CHAPTER II

LITERATURE REVIEW

Literature review in this study will be explained in this chapter. The literature study consists of basic theory which support the research as well as related previous research derived from journals, academic reports, and seminar proceedings.

2.1. Empirical Review

There are number of researches and studies about applied electromyograph to identify muscle contraction as well as carpal tunnel syndrome analysis which applicated in various aspects, especially office ergonomics.

Lin et al. (2004) applied EMG to quantify finger muscle activities on prolonged and repetittive typing activities and identify the possibility of muscle fatigue occurred. Thirthy healthy female typists were enrolled in this study and asked to type consecutively for two hours and electrical activity of extensor digitorum communis (EDC) and flexor digitorum superficialis (FDS) were recorded. The sampling rate of EMG recording set in 1024 Hz with 10-500 Hz bandpass filter. There was changing Maximum Voluntary Electrical Activation (MVE) after two hours typing and did not recover within 10 minutes break. The study conclude that prolonged and repetitive typing activity may regenerate muscle fatigue.

An electromyography analysis towards computer interaction devices were done by Soewardi et al. (2015) by identifying *Flexor Pollicis Brevis* (FPB), *Flexor Digitorium Superficiallis* (FDS) and *Abductor Pollicis Brevis* (APB) muscle activities with average Root Mean Square (mRMS) as the parameter. Fifteen university students become the respondents to do the task by using mouse, keyboard, and joystick. The study shows the usage of mouse would be the safest based on the lowest EMG mRMS (FPB: 53.4 mV, FDS: 34.87 mV, APB: 60 mV) followed by keyboard use (FPB: 72 mV, FDS: 53.13 mV, APB: 130.47 mV), and joystick use (FPB: 275.4 mV, FDS: 48.93 mV, APB: 252.67 mV).

A study from Soewardi et al. (2017) developed the ergonomic range posture for Indonesian using EMG. *Cervical Erector Spinae* (CES) muscle contraction become the object of the study and involving 70 subjects as the respondents. The task given is to copy a manuscript for 30 minutes while the signal contraction were recorded. The signal data was normalized using %MVC and the result of the study is the recommended maximum range of neck posture is 30˚ below ear-eye line for flexion and 30˚ above ear-eye line for extension with %MVC value of 20% and 17.42%, respectively.

Oikawa et al. (2011) carried out the experiment to identify the muscle load with respect to wrist positioning during piano playing. Fourteen novice piano students were asked to play certain piano task while the wrist extensor and wrist flexor were recorded using electromyograph. The percentage of MVC were calculated to normalized the data and the result is neutral wrist position was highly suggested since it has the lowest muscle load (38.00±19.8 %MVC at pianissimo on wrist extensor and 12.3±10.2 %MVC at pianissimo on wrist flexor).

A research by Safee et al. (2014) used electromyography to compare the muscle contraction of rectus femoris (RF) and biceps femoris (BF) in prostration motion during *salat* and squat exercise. Eight healthy undergraduates students are participated in this study. EMG recordings were set at 10-500 Hz bandwith filter and 1500Hz sampling rate. The percentage of %MVC value were calculated and the result is the %MVC in prostation motion in *salat* (RF: 70.18%MVC and BF: 75.43 %MVC) are slight different with the %MVC in squat exercise (RF: 78.81%MVC and BF: 86.86 %MVC). This study conclude that *salat* position could be one of the exercise to maintain lower limb.

Wilson et al. (2014) evaluated the effects of wrist posture and fingertip force in median nerve towards the blood flow velocity with using ultrasonography. Nine participants with CTS symptoms and nine healthy participants as the control group participated in this study. The result of the study shows there is a significance value between the experiments, with the lowest blood flow velocity in neutral wrist position (2.87 cm/s) followed by flexed 15˚ (3.27 cm/s), extended 30˚ (3.29 cm/s), and flexed 30˚ (3.37 cm/s). The study conclude that the vascular changes in wrist might be influenced by the non neutral wrist posture.

