Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2017
(ICMERE2017) 18 – 20 December, 2017, Chittagong, Bangladesh

ICMERE2017-PI-358

COMPARATIVE STUDY OF HEART RATE VARIABILITY USING TIME DOMAIN METHODS IN NORMAL SUBJECTS AND SLEEP APNEA

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Abstract*-Time domain methods have been used in order to evaluate the parameters of the heart rate variability (HRV) in both normal subjects and patients with sleep apnea. The aim of this research was to assess the diagnostic potential of sleep apnea using time domain analysis of HRV. Data subjects collected from Physionet database were analyzed to find out the time domain measures of HRV. Standard Time domain HRV parameters such as Mean RR, SDNN, Mean HR, STD HR, RMSSD, NN50, PNN50, HRV triangular index and TINN were analyzed for five minutes segment of ECG for each subject. The preliminary results prove the effectiveness of Mean HR, RMSSD, NN50, PNN50 and TINN as potential detectors of SA. In conclusion,this result can be used in order to develop apnea detectors from HRV.*

Keywords: Sleep apnea, time-domain methods and heart rate variability

1. INTRODUCTION

Sleep apnea is a sleep-related breathing disorder [1-3]. SA causes the interruptions of breathing during sleep. It leads to excessive daytime sleepiness and early morning headaches. Early recognition as well as treatment of sleep apnea is very essential [4]. The consequences of sleep apnea include sexual dysfunction, irritability, learning difficulties, depression, memory difficulties and falling asleep [5]. Sleep apnea also increases high blood pressure, hypertension, irregular heart rhythm, heart attack and stroke [4, 6-12]. It is an important risk factor for cardiovascular diseases, neurocognitive deficits, myocardial infarction and hyperactivity [13-20]. 2-4% of children suffer from sleep apnea [21-22]. As a result, detection of sleep apnea is very important and will reduce the risks. In this paper, we have examined the ability of HRV parameters in time domain to detect sleep apnea.

Heart rate variability reflects the autonomic nervous function and the HRV analysis is used for stress or sleepiness estimation and cardiovascular disease monitoring [23-29]. Analysis of heart rate variability has become popular for assessing cardiovascular autonomic control [30-32].Many methods have been used to analyze heart rate variability [33-35]. HRV parameters changes in sleep apnea patients [36-40]. HRV analysis is proposed as a screening tool for sleep apnea [41-43].Many researchers have used different measures of HRV to detect sleep apnea [44-47].

This study was performed to evaluate the ability of the time domain measures of HRV to distinguish between normal subjects and sleep apnea subjects. We have examined the HRV of both normal and sleep apnea subjects to find out what parameters in time domain analysis are the best to reflect the sleep apnea. We have considered Mean RR, STD RR, Mean HR, STD HR, RMSSD, NN50, pNN50, HRV triangular index and TINN.

2. MATERIALS AND METHODS

2.1 Database

In this study, the apnea-ECG database and MIT-BIH Normal Sinus Rhythm Database are used from PhysioNet [48-49]. 18 sleep apnea ECG recordings were used from apnea-ECG database and 18 normal ECG recordings were used from MIT-BIH Normal Sinus Rhythm Database. The sleep apnea recordings had varying length from slightly less than 7 hours to nearly 10 hours each and were collected from SA patients. The apnea was annotated on a one-minute basis by human experts [49]. We have selected five minutes segment from every hours long recording. The MIT-BIH Normal Sinus Rhythm Database includes 18 long-term ECG recordings from 5 men, aged 26 to 45 and 13 women, aged 20 to 50. 5 minutes long portion of every recording was selected for analysis with the help of annotations of the experts [49]. Table 1 and Table 2 give the details of every portion with starting time and ending time according to the recordings [49].Sample names are given according to the apnea-ECG database and MIT-BIH Normal Sinus Rhythm Database of PhysioNet.

