INFLUENCE OF STRESS ON BLOOD PRESSURE, HEART RATE, LEVELS OF SALIVARY AMYLASE AND SKIN TEMPERATURE

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Abstract *Productivity is the key to improved standard of living of a Country. Productivity growth represents the key to economic success. In this perspective we could increase productivity, one through human resources productivity that represents a potential contained within each human being. From understanding of human resources, then human health is one factor that important to support good human resources. And stress is one of human health problems that can be classified as dangerous phenomenon that leads to deterioration of people's total functioning The physiological stressors activate two stress response systems; the HPA axis (hypothalamic-pituitary-adrenal) and SAM sympatho-adrenal-medullary axis. SAM activates two regulatory systems, i.e. systems hormones norepinephrine and direct system sympathetic innervations. Both affect increased secretion of salivary amylase. Increased levels of norepinephrine associated with the increased of blood pressure, heart rate, and skin temperature. In this research we use blood pressure, heart rate, skin temperature and salivary amylase because the four physiological factors can be measured by non-invasive way and without requiring special skills. Ten people volunteered to participate in this study. All study participants were healthy adults and aged between 23 until 35 years old. All of them are not smoker. The subject consisted by five males and five females. All of them will measured their blood pressure (BP), heart rate (HR), salivary amylase, and skin temperature. Further, the experiment data will analyzed using statistical analysis – Ordinal Logistic Regression to know the influence of stress on physiological factors. Two physiological factors namely amylase and heart rate that affected by stress. For blood pressure and skin temperature revealed no effect. No effect in this case based solely on the statement of the hypothesis only. Indeed for the results of the effect of stress on blood pressure and skin temperature result still not clear. Due to it can be both factors at the time of acute stress response. While this study only used to determine the effect of stress on physiological factors immediately.*

Key words *stress, physiological factors, ordinal logistic regression*

1. INTRODUCTION

1.1. Human Resources Productivity

Productivity is the key to improved standard of living of a Country. Productivity growth represents the key to economic success [1]. Only through increased productivity can there be sustained increases in real income and rising levels of economic well-being for a country. In this perspective we could increase productivity, one through human resources productivity that represents a potential contained within each human being.

From understanding of human resources that have been described above, then human health is one factor that important to support good human resources. And stress is one of human health problems. According to 'Handbook of Stress, Coping, and Health' [2], many different disciplines (e.g., psychology, social psychology, nursing, and medicine) have identified stress and coping as important vari-ables affecting health. It has been linked to the onset of diseases, such as cardiovascular condi¬tions, can¬cer, breast cancer, and colds, as well as the exacerbation of symptoms such as asthma, irritable bowel syndrome, ulcerative colitis, arthritis, respiratory diseases, and diabetes.

1.2. Stress

One of the most widely accepted definition about stress said "stress to be a dynamic relationship between an individual and his or her environment perceived by the person as demanding or exceeding his or her resources"[3]. Stress as dangerous phenomenon that leads to deterioration of people's total functioning [4]. While a certain level of stress is healthy and perhaps necessary, high levels of persistent and intense stress can lead to a host of negative outcomes affecting behavioral, social, health, and psychological functioning [5].

According to Vermeulen [6] further distinguish stress between three types of stress,

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i.e. physical stress, psychological stress, psychosocial stress. Physical stress is the stress a human body can feel (headache, ulcers, sleeplessness or pain muscles and organ). And psychological stress is the results of our attitudes, emotions and reactions such as depression, habitual negativity, lack of concentration and low creativity. While psychosocial stress involves the stressors that arise from interpersonal relationships and inadequate or inappropriate social interactions such as aggression. Both physical stress and psychological stress will have an impact on the physiological changes in individuals.

1.3. Physiological Responses To Stress

Physiological response to stress is a latent-insidious condition that does not look real degrades performance in physical and human resource. Response to stress divided into three stages: the alarm stage, an activity of sympathetic nervous system and the HPA axis; the resistance stage, during which the body selects the most effective defense; and the exhaustion stage, during which physiologic resources are depleted and signs of system damage appear [7].

The physiological stressors activate two stress response systems; the HPA axis (hypothalamic-pituitary-adrenal) and SAM sympatho-adrenal-medullary axis [8]. SAM activates two regulatory systems, i.e. systems hormones norepinephrine and direct system sympathetic innervations. Both affect increased secretion of salivary amylase. In the other hand, the activation of HPA axis increases salivary cortisol [8]. In this research we use blood pressure, heart rate, skin temperature and salivary amylase because the four physiological factors can be measured by non-invasive manner and without requiring special skills.

1.4. Blood Pressure

Blood pressure (BP), sometimes referred to as arterial blood pressure, is the pressure exerted by circulating blood upon the walls of blood vessels, and is one of the principal vital signs. The blood pressure in the circulation is principally due to the pumping action of the heart [17]. On the measurement of blood pressure, usually there are three kinds of pressure. The first is the maximum pressure (systolic), minimum pressure (diastolic) and pulse pressure (pulse). Figure 1 shows about adult blood pressure conditions ranging from hypotension, normal, until hypertension.