A carpal tunnel pressure analysis were done by Keir et al. (2007) to develop the wrist posture threholds in general movement. Thirty seven participants enrolled this study and asked to slowly moved the hands in flexion, extension, ulnar and radial motion while the carpal tunnel pressure were recorded using a saline-filled catheter and connected to a pressure transducer. The threshold based on the experiment result were 32,7˚ wrist extension, 48,6 ˚ wrist flexion, 21,8 ˚ radial deviation, and 14,5˚ ulnar deviation of 30 mmHg Carpal Tunnel Pressure applied.

Based on previous studies above, it is possible to undertake an upcoming research to determine the maximum range of wrist posture of flexion, extension, ulnar, and radial in typing activity for Indonesian by identifying muscle contraction using Electromyograph.

2.2. Theoretical Study

2.2.1. Ergonomics

Ergonomics terms is derived from the Greek phrase which consists of two words, namely Ergon, which means work and Nomos, which means law. There are several definitions about ergonomics. Tayyari and Smith (1997) define ergonomics as a branch of science that studies about getting the optimal relationship between workers with their work environment with attention to the capabilities and limitations of humans themselves. Brooks (1998) state that ergonomics is a system which includes the worker, work environment (physical and organizational), the task and the workspace which interacts well. However, the main idea of ergonomics is to achieve safety, productivity, and operator satisfaction (Helander, 2005). There are numerous interdisciplinary in ergonomics, which categorized in three main fields of research (Salvendy, 2012).

1. Physical Ergonomics

   Physical ergonomics refers to any human interactions in terms of human anatomy, anthropometry, physiology and biomechanics itself. Topics related to physical ergonomics including posture, material handling, musculoskeletal disorders, movement, repetitive, work space and health.

2. Cognitive Ergonomics

   Cognitive ergonomics refers to anything that affects human mental processes when interacting with all elements of a system such as perception, memory, reasoning, and motor responsiveness. Topics related to cognitive ergonomics include mental workload, decision making, human computer interaction, and relating to human-system design.

3. Organizational Ergonomics

   Organizational ergonomics refers to sociotechnical optimization including organizational structure, policies and processes. Topics related to organizational ergonomics are participatory ergonomics, quality management, working time design and human resource management.

In order to solve the problems related to ergonomics, it is important to identify the problem, analyze, and suggest improvement, most of the improvements were in form of designing (Helander, 2005). Some practical ergonomics research methods were found by previous research and could be utilized for the upcoming research.

Table 2. 1. Ergonomics Research Methods

Physical Methods	**Psychophysiological Methods**
PLIBEL	Electrodermal measurement
Dutch musculoskeletal questionnaire (DMQ)	Electromyography (EMG)
Quick exposure checklist (QEC)	Heart Rate Variability
Rapid upper limb assessment (RULA)	magnetic resonance imaging (fMRI)
Rapid entire body assessment (REBA)	Blood Pressure
Occupational repetitive-action (OCRA)	Respiratory Measurement
Etc.	Etc.

Behavioral and Cognitive Methods	Team Methods
Observation	Team Training
Heuristics	Event-based approach to training (EBAT)
Hierarchical task analysis (HTA)	Behavioral observation scales (BOS)
Etc.	Etc.
Environmental Methods	**Macroergonomic Methods**
Thermal Measurement	Macroergonomic organizational questionnaire survey (MOQS)
Noise Measurement	Participatory ergonomics (PE)
Vibration Exposure Measurement	Kansei Engineering
Etc.	Etc.

2.2.2. Office Ergonomics

Office ergonomics is part of physical ergonomics. It is specifically the ergonomics of computer workstations which already been discussed for past decades, as the information technology device uses was increasing (Helander, 2005). It was presented in number of forms, whether in journals, scientific articles, guidelines, and website lately (Cook & Burgess-Limerick, 2003). There are several aspects need to be considered in office ergonomics, such as sitting or standing posture, viewing angle and distance, body support, workstation design, and resting time. Office ergonomics evaluation and analysis aims to minimize the risk of visual fatigue, bad working posture, work pressure, poor job satisfaction, and musculoskeletal disorders.

