Stress of Kindergarten Teachers: How we tried to detect and to reduce it by using a small and wearable ECG and acceleration measuring device?

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Dr. Ikemi Yujiro's successors use the name of Mind-Body medicine, not psychosomatic medicine.

Workplace stress at kindergarten

Many female teachers resign their jobs due to stress caused by human relationships between themselves. In Nazareth Kindergarten, 4 female teachers resigned by this reason in 2014.

For good quality education, kindergartens have to keep good teachers. Furthermore, teacher's stress not only adversely influences their mental health and may cause incoordination in their autonomic nervous system's activity (ANSA) or development of depression, but also is tightly intertwined neurologically with the mechanisms responsible for cognition, decision making, problem solving, and adaptation to unpredictable environments, such as educating and caring children. Hence, stress of kindergarten teachers must be reduced.

Our study

Phase1 Find teachers with large stress

Phase2 Find teachers with unhealthy ANSA

Phase3 Find teachers with possibilities of becoming unhealthy ANSA

Phase1 Stress evaluation so far

Stress has been measured in two conventional ways –through the use of interview format, self-rating scales and direct observation and the use of physiological data. However, stress evaluation method by physiological data was not established yet, and despite being criticized for their subjectivity, self-rating scales have been a primary modality for stress measurement.

Most self-rating scales have measured the frequency and quality of stressors or the degree of life changes. The Social Readjustment Rating Scale (SRRS) is one of the best-known life event scales, and its total score is known to have some predictive value in terms of anticipating disease or illness. However, the scale has also been criticized for its limited clinical utility and for having a low predictability of illness. For workplace stress, Job Content Questionnaire is widely used.

On the other hand, there are many stress measures was originated from clinical research in psychopathology, such as depression rating scales.

Phase1 What we had to measure : Needs for using physiological data

Workplace stress which we had to measure originated not from work related matters or relationships supporting the work, but from human relationships between colleagues,

“her attitude and/or wording is bad, today” or

“she ignored me from yesterday” etc.,

and the level of stress always changes frequently. In Japan, emotional factors, such as, jealousy, quarrel, neglect and bullying between colleagues are the main sources of stress at workplace. How many times in a day one feels this kind of stress? Self-rating scales of stress, Social Readjustment Rating Scale or Job Content Questionnaire et al. cannot measure this kind of stress. We had to use physiological data.

In 2014’s case, our preliminary interview investigations for teachers revealed that there was a stressor, a certain middle aged teacher. For younger teachers, although she was just an elder colleague with the same rank, her less polite attitude and words caused stress. In 2014 school year, her existence made 4 good teachers resigned. We could not stop their resigning.

Phase1 Sympathetic nervous system's activity and M-BIT

In principle, stress activates sympathetic nervous system's activity (SNSA) and shortens RR intervals. Hence the monitoring of RR intervals variation (RRIV) through ECG measurement gives us the objective measure of stress, and most simple and direct method However, stress evaluation method by RRIV or physiological data was not established yet. One of possible reason of this situation might be the difficulty of perfect unconstrained ECG measurement of working subjects. The development of M-BIT made this unconstrained ECG measurement of working subjects and objective measurement of stress through SNSA possible.

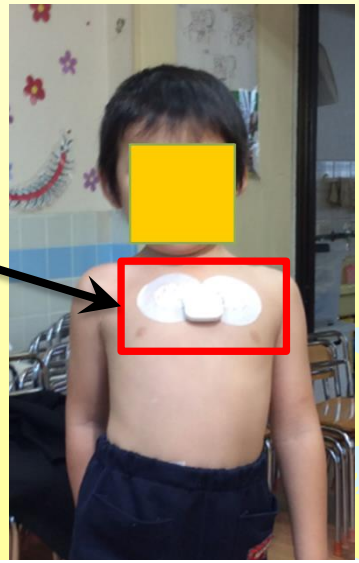
M-BIT

A wearable acceleration(ACC) and ECG measuring device

Sampling frequency (ECG:128Hz, ACC:1Hz)
Sampling duration (25 hours)

He can enter sleep without paying attention to M-BIT.

He can do everything he wants.



a four years old boy wearing M-BIT
(size: 40×39×8mm, weight: 14g)

Phase1 24 hours measurement with M-BIT: Subjects

Since most teachers of kindergartens are female in Japan, all the subjects in this study were female.

On the occasion of measurement of the children in the Nazareth kindergarten (December 2008), we also performed teachers' measurement (n=19, age=40.7±15.1). We used these data (data no=30) to establish stress evaluation protocol from SNSA and RRIV.

Then, we performed 24 hour's simultaneous measurements of teachers (n=11, age=33.7±11.8) at February 18, 2015. They were persons in charge of the class who perform the care and the education of children.

For the sake of comparison we performed the measurements of patients who suffered adjustment disorder, panic disorder and clinical depression (n=6, age=42.2±8.8) at Ikemi Memorial Clinic of Mind-Body Medicine, Megumi-Kai (Fukuoka, Japan).

From this school year (2015), to prevent the resign of teacher due to workplace stress, Nazareth kindergarten started to check their stress. In this season (May-June) 26 teachers (age=41.4±15.7) volunteered the 24hours stress measurements.

