Galvanic Skin Response as a Simple Physiology Lab Teaching Tool- An Alternative Indicator of Sympathetic Arousal

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ABSTRACT

Background

Sympathetic arousal response due to rewarding emotion may not be considered threat to the well-being but such arousal response evoked by fear or punishment can be stressful. When such changes are recorded in lab as biological signals, induced with appropriate stimulus, the observed response may serve as a good indicator of homeostatic alteration. In this study, skin conductance was utilized to record sympathetic response for cognitive load, by application of simple subtraction task.

Objective

To detect sympathetic arousal by utilization of galvanic skin response during mental arithmetic task.

Method

Total of eighty two subjects, forty two female and forty male participated in the study. Twenty two subjects were provided mental task to record skin conductance. In sixty subjects, galvanic skin response, pulse rate, respiratory rate and temperature were recorded by appropriate transducers to obtain baseline and task response to detect differential recordings. Subjects performed the mental exercise of arithmetic task (MAT) with transducer placed in upper limbs. Mean of averages for respective variables were statistically calculated from obtained recordings.

Result

For measured galvanic skin response, 57 subjects showed increased skin conductance (rise in amplitude) whereas, 25 subjects had no rise in amplitude (“A peak”) while performing the mental arithmetic task, when compared to control recording. However, in 20 subjects, pulse rate and respiratory rate showed significant rise though, the change in the skin conductance was not significant.

Conclusion

Galvanic skin response is useful for demonstration of sympathetic activation induced by simple mental subtraction task, and can be utilized along with vital parameters mentioned in this study to discuss in vivo variation that exist as differential for core and superficial sympathetic outflow among individuals.

KEY WORDS

Arousal, Conductance, Galvanic, Mental, Sympathetic

INTRODUCTION

Sympathetic arousal response due to rewarding emotion may not be considered a threat to the well-being but such arousal response evoked by fear or punishment can be stressful.[1] One of such stressors is academic stress in young medical students.[2-6] Additionally, the subtle change in vital clinical parameters like pulse and temperature recorded manually or digitally, when falls within clinical normal range, it is inappropriate to interpret the response as alarming and deleterious because such fleeting response is integral to the body physiology. However, when such changes are recorded in lab as biological signals, induced with appropriate stimuli, the observed response may serve a good predictor of homeostatic alteration.[7] Sympathetic Galvanic skin response (GSR) is a simple electrophysiologic test that confirms clinical dysautonomia.[8] Abnormalities of GSR are seen in many disease states, including general autonomic failure, peripheral neuropathy and even CNS degeneration such as Alzheimer's disease.[9-11] Sudomotor activity detected by sympathetic skin response is a valuable test for investigation of dysautonomia in diabetic peripheral neuropathy.[12] Moreover, GSR does serve as the indicator for revelation of sympathetic activity in healthy subjects.[13] Thereby, in this study, metrics of GSR are compared between control and mental arithmetic task (MAT), an inducer of sympathetic stress. To discern the unobtrusive variation in autonomic response, the noninvasive test galvanic skin response is studied along with vital parameters; pulse rate, respiratory rate and temperature, during mental arithmetic task.

METHODS

Undergraduate medical students at Kathmandu University School of Medical Sciences (KUSMS) were selected randomly for the study after obtaining the ethical clearance from institutional review committee. Students were explained the procedure before the verbal consent was obtained. Those who consented were included after matching the inclusion criteria. This study was performed from March 2015 to July 2016 at department of physiology at KUSMS as part of the protocol preparation for the galvanic skin response utilization for the autonomic function test. Total of forty two female and forty male volunteers participated during the study and performed the mental exercise of arithmetic subtraction task with transducer placed in two fingers. Twenty two subjects, ten males and twelve females were studied for skin conductance to detect the sympathetic arousal. The study was continued in sixty more subjects. Recordings were obtained in thirty females and thirty males for respiratory rate, pulse rate and temperature in addition to the skin response.

