HUBUNGKAIT GERAK KERJA STATIK TERHADAP KELESUAN OTOT DAN KADAR PEMULIHAN KELESUAN

(THE RELATIONSHIP OF STATIC WORK TOWARD MUSCLE FATIGUE AND FATIGUE RECOVERY RATE)

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LIST OF SYMBOL

No.	Symbol	Description of symbol	Unit SI
1	O	Operator	
2	C	Condition	
3	S	Sex	
4	A	Age	year
5	H	Height	cm
6	W	Weight	kg
7	BMI	Body mass index	kg/m^2
8	L	Load	kg
9	bHR	Base heart rate	Pulse/min
10	bSYS	Base systolic	mmHg
11	bDIAS	Base diastolic	mmHg
12	bBP	Base blood pressure	mmHg
13	HRmax	Heart rate maximum	Pulse/minute
14	HR0	Heart rate on 0 minute	Pulse/minute
15	%RHR0	Relative heart rate on 0 minute	Pulse/minute
16	SYS0	Systolic 0n 0 minute	mmHg
17	DIAS0	Diastolic on 0 minute	mmHg
18	BP0	Blood pressure on 0 minute	mmHg
19	RSYS0	Relative systolic on 0 minute	mmHg
20	RDIAS0	Relative diastolic on 0 minute	mmHg
21	RBP0	Relative blood pressure on 0 minute	mmHg
22	HR1	Heart rate on 1st minute	Pulse/minute
23	%RHR1	Relative heart rate on 1st minute	Pulse/minute
24	SYS1	Systolic on 0 minute	mmHg
25	DIAS1	Diastolic on 0 minute	mmHg
26	BP1	Blood pressure on 1st minute	mmHg
27	RSYS1	Relative systolic on 1st minute	mmHg
28	RDIAS1	Relative diastolic on 1st minute	mmHg

29	RBP1	Relative blood pressure on 1st minute	mmHg
30	HR2	Heart rate on 2nd minute	Pulse/minute
31	%RHR2	Relative heart rate on 2nd minute	Pulse/minute
32	SYS2	Systolic on 2nd minute	mmHg
33	DIAS2	Diastolic on 2nd minute	mmHg
34	BP2	Blood pressure on 2nd minute	mmHg
35	RSYS2	Relative systolic on 2nd minute	mmHg
36	RDIAS2	Relative diastolic on 2nd minute	mmHg
37	RBP2	Relative blood pressure on 2nd minute	mmHg
38	HR3	Heart rate on 3rd minute	Pulse/minute
39	%RHR3	Relative heart rate on 3rd minute	Pulse/minute
40	SYS3	Systolic on 3rd minute	mmHg
41	DIAS3	Diastolic on 3rd minute	mmHg
42	BP3	Blood pressure on 3rd minute	mmHg
43	RSYS3	Relative systolic on 3rd minute	mmHg
44	RDIAS3	Relative diastolic on 3rd minute	mmHg
45	RBP3	Relative blood pressure on 3rd minute	mmHg
46	time	Time to fatigue	sec
45	M	Male	
46	F	Female	

ABSTRAK

Objektif yang dipelajari daripada projek ini adalah untuk mencari hubungkait atau perkaitan tentang kerja statik terhadap keletihan otot dan masa untuk mengembalikan atau memulihkan keadaan letih. Seramai 19 orang operator digunakan dalam ekperimen ini yang terdiri daripada 9 orang lelaki dan 10 orang perempuan (umur: 22 – 25 tahun, tinggi: 1.48 – 1.79 m, berat: 36 – 75 kg) untuk diuji kepada kerja statik dengan memegang beban yamg berbeza pada keadaan yang berbeza iaitu pada paras pergelangan tangan, paras siku dan paras bahu. Kerja statik adalah sangat cepat untuk merasa penat pada bahagian otot-otot berbanding denagn kerja bergerak. Keputusan daripada data-data ekperimen ini menunjukkan: (1) hubungkait di antara beban atau pemberat yang berbeza, masa untuk merasa penat, perbandingan denyutan jantung, perbandingan tekanan darah iaitu systolic dan diastolic. (2) Nilai persamaan di antara pembolehubah-pembolehubah itu sama ada mempunyai perkaitan atau tidak. (3) bentuk-bentuk graf yang diperolehi daripada perkaitan pembolehubah-pembolehubah sama ada graf berkadaran terus ataupun berkadaran songsang. Ini menunjukkan apabila beban atau pemberat yang digunakan itu meningkat, nilai perbandingan denyutan jantung juga akan meningkat. Tetapi, apabila beban kerja meningkat, masa untuk merasa penat adalah lebih cepat dan masa menurun dengan pertambahan berat pada beban.

ABSTRACT

The aim of this study was to find the relationship of the static work toward muscle fatigue and fatigue recovery time. The healthy subjects of nine male and ten female subjects (age: 22-25 years, height: 1.48-1.79 m, weight: 36-75 kg) are exercised on a static work task which is hanging the different of work loads with to their wrist condition level, elbow condition level, and shoulder condition level.. The result of the study show that, (1) the relationship between the load, time to fatigue, relative heart rate, relative systolic, and relative diastolic, (2) the significant correlation value between each item (load, time to fatigue, RHR, RSYS, and RDIAS), (3) the trend of the graph between the relationship variables. The relationships for these items are linear relation (direct or inverse relation). That means, when the load is increase, the relative heart rate is increase too. For the time to fatigue, it is show the strongly relationship and the relationship is inverse relation with the load that means when the load increasing, hence the time to become fatigue is rapidly decrease.

CHAPTER 1.0: INTRODUCTION

1.1 Background

This experiment is purpose the study or the relationship of the static work toward muscle fatigue and fatigue recovery time. Static and intermittent static muscular work is a known risk factor for musculoskeletal disorders (MSD). Estimation of MET to accommodate a percentage of the worker population is a necessary step in determining appropriate work-rest regimens for static muscular work in industrial settings.