Phase1 24 hours measurement with M-BIT: ACC Data analysis

Our epoch duration for analysis was 1 minute.

Times in bed and sleeping postures

Posture vectors (up-down, left-right, anterior-posterior) of subject's thorax, M-BIT attaching portion, were derived from 3-axes acceleration. We obtained their epoch averages, and searched "in bed" area - the area where horizontal postures of up-down direction were continued. As for "in bed" area, we classified sleeping posture as follows: supine, left lateral, prone, right lateral, and obtained their distributions and numbers of changing.

Sleep/awake identification by body movement

For sleep/awake estimation, we classified epochs with and without body movement at first. For each sampling, we selected "sampling difference" as maximum value among 3-axes difference of acceleration with previous sampling, and put "epoch difference (EPD)" as the epoch maximum of sampling difference. We set threshold for with or without movement based on the average of EPD within whole analyzed area, and judged epoch without movement (ENMV) when EPD was less than the threshold.

Then we searched "inactive areas (IAAs)", areas where ENMV were continued, and combined two successive IAAs if the duration of separation between them was one epoch or average of ENMV during separation was less than four times the threshold. Finally, we selected sleep area among these IAA, details for this selection is publicly available.

Phase1 24 hours measurement with M-BIT: ECG Data analysis

We detected time locations of the R waves on the ECG signal based on a robust real time QRS detection algorithm currently in broad use worldwide.

We re-sampled RR interval time series with a re-sampling frequency of 4Hz, and performed time frequency analysis with SPWV (Smoothed Pseudo Wigner-Ville) method, and obtained time frequency map.

For the index of autonomic nervous systems activity, we calculated LF (0.04Hz-0.15Hz), HF (0.15Hz-0.40Hz) as the sum of the absolutes of mapped values of corresponding frequency bands along the frequency axis and their average along the time over the map. We calculated an instantaneous central frequency (CFR) from 0.15 Hz (lower limit of high frequency band) to the half frequency of the average heart rate for the epoch. We set HF and LF/HF as indexes of para-sympathetic (PSNS) and sympathetic (SNS) nervous systems activity representing this epoch, together with average heart rate (HR). We calculated coefficient of variation of RR intervals (CVRR) as the ratio of epoch standard deviation to epoch mean length of RR intervals.

Phase1 24 hours measurement with M-BIT: Sleep Apnea Detection

Usually, for automatic sleep apnea detections from ECG data, both of RRIV and ECG derived respiration which based on the variation of R wave heights, and detection of Cyclic Variation of Heart Rate (CVHR) were used and high accuracy of 83.0%-89.4% were achieved [38]. However, since R wave height is not always quantitatively reliable over the sleep duration in M-BIT measurement, we automatically detected SA only from RRIV based on CVHR. Our accuracy was 75.6%. Details are publicly available [39].

According to American Academy of Sleep Medicine's recommendation [40], we classified severity of SA occurrence of each one hour of sleep time, as NO_SA (bellow 5 epochs), Mild (5 to 15 epochs), Moderate (15 to 30 epochs) and Severe (greater than 30 epochs).

[38] T. Penzel, J. McNames, P. de Chanzal et al., "Systematic Comparison of Different Algorithms for Apnoea Detection Based on Electrocardiogram Recordings," Med. & Bio. Eng. & Comput., 40, pp.402-407, 2002.

[39] S. Shirouzu, H. Kondo and S. Katayama, "Automatic Detection of Sleep Apnea Based on RR Interval Variation," Human Development for ALL, 3, pp.25-30, No.1, 2013. (in Japanese)

[40] The Report of an American Academy of Sleep Medicine Task Force, "Sleep–Related Breathing Disorders in Adults: Recommendations for Syndrome Definition and Measurement Techniques in Clinical Research," SLEEP, 22, pp.667-689, 1999.

Phase1 Protocols to detect a subject with large or remaining stress

Since stress is the total assessable influence impinging upon human beings from external sources, SNSA continues increase and decrease frequently. Hence, we may define a subject who suffers large stress (LS subject), as a subject whose SNSA values shows large peaks and tends to stay large level, and a subject who remains stress (RS subject), as a subject whose SNSA does not decrease below a certain level. For this purpose, we characterized epoch (1 minute) SNSA values' distribution by 4 quantiles.

Generally, subjects' stress level due to workplace stress, and thus, during they are working, their SNSA values are thought to be maximum. Hence, we divided awaking time zone of one day into three zones, during working (WORKING), before and after working (BEFORE and AFTER), and at the first step, for the discrimination of LS subjects, we searched threshold values in maximum values and the third quantile of subjects' SNSA values in WORKING zone.