Table 1. Sleep apnea Samples

Sample Name	Selected 5 minutes long Portion
A01	2:51:40 to 2:56:40
A02	11:21:37 to 11:26:37
A03	13:11:37 to 13:16:37
A04	13:28:36 to 13:33:36
A05	13:09:20 to 13:14:20
A06	13:58:03 to 14:03:03
A07	0:45:44 to 0:50:44
A08	0:21:15 to 0:26:15
A09	13:54:58 to 13:59:58
A10	1:56:05 to 2:01:05
A11	13:46:34 to 13:51:34
A12	14:05:34 to 14:10:34
A13	14:09:10 to 14:14:10
A14	13;55:26 to 14:00:26
A15	14:57:10 to 15:02:10
A16	15:55:30 to 16:00:30
A17	14:35:22 to 14:40:22
A18	14:29:41 to 14:34:41

Table 2. Normal ECG Samples

Sample Name	Selected 5 minutes Segment
16265	8:25:17 to 8:30:17
16272	11:17:21 to 11:22:21
16273	8:17:33 to 8:22:33
16420	10:09:23 to 10:14:23
16483	10:09:40 to 10:14:40
16539	9:42:01 to 9:47:01
16773	18:13:13 to 18:18:13
16786	12:05:13 to 12:17:13
16795	13:57:11 to 14:02:11
17052	18:10:15 to 18:15:15
17453	9:45:18 to 9:50:18
18177	12:24:29 to 12:29:29
18184	10:01:02 to 10:06:02
19088	12:54:21 to 12:59:21
19090	14:10:25 to 14:15:25
19093	10:47:00 to 10:52:00
19140	11:47:35 to 11:52:35
19830	10:11:35 to 10:16:35

2.2 Time-domain Methods

The time-domain parameters [52-53] of heart rate variability such as Mean RR, SDNN, Mean HR , STD HR , RMSSD , NN50, pNN50 , HRV triangular index and TINN are calculated for normal subjects and sleep apnea subjects using Kubios HRV software [50-51] .

The standard deviation of RR intervals (SDNN) is defined as

$$SDNN = \sqrt{\frac{1}{n-1}\sum_{j=1}^{N}(RR_j - \overline{RR})^2} \quad (1)$$

RMSSD is given by

$$RMSSD = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N-1}(RR_{j+1} - RR_j)^2} \quad (2)$$

NN50 is the number of successive intervals differing more than 50ms. The corresponding relative amount

$$pNN50 = \frac{NN50}{N-1} \times 100\% \quad (3)$$

The HRV triangular index is calculated as the integral of the RR interval histogram divided by the height of the histogram .TINN is the baseline of the RR histogram evaluated through triangular interpolation [52-53].

3. RESULTS

Time-domain measures of heart rate variability of normal subjects are given in Table 3 and Table 4. In table 3, values of Mean RR, SDNN, Mean HR, STD HR and RMSSD for normal subjects are given. Table 4 shows all values of NN50, pNN50, HRV triangular index and TINN for normal subjects.

Table 3. Time domain parameters of normal subjects

Sample name	Mean RR (ms)	SDNN (ms)	Mean HR (1/min)	STD HR (1/min)	RMSSD (ms)
16265	694.91	38.568	86.628	4.6685	21.439
16272	1078	53.003	55.803	2.7905	35.991
16273	816.79	33.384	73.594	3.066	30.779
16420	788.99	36.748	76.215	3.5638	35.642
16483	667.47	28.07	90.048	3.6708	11.801
16539	1005	149.44	60.956	8.4978	175.08
16773	750.96	77.467	80.782	8.1592	34.932
16786	843.5	56.927	71.482	4.9883	34.714
16795	620.32	15.358	96.783	2.3749	8.2747
17052	715.15	33.307	84.16	3.7958	17.899
17453	737.15	45.149	81.807	4.7971	29.584
18177	681.46	36.461	88.293	4.6126	21.709
18184	787.35	57.838	76.63	5.584	34.16
19088	630.36	53.943	95.935	8.0083	24.652
19090	779.53	53.518	77.367	5.4571	23.69
19093	895.89	57.966	67.38	4.6645	26.351
19140	654.32	25.8	91.867	3.5887	16.415
19830	575.11	25.708	104.53	4.4842	9.7129