In industrialized countries around 20% of workers are still employed in jobs requiring muscular effort. The number of conventional heavy physical jobs has decreased, but, on the other hand, many jobs have become more static, asymmetrical and stationary. In developing countries, muscular work of all forms is still very common.

In contrast to fatigue involving the whole body, the concept of muscle fatigue has been used to indicate the effects of work (exercise) on a specific group of muscles. Fatigue is a common phenomenon that people experience in their daily activities, and it can be generally indicated by a reduced ability to perform muscular work. Fatigue is also often accompanied by substantial increases in physiological measures, such as heart rate, minute ventilation, body temperature, or oxygen uptake.

The fatigue recovery time is a measurement related to static muscular work. It represents the maximum time during which a static muscle load can be maintained (usually associated with a job task). The fatigue recovery time is especially used to determine an acceptable duration for maintaining a static muscular contraction is also used in rest allocation models to calculate recovery time following static muscular work.

1.2 Problem Statement

The study of the static work toward muscle fatigue and fatigue recovery rate is newly information for our ergonomic field today. It is because, there are only a few researchers doing their research about the static work. The static muscular work is unknown and lacked of information in the industry ergonomic. So that, the published journal is also difficult to search and there a not many reference of handbook to find the general information about the static muscular work and localized muscle fatigue.

1.3 Objective

The objectives of this project are to:

1. To study the relationship of the static work towards muscle fatigue and fatigue recovery time to duration of performing task and work load value.
2. To find the relationship variables and the level of the relationship from the significant correlation value.
3. To estimate localized muscle fatigue (LMF) associated with the job task. Based on task analysis the factors that are studied included static work condition level (wrist, elbow, and shoulder) and work load (a different work load hanging during the static work task).
4. To gather information about static work toward muscle fatigue, an affect the rate of fatigue and the time to muscle to recover. It is also to define the physiological and biochemical events that cause muscle fatigue.

1.4 Scope of the Project

1. This study of the static work provides a gather information about the definition of the static work, muscle fatigue and recovery rate. Besides, this project is give more knowledge about the relationship between different of work load, different gender, time to become fatigue and fatigue recovery time during the static muscular work.
2. The data collected is based on the value of the heart rate, the blood pressure (systolic and diastolic), the different of work load (0.5 kg to 3.0 kg) and the time to become fatigue. All the data is taken until 3rd minute of the recovery time, that's mean, the value of heart rate and blood pressure is taken each one minute after become fatigue.
3. The experimental of the static work toward muscle fatigue and fatigue recovery time was investigated of 9 males and 10 females where they are needed to hold the load in static work condition (wrist, elbow and shoulder).
4. The data and analysis section, the relationship of the variables is shown and presented by the correlation tables, graphs and histogram between each other.
5. The several recommendations for this project also are provided to improve the ergonomic field and relevance this study to the industry.

CHAPTER 2.0: LITERATURE REVIEW

2.1 DEFINITION

<u>STATIC WORK</u>

"Static work" refers to the musculoskeletal effort required to hold a certain position, even a comfortable one. For example, when we sit and work at computers, keeping our head and torso upright requires either small or great amounts of static work depending upon the efficiency of the body positions we choose.

Static work produces fatigue quickly. Blood brings oxygen to the muscle groups to allow them to function properly. During periods of rest, the demand for oxygen is low. However, in static work such as holding the arm in an elevated position while do the work, oxygen demand is increased due to the static load placed on the shoulder muscles but blood flow is not increased and there may be constriction of vessels at pressure points. Such static work procedures fatigue, causing tension, soreness and pain.

Avoid arm, wrist and hand positions that can reduce strength. Correct posture allows the muscle groups to function freely without restriction (neutral positions). Deviation from these neutral positions places stress on the muscle groups, reducing available strength. This mean more exertion will be required to complete the same task than if the arm, wrist and hand were in a more correct posture.

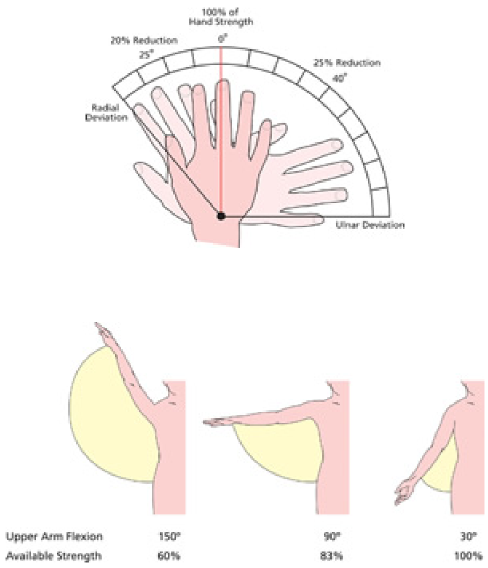

Figure 1: The correct posture of the arm, wrist, elbow and shoulder

MUSCLE FATIGUE

Power is concerned with the intensity of exercise that can be sustained while work is concerned with the amount of exercise is determined by physiological factors such as maximum rate of O_2 uptake, maximum heart rate and stroke volume, maximum muscle strength and others. In the case of maximum work, a tie factor is involved. Muscle fatigue is the transient decrease in performance capacity of muscles, usually evidenced by a failure to maintain or develop a certain expected force or power.

Fatigue is the reduction in performance ability caused by a period of excessive activity followed by inadequate recovery time. Muscle fatigue is accompanied by a buildup of lactic acid in the working muscle. Fatigue curves vary between individuals and within individuals depending upon the conditions that exist. Muscle fatigue can occur in two basic mechanisms a) central involves proximal motor neurons (mainly in the brain); and b) peripheral involves within the motor units (i.e., motor neurons, peripheral nerves, motor endplates, muscle fibers). In peripheral muscle fatigue there are at least two different sites where repeated contractions may cause impairment: the “transmission mechanism” (neuromuscular junction, muscle membrane, and endoplasmic reticulum), and the “contractile mechanism” (muscle filaments).