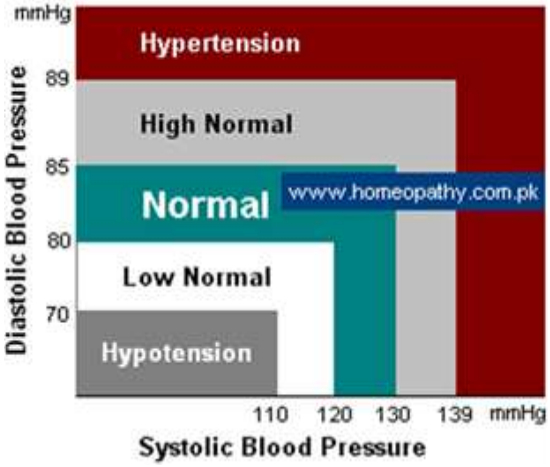

Fig. 1. Blood Pressure Chart

Hypotension, normal, until the hypertension associated with high or low blood pressure. High blood pressure related to hypertension. Arterial hypertension can be an indicator of other problems and may have long-term adverse effects. Persistent hypertension is one of the risk factors for strokes, heart attacks, heart failure and arterial aneurysms, and is the leading cause of chronic renal failure. At severely high pressures, mean arterial pressures 50% or more above average, a person can expect to live no more than a few years unless appropriately treated [11].

Low blood pressure related to hypotension. When arterial pressure and blood flow decrease beyond a certain point, the perfusion of the brain becomes critically decreased (i.e., the blood supply is not sufficient), causing lightheadedness, dizziness, weakness or fainting. Hypotension is a medical concern if it causes signs or symptoms, such as dizziness, fainting, or in extreme cases, shock [12].

While pulse is depicted as the up and down fluctuation of the arterial pressure results from the pulsatile nature of the cardiac output i.e. the heartbeat. The pulse pressure is determined by the interaction of the stroke volume of the heart, compliance (ability to expand) of the aorta, and the resistance to flow in the arterial tree. By expanding under pressure, the aorta absorbs some of the force of the blood surge from the heart during a heartbeat. In this way, the pulse pressure is reduced from what it would be if the aorta wasn't compliant [10].

1.5. Heart Rate

Heart rate is often defined as the number of heartbeats per unit of time, typically expressed as beats per minute (BPM). In the measurement of heart rate, we can also find the heart rate variability (HRV). HRV analysis has gained much importance in recent years as a technique employed to explore the activity of ANS, and as an important early marker for identifying both physiological and pathological conditions [9]. Heart rate can vary according to the needs of the body of oxygen, such as during exercise or sleep. Measurement of heart rate is used by medical professionals to assist in the diagnosis and tracking of medical conditions.

1.6. Salivary Amylase

Stress measurement by using non-invasive measurement of salivary amylase level was very popular over the past decade in psychological and biomedical research. Salivary alpha-amylase is an enzyme found in saliva that has been thoroughly studied in oral biology. Its primary function is the digestion of carbohydrates and starches, although it has also been identified as the first line of immune defense because it helps clear bacteria from the mouth.

1.7. Skin Temperature

Skin temperature is an effective indicator for objectively evaluating human sensations, because it is controlled by sympathetic nerve activity which reflects the course of information processing in the brain [16]. Their research concluded that there is a high correlation among stress, skin temperatures on nose and forehead.

Sometimes we can feel our hands getting cold and sometimes warm. Like after or before examination, doing a sports challenge, etc. Warm hands indicate relaxation while cold hands reflect tension [18].

Table 1. The range over which temperature fluctuates and changes

High Tension	Slight Tension	Mild Calm	Quietly Relaxed	Deeply Relaxed
Below 26°	26-29°	29-32°	32-35°	Above 35° (C)
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2. MATERIAL AND METHOD

2.1. Q & A Before Test

Q & A means question and answers that conducted shortly before experimental started. It's like some sort of questionnaire, but only contains a few questions about the condition of each subject while before doing the experiments, including the possible things that will affect the measurement parameters, such as the food and beverages that consumed by subjects, cigarettes, and so forth. They were further asked to give their subjectivity about their stress/emotional condition in every period of measurement time (i.e. pre-stressor, stressor-I, stressor-II, and post-stressor period).

2.2. Stressor Conferment

After subjects fill the Q & A sheet then the experiment started. We give two kinds of stressors to measure the stress level of each person. In stressor-I period, we give the stressor namely Pauli-test. Pauli-test including in psychological test, which is shaped like a sheet of paper newspaper that containing rows of numbers that make up columns. Pauli test will be used as:

a. Can you work under pressure?
b. How do you handle conflict?
c. Tell me about a situation in which your work was criticized by others!
d. As far as what you can handle the change?
e. Type of person who would make you has trouble for work?

But in this study, the objective of Pauli-test only subject to condition under pressure. On this test, subjects were instructed to do the test as fast as possible for 30 minutes. This test is performed by adding any two numbers from top to bottom and write the results in the next column. Further, every 2 minutes we give the cue to the subject to give the "line" wherever they stopped counting, and continue counting again until the time finish (30 minutes). Once the stressor is completed then the next one, given both the mental arithmetic stressor test. In the second period stressor is done in just 15 minutes. Each subject answered 40 questions mental arithmetic test with different time in each questions. The time that given in each questions indeed varies depend on the weight of problems.

2.3. Blood Pressure Measurement

In this study, we used OMRON HEM-6200 wrist blood pressure monitor to measure blood pressure (BP) each subject. This device is

very easy to use even though for untrained staff. The OMRON Wrist BP monitor displays a measurement range from 0 to 299 mmHg for pressure readings and 40 to 180 beats/minute for pulse rates. The accuracy rate stands at ±3 mmHg for pressure and ±5 % of reading for pulse. Each subject has to use this device to measure their BP on sitting position in every period.