Sampling rate of 50:1, and detection adjustment for minimum peak height of 2 S.D. was used to record the skin conductance. Subjects were asked to perform simple hand wash, dry and visit the lab. Similarly, thick clothing was avoided before the recording was made. Respiratory belt was strapped around the mid thorax to ensure the site for maximum expansion of the fourth intercostal space. Index finger and middle finger of the right hand were utilized to record the GSR and index finger of the left hand was used for recording pulse using a transducer. Similarly, temperature was recorded by a transducer from the ring finger of left hand. Pre-test and habituation was performed before recordings were obtained. The purpose of the pre-test was to detect the neutral baseline shift, while recording at rest, with normal breathing, minimum limbs movement, with quiet and comfortable position of the subject. Habituation was performed by asking the subjects non-provoking questions such as name of the subject and the site of their residence for three times. Thereafter, the baseline recording was obtained for a minute that served as control data for the study in respective volunteers following which standard test for mental arithmetic was provided for subjects and the subjects were asked to solve the subtraction task mentally as rapid as they could, for one minute. For measured galvanic skin response waveforms, 23 metrics were obtained during rest and during MAT for all subjects, for one minute. Peaks detected with default adjustment for minimum peak height of 2 S.D. are non-specific skin conductance response (skin conductance level) and the value of "Apeak" is the highest value of peak achieved. Average of all variables were produced spontaneously by the professional version 7.0 software of AD instruments system. Mean of averages for respective variables were statistically calculated from obtained recordings. In addition, pulse rate, respiratory rate and temperature were obtained by appropriate transducers from 60 subjects and 'mean' of the parameters were compared for changes during the mental arithmetic task. It was observed that above mentioned vitals reflected the sympathetic activation with pulse rate and temperature having the increment within the normal range, and respiratory rate shooting slightly above normal value as defined for adults in clinical settings.

Mean and median of the average of all GSR variables is computed to compare the effect of mental task. Data obtained was entered in excel spreadsheet and SPSS version 23 was used to analyze it. As the data obtained was not normally distributed, non-parametric test was utilized to analyse the obtained values. Wilcoxon signed rank test was utilized. Significance level is 0.05.

RESULTS

Descriptive values of obtained 23 variables for skin conductance at rest and task performance is expressed in mean and standard error of mean. When those values were compared by signed rank test, the metrics studied were found to be significant ($p<0.05$) and non-significant. The mean of average of "Baseline", "A peak", "Peak wave

Table 1. Mean and standard error of mean of significant variables before and during cognitive task in 82 (n=22+60) subjects.

Variables	Mean+SEM (n=22)	Wilcoxon test p-value (<0.05) (n=22)	Mean+SEM (n=60)	Wilcoxon test p-value (<0.05) (n=60)	Unit
Baseline- Cntrl	-0.4641+0.26791	0.005	2.9782+0.84942	0.001	µS
Baseline- MAT	2.6098+1.09000		4.2905+1.02145		
A peak- Cntrl	0.1903+0.29494	0.002	3.4695+0.84729	0.001	µS
A peak- MAT	3.7423+1.25102		4.5056+0.98200		
Peak wave height- Cntrl	0.6545+0.14012	0.025	0.4913 + 0.07516	0.261	µS
Peak wave height- MAT	1.1325+0.22315		52.9767+52.30292		
Maxslope- Cntrl	1.3578+0.26037	0.117	3.1352+2.04767	0.030	µS/s
Maxslope- MAT	1.6212+.23602		1.8597+0.47817		
Minslope- Cntrl	-1.1868+0.20994	0.279	-1.0765+0.15106	0.019	µS/s
Minslope- MAT	-1.3731+0.18894		43.7102+45.04884		
A maxslope- Cntrl	-0.2112+0.27002	0.005	3.1352+2.04767	0.002	µS
A maxslope- MAT	3.0791+1.16321		4.0575+0.95295		
A minslope- Cntrl	-0.0569+0.27668	0.004	3.2750+0.84973	0.001	µS
A minslope- MAT	3.3506+1.20712		33.4614+29.14916		
TEnd- Cntrl	30.1520+2.13603	0.049	33.7700+1.53610	0.375	s
TEnd- MAT	34.4737+2.39557		185.6239+149.36491		
Pulse rate- Cntrl			78.20+1.09	0.000	per/min
Pulse rate- MAT			83.73+1.44		
Respiratory rate- Cntrl			19.342+0.41	0.000	per/min
Respiratory rate- MAT			22.742+1.19		
Temperature- Cntrl			35.0873+0.07	0.000	°C
Temperature- MAT			35.2918+0.23		

GSR- Galvanic skin response, Cntrl- Control, MAT- Mental Arithmetic Task, SEM- Std. Error of Mean.
µS-microsiemens, µS.s-microsiemens x second, µS/s-microsiemens per second.
Here, 'A peak' is the sample value at the peak not relative to baseline.
A maxslope is the sample value at Max slope.
A minslope is the sample value at Min slope.
Maxslope -At each sample in region from start to end a slope is calculated using 5 point linear regression centered on the sample. The maximum of these slopes is taken as Max slope.
Minslope-At each sample in region from start to end a slope is calculated using five point linear regression centered on the sample. The minimum of these slopes are taken as Minslope.
Peak wave height- Apeak minus the Baseline.
TEnd-Time period from the beginning of the analysis region in the current block to end.