RECOVERY TIME

Recovery time is defined as a work periods when task demands are light or when rest breaks are scheduled, permitting a person to recover from heavy effort work such as prolonged fixed postures. Recovery time is time quantification of rest, performance of low stress activity, or performance of an activity that allows a strained body area to rest. Short work pauses have reduced perceived discomfort (Hagberg and Sundelin, 1986) and rest periods between exertions have reduced performance decrement (Caldwell, 1970). The recovery time needed to reduce the risk of injury increases as the duration of risk factor increases. Specific minimum recovery times for risk factors have not been established.

- This refers to the number of cycles per day or week (Konz, 1990). It is thought to be beneficial for keyboard operators to take rest pauses every hour (Kroemer, 1993).

- It has been suggested that CTDs occur in tasks with cycle times of 30 seconds or less (Pulat, 1992).
- Measuring the total recovery pulse is a good measure of workload. For an 8-hour workday, the first reading should not exceed 110 (pulses per min.) with a fall of at least 10 pulses between the first and third readings (Kroemer & Grandjean, 1997).

2.2 THE PHYSIOLOGYC OF STATIC WORK

The cardiopulmonary responses associated with static work reflect the human reaction to isometric muscle contraction as described by Petrofsky and Phillips [3]. When isometric contractions are sustained at muscle forces that are non-fatiguing (forces that are below 10% to 15% of the muscle's maximum strength), heart rate and blood pressure rise to a certain level and are then maintained throughout the duration of the static work. This represents a steady-state response in which the blood pressure will rise 10–20 mmHg, and the heart rate will rise 10–20 beats per minute. However, there is a dramatic rise in blood pressure (both the systolic pressure and the diastolic pressure) during the time course of the fatiguing isometric muscle contractions.

Cardiac output increases modestly during fatiguing static work. A resting cardiac output of 5 l=min will usually only become boosted to about 8 l=min over the duration of fatiguing static work. During static work the heart rate rarely exceeds 120 beats=min. Oxygen consumption (VO2) during fatiguing static work also intensives modestly. However, ventilation (VAIR) can increase markedly. Some individuals will actually experience a distinct hyperventilation. Although heart rate and blood pressure continuously rise throughout the time course of fatiguing static work, there is little change in ˙ VAIR or ˙ VO2 until approximately halfway into the duration of fatiguing static work. After that, these parameters increase and may become enhanced markedly.

STATIC WORK AND LOCAL MUSCLE FATIGUE

While body fatigue is often associated with prolonged dynamic whole body activities that exceed an individual‘s MPWC, local muscle fatigue is often observed in jobs requiring static muscle contractions. Dynamic muscle activities provide a "muscle jump" that massages the blood vessels and assists blood flow through the muscle's rhythmic actions. Static muscle contractions, in contrast, impede or even occlude blood flow to the working muscles because the sustained physical pressure on the blood vessels prevents them from dilating as long as the contraction continues. The lack of adequate oxygen supply forces anaerobic metabolism, which can produce local muscle fatigue quickly due to the rapid accumulation of waste products and depletion of nutrients near the working muscles.

The maximum length of time a static muscle contraction can be sustained (muscle endurance time) is a function of the exerted force expressed as a percentage of the muscle's maximum voluntary contraction (MVC), whish is the maximal force that the muscle can develop.

STATIC MUSCLE WORK

In static work, muscle contraction does not produce visible movement, as, for example, in a limb. Static work increases the pressure inside the muscle, which together with the mechanical compression occludes blood circulation partially or totally. The delivery of nutrients and oxygen to the muscle and the removal of metabolic end-products from the muscle are hampered. Thus, in static work, muscles become fatigue more easily than in dynamic work.

The most prominent circulatory feature of static work is a rise in blood pressure. Heart rate and cardiac output do not change much. Above a certain intensity of effort, blood pressure increases in direct relation to the intensity and the duration of the effort. Furthermore, at the same relative intensity of effort, static work with large muscle groups produces a greater blood pressure response than does work with smaller muscles. In principle, the regulation of ventilation and circulation in static work is similar to that in dynamic work, but the metabolic signals from the muscles are stronger, and induce a different response pattern.

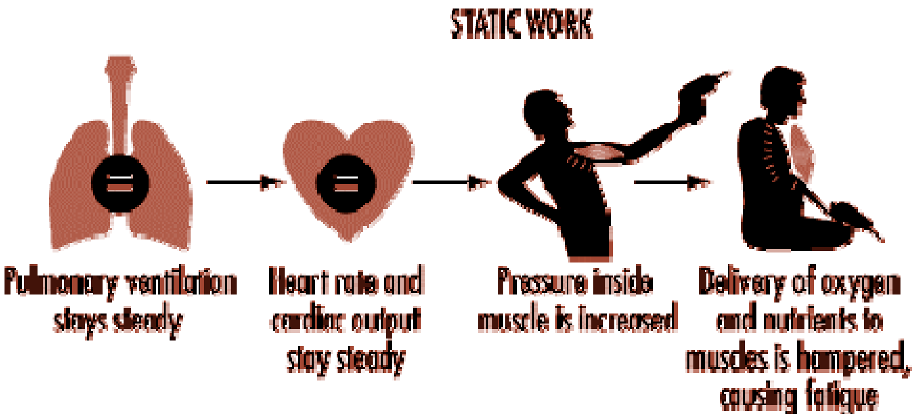

Figure 2: Static muscular work

ACCEPTABLE WORKLOAD FOR STATIC MUSCULAR WORK

Static muscular work is required chiefly in maintaining working postures. The endurance time of static contraction is exponentially dependent on the relative force of contraction. This means, for example, that when the static contraction requires 20% of the maximum force, the endurance time is 5 to 7 minutes, and when the relative force is 50%, the endurance time is about 1 minute.

