respiratory (HF ms^2) or vasomotor (LF

Table 1. *Standards for HRV in racing skiers with dominating HF-waves at rest and optimal responses to orthostasis at different variation ranges of RR-intervals (MxDMn)*

№ of tests	MxDMn range, ms	HR, bpm		MxDMn, ms		SI, c.u.		TP, ms^2		HF, ms^2		LF, ms^2		VLF, ms^2		ULF, ms^2	
		lying	standing	lying	standing	lying	standing	lying	standing	lying	standing	lying	standing	lying	standing	lying	standing
29	MxDMn 151-250	65	89	205	151	149	410	1515	842	824	79	326	360	149	200	216	203
	M±m	6	8	27	33	58	199	450	415	363	52	151	192	60	145	161	215
80	MxDMn 251-350	59	83	303	201	54	235	3425	1569	1880	236	782	783	293	263	469	287
	M±m	6	10	27	57	14	155	768	942	621	266	288	607	122	159	307	242
108	MxDMn 351-450	54	79	397	238	29	188	5602	2126	2889	302	1205	1034	562	386	945	404
	M±m	7	11	26	68	7	194	1153	1244	1046	326	427	746	301	278	683	345
43	MxDMn 451-550	54	79	492	275	19	139	7273	2712	3641	428	1511	1246	605	519	1516	519
	M±m	7	12	33	85	5	121	1456	1584	1077	588	498	721	223	407	913	472
18	MxDMn 551-650	52	76	591	259	12	123	11492	2315	3927	309	2336	976	1388	566	3841	465
	M±m	5	10	28	71	4	66	3312	1208	1184	272	547	701	354	439	3308	293
4	MxDMn >650	54	70	711	403	10	50	12456	6497	4066	767	2204	1752	1152	882	5034	3097
	M±m	3	14	80	121	1	35	6955	3323	735	520	779	710	409	408	6107	2467

Table 2. *Standards for HRV in racing skiers with dominating HF-waves at rest and paradoxical responses to orthostasis at different variation ranges of RR-intervals (MxDMn)*

№ of tests	MxDMn range, Ms	HR, bpm		MxDMn, ms		SI, c.u.		TP, ms^2		HF, ms^2		LF, ms^2		VLF, ms^2		ULF, ms^2	
		lying	Standing	lying	standing	lying	standing	lying	standing	lying	standing	lying	standing	lying	standing	lying	standing
41	MxDMn<150	57	78	84	212	1047	216	239	1550	94	283	42	676	34	302	69	289
	M±m	4	8	29	85	675	145	155	1674	80	421	37	600	24	542	53	346
29	MxDMn 151-250	58	74	205	283	121	97	1616	2831	852	306	334	1685	160	488	270	351
	M±m	9	7	26	65	35	45	424	1741	339	256	184	1591	71	311	182	238
6	MxDMn 251-350	47	66	307	363	48	57	3886	3060	1811	447	891	1132	332	618	853	862
	M±m	8	14	35	88	24	37	709	1397	417	433	370	1022	100	278	399	631
4	MxDMn 351-450	49	73	400	455	23	41	6165	4912	3728	489	998	2900	621	809	816	714
	M±m	7	8	30	72	9	5	1347	1479	1412	287	256	1507	206	335	203	181
3	MxDMn 451-550	45	65	495	621	18	19	7831	12612	3362	1177	2457	6962	865	3221	1148	1252
	M±m	4	15	46	52	6	9	1552	8461	1529	555	1564	5249	282	2872	305	504
	▨	* The marked HRV rates at rest and in orthostasis indicate a deviation from the norm.															

Table 3. *Standards for HRV in racing skiers with dominating LF-waves at rest and optimal responses to orthostasis at different variation ranges of RR-intervals (MxDMn)*

№ of tests	MxDMn range, ms	HR, bpm		MxDMn, ms		SI, c.u.		TP, ms^2		HF, ms^2		LF, ms^2		VLF, ms^2		ULF, ms^2	
		Lying	standing	lying	Standing	lying	standing	lying	standing	lying	standing	lying	standing	lying	standing	lying	standing
14	MxDMn 151-250	60	83	217	153	122	410	1576	1222	417	77	574	618	200	268	385	259
	M±m	11	15	23	44	36	308	359	904	208	89	198	584	50	187	281	199
33	MxDMn 251-350	61	85	303	197	65	295	3171	1708	836	141	1392	1035	361	264	584	269
	M±m	10	13	25	57	20	341	713	1108	400	134	615	804	194	219	402	207
9	MxDMn 351-450	57	79	413	263	31	145	6331	2556	1739	248	2380	1249	814	568	1399	491
	M±m	6	12	25	88	6	119	779	1959	368	168	402	835	174	550	877	654
41	MxDMn 451-550	55	78	496	291	24	133	9148	3892	2193	614	4461	2114	1192	667	1302	496
	M±m	7	11	26	100	10	147	2612	3400	733	909	1849	2044	651	669	866	563
24	MxDMn 551-650	53	79	596	266	15	167	13952	3094	2848	413	5671	1255	2286	790	3146	636
	M±m	6	10	29	112	5	142	3267	2259	857	779	2127	919	1143	754	2617	530
6	MxDMn >650	49	79	702	256	9	133	14486	2867	2566	383	5171	1313	2592	568	4157	603
	M±m	7	12	72	85	4	96	2968	2182	815	307	1824	715	1072	659	2474	705