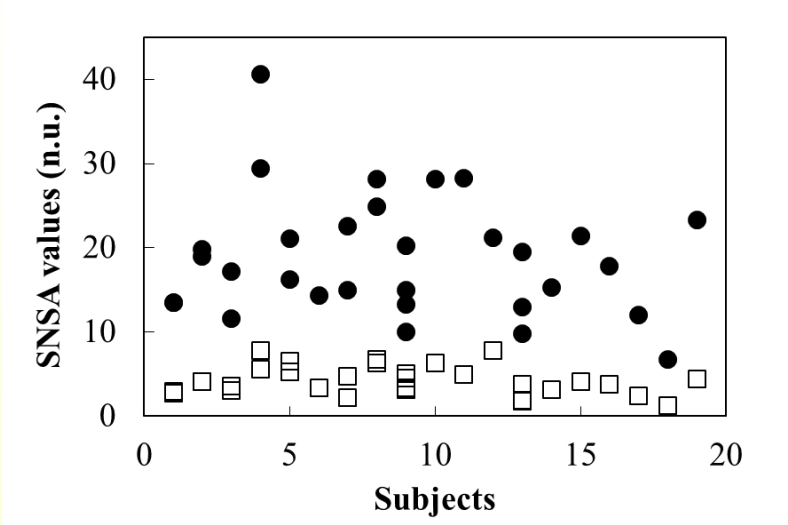
On the other hand, since subjects' stress level and SNSA values should show their minimum level during sleeping (IN-BED), we searched thresholds in minimum values and the first quantile of their SNSA values during in IN-BED for the discrimination of RS subjects.
We set each subject's IN-BED zone as from her bedtime to rise time.

Phase1 Protocols to detect a subject with large or remaining stress

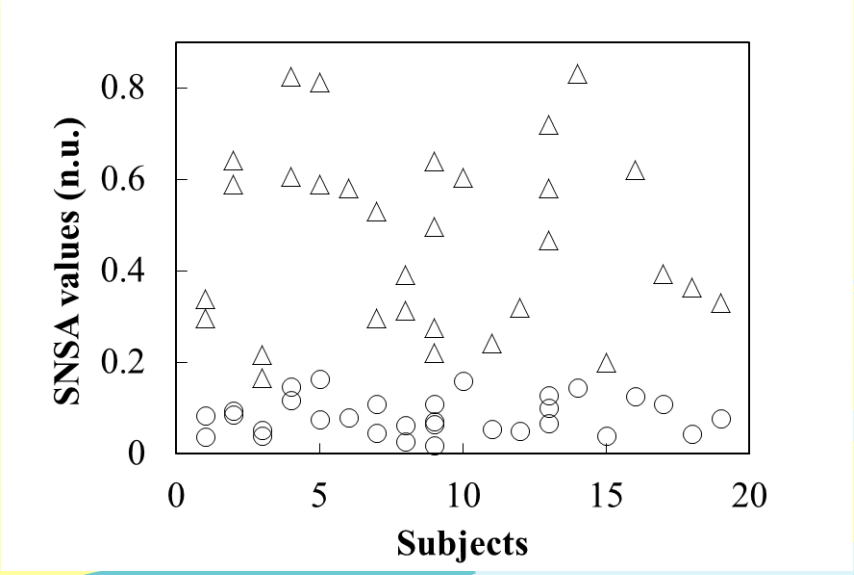
Maximums and the third quantiles of epoch SNSA values distribution in WORKING of step1 subjects were.

As shown, large intra and inter subject difference were observed in maximums and the third quantiles of SNSA.