Fig. 2. Blood Pressure Monitor

2.4. Heart Rate Measurement

For measuring heart rate we use device which is a watch that comes with a transmitter namely POLAR. In this study using Polar RS800CX type. This Polar system consists of (1) Polar RS800CX training computer displays and records to the subject's heart rate and other exercise data is during exercise and (2,3) Polar Wear Link WIND to the transmitter sends the heart rate signal to the transmitter, consist of a connector (2) and strap (3) as shown in figure 3 below.

All subjects had to using Polar heart rate monitors at the time of the study were installed correctly. Improper use will result in ambiguous data because the heart rate is not recorded as a whole. Heart rate data were recorded during the study is further processed in the Polar Pro Trainer 5 software.

Fig 3. POLAR RS800CX

2.5. Salivary Amylase Measurement

For measuring salivary amylase we use salivary amylase monitor namely NIPRO from (NIPRO Co., Ltd.). This device can measure amylase level from 10 to 200 kIU/l, consists of a measurement device (1) and a strip-marker (2) as shown in figure 5 below. The subjects have to input the strip-maker under their tongue ± 30 seconds to get clean saliva. The value of salivary α-amylase can be collected ± 1 minute. Salivary α-amylase is the shortcut to measure physiological stress with non-invasive way.

Fig. 4. Salivary Amylase

2.6. Skin Temperature Measurement

For measuring skin temperature we use a radiation thermometer that collected in every experimental period. Each subject measured their hands temperature as soon as possible by observer. This data collection expected given information the differences between temperature in the right hand and left hand.

Fig. 5. Infrared Thermometer

2.7. Experimental Procedure

Ten people volunteered to participate in this study. All study participants were healthy adults and aged between 23 until 35 years old. The subject consisted by five males and five females. All of them are not smoker. Data collection was performed in five times. Each subject was only charged one-time data collection, so that each data collection consisted of two people. We collected each data in different days. It is because of limited human resources as an observer. All subjects exposed to the methods and the same type of stressor. Each subject worked on two kinds of stressors namely Pauli-Test and mental arithmetic test. The first until last sampling (I-IV) that collect data from blood pressure, amylase, and skin temperature, because heart rate data was already collected continuously by Polar system. The study was conducted in a relatively short period of time for 80 minutes and divided into four periods, shown in this Figure 6. After finished all the experimental process, then the data must be treated with statistical analysis. In this picture below shown the procedure of data analysis in Figure 7.