Table 4. Time domain parameters of normal subjects

Sample name	NN50	pNN50 (%)	HRV Triangular index	TINN (ms)
16265	13	3.0162	8.64	190
16272	46	16.606	13.9	270
16273	43	11.749	9.4103	165
16420	60	15.831	10.27	195
16483	1	0.22321	8.3148	145
16539	217	73.064	22.923	595
16773	51	12.814	19.95	395
16786	55	15.493	14.24	280
16795	0	0	4.9897	85
17052	7	1.6706	9.5455	170
17453	32	7.8818	10.175	225
18177	13	2.9613	8.6275	175
18184	57	15	11.906	265
19088	25	5.2632	17	250
19090	10	2.6042	15.4	265
19093	19	5.7057	11.929	255
19140	2	0.43668	6.9545	130
19830	1	0.19231	6.4321	135

In table 5 and table 6, time domain parameters of sleep apnea subjects are given. In table 5, we have listed of Mean RR, SDNN, Mean HR, STD HR and RMSSD and in table 6. NN50, pNN50, HRV triangular index and TINN are included.

Table 5. Time domain parameters of sleep apnea

Sample name	Mean RR (ms)	SDNN (ms)	Mean HR (1/min)	STD HR (1/min)	RMSSD (ms)
a01	941.78	88.204	64.281	6.1041	75.388
a02	820.07	39.517	73.338	3.4849	13.679
a03	1004.9	156.41	61.077	9.0289	75.985
a04	915.28	54.768	65.793	3.9472	19.675
a05	952.89	70.535	63.341	4.7662	39.67
a06	968.7	59.48	62.172	3.6069	65.532
a07	846.15	61.841	71.304	5.1218	39.575
a08	735.01	74.589	82.48	8.3787	38.557
a09	966.14	30.641	62.166	1.9535	25.379
a10	881.77	59.588	68.378	4.7051	33.372
a11	824.85	28.789	72.829	2.5002	15.123
a12	800.57	19.803	74.993	1.8469	17.985
a13	788.31	83.089	77.053	8.958	32.025
a14	1173.7	102.09	51.541	4.86	126.66
a15	913.51	72.943	66.105	5.3516	26.025
a16	878.19	53.211	68.57	4.0644	33.516
a17	797.86	73.541	75.849	6.9844	47.676
a18	968.5	28.881	62.006	1.8322	15.581

Table 6. Time domain parameters of sleep apnea

Sample name	NN50	pNN50 (%)	HRV Triangular index	TINN (ms)
a01	159	50.158	22.714	390
a02	0	0	10.457	175
a03	80	26.936	14.19	680
a04	5	1.5291	14.909	265
a05	68	21.656	17.5	325
a06	117	37.987	11.885	305
a07	52	14.731	16.857	290
a08	39	9.5588	15.148	415
a09	12	3.8835	7.561	140
a10	48	14.159	14.167	250
a11	5	1.3812	8.25	135
a12	3	0.80214	5.597	100
a13	28	7.3879	14.615	305
a14	164	64.314	17.067	465
a15	22	6.7278	16.4	310
a16	31	9.1176	12.179	245
a17	66	17.6	16.348	455
a18	1	0.32362	8.1579	135

The comparative data of the two groups is given in Table 5. The table is showing time domain measures (mean± standard deviation) of the two groups briefly. The differences of STD HR (5.4±3.1 vs. 5.4±3.6 1/min) between the groups are not significant. Moreover, HRV triangular index(13.96±8.97 vs. 14.16± 8.56) is not significantly different between the normal subjects and the sleep apnea subjects. The RMSSD in Sleep apnea subjects (70.2±56.5 ms) is lower than the RMSSD in the normal subjects (91.7±83.4 ms). NN50 (108.5±108.5 vs. 82±82) is higher in normal subjects than sleep apnea subjects. Mean HR (80.2±24.4 vs. 67.01±15.5) is significantly different in the two groups. Mean RR (826.6±251.4 vs. 954.4±219.3) is higher in sleep apnea subjects than normal subjects.