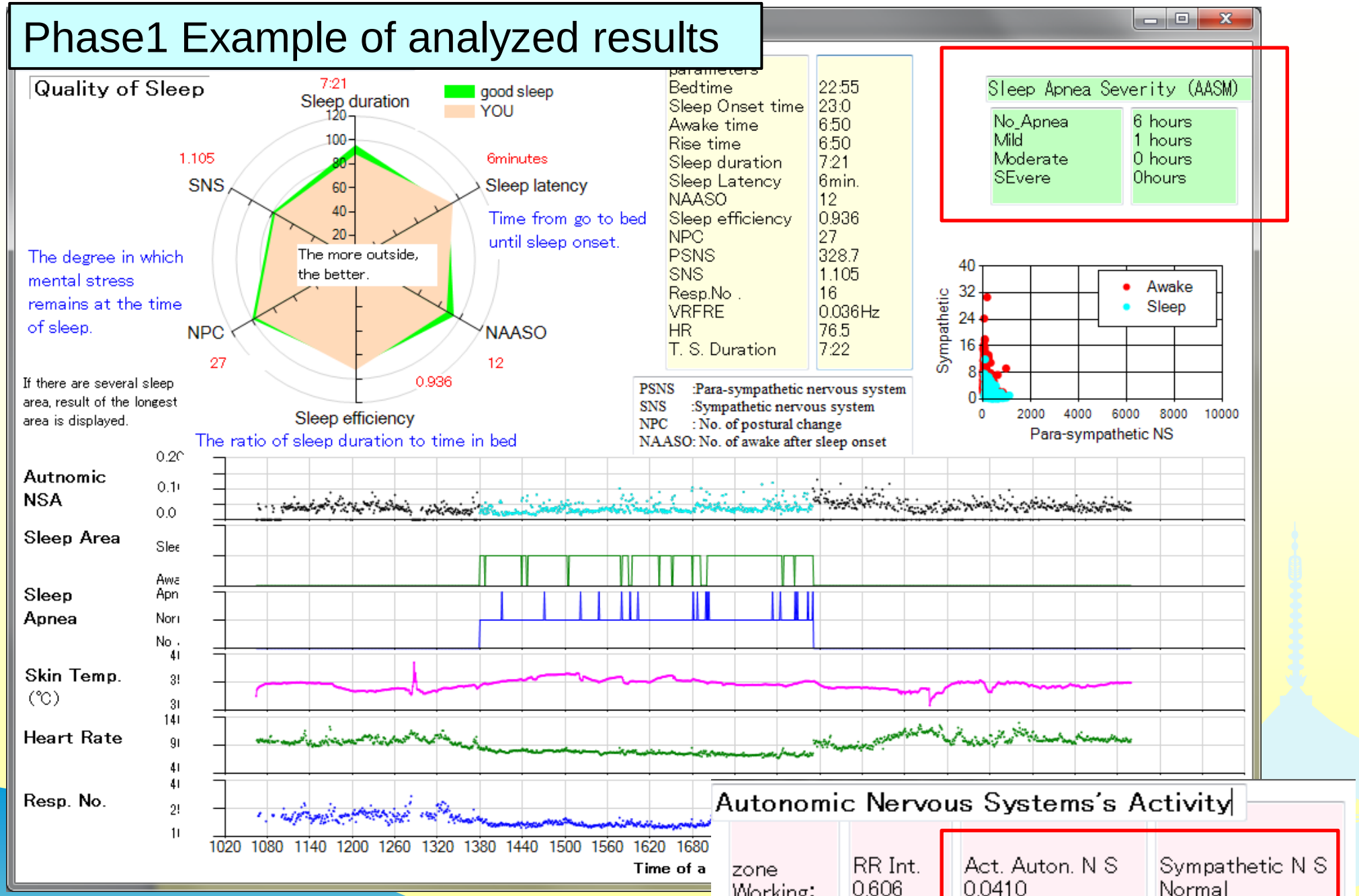
From this figure, we set threshold values for LS subject discrimination as maximum over 25.0 and the third quantile over 5.0 as a working hypothesis. Here, subjects 4(2data/2data), 8(1/2) and 10(1/1) were discriminated as LS subjects.



Minimums and the third quantiles of epoch SNSA values in IN-BED of step1 subjects are shown. From this figure, as a working hypothesis, we set threshold values for RS subject discrimination as minimum over 0.1 and the first quantile over 0.8. Here, subjects 4(1/2), 5(1/2) and 14(1/1) were discriminated as RS subjects.



Phase1 Example of analyzed results



Phase1 Stress scene of kindergarten teachers at February 18, 2015

		Large Stress & Remaining Stress				Sleep Apnea (hours)			
Subjects	age	BEFORE	WORKING	AFTER	IN-BED	Severe	Moderate	Mild	NO_SA
a	27	N.D.				0	4	4	1
b	25	N.D.	Large	N.D.	N.D.	0	5	3	1
c	34					3	4	0	1
d	36	N.D.				0	0	0	4
e	25	N.D.				0	4	4	0
f	65	N.D.	Large	Large		0	0	3	5
g	26	N.D.	Large	Large	Remaining	0	0	0	2
h	24					1	5	1	0
i	33					0	0	4	4
j	42	Large	N.D.	N.D.		0	0	2	2
k	29		Large	Large		0	0	3	2

N.D. No data

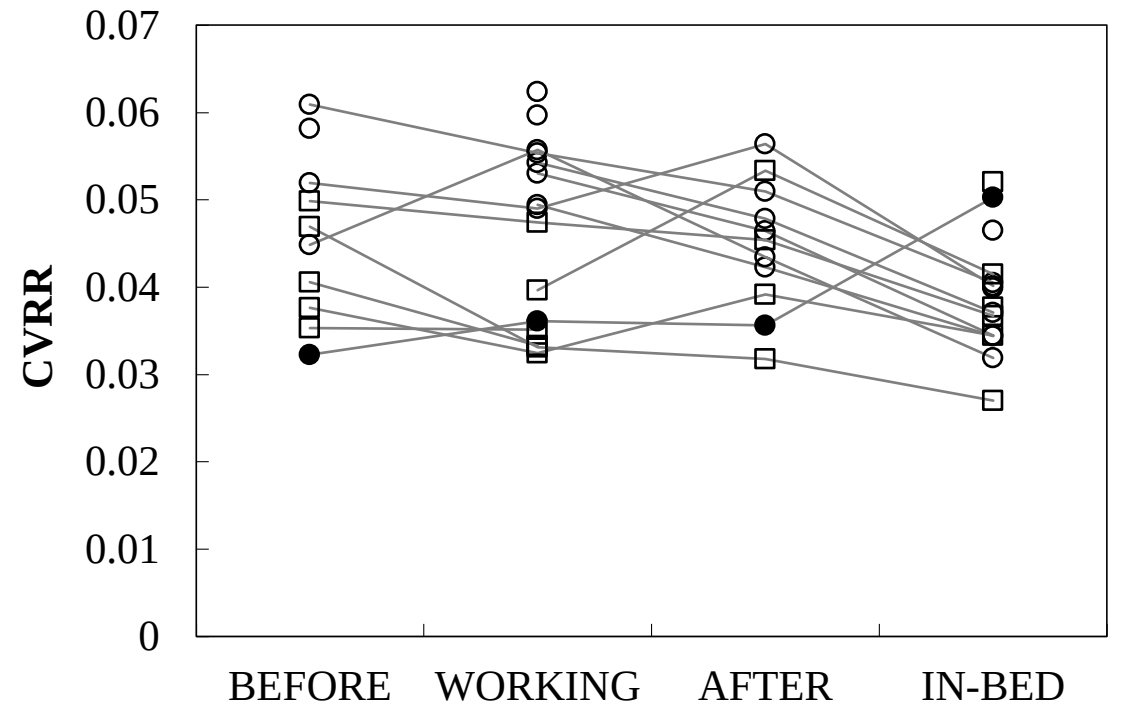
Subjects a, b and d were made up their mind to reign due to stress in this time, and subject c was the stressor in this workplace. Although some teachers who decided resign (a, d) did not show large stress anymore, five teachers within total 11 measured teachers had larges stress. Furthermore, two teachers show at least one hour of severe SA and other three teachers showed 4 or 5 hours moderate SA. Thus, we could understand how stressful this workplace was and teachers' sleepiness and tiredness. Although subject h had complaint she felt stress, her stress level was not so large but had severe SA. In the measurement of stress, we have to consider the sleepiness and fatigue due to SA, too.