Older studies indicated that no fatigue will be developed when the relative force is below 15% of the maximum force. However, more recent studies have indicated that the acceptable relative force is specific to the muscle or muscle group, and is 2 to 5% of the maximum static strength. These force limits are, however, difficult to use in practical work situations because they require electromyography recordings.

For the practitioner, fewer field methods are available for the quantification of strain in static work. Some observational methods (e.g., the OWAS method) exist to analyze the proportion of poor working postures, that is, postures deviating from normal middle positions of the main joints. Blood pressure measurements and ratings of perceived exertion may be useful, whereas heart rate is not so applicable.

2.3 METHODS TO MEASURE FATIGUE

2.3.1 Fatigue Measurement

Fatigue has been measured in three ways: subjectively through the use of rating scales, with changes in task performance, and objectively through physiological changes in the muscle. Due to the complexity of their fatigue process, it is difficult to define fatigue using only one measurement. Therefore, the fatigue measurement would be classified into three different categories.

1. Subjective fatigue: feeling of discomfort and pain
2. Objective Fatigue: changes in work output
3. Physiological Fatigue: physiological changes in the muscle activation process (the ability to generate a maximum force).

2.3.1.1 Subjective fatigue: Ratings of Perceived Discomfort

Psychophysical methods of quantifying task demands are common in the field of ergonomics. These are typically difficulties in directly assessing the levels of exertions for manual work tasks due to the complexity of movements and lack of exposure guidelines. Objective measures of fatigue are often more difficult to collect and interpret while providing little difference in the quality of the data.

In addition to being easy to collect and interpret, changes in discomfort may be the first indicators of fatigue and occur prior to physiological changes (Valencia, 1986). Borg (1970) also noted that subjective ratings were important because perception of discomfort may result in performance changes regardless of whether the discomfort has manifested in physiological changes within body. Subjective fatigue measures may even be the preferred method of gauging a global shoulder fatigue due to the complex structure of the shoulder girdle. Borg (1982) developed a 10-point rating scale with ratio properties, which is commonly used in a variety of situations to facilitate quantifying subjective perceptions of discomfort. The scale has numerical rating s well as verbal anchors. Advantages of the scale include the ease of use, effectiveness in evaluating intermittent tasks (Borg, 1970), repeated reliability, and correspondence with effort level.

The disadvantages associated with this scale are inherent to most subjective measurement devices. Participants are often not able to differentiate between the variable being measured and the entire work task.

2.3.1.2 Objective fatigue: Performance

The use of measures of performance to quantify fatigue is not as common in the literature as the other two fatigue measurement methods. A loss of precise and coordinated movements can often result in a negative impact on the output quality. Typical performance decreases that have been associated with localized muscle fatigue are an increase in the amount of time it takes a person to perform a variety of tasks and an increased likelihood of overestimating light loads (Chaffin, 1973). Chaffin (1973) also suggested that a clear relationship between localized muscle fatigue and an effect on performing manual tasks is not well defined.

One disadvantage associated with this data collection method is that changes in accuracy may represent psychological fatigue changes derived from boredom (De Luca, 1984). Lack of interest in the task may show similar performance changes that could also be attributed to a deterioration of the muscle condition. A second disadvantage is performance-based measurements of fatigue may be difficult to collect and interpret for certain tasks. Data collection methods may require expensive and inhibiting motion analysis systems.

2.3.1.3 Physiological fatigue: Maximum Voluntary Exertion (MVE)

The MVE can be defined as the maximum force generated while an individual is encouraged to perform at a maximal level. Measuring MVE is a direct measurement of localized muscle fatigue and is generally accepted as a standard (even ‘gold’ standard) method of measuring fatigue (Vollestad, 1997). With the onset of localized muscle fatigue, the muscle is not capable of generating as much force, thus maximum exertion capabilities are reduced. This fact is particularly important for work designers to keep in mind while designing tasks that work at a certain percentage of the MVE. A task that is designed to work in the 20% MVE range during hour two of the workday will require a greater percentage of MVE to perform the same task in hour seven of the workday due to the onset of fatigue and reduced strength capabilities.

Maximum force generating abilities can very greatly depending on individual factors, such as motivation (Vollestad, 1997). To control for this, participants should be encouraged to perform at their highest level and encouragement should remain constant through out the entire testing condition.

2.4 METHODOLOGY REVIEW

K. EI ahrache, Imbeau D. and Farbos B. (2005) were proposed that the maximum endurance time (MET) is a measurement related to static muscular work. It represents the maximum time during which a static muscle load can be maintained (usually associated with a job task). The MET is especially used to determine an acceptable duration for maintaining a static muscular contraction. The MET is also used in rest allocation models to calculate recovery time following static muscular work. They also proposed that, for eight levels of relative exertion (10%MVC, 20%MVC, 30%MVC, 40%MVC, 50%MVC, 60%MVC, 70%MVC, 80%MVC), the analyses of variance were done to compare three categories of MET models amongst themselves: (1) those related to the upper limbs, (2) those related to the back/hip, and (3) general application models.

Chaffin (1973) first used the term localized muscle fatigue to describe a type of fatigue associated with such external manifestations such as the inability to maintain a desired force output, muscular tremor, and localized pain. The effects of this fatigue are localized to the muscle group of synergistic muscles performing the contraction (DeLuca, 1994). Chaffin,D.B. (1973) assert that increased muscle tremor after sustained exertion of muscles used to support the forearm and hand in static posture, result in a great increase in the time it takes a person to perform 2 different types of task requiring precision positioning of the hands. He describes neuromuscular theory for fatigue mechanism: a sustained contraction of a muscle can result in the fibers losing their tension producing capacity additional motor units are then needed to maintain the total tension state of the muscle. The increased number of active motor units is accomplished by increased tension in the spindle sensory systems, thus facilitating central nervous system commands to the motor units that produce movement and tension.