Table 2. Mean, Median and p value for four variables of 20 subjects with lower average 'A peak' during MAT.

	A peak (µS)		Pulse rate (per min)		Respiratory rate (per min)		Temperature (˚C)	
	Control	MAT	Control	MAT	Control	MAT	Control	MAT
Mean	1.859	0.916	78.150	83.050	19.550	21.400	35.219	34.904
*Median (20)	*0.430	*-0.189	*77.500	*81.500	*19.000	*21.000	*35.230	*35.510
P value	0.000		0.001		0.001	1	0.108	
(P<0.05)Median (60)	0.741	1.644	76	82	19	22	35.19	35.31

*Median (20): Median of 20 subjects, Median (60): Median of 60 subjects.

height", "A maxslope", "A minslope" and "Tend" of metrics of GSR in 22 subjects was found to have significantly high during mental arithmetic task (MAT). Similarly in other 60 subjects, "Baseline", "A peak", "Maxslope", "Minslope", "A maxslope" and "A minslope" were the metrics found to be significantly high during mental arithmetic task as depicted in Table 1. The comparison was highly significant (p<0.001) between control and MAT for pulse rate, respiratory rate and temperature in 60 subjects.

Out of 22 subjects, 2 subjects had equalizer in amplitude ("A peak") during task, compared with baseline value. Three subjects had lower average "A peak" during MAT.

Table 3. Difference of Mean of response in male and female subjects for measured variables in 60 subjects.

Variables	Male (Mean+SD)	Female (Mean+SD)	p-value (p<0.05)
Pulse rate	3.66+5.01	7.40+7.52	0.094
Respiratory rate	2.64+2.09	4.33+11.98	0.526
Temperature	0.15+2.52	0.52+0.28	0.574
Skin conductance:			
Peak wave height (µS)	0.40+1.62	-0.64+0.36	0.017*
Amplitude (µS) (A peak)	1.55+4.75	0.73+1.14	0.813

When 23 variables of GSR of 82 samples (n=22+60) were observed, 25 subjects (n=5+20) i.e. 30.48% wherein, 12 female (28.5%) and 13 male (32.5%) had no rise in average "A peak" for MAT than that of control (at rest) recording. Among 25 subjects, three subjects (3.6%), i.e. two female (4.7%) and one male (2.5%), had equal "A peak" average values during rest and task alike.

In the group of 60 subjects, 20 subjects had significant rise of pulse rate and respiratory rate, though the "A peak" was significantly less during MAT as shown in Table 2.

As shown in Figure 1, forty subjects (48.8%), wherein 22 male (55%) and 18 female (42.8%) had 'negative average baseline' or below zero recording at rest. However, 24 subjects (29.2%) had 'negative baseline' recording during MAT. In all 24 cases, during MAT, average 'A peak' became less negative.

Mean of 'Height' of peak waves was only parameter to differ between the genders in the population of 60 subjects, as depicted in Table 3.

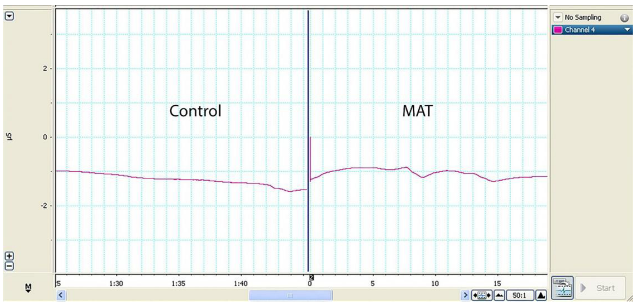

Figure 1. Recording during control and MAT, showing negative value. Taken from AD instruments labchart Pro (Original recording).

DISCUSSION

Autonomic nervous system has been studied in health and disease states alike.[14-17] Various tests are performed to detect sympathetic changes.[18-20] In this study, galvanic skin response was utilized to evaluate sympathetic arousal. There is a derth of uniformity in information across the literature on methodology for GSR analysis. Additionally, different tools are found to be used to record the skin conductance based on the fundamental principle of increased conductance due to sweat gland activation during

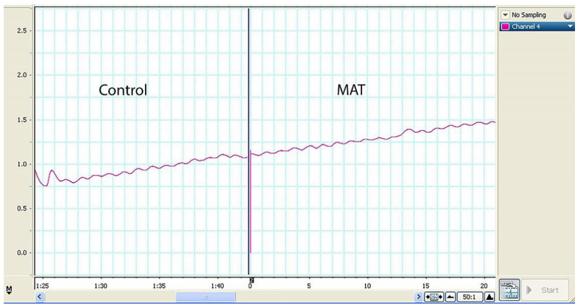

Figure 2. Compared curve for the baseline recording from control and task performance of a single subject. Taken from AD instruments labchart Pro (Original recording).