Phase2 Comparisons of CVRR with Mind and Body medicine patients

				Large Stress & Remaining Stress				Sleep Apnea (hours)			
Subjects	Age	Diagnostic	Severity	BEFORE	WORKING	AFTER	IN-BED	Severe	Moderate	Mild	NO_SA
a	53	panic	medium	0	0	0	0	1	1	5	1
b	48	adjust	light	0	0	0	0	0	0	1	9
c	50	adjust	medium	0	0	0	0	0	0	1	7
d	34	depression	medium	0	0	0	0	0	7	4	1
e	29	depression	medium	0	0	0	0	0	3	5	1
f	30	adjust	medium	0	0	0	Remaining	0	0	3	2

Results of detection of large stress subject in BEFORE, WORKING, AFTER and remaining stress subject in IN-BED of Mind and Body medicine patients were summarized together with their SA severity. There were no patients with large stress suggesting the possibility that SNSA do not increase if the degree of chronic unhealthy of ANSA is large such as depression state. Only one patient showed remaining stress. One patient showed severe SA one hour and another patient showed 7 hours moderate SA.

Phase2 Comparisons of CVRR with Mind and Body medicine patients

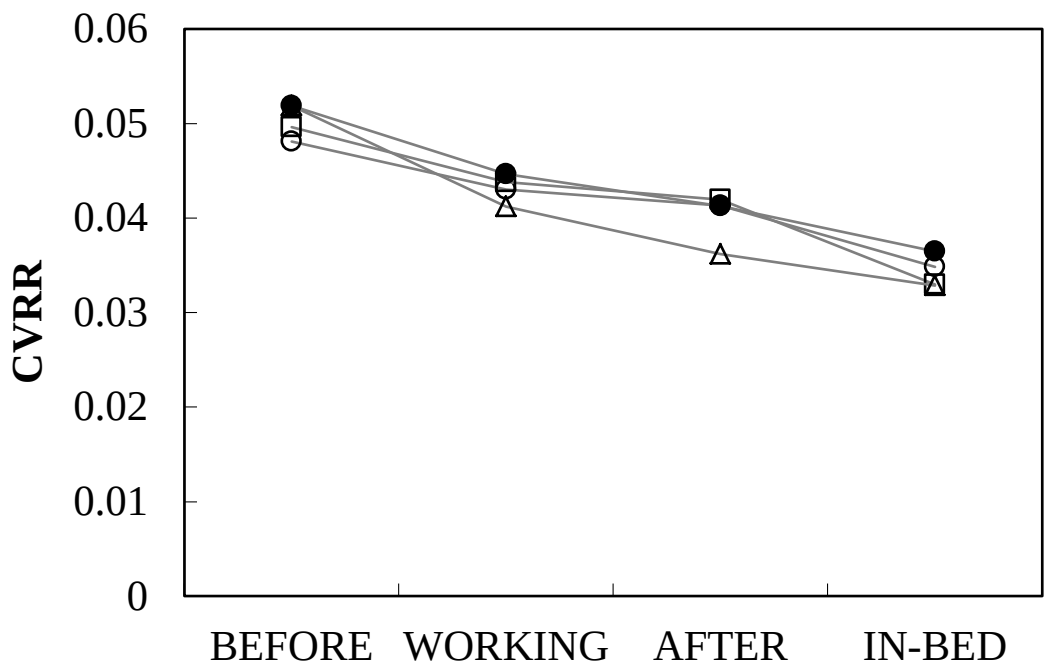


CVRRs of teachers and MBM patients at 4 time zones.
(○: teachers, □: MBM patients, ●stressor in teachers)

Comparisons of CVRR values in BEFORE, WORKING, AFTER and IN-BED teachers and MBM patients. Clear differences between teachers and MBM patients are observed in WORKING. CVRR values of MBM patients are smaller than those of teachers, except one subject, the stressor. The difference teachers and MBM patients become unclear in BEFORE and AFTER, and vanish in IN-BED.