The mechanization of industrial work processes has resulted in simplified work movements: however, the use of the arms and the number of movements required per unit time has increased (Jonsson, 1982; Hagberg, 1981). Work tasks demand less energy, but the velocity and monotony involved represent a local stress on skeletal muscles, primarily in the back, neck, shoulders, and upper arms. They include awkward posture (shoulder abduction, neck flexion, arm extension), static postures (sustained positions for prolonged periods of time), and lack of sufficient rest.

Herberts et al. (1984) found that the infraspinatus muscle in particular was very sensitive to small increases in hand held weight when the arm was in elevated position. In addition, the deviation of the upper arm from the vertical position increases the load on the upper trapezius and rotator cuff muscle. Hagberg (1984) proposed that working with elevated arms may accelerate the degree or rotator cuff tendon generation through impairment of circulation due to static tension in tendons and humeral compression against the coracoaromial arch.

Rohmert (1973) quantitatively described the onset of muscle fatigue for static postures and constant loads. Rohmert's curve shows that exertion with a low level exertion (15-18% of the maximum voluntary exertion, MVE) could be held for an indefinite amount of time. Chaffin (1973) showed that sustaining low-level exertions (15% of MVE) either with prolonged exertions, or with frequent contracts followed with very little rest, does result in a decrease of the force producing capabilities of that muscle group.

CHAPTER 3.0: METHODOLOGY

3.1 Methods

3.1.1 Subjects

Nineteen healthy subjects (9 male, 10 female; age range 22-25) are recruited into this study from students in this campus. The selection criteria for the subjects are to be healthy without a history neck pain, headache, injury or operation in the cervical spine. All subjects are given full information (precaution step) and gave full informed consent prior to participation in the study of this experiment. Before doing this experiment, all of the subjects must be in the rest condition and not nervous. The base heart rate and blood pressure of the subjects is been taken before doing this experiment. Their mean age, height, weight, body mass index (BMI), base heart rate and blood pressure are shown in Table 1.

Table 1: Means and the range for the age, weight, height, BMI, base heart rate, and base blood pressure of the subjects.

	Women		Men	
	Mean	Range	Mean	Range
Age (year)	136.8	22-25	139.3	22-25
Weight (kg)	297.6	36 - 65	376	50 -75
Height (cm)	940.2	148 - 170	1012.7	165 – 179
BMI	121.2	16.44 - 26.71	132.3	17.51 - 26.08
Base heart rate (pulse/min)	417.0	53 - 74	375.3	50 – 71
Base blood pressure (mmHg)	209.4	30 - 44	233.3	32 – 46

3.1.2 Apparatus

The digital blood pressure monitor was used to count the heart rate and blood pressure together. The normal rate of the base heart rate blood for the healthy person was 58 to 68 pulses per minutes. However, the normal rate of base blood pressure was 120/80 mmHg. The blood pressure reading was recorded as systolic/diastolic in mmHg. The measurement of the blood pressure must be repeated to get the accurate value. It is because, when we take the reading of the systolic and diastolic blood pressure, its value was decrease rapidly. For avoided these error when taking the reading of the blood pressure, we should be take two or three time to get an average value. Besides, the plastic bag and the soft span were used to fill the load when the subjects hanging the load during this experiment.

3.1.2.1 List of Apparatus

i. Digital Blood pressure monitor
ii. Stop watch
iii. Plastic bag
iv. Span
v. Load of (0.5, 1.0, 1.5, 2.0, 2.5, and 3.0) kg

3.1.2.2 SPSS and Table Curve 2D v5.0 Trial Software

The SPSS and Table Curve 2D v5.0 Trial Software is used in this project to make the comprehensive analytical and statically. SPSS software is used to find the significant correlation between all the variables before making a graph for analysis. The data for Excel file is transfer to the SPSS data variable and then the data could be analyzed to get the table of the correlation. From the correlation table, we can see the correlation between the variables either it is significant or not.

After the correlation tables already have, we can make the graph correlation from the Table Curve 2D v5.0 Trial Software. From the correlation table, we only have to choose what kind of graph that we are wanted to analyze.

3.1.3 Experimental Procedure

1. At the arrival to the laboratory, the weight and the height of the subjects are determined. Thereafter, subjects will sit on the chair in the rest conditions. Make sure that the subjects are in the comfortable situation and not in nervous.
2. A few minute later, take the base heart rate and base blood pressure for each subject. The digital blood pressure monitor is used to count the heart rate and blood pressure together. The value of base heart rate, systolic and diastolic of the blood pressure value is recorded in the form given.

Figure 3: The digital blood pressure monitor.

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3. After that, the subjects must hang the static load in the static work condition with hanging the plastic bag that is filled with the different of load. The first condition of the static work task is the subjects should hang the load by his/her wrist level. Their wrist must be supported by table while the subjects hanging the load.

Figure 4: The static load is hanging with wrist level condition.

4. The subjects must hang the load until their fatigue. The time to fatigue should be taken during the subjects hanging the load by using the stop watch. After the subject feel fatigue, the heart rate and the blood pressure (systolic/diastolic) of that subject were measured immediately after they completed the task.

Figure 5: The stops watch that are used to take the time to fatigue

5. The heart rate and the blood pressure (systolic/diastolic) were taken again to show the relationship between the heart rate, blood pressure and fatigue recovery time during static work task. Then, the same procedure was repeated for the different loads for the wrist level condition.
6. Then, the subjects should be in the rest condition and had a stable heart rate and blood pressure before repeated the experiment for others condition level. The second condition is the elbow condition level. The subjects should be hanging the load with elbow level. The same procedure with wrist level is repeated during elbow level.

Figure 6: The static load is hanging with elbow level condition.

7. After the elbow level, the subjects also should be in the rest condition before proceeding to the third condition. The third condition is the subjects should be hanging the load with shoulder level in the dominant arm in 90 degree shoulder flexion. The same procedure with wrist level and elbow level are repeated for shoulder condition level.

Figure 7: The static load is hanging with shoulder level condition.