sympathetic activation. Skin conductance response (SCR) recorded during the task application is said to be higher in value (microsiemens) than skin conductance recorded at rest and is termed as skin conductance level (SCL). During conductance rise, baseline itself shifts up and thus the peak is at higher value as depicted in Figure 2. Our approach in this study is to report the various suitable parameters of the waveform, to detect and differentiate the arousal during sustained stimuli of repeated design by mental arithmetic task, with application of basic statistics procedure for recordings obtained as depicted in 'Table 1'. As shown in 'Table 1', different metrics imply the significant difference among the 23 metrics of analysed waveforms. Metrics shown in table-1, having significant difference (p>0.05) in both the group (n=22) and (n=60), can be utilized for identification of raised skin conductance for sympathetic arousal. However, it has been noted in this study, the 'height' (amplitude of the wave recorded) of the waveform during rest (SCL) may not be higher than amplitude of waveform recorded during task performance (SCR). The amplitude of the waveform is not increased during the task (SCR) than the control recording (SCL). Thereby, use of metric "amplitude rise" during task performing mental exercise (skin conductance response) leading to rise in skin conductance by heightened arousal response is rather a misnomer. And, rise in height of a waveform as recorded during nerve conductance test, is not a suitable parameter for waveform in galvanic skin response to be considered as amplitude. Compared curve for the baseline recording from control and task performance of a single subject, as shown in figure 2, is rather self-explanatory to this view. It is the "A peak" i.e 'amplitude irrespective of the baseline', which is significantly raised during the task, implying the heightened sympathetic activity resulting into increased skin conductance, while solving the provided exercise. Thus, "A peak" is appropriate metric to detect the conductance rise.

Three subjects (3.6%), i.e. two female (4.7%) and one male (2.5%), had equal "A peak" average values during rest and task alike. Median compared for pulse rate and respiratory rate showed significant rise during MAT in 20 individuals though the "A peak" was significantly less during MAT. As per findings, the sympathetic stimulation was not coupled with rise in "Apeak" during MAT. This is contradictory to the sympathetic activation effect onto sweat glands and thereby the GSR recording obtained as "Apeak" during the MAT, wherein peak should have risen higher than control/ baseline recording. Perhaps, sympathetic outflow recorded for the autonomic nerves of skin through transducers of galvanic skin response is not effective to detect the degree of autonomic activation. The detection of degree of autonomic activation depends upon number of sympatho-cholinergic fibers innervating sweat glands that are stimulated during the task which increase the conductance over the skin surface. But, there exists the evidence for the dissociative response of autonomic activation by rise in pulse rate and respiratory rate in those subjects. Perhaps the dissociative response observed here in 20 subjects of the population studied put forward the limitation of the galvanic skin response, for detection of dysautonomia.[21] Stepping onto the analogy, it may be conjectured, these 20 subjects of the study population belongs to 'electrodermal labiles' and the rest to 'electrodermal stabiles'. In the electrodermal labiles, skin conductance responses (SCR) rise very slowly and show increased number of non-specific skin conductance responses during baseline (SCL) recording.[2,13] To ensure this, the recording of the SCR during mental arithmetic task should have been performed for prolonged period in the reported subjects. To overcome these limitations, sampling rate should have been increased and down sampling had been avoided. Highly significant parameters pulse rate, respiratory rate and temperature as reported in table 1 for sympathetic arousal during simple cognitive task though lie within the clinically defined normal range for vitals recorded, has been found in this study to serve supportive investigation for sympathetic system activation when coupled to the test for skin conductance. Additionally, to demonstrate the adrenaline response during mental task, using GSR alone could falsely be misinterpreted for absence of sympathetic stimulation in subjects, who may be electrodermal labiles.

CONCLUSION

The parameter, peak wave height ('A peak' minus the baseline), considered ideally to be amplitude in any wave recorded, was not found to be significantly different when compared between control and MAT recordings. Metrics of galvanic skin response with significant 'p value', can be valid and reliable parameters for discretion of subtle sympathetic outflow for mentally stressful stimuli, such as subtraction task, supplied as academic stressor in this study. Ephemeral rise of vitals when recorded digitally can be a good indicator and comparator for sympathetic outflow caused by non-physical yet cognitively stressful stimuli, which may be unnoticeable when examined the vitals, manually. Additionally, galvanic skin response is useful for demonstration of sympathetic activation, and can be utilized along with vital parameters mentioned in this study to discuss, in vivo variation that exist as differential, for core and superficial sympathetic outflow among individuals.

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