Table 7. Comparative Data of Two Groups

Parameter	Normal Subjects	Sleep Apnea
Mean RR (ms)	826.6±251.4	954.4±219.3
STD RR (SDNN) (ms)	82.4±67.04	88.1±68.3
Mean HR (1/min)	80.2±24.4	67.01±15.5
STD HR (1/min)	5.4±3.1	5.4±3.6
RMSSD (ms)	91.7±83.4	70.2±56.5
NN50	108.5±108.5	82±82
pNN50 (%)	36.532±36.532	32.157±32.157
HRV Triangular Index	13.96±8.97	14.16±8.56
TINN (ms)	340±255	390±290

Figure 1.shows the boxplot of HRV triangular index of both groups.

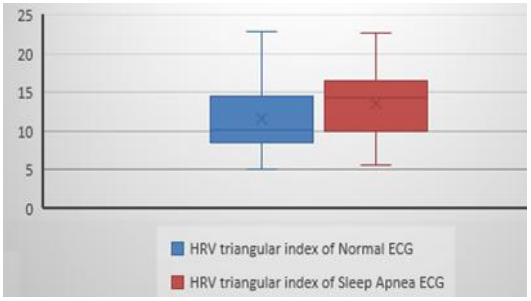

Fig. 1: Boxplot of HRV Triangular Index

Figure 2.shows the boxplot of RMSSD (ms) of normal subjects and sleep apnea subjects

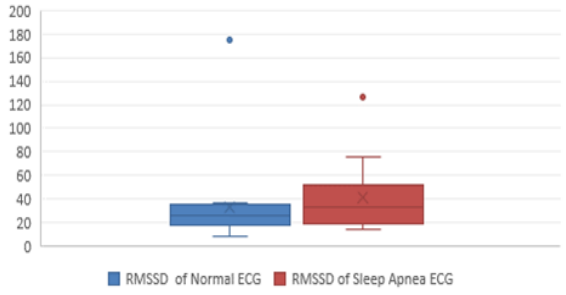

Fig. 2: Boxplot of RMSSD

Figure 3.shows the boxplot of TINN (ms) for normal subjects and sleep apnea.

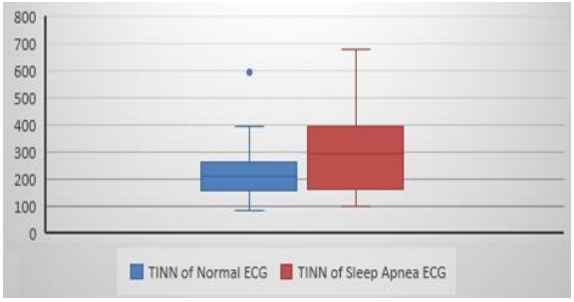

Fig. 3: Boxplot of TINN

Figure. 4. Shows the boxplot of pNN50 (%) of both groups.

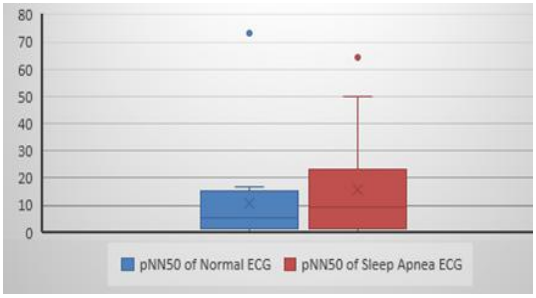

Fig. 4: Boxplot of pNN50

4. CONCLUSION

This research has been conducted for detecting the relationship between the time domain measures of HRV and sleep apnea. In time domain analysis, most of the HRV parameters failed to be significant in the statistical comparison between the groups. Only some time-domain measures such as Mean HR, RMSSD, NN50, PNN50 and TINN demonstrate the significant differences. These parameters can be used for sleep apnea detection. It requires further study using larger data set with different severity levels.

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6. NOMENCLATURE

Symbol	Meaning	Unit
Mean RR	The mean of RR intervals	(ms)
Mean HR	The mean heart rate State transition matrix	(1/min)
SDNN	Standard deviation of RR intervals	(ms)
STD HR	Standard deviation of instantaneous heart rate values	(1/min)
RMSSD	Square root of the mean squared differences between successive RR intervals	(ms)
pNN50	NN50 divided by the total number of RR intervals	(%)
HRV tri-angular index	The integral of the RR interval histogram divided by the height of the histogram	Dimensio-n less
TINN	Baseline width of the RR interval histogram	(ms)