The upright sitting posture was recommended by several studies (Kroemer & Grandjean, 1997; Kroemer et al., 2001) to lowering lumbar disc pressure and maintain the natural shape of the spine. This posture guidelines recommends the computer user to keep the hips, knees, and elbow at approximately 90˚- 120˚ flexion with floating posture as shown in figure 2.1 below.

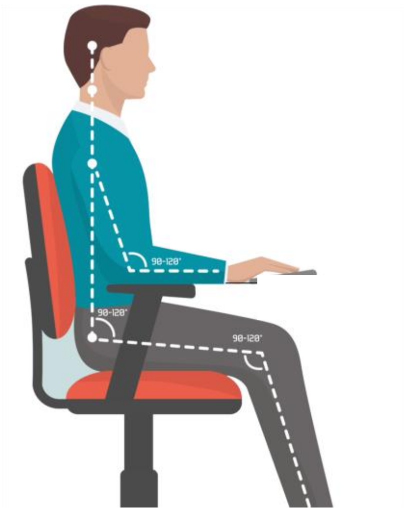

Figure 2.1. Recommended Sitting Posture

The usage of computer hardware components also needs to be considered. Some of them are monitor, mouse, joystick, and keyboard. The keyboard is a device for typing or entering certain letters, numbers or symbols to the software or operating system run by the computer (OHCOW, 2008). The keyboard consists of box-shaped buttons with letters, numbers or symbols printed on it. Some ergonomics ways of typing usage to avoid muscle injury is described as follows:

1. Positioning the keyboard comfortably and the front forearms in a horizontal state.
2. The shoulder state in the relax position, which is not tense and lifted up. The wrist is in a straight position, not bending up or down.
3. Pressing the button smoothly so that the hands and fingers in a state of relaxation.
4. Seek straight keyboard positions with the user's arm or hand.

2.2.3. Work Related Musculoskeletal Disorders

Musculoskeletal Disorders (MSDs) are known as injuries or disorders of the musculoskeletal system including muscles, nerves, tendons, ligaments, joints, cartilages and spinal discs. Issues Work-related Musculoskeletal Disorders (WMSDs) are becoming well known in the work field as musculoskeletal disorders caused by the work environment and the impact of work performance or musculoskeletal disorders worsened by long-term work (Cohen et al., 1997). Work-related Musculoskeletal Disorders not only occur because of the intensity of work done, but also can occur when doing daily activities and exercise (Luttmann et al., 2003).

MSDs can be caused by the unbalanced energy, such as ATP, of the muscles or joints with the force released. The risk and effects will become greater if it done cumulatively over a long period of time (Sa-ngiamsak, 2016). According to Luttmann (2003), factors below cause the affected musculoskeletal disorders described are as follows:

4. Excessive workload, which will cause muscle excessive contraction
5. Utilizing the same musculoskeletal system repetitively
6. Awkward posture
7. Static posture by doing repetitive and monotonous work
3. Work that does not move the muscle in a long time, such as prolonged sitting and standing
4. Unsupportive work environment, especially coldness which can affect blood circulates ineffectively

Besides physical factors, MSDs also can be caused by organizational or psychosocial, personal, and social-related factors (Abbis & Laursen, 2005). Bad organization management will induce inadequate resting time for employees and high work pressure. Medical history, physical capacity, and habit are some of the individual factors which need to be concerned. Social-related factors including lifestyle and type of sports also contributed in affecting MSDs.

2.2.4. Carpal Tunnel Syndrome

Carpal Tunnel Syndrome is a symptom of neuropathy compression on medianus nerve at the wrist level, characterized by evidence of increased pressure in the carpal tunnel and decreased nerve function (Latinovic et al., 2006; Chammas et al., 2014). Carpal Tunnel Syndrome can be caused by various factors and conditions and begins with complaints of numbness, tingling, hand and arm pain and muscle dysfunction.