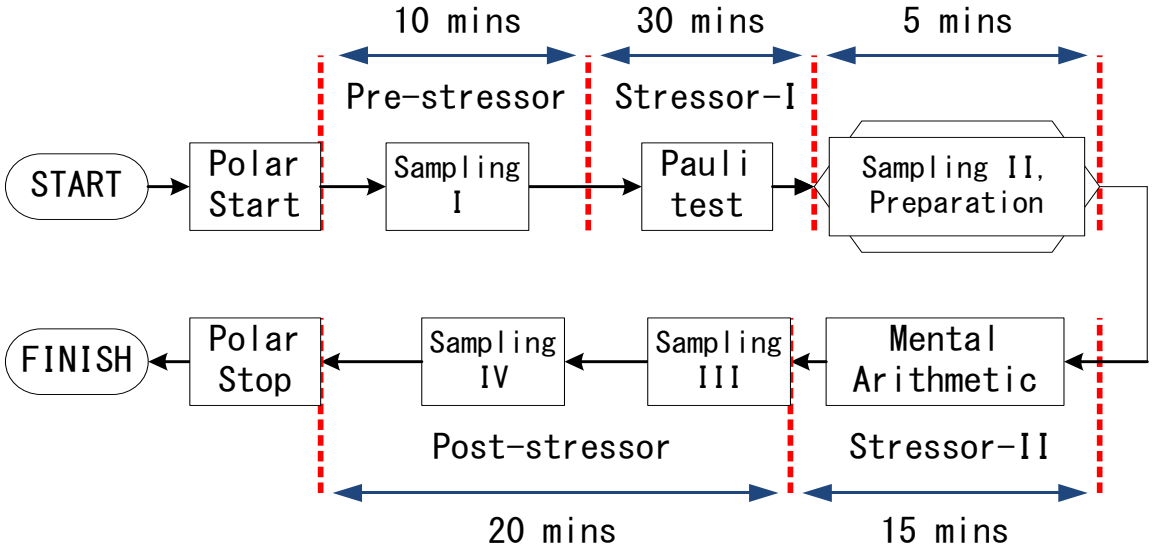

Fig 6. Experimental flowchart

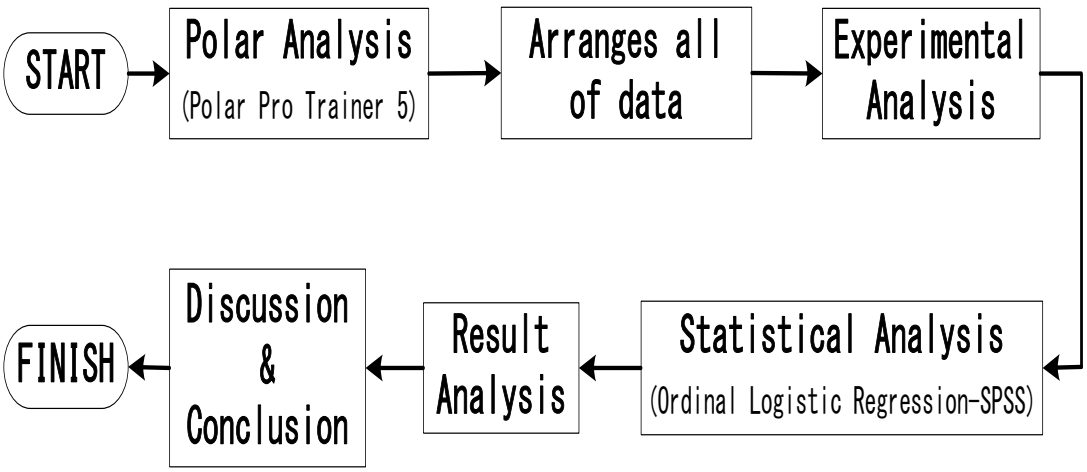

Fig 7. Data Analysis Flowchart

2.8. Statistical Analysis

In this study we use Ordinal Logistic Regression analysis. Regression model is an important component in the data analysis by describing the relationship between the response variable (Y) and one or more independent variables (X). In general, regression analysis is used to analyze the data with quantitative data such as response variables. But often also encountered cases with the response variable is qualitative or category. To overcome these problems can be used logistic regression models [14]. Logistic model for ordinal response data with category k (k> 2) is an extension of the logistic model for nominal data with two categories (binary logistic models). As in other regression models, two or more independent variables included in the analysis. The independent variables can be either quantitative data or qualitative data. Qualitative data for the independent variables can be nominal and ordinal data [15]. Logistic models for ordinal response is often referred to as the cumulative logit model. Response in the form of cumulative logit models stratified the data that begins with the number 1, 2, 3, …, k, where k is the number of response categories [13]. This figure below show the data when analyzed in SPSS software