Table 4. *Standards for HRV in racing skiers with dominating LF-waves at rest and paradoxical responses to orthostasis at different variation ranges of RR-intervals (MxDMn)*

№ of tests	MxDMn range, ms	HR, bpm		MxDMn, ms		SI, c.u.		TP, ms^2		HF, ms^2		LF, ms^2		VLF, ms^2		ULF, ms^2	
		lying	standing	lying	standing	lying	Standing	lying	standing	lying	standing	lying	standing	lying	standing	lying	standing
22	MxDMn<150	55	74	121	237	352	131	566	2346	115	403	194	1118	126	435	131	390
	M±m	4	8	15	64	104	74	175	1812	59	719	71	1010	48	289	75	277
21	MxDMn 151-250	58	79	201	265	136	115	1503	2776	341	244	579	1553	227	524	356	455
	M±m	14	13	22	56	49	48	369	1440	143	192	282	1108	112	289	269	283
17	MxDMn 251-350	58	75	294	386	71	53	3004	5858	609	592	1230	3615	426	824	740	828
	M±m	16	13	26	65	23	25	726	3132	300	317	448	2570	180	371	532	656
3	MxDMn 351-450	47	68	394	492	32	38	6426	10867	1471	1604	2936	6101	896	1752	1122	1410
	M±m	9	15	33	141	10	32	4981	4828	1844	1409	2942	131	741	1971	536	1446
1	MxDMn 551-650	42	68	559	577	8	17	22757	14991	3802	3967	12231	6444	3698	3027	3025	1554
	M±m	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	▨	* The marked HRV rates at rest and in orthostasis indicate a deviation from the norm.															

ms^2) waves that may predominate, indicating different autonomic balance types and the need to take this into account when designing individual training loads for racing skiers.

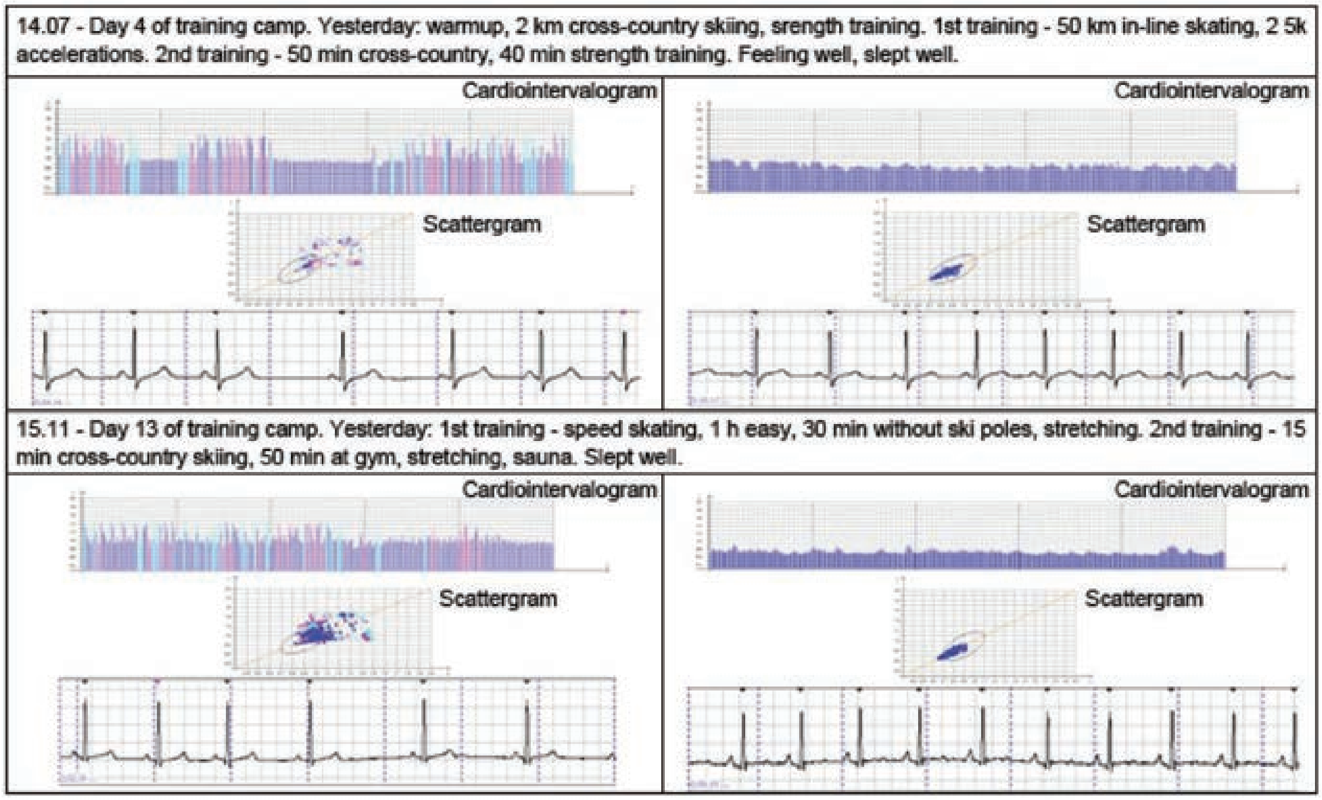
The predominance of the HF component in the HRV power spectrum was found in 365 cases (Table 1), of which 22.7% had a paradoxical response to orthostasis mainly within the low MxDMn ranges - <150 and 151-250 ms (Table 2).