Carpal tunnel is a space composed of bone and fibrous connective tissue located flexor retinaculum located at wrist. Inside the carpal tunnel, there are medianus nerve, along with four tendons from the superficial flexors of fingers (*Flexor Digitorum Superficialis*), four tendons of deep flexors of fingers (*Flexor Digitorum Profondus*), and one deep long flexor of the thumb (*Flexor Pollicis Longus*) (Chammas et al., 2014). A short motor branch in median nerve also supplies *Abductor Pollicis Brevis* to move the thumb. The median nerve innervate the palmar face of three fingers, which are thumb, index, and middle finger and half of ring finger.

CTS become one of the most common Work-Related Musculoskeletal Disorders (WMSDs) which can cause work disability. Based on the data from Reed (2005), the work disability length could be various, depends on the level of severity. In medical treatment, it needs minimum of 0 to 63 days of recovery while in surgical treatment, it needs 1 day minimum to 84 days to fully recovered. Thus, the loss would be considerable. According to Dartmouth–Hitchcock Medical Center, surgical treatment of carpal tunnel could cost more than $7000 per hand. Moreover, the income loss per CTS patients was estimated at $45,000–89,000 compared with controls (Foley et al., 2007)

According to Jagga et al. (2011), several jobs which has high risk for Carpal Tunnel Syndrome are:

1. Workers exposed to vibrations
2. Assembly station workers
3. Food processing & frozen food factory workers
4. Shopkeeper
5. Industrial Workers
6. Textile Workers
7. Computer Users

Carpal Tunnel Syndrome clinical approach can be done in several ways in order to diagnose the occurrence of CTS, including:

1. Physical examination

Examination is performed thoroughly in patients with special attention to function, motor, sensory and autonomous hands. According to Katz & Simmons (2002) some examples of physical examination in diagnosing CTS are:

a) Phalen's test
b) Torniquet test
c) Tinel's sign
d) Flick's sign
e) Thenar wasting
f) Assess muscle strength with dynamometer
g) Wrist extension test
h) Pressure test
i) Luthy's sign
j) Sensibility check
k) Examination of autonomous functions

2. Neurophysiology Examination (electrodiagnostic)

   This check is performed using an electromyography (EMG) device which can indicate the presence of fibrillation, positive waves and reduced number of motor units in the thenar muscles (Latov, 2007).

3. Radiological Examination

   An X-ray examination of the wrist may help to see if there are other causes such as fracture or arthritis. Ultrasound is performed to measure the cross-sectional area of the median nerve in Carpal Tunnel Proximal which is sensitive and specific to Carpal Tunnel Syndrome.

2.2.5. Wrist Motion

In hand, there are numbers of muscles and tendons and three nerves, which are median, ulnar, and radial (Raven, 2017). As seen in figure 2.2, the six wrist possible motions are flexion, extension, ulnar, radial, pronation, and supination, although both pronation and supination are a resultant of forearm movement. The wrist motion moves along two axes, transverse for flexion and extension, and anteroposterior for ulnar and radial deviation (Ombregt, 2013). The amplitude and extension and flexion motion range are larger than ulnar and radial due to its elastic end-feel. Extension describes the raising wrist posture, flexion describes the bending wrist posture down, ulnar describes the bending wrist posture towards the ulnar bone or little finger side, and radial describe the bending wrist posture towards the radial bone or thumb side (Norkin & White, 2016).