8. Repeated the procedures to the different subjects and jot down the data that have been taken. All the data must be writing down in the table to record for result and analysis.

3.1.4 Precaution Step

1. Make sure that all the subjects in the rest condition and not in nervous before doing the experiment and before take the base heart rate and base blood pressure.
2. All the subjects must take a rest or time for relaxed and had a stable heart rate and blood pressure before proceed the next condition level.
3. Used the soft span during hanging the load with plastic bag.
4. The blood pressure reading must be repeated two or three times to get the best value of systolic and diastolic pressure.

CHAPTER 4.0: DATA AND ANALYSIS

Due to the methodology as presented from the Chapter 3, the data were collected during the static work experiment, statistically analyzed, and the results are shown in this chapter. From the data collected, it is presented to a graph view to show the relationship between the variables.

The experiment task is hanging the load with the wrist, elbow and shoulder level condition with different of load. The experiment is started with hanging the load of 0.5 kg until 3.0 kg in static work and static load task. The experiment also should be show the fatigue recovery time. That means, the heart rate and blood pressure have been taken every 1 minute after hanging the load with the different load. The subject should be in the rest condition before doing the experiment and had a stable heart rate and blood pressure.

The analysis is done to find the relationship and the correlation between of the several of variables which is a load; relative heart rate (RHR), relative systolic (RSYS), relative diastolic (RDIAS) and the time to fatigue that has been calculated from the data collected in this experiment. The correlation between the variables that are should be to research is found from the SPSS software. Then, from the correlation table given from the SPSS, the graph is done by using the Table Curve 2D v5.0 Trial Software.

The hypothesis of this experiment can be done from this data and analysis table are following below:

1. When the load is increase, the time of the fatigue is decrease. The relationship shows the inverse relation between each item.
2. When the relative heart rate (RHR) is increase, the value of relative systolic (RSYS) and relative diastolic (RDIAS) are increase too.
3. When the load is increase, the time to become fatigue is shorter. So that, the value of the relative heart rate, relative systolic and relative diastolic are also increase.
4. When the value of relative heart rate, relative systolic and relative diastolic is increase, the value of time to fatigue is decrease. It is because the highest of load hanging, the shortest of time to fatigue. So that, when the subject hanging the highest of load, they become fatigue quickly and the item of RHR, RSYS and RDIAS are increase rapidly.

4.1 Data Analysis for Wrist Condition

Table 2**:** The correlation variables between load, relative heart rate (RHR), relative systolic (RSYS), relative diastolic (RDIAS), and time to fatigue for wrist condition on 0 minute time of recovery time.

		LOAD	RHR	RSYS	RDIAS	TIME
LOAD	Pearson Correlation	1	.252(**)	-.090	-.065	-.801(**)
	Sig. (2-tailed)		.007	.342	.495	.000
	N	114	114	114	114	114
RHR	Pearson Correlation	.252(**)	1	-.141	-.141	-.305(**)
	Sig. (2-tailed)	.007		.135	.136	.001
	N	114	114	114	114	114
RSYS	Pearson Correlation	-.090	-.141	1	.600(**)	.173
	Sig. (2-tailed)	.342	.135		.000	.065
	N	114	114	114	114	114
RDIAS	Pearson Correlation	-.065	-.141	.600(**)	1	.143
	Sig. (2-tailed)	.495	.136	.000		.130
	N	114	114	114	114	114
TIME	Pearson Correlation	-.801(**)	-.305(**)	.173	.143	1
	Sig. (2-tailed)	.000	.001	.065	.130	
	N	114	114	114	114	114

** Correlation is significant at the 0.01 level (2-tailed).

Description:

Table 2 is showed the correlation between of each variable is significant or not. The significant at the 0.01 level is the best point and very closes correlation between each item given in the table. We can see that the correlation between the load, RHR, RSYS, RDIAS and time to fatigue. The time to fatigue has a very strong relation with load and has a significant correlation -0.801 values. Besides, the relative systolic has a strong relation with the relative systolic, which has significant correlation 0.600 values. The relative heart rate has a low relation with the load and time to fatigue. The detail explanation is shown in the graph below.

Description

Due to the Figure 8, the time to fatigue versus load for wrist condition on 0 minute, 1st minute, 2nd minute, and 3rd minute of recovery time, we can see that the relationship is very strong relation but in inverse relation. From the Table 2, we can see that the time has significant correlation about -0.801 with the load . The simplistic linear equation is y = -333.33x + 1050 between the points 0 and 3 at the x-axes. So that, we can concluded that when the load is increase, the time to fatigue is decrease.

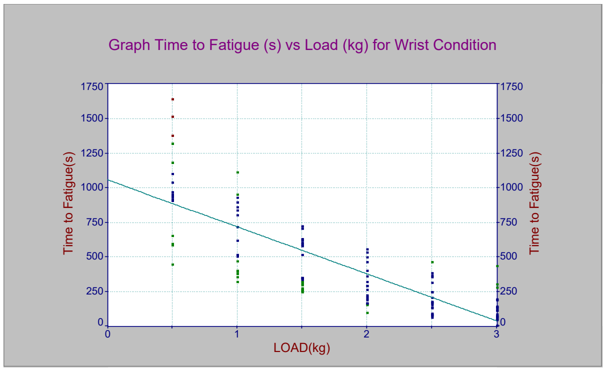

Figure 8: Graph Time to Fatigue (s) vs Load (kg) for Wrist Condition Level on recovery time.

Description:

The Figure 9 is relative heart rate (RHR) versus load (kg) for wrist condition at 0 minute of recovery time shows that the direct relation to each item. When the load is increase, the value of relative heart rate is increase too. In static work, heart rate and cardiac output do not change much, as we can see from the graph. . From the table correlation above, the relative heart rate have the significant correlation 0.252 values with load. The significant correlation values show that the relative heart rate has a low relation with the load. The simplisctic linear equation is y = 2x + 2 between the points at 0 and 3 of the x-axes.