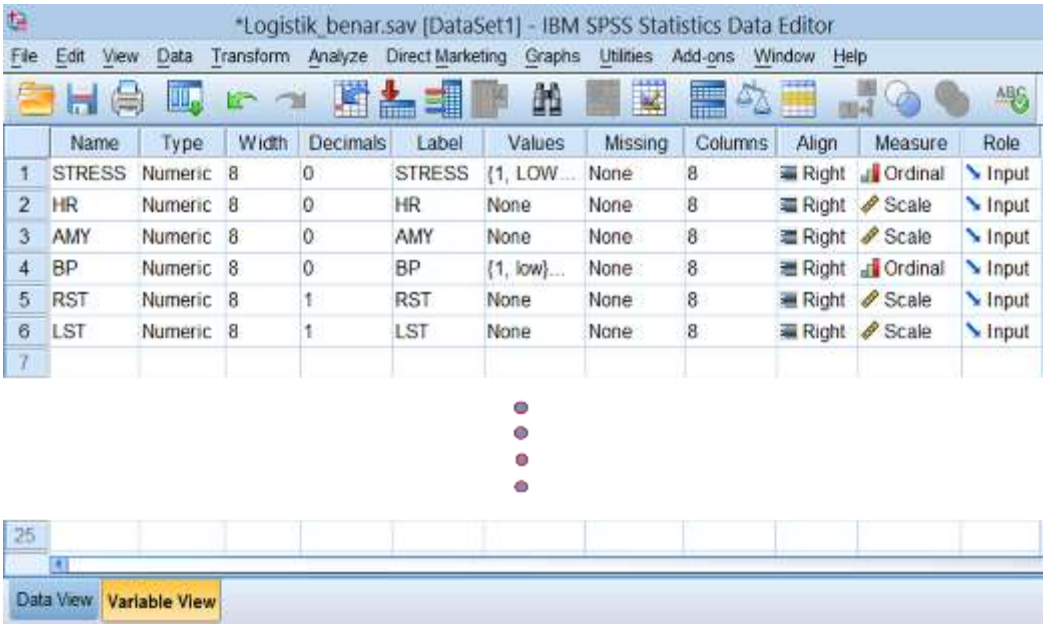

Fig. 8. Variable view on Ordinal Logistic Regression using SPSS 21

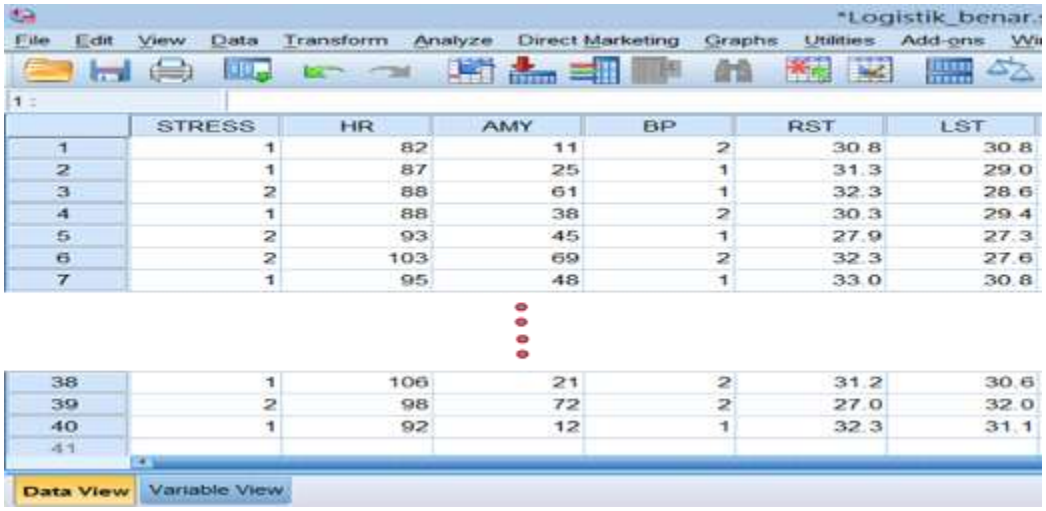

Fig 9. Data view on Ordinal Logistic Regression using SPSS 21

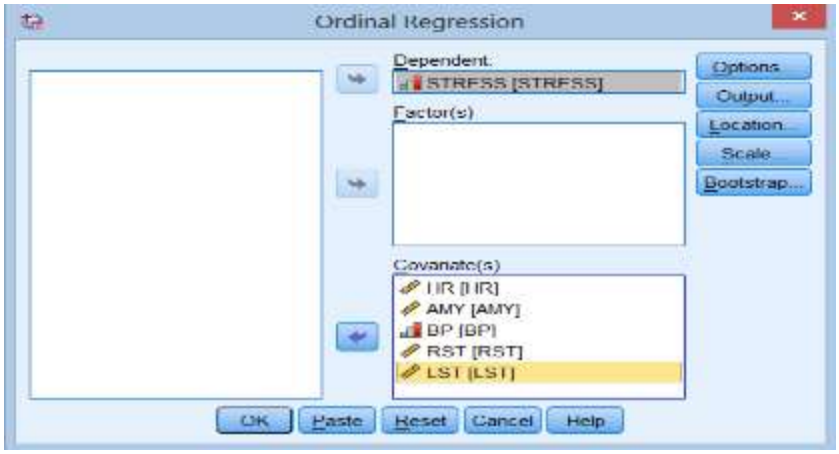

Fig 10. Ordinal Logistic Regression using SPSS 21

3. RESULTS

3.1. Raw Data Results

a. Blood Pressure from all subjects

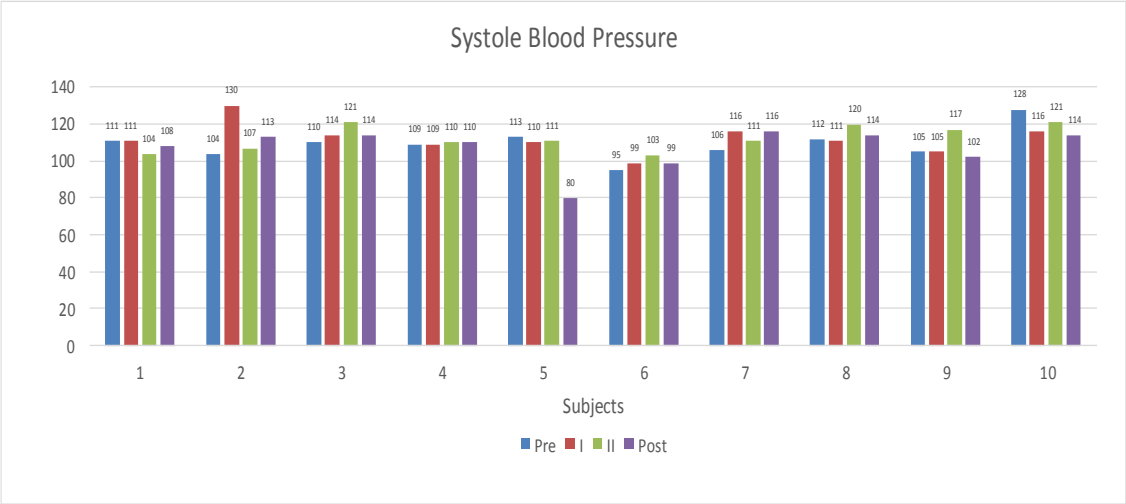

Fig. 11. Systole Blood Pressure Results for All Subjects

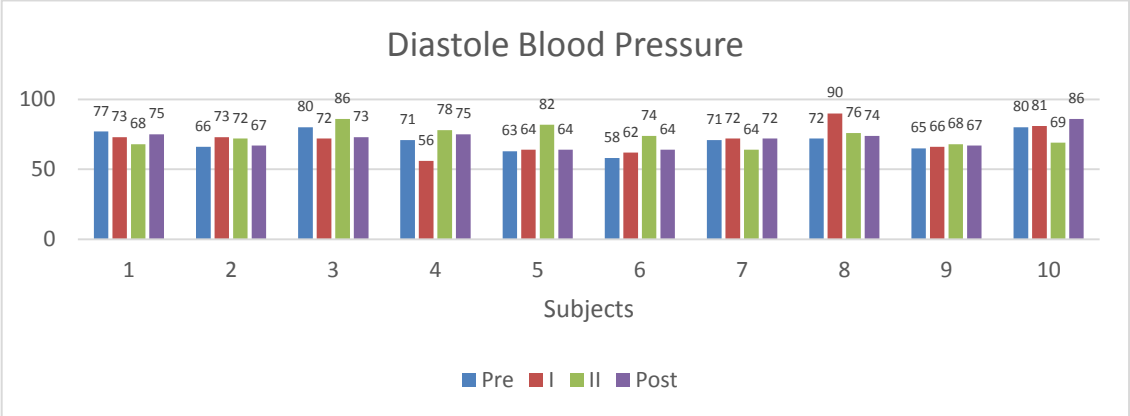

Fig. 12. Diastole Blood Pressure Results for All Subjects