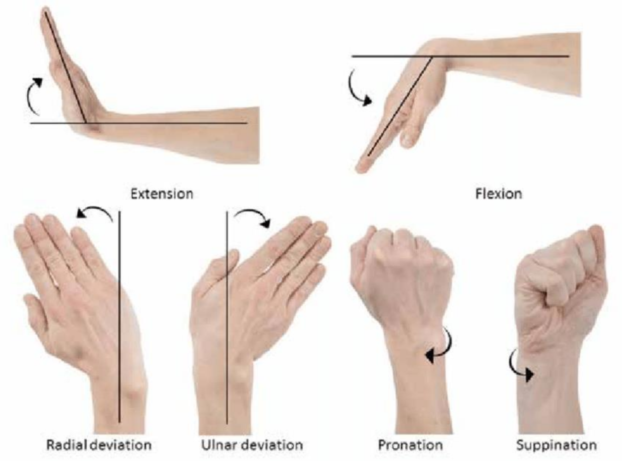

Figure 2.2. Wrist Motions

2.2.6. Muscle

The muscular system in human body is responsible to the movement function. There are three types of muscle tissues; visceral, cardiac, and skeletal. Visceral muscle or familiarly called as smooth muscle located inside organs such as stomach and blood vessels and has function for sustained contractions. Cardiac muscle is only found in the heart, it was responsible to pump the blood throughout the body. Both visceral and cardiac muscle are an involuntary muscle and cannot be controlled consciously. While, skeletal muscle can be controlled consciously and responsible to all physical action. It generates force and power from the energy to maintain posture and generate movements (Forentra & Ochala, 2014).

Skeletal muscle consists of bundles of muscle bundles, where bundle muscle bundles are wrapped into a whole muscle unit called epimysium. Bundles muscle that is bound to white fibrosis tissue is called the perimysium. Bundle muscle itself consists of thousands of muscle fibers (muscle fibers). While, muscle bundles are covered by the sheath of the supporting tissue called endomysium (Suhartono, 2005).

Muscles and nerves have potential energy stored. In resting or polarized condition, each nerve cell produces few negative ions inside cell and positive ions outside the cell membrane. When there is a stimulus in the form of physical, chemical, or electrical signals into the muscle, the neuron will be stimulated and Na^+ ion will enter the cell which causes potential difference due to more positive ion entered the cell rather than outside the cell, which called depolarization. This potential action will be spread along the axon (Drum et al., 2016). Depolarization that occurs in muscles causes electrical activity that can be recorded by electromyography (EMG) (Tayyari & Smith, 2003).

Muscle contraction occurs when muscle fiber generates tension after receiving signals from the nerve system. The force of contraction was generated by proteins called actin and myosin which transmitted longitudinally and laterally within the fiber (Forentra & Ochala, 2014). The skeletal muscle contraction is able to generate varying levels of contractile force. Based on Grandjean (1986), the maximum resistance of maximal force of muscles against time is as follows, which also illustrated in figure 2.2:

1. At 25% of maximum strength: 3.4 minutes
2. When 50% of maximum strength: 1 minute
3. When 75% of maximum strength: 0.35 minutes
4. When 100% of maximum strength: 0.1 minutes

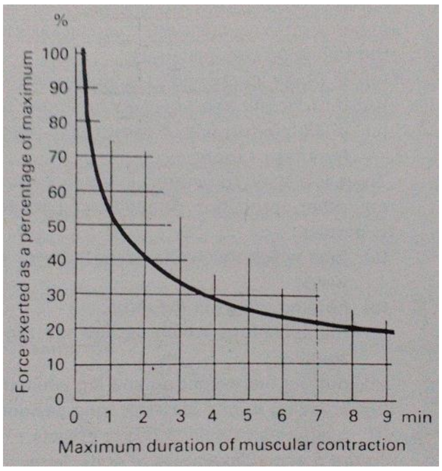

Figure 2.3. Duration of Maximum Muscle Contraction

The maximum muscle contraction also can be observed based on the perceived effort. Bernard (2012) developed the observational scale rating based on Moore and Garg strain index to assess the risk of MSDs to the hand and wrists.

Table 2.2. %MVC Observational Scale

Observation	**%MVC**
Barely noticeable or Reflexed Effort	5
Noticeable or definite effort	20
Obvious effort; Unchanged facial expression	40
Substantial effort; Changes facial expression	65
Uses shoulder, trunk, or whole body for force application	90

2.2.7. Electromyography

One way to measure muscle activities is by using electromyography. It is done by measuring the workload of muscle and muscle contraction that occurs. Electromyography / Electromyograph (EMG) is an experimental technique focused on analyzing the recording of myoelectric signals in muscles. The myoelectric signal is formed from physiological changes in the muscle fiber membrane (Konrad, 2005).