The predominance of the LF component was found in 193 cases at rest, of which 32% had adverse response to the orthostasis mainly within the following MxDMn ranges: <150, 151-250, and 251-350 ms (Table 4).

Table 5. *HRV rates in overtrained racing skier K. at rest and in orthostasis with high MxDMn values in training and competitive periods*

Date	HR, bpm		MxDMn, ms		SI, c.u.		TP, ms^2		HF, ms^2		LF, ms^2		VLF, ms^2		ULF, ms^2	
	lying	Standing	Lying	standing	lying	standing	lying	standing	lying	Standing	lying	standing	lying	standing	Lying	standing
14.07	55	72	618	261	19	81	29467	2265	1655	486	9343	1058	3895	365	14574	355
15.11	57	81	606	223	16	131	19060	2106	3550	223	7783	1029	5027	540	2700	314

▨ * The marked HRV rates at rest and in orthostasis indicate a deviation from the norm.



14.07 - Day 4 of training camp. Yesterday: warmup, 2 km cross-country skiing, srength training. 1st training - 50 km in-line skating, 2 5k accelerations. 2nd training - 50 min cross-country, 40 min strength training. Feeling well, slept well.

15.11 - Day 13 of training camp. Yesterday: 1st training - speed skating, 1 h easy, 30 min without ski poles, stretching. 2nd training - 15 min cross-country skiing, 50 min at gym, stretching, sauna. Slept well.

Cardiointervalograms, HRV scattergrams and ECG at rest and in orthostasis at high MxDMn values in overtrained racing skier K.

The MxDMn data given in Tables 1-3 indicate the predominant type of autonomic regulation. At MxDMn <150 ms, the highest SI values and low HF-, LF- and especially VLF- and ULF-waves of the HRV power spectrum were observed. At the same time, 100% of the examined racing skiers had paradoxical responses to orthostasis (Tables 2 and 4).

The paradoxical response to orthostasis is an indicator of an unfavorable prognosis both in the athlete's state of health and his sports results [3, 4].

The moderate influence of the central regulatory mechanisms on the heart rhythm corresponds to the MxDMn range of 151-250 ms (I type of regulation), where 51.0% of racing skiers were also found to have an impaired autonomic reactivity to orthostasis and slow recovery (Tables 2 and 4).

The MxDMn range of 251-350 ms represents the lower boundary of the state between the I and III types of regulation, 351-450 ms - the in-between state, and 451-550 ms - the upper boundary of the optimal state of the autonomous regulation circuit (III type of regulation). These racing skiers are characterized by good adaptability to training loads, absence of paradoxical responses to orthostasis, and fast recovery. In case of unfavorable responses to orthostasis at the III type of regulation, but in the absence of heart rhythm disorders on ECG, racing skiers need rest and correction of their training mode.

The expressed predominance of the autonomous regulation circuit is characterized by MxDMn ranging within 551-650 ms (IV type of regulation). An increase of MxDMn to >651 ms may indicate both various heart rhythm disorders and their absence. In this case, visual monitoring of cardiointervalograms, HRV scattergrams, and ECG at rest and in orthostasis is mandatory.

Table 5 and Figure 1 illustrate the results of the HRV analysis of the overtrained racing skier K. with the expressed MxDMn values - >600 ms.

Most of the examined racing skiers were found to have multiple changes in the MxDMn values - from favorable to unfavorable - due to the sinus node malfunction, insufficient or paradoxical adaptive-regulatory processes, and primarily due to physical overloads. Moreover, at rest, several racing skiers (Tables 2 and 4) had pronounced bradycardia, which cannot be considered a positive change, as there were negative reactions to orthostasis. This confirms once again that HR does not provide true information on the functional state of the cardiovascular system, without taking into account its regulation according to the HRV analysis.

Conclusion. The study found that the predominant type of regulation at rest in each athlete defines the bounds of the MxDMn range, divisions of the autonomic nervous system, and level of the body's functioning as a whole. Therefore, racing skiers with different MxDMn values and vegetative balances should be subjected to different training loads, which would help timely prevent overstrain and overtraining.

The lack of clarity over the bounds of the optimal MxDMn range, or disregard of this indicator in the HRV analysis of racing skiers cannot provide researchers with true information on the level of tolerance to physical loads.

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