Among teachers, CVRR values of the stressor were quite different from other teachers and close to MBM patients, suggesting the degree of chronic unhealthy of ANSA of the stressor was large such as incoordination in ANSA or depression. This fact and her severity of sleep apnea are the evidences that the stressor has a problem related mind and body medicine, and her “bad attitudes and wordings” were caused by this problem.

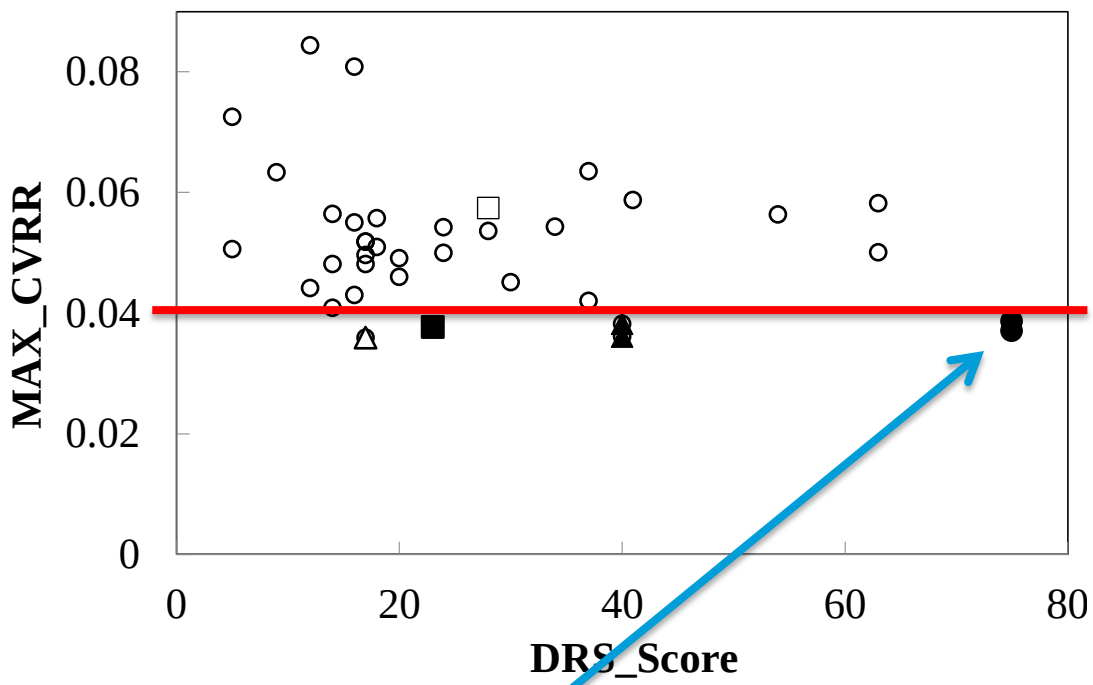
Phase2 Usefulness of CVRR as a measure of unhealthy of ANSA



CVRR values in four zones.
Four days measurement of a subject

Results shown in previous panel also demonstrate the usefulness of CVRR as the measure of chronic unhealthy of ANSA. However, our extended measurement duration to 24 hours suggested their dependences to measuring condition, WORKING, BEFORE and AFTER. Here, four days data are shown as an example of condition dependences and reproducibility. Since she has to decide everything to run kindergarten, she was very busy and always felt moderate level stress during WORKING. If we only measure her CVRR only during work, we may conclude her degree of chronic unhealthy of ANSA is large. However, with CVRR values during BEFORE and AFTER, we could understand her ANSA is healthy and decrease of CVRR in WORKING was caused by temporal stress. Hereafter, we use MAX_CVRR, the maximum value of CVRRs in WORKING, BEFORE and AFTER, as a measure of degree of chronic unhealthy of ANSA.

Phase2 Stress check of kindergarten teachers at May-June, 2015



(●: Subject 1 (43 y.o.), ▲: Subject 2 (34 y.o.), ■: Subject 3 (56 y.o.), △: Subject 4 (45 y.o.), □: Subject 5 (21 y.o.),)