b. Heart Rate from all subjects

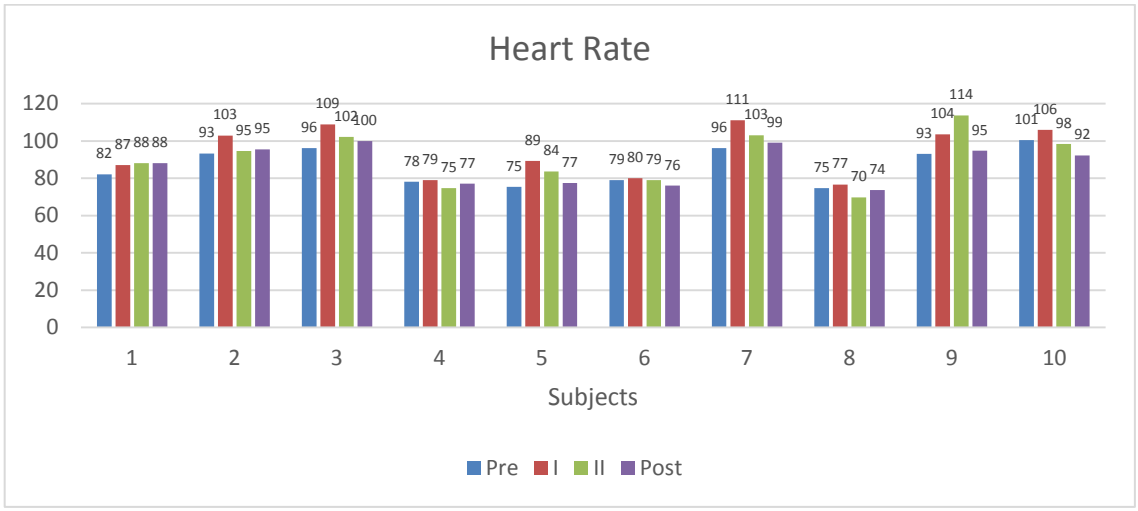

Fig. 13. Heart Rate Results for All Subjects

c. Amylase from all subjects

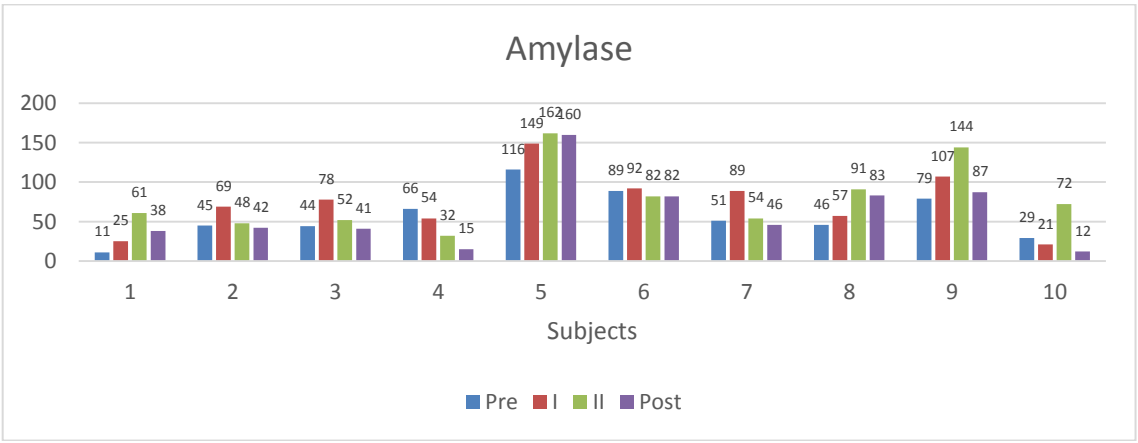

Fig. 14. Heart Rate Results for All Subject

d. Skin Temperature from all subjects

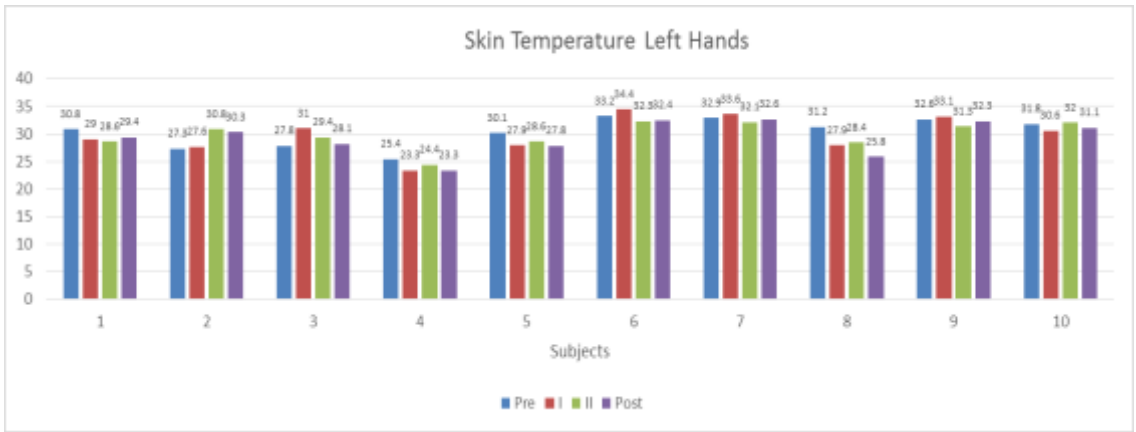

Fig. 15. Skin Temperature Left Hands Results for All Subjects

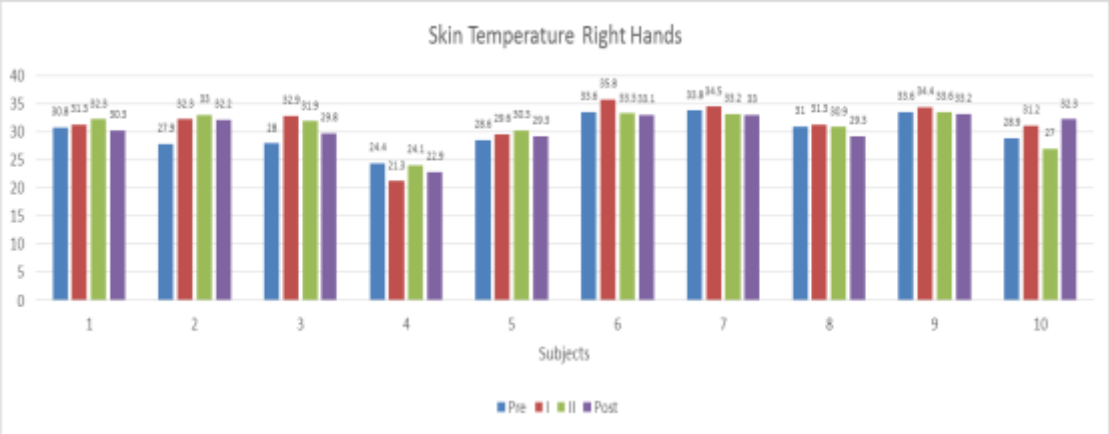

Fig. 16. Skin Temperature Right Hands Results for All Subject

3.2. Experimental Analysis

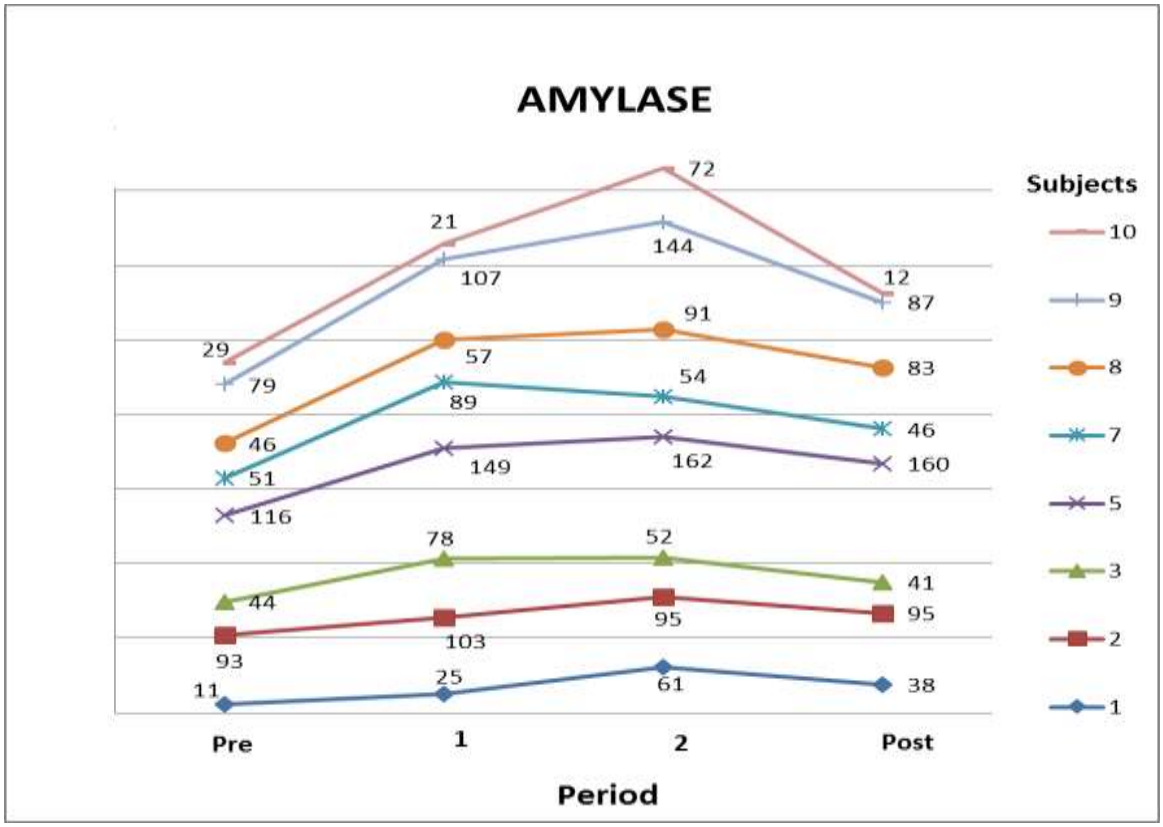

Fig. 17. Experimental Analysis for Amylase

Figure 17 explain the representative results. From the figure above we know that amylase is influenced by stress. There are 8 subjects from 10 subjects that give appropriate results. Eight subjects provides increased amylase after the stressor given. While 2 subject give the straight trend from pre-stressor until post-stressor periode, or down at the stressor-I and stressor-II periode. Thus, we have to rejected those result because the subjects got stress at relax time and relax at stress time.