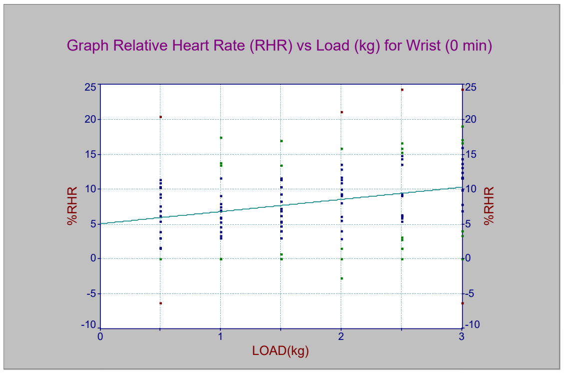

Figure 9: Graph Relative Heart Rate (RHR) vs Load (kg) for Wrist on 0 minute.

Description:

Due to the Figure 10 below, we can see the relationship between the time to fatigue with the relative heart rate for wrist condition at 0 minute . The graph shows the inverse relation because when the value of relative heart rate is increase, the time to fatigue is decrease. The relative heart rate has a significant correlation -0.305 with the time to fatigue and has a low relation . The simplistic equation is equal to $y = -26x + 800$.

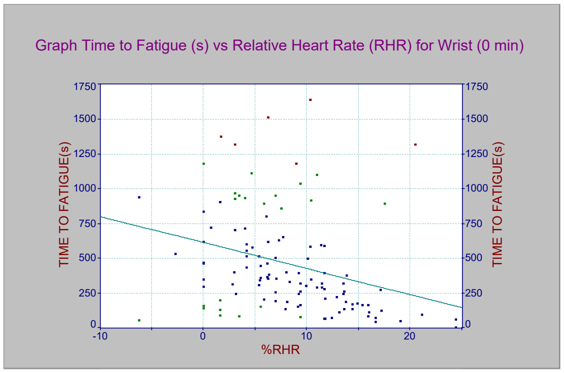

Figure 10: Graph Time to Fatigue (s) vs Relative Heart Rate (RHR) for Wrist on 0 minute.

Description:

From the Figure 11, relative diastolic (RDIAS) versus relative systolic (RSYS) for the wrist condition at 0 minute, is showed direct relation and equal to $y = 1.14x - 11$ of the simplistic linear equation between -30mmHg until to 30mmHg of the x-axes. From the Table 2, we found that the relative diastolic has a significant correlation 0.600 value with the relative systolic and shows the strong relation to each variable. It can proof when the relative systolic is increase, the value of the relative diastolic is increase too.

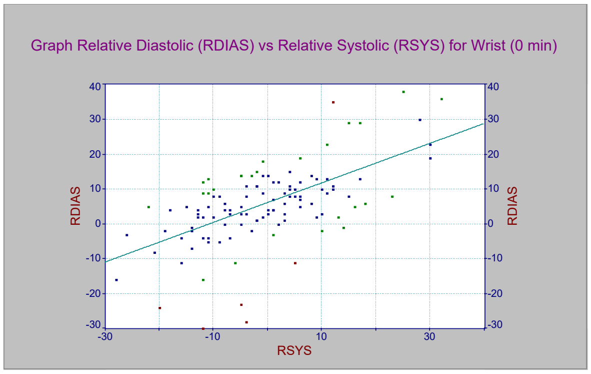

Figure 11: Graph Relative Diastolic (RDIAS) vs Relative Systolic (RSYS) for Wrist on 0 minute.

Table 3: The correlation variables between load, relative heart rate (RHR), relative systolic (RSYS), relative diastolic (RDIAS), and time to fatigue for wrist condition on 1st minute time of recovery time.

		LOAD	RHR	RSYS	RDIAS	TIME
LOAD	Pearson Correlation	1	.218(*)	-.048	-.069	-.801(**)
	Sig. (2-tailed)		.020	.609	.465	.000
	N	114	114	114	114	114
RHR	Pearson Correlation	.218(*)	1	.223(*)	.196(*)	-.260(**)
	Sig. (2-tailed)	.020		.017	.037	.005
	N	114	114	114	114	114
RSYS	Pearson Correlation	-.048	.223(*)	1	.708(**)	.010
	Sig. (2-tailed)	.609	.017		.000	.912
	N	114	114	114	114	114
RDIAS	Pearson Correlation	-.069	.196(*)	.708(**)	1	-.008
	Sig. (2-tailed)	.465	.037	.000		.931
	N	114	114	114	114	114
TIME	Pearson Correlation	-.801(**)	-.260(**)	.010	-.008	1
	Sig. (2-tailed)	.000	.005	.912	.931	
	N	114	114	114	114	114

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Description:

From the correlation Table 3, we can know the correlation of each item is significant or not. For significant at the 0.01 level (2-tailed) is the best point and very close correlation between each item. From the table, we can see that relative heart rate has a significant correlation 0.218 values with load and shows the low relation. The time to fatigue has a significant correlation -0.801 and very strong relation between each variables. The relative heart rate shows the low relation which has a significant correlation -0.260 values with the load. Besides, the relative diastolic has a significant correlation 0.708 with the relative systolic and has a strong relation between them. All the correlation is shows the direct relation except the correlation between the load with the time to fatigue and the correlation between the relative heart rate with the time to fatigue. That means when the load is increase, the value of relative heart rate is increase too.

Description:

From the Figure 12, shows that the relationship of the relative heart rate (RHR) versus load for wrist condition at first minute. We can see that the relationship is linear line from load 0.5kg to 3.0kg. The relative heart rate has a significant correlation 0.218 values with load and has a low relation. The simplistic linear equation is y = 1.33x + 8 between the point 0 and 3 at the x-axis. It can be proof when the load is increases, the relative heart rate is also increase.

Figure 12: Graph Relative Heart Rate (RHR) vs Load (kg) for Wrist on 1st minute.