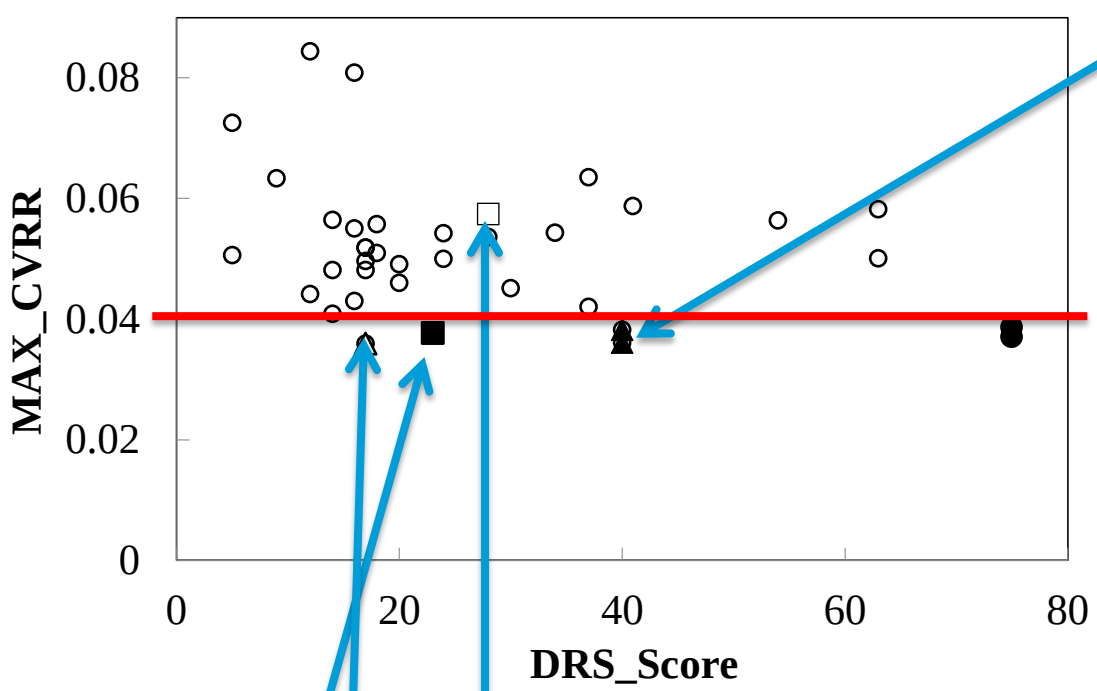
This time we extended our interest to chronic unhealthy of ANSA and introduced a Depression rating scale, D.R.S-S78 (described in Panel 18) whose score (DRS_Score) shows the degree of unhealthy of ANSA (the smaller, the better).

We tried to evaluated subject's ANSA by two dimensionally plots with MAX_CVRR and D.R.S-S78 score.

At present, we set thresholds for normal as MAX_CVRR is over 0.04 or DRS_Score is below 25.0.

Subject 1 was in a depressed state due to chronic serious stress at home and underwent specialist's medical treatment. We performed the measurement of this teacher twice, and close MAX_CVRR values were obtained. Nazareth kindergarten is offering all possible support including mental support.

Phase2 Stress check of kindergarten teachers at May-June, 2015



(●: Subject 1 (43 y.o.), ▲: Subject 2 (34 y.o.), ■: Subject 3 (56 y.o.), △: Subject 4 (45 y.o.), □: Subject 5 (21 y.o.),)

Subject 2 was thought to be in incoordination of ANSA. We performed the measurement of this teacher twice, and close MAX_CVRR values were obtained in this subject, too. Our preliminary interview investigations for teachers revealed that subject 2 was the stressor (STR) and her "bad attitudes and wordings" were the source of workplace stress which let other teachers decided resignation. She showed severe sleep apnea too. Her "bad attitudes and wordings" were suggested to be originated MMB problem.

Subject 3, 4 and 5 were thought to be belongs to normal group. The reason why MAX_CVRR value was below 0.04 in subjects 3 was thought to be the decrease due to aging. Since the numbers of data were small even in normal subjects, we could not figure exact age dependencies. We have to collect many data of normal, incoordination of ANSA and depression groups, and figure exact age dependencies and refine threshold values. Subjects 4 and 5 had very severe annoyed personal matters. Stress due to these matters thought to be lowered subject 4's MAX_CVRR and increased 5's DRS_Score, respectively.

Phase2 Syowa University Depression-Rating-Scale 78 (D.R.S-S78)