According Konrad (2005) outline techniques Electromyograph used for various kinds of research, among others:

1. Medical research
2. Rehabilitation
3. Ergonomics
4. Sports science

Surface electromyography (sEMG) or usually called as surface electromyography is an EMG tool attached to the skin to determine muscle activity. The use of surface electromyograph is often used because it is safe to use (no need to penetrate the skin), easy to use and able to know the energy released from the muscle, but the use of electromyographic skin also has the disadvantage of not able to measure the complex muscle activity because the signal recorder of this tool only able to record up to 4 observations only.

A signal that has not been filtered and has not done the process of the signal obtained directly from the recorded muscle is also called EMG Raw Signal shown in figure 2.3 (Konrad, 2005).

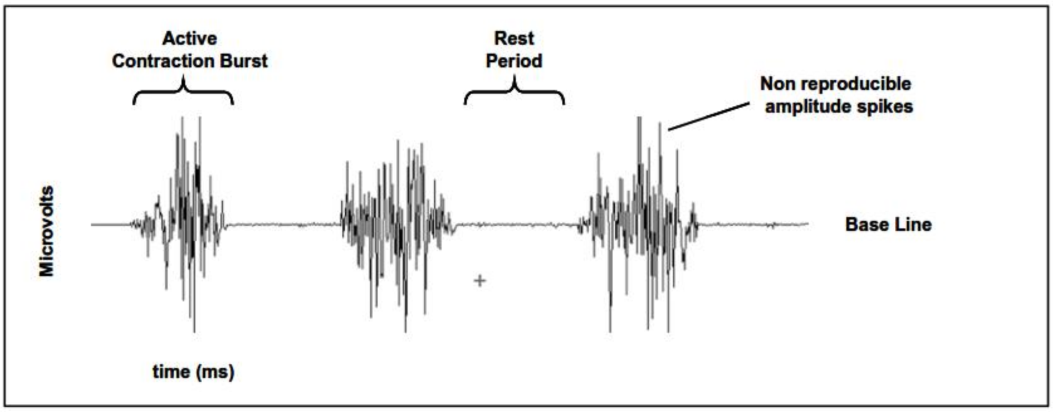

Figure 2.4. EMG Raw Signal

Filtering process is used to reduce the noises in muscle contraction signal that recorded in raw EMG signal. Filtered muscle contraction signal of EMG raw is formed as EMG filtered which has been filtered by the form of Low and High Band-Pass Filter which reduces the effect of a varying baseline on signals, improving data. EMG Filtered has negative signal which will has mean value near to zero. The recommended filter based on SENIAM is located between 10 to 500 Hz, where the ambient interferences like pressure appear, arrangement or closer apparatus.

The next step in analyzing the resulting raw signal is by converting negative amplitude to positive or by reflecting on it, which also stated as rectifying the signal (Konrad, 2005). This procedure has the purpose to turn all the signal values integrative, submitting them to the cut of all negative values, that means, to delete the values that are under the baseline, or to turn all the negative values to positive adding the values, making them integrative. The aim of this procedure is to avoid the mean value of near to zero and ease the researcher to identify the standard amplitude parameter such as mean and peak value.

Smoothing the signal is the final step in processing the EMG signal, although digital filtering sometimes applied, but it is not necessarily needed in regular kinesiological EMG studies. The smoothing and the filtration have some similar parameters, mostly because both have the intention of taking out the steep amplitudes, the parts that are considering noises. Smoothing creates a linear envelope in the signal, leaving only a centre part of the signal. There are two algorithms which usually used, moving average and root mean square. Root Mean Square (RMS) will reflects the mean power of the signal and will be used in this study. Figure 2.4 shows the EMG signal which been converted (Altimari et al., 