Description:

Figure 13 is shows the time to fatigue versus relative heart rate for wrist condition at first minute. We can see that the time to fatigue is decrease when the relative heart rate is increase. From the correlation Table 3, the relative heart rate has a significant correlation -0.260 values with time to fatigue and has a low relation. In other word, we can say that the the time to fatigue and relative heart rate are shows inverse relation and the simplistic linear equation that equal to y = -24.8x + 800 between point -15 and 25.

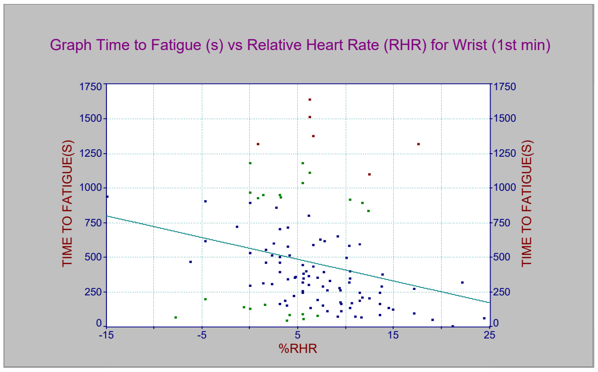

Figure 13: Graph Time to Fatigue (s) vs Relative Heart Rate (RHR) for Wrist on 1st minute.

Description:

Refer to the Figure 14 relative diastolic (RDIAS) versus relative systolic (RSYS) for the wrist condition at first minute, we know that each item is shows the direct relation and equal to simplistic linear equation, y = 0.675x + 36 between the point at -40mmHg to 40mmHg. From the Table 3, the relative diastolic has a significant correlation 0.708 value with the relative systolic and shows the strong relation between each variable. It can proof when the relative systolic is increase, the value of the relative diastolic is increase too.

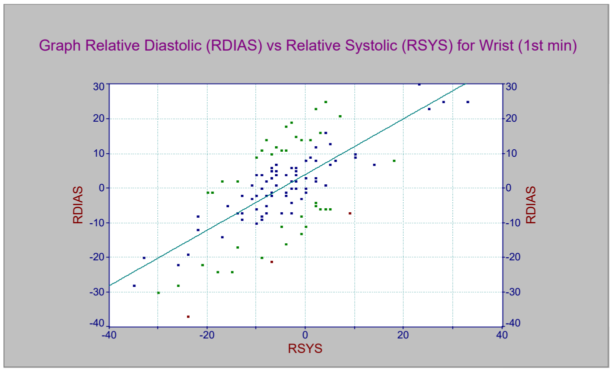

Figure 14: Graph Relative Diastolic (RDIAS) vs Relative Systolic (RSYS) for Wrist on 1st minute.

Description:

From the Figure 15 relative systolic (RSYS) versus relative heart rate (RHR) for wrist condition at first minute of fatigue recovery time, we can see the line is linearly and equal to the simplistic linear graph equation, y = 0.424x + 3. From the correlation at Table 3, the relative systolic has a significant correlation 0.223 value with the relative heart rate and it is means each item has a low relation. We can summarize that when the value of the relative heart rate is increase, the relative systolic is increase too.

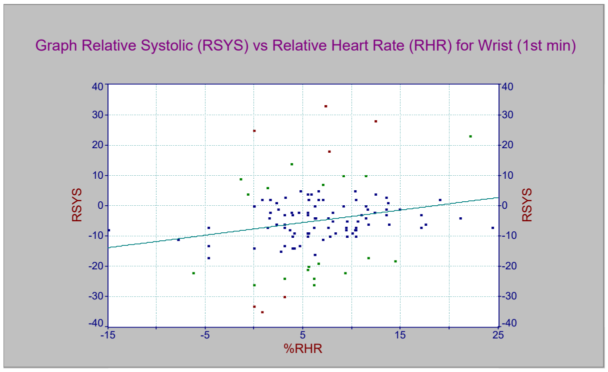

Figure15: Graph Relative Systolic (RSYS) vs Relative Heart Rate (RHR) for Wrist on 1st minute.

Table 4: The correlation variables between load, relative heart rate (RHR), relative systolic (RSYS), relative diastolic (RDIAS), and time to fatigue for wrist condition on 2nd minute time of recovery time.

		LOAD	RHR	RSYS	RDIAS	TIME
LOAD	Pearson Correlation	1	.161	.057	.002	-.801(**)
	Sig. (2-tailed)		.087	.545	.984	.000
	N	114	114	114	114	114
RHR	Pearson Correlation	.161	1	.084	.210(*)	-.203(*)
	Sig. (2-tailed)	.087		.373	.025	.030
	N	114	114	114	114	114
RSYS	Pearson Correlation	.057	.084	1	.574(**)	-.066
	Sig. (2-tailed)	.545	.373		.000	.484
	N	114	114	114	114	114
RDIAS	Pearson Correlation	.002	.210(*)	.574(**)	1	-.081
	Sig. (2-tailed)	.984	.025	.000		.391
	N	114	114	114	114	114
TIME	Pearson Correlation	-.801(**)	-.203(*)	-.066	-.081	1
	Sig. (2-tailed)	.000	.030	.484	.391	
	N	114	114	114	114	114

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Description:

From the correlation Table 4, we can see that the correlation between of each variable is significant or not. The significant at the 0.01 level (2-tailed) is the best point and very closes correlation between each item given in the table. We can see that the correlation between the load, RHR, RSYS, RDIAS and time to fatigue. The load and the time to fatigue show the very strong relation each of variables and have significant correlation 0.801 values. The relative systolic and relative diastolic is shown the some relation between them with significant correlation 0.574 values. Besides, for the relationship between relative heart rate with the relative diastolic is shown the low relation and has a significant correlation 0.210 values. The relative heart rate also shows the low relation with time to fatigue and relative diastolic. The correlation of each item is significant at the 0.05 level (2-tailed).