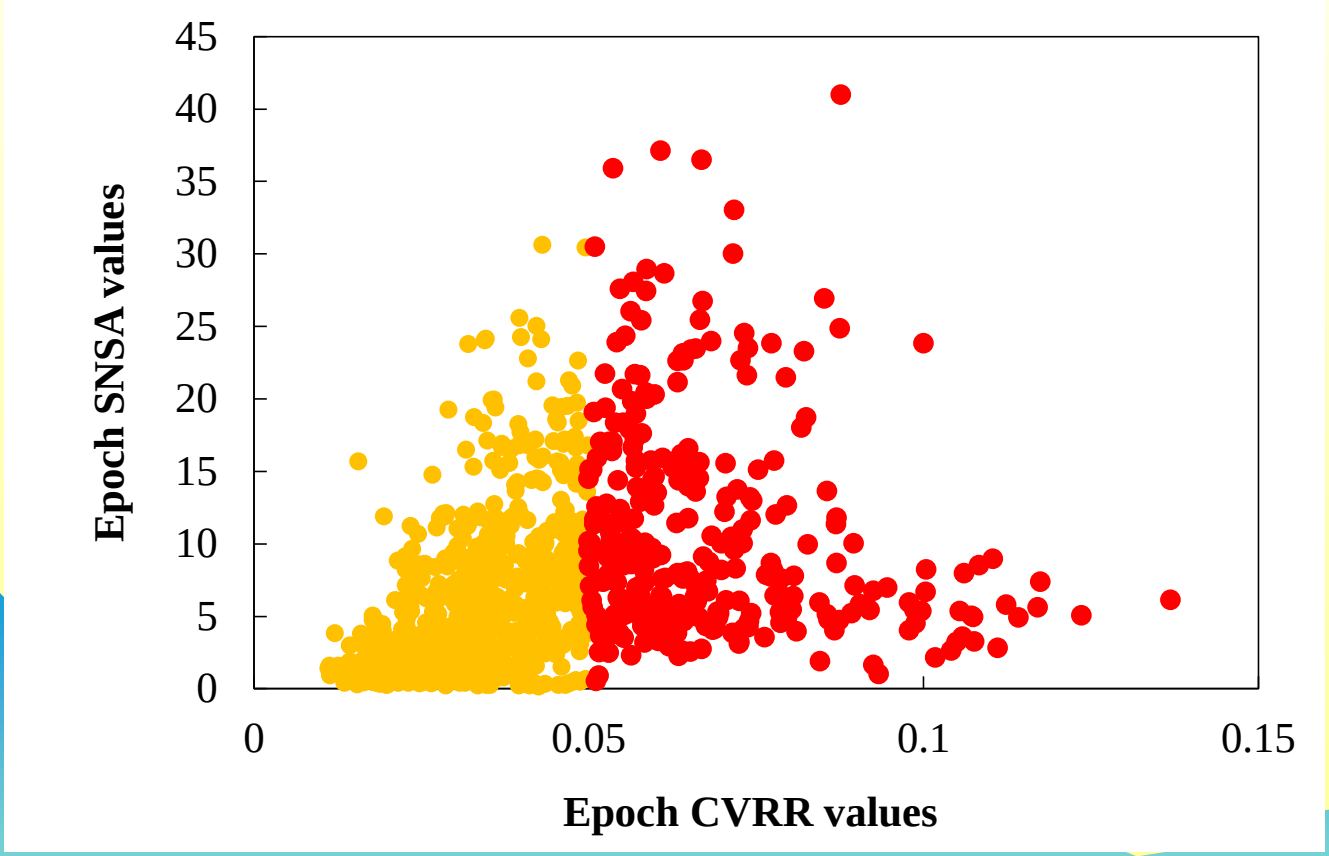
For depression, many rating-scales were developed since Depression-Elation-Test (1930, Jasper, H. H.[22]), including inventories of Lorr[23], Beck[20], Overall[24], Wechsler[25] and Zung[26]. In Japan, Japanese version of self-rating-scales of Beck [20] and Zung [26] are widely used and applied.

In order to measure psychiatric symptoms more strictly, we have to define symptoms precisely, and have to make the standard of the severity clearly. Furthermore, questionnaires of self-rating scale must be understandable for patients. Takenaka collected complaints of depression patients and depression related complaints of patients of other mental disturbances [27], and Inaba summarized them to the questionnaire composed by 53 questions expressed by easy to understandable Japanese and divided to 10 groups as Syowa University Depression-Rating-Scale 78 (D.R.S-S78) [28].

[20] A. T. Beck, C. Ward, M. Mendelson et al., "An inventory for measuring depression" Arch Gen Psychiatry, 4, pp.53–63, 1961.
[22] H. H, Jasper, J. Abnorm. Soc. Psychol., 25, pp.307-, 1930.
[23] M. Lorr, Psycholog. Bull., 51, pp.119-, 1954.
[24] J. E. Overall and D. R. Gorham, Psychol. Rep., 10, pp.799-, 1962.
[25] H. Wechsler, Arch. Gen. Psychiatry, 9, pp.334-, 1963.
[26] W. W. K. Zung, Arch. Gen. Psychiatry, 12, pp.63-, 1965.
[27] K. Takenaka et al., Journal of the Showa Medical Association, 24, pp.17-, 1965.
[28] H. Inaba, Journal of the Showa Medical Association, 43, pp.189-, 1983.

Phase3 Two dimensional plots of CVRR

Comparison of the analyzed result of the data measured in 2008 and 2015 revealed that although stress or SNSA of chief teacher of kindergarten and other people in responsible position was considered always large, their ANSA are still healthy. Hence, chronic continuation of large SNSA does not always lead to chronic unhealthy state of ANSA. Here, we proposed two dimensional evaluation of SNSA with CVRR, and separation of stress to passive stress and active stress by the CVRR value.



Here, we divided active and passive stress, SNSA with trial threshold CVRR=0.05 (passive: Orange, active: Red)

Our hypothesis is that chronic continuation of only passive large stress may lead to chronic unhealthy state of ANSA.

Conclusion

We proposed the method of detecting subjects with large stress and remains stress by the distribution of epoch values of sympathetic nervous system's activity (SNSA) during awake and sleep, respectively.

We also proposed the method to evaluate the degree of chronic unhealthy of ANSA, normal, incoordination of ANSA or depressed state based on epoch values of coefficients of variation of RR intervals (CVRR) during awake, and co-use of Self-Rating Scale increases the accuracy of evaluation.

We found that the chronic continuation of large SNSA does not always lead to chronic unhealthy state of ANSA. Hence, we proposed two dimensional evaluation of SNSA with CVRR, and separation of stress to passive stress and active stress.