Fig. 18. Experimental Analysis for Heart Rate

Figure 18 explain the representative results. From the figure above we know that amylase is influenced by stress. There are 7 subjects from 10 subjects that give appropriate results. Seven subjects provides increased amylase after the stressor given. While 3 subject give the straight trend from pre-stressor until post-stressor periode, or down at the stressor-I and stressor-II periode. Thus, we have to rejected
those result because the subjects got stress at relax time and relax at stress time.

3.3. Ordinal Logistic Regression Results

From table 2 above displays the significant regression results from SPSS 21. All independent variables show the significant value. In this study we use a specified alpha level 0.05 that compare with p-value (sig. value), our willingness to accept a type I error. If p-value smaller than specified alpha level, would lead us to conclude that at least one of the regression coefficients in the model is not equal to zero. But if the results is opposite (p-value bigger than specified alpha level) then we must accept null hypothesis. Thus, from the figure above we can conclude only amylase and heart rate that be influenced with stress because amylase p-value 0.024 < 0.05 and heart rate p-value 0.039 < 0.05. While blood pressure (p-value 0.161 > 0.05), skin temperature for left hands (p-value 0.206 > 0.05), and skin temperature for right hands (p-value 0.128 > 0.05) did not influenced by stress.

3.4. Final Results

From Table 3 above we get the same result that only amylase and blood pressure suitable.

4. DISCUSSION

Now the word "stress" became very popular in almost all dictionaries. Stress vocabulary is almost always pronounced all people to express what they feel like emotions, depression, or an expression of pain such as headaches, stiffness in the shoulders, etc. Stress has become a problem, especially for physiological health of a person. If a person is not healthy then it will reduce the productivity that called Human Resources Productivity.

Physiological stress can be researched through many physiological factors and also a lot of methods, one of them with probabilistic through statistical studies. Statistical methods can be used as the starting point to see the effect of stress on physiological factors. because the stress data that are qualitative (ordinal) which will be known physiological effect on 4 factors, i.e. blood pressure, heart rate, salivary amylase levels, and skin temperature. And the fourth factor is a factor that easy to collect sample, can be done by non-invasive, and tend to spend a cheap experiment.

Table 2. Statistical Results – Ordinal Logistic Regression

Parameter Estimates								
							95% Confidence Interval	
		Estimate	Std. Error	Wald	df	Sig.	Lower Bound	Upper Bound
Threshold	[STRESS = 1]	17.619	6.664	6.990	1	.008	4.557	30.680
	[STRESS = 3]	22.026	7.267	9.188	1	.002	7.784	36.269
Location	HR	.108	.052	4.282	1	.039	.006	.210
	AMY	.126	.035	13.082	1	.000	.058	.195
	BP	.687	.490	1.964	1	.161	**0.000298**	1.647
	RST	.369	.243	2.316	1	.128	-.106	.845
	LST	-.359	.283	1.603	1	.206	-.914	.197

Link function: Logit.

Table 3. Final Results

Experimental Analysis results	Reason	Statistical Analysis Results	Reason
Amylase	8 subjects representative	Amylase	p-value 0.000298 < 0.05
Heart Rate	7 subjects representative	Heart Rate	p-value 0.000298 < 0.05

Of both methods obtained the same results, only two physiological factors namely amylase and heart rate that affected by stress, because in this research:

- HR measured with Polar system that used during experiment (continuously)
- Sometimes there are misconnections between Polar training computers with transmitter because the water inside the belt was dry. And we suggest using ECG GEL to avoid this problem.
- Amylase measurement is always done in first sequence of sampling period so that the results obtained appropriate.

Salivary alpha-amylase levels were also found to respond to psychological stress or relaxation intervention [19]. While the effect of stress on blood pressure and skin temperature was not found in this study. The relationship between stress and blood pressure and skin temperature still unclear, because in this research:

- We use only one devices to measure skin temperature and blood pressure
- Skin temperature measurements, performed last at each sample session
- This research does not contribute directly to the subjects. Subject's role only as participants

And for further research, we suggest:

- There should be one person observer for each subject in order to obtain more accurate results
- All subjects / participants must follow the research at the same time, to get same environmental conditions
- In pre and post period (relax period), the circumstances at the time of the study should be relax also. For example, the subject must be conditioned really relax by listening to music, performed in a quiet situation, clean air, etc.

5. CONCLUSION

In conclusion, the results of this study indicate similarities between data were analyzed manually (by looking at the trend), with the results of analysis of statistical methods. So that calculations using statistical methods used here to reinforce the trend analysis results manually.

Of the two kinds of methods known that stress affects the amylase and heart rate. For two other physiological factors, namely blood pressure and skin temperature revealed no effect. No effect in this case based solely on the statement of the hypothesis only. Indeed for the results of the effect of stress on blood pressure and skin temperature result still not clear. Because it can be both factors at the time of acute stress response. While this study only used to determine the effect of stress on physiological factors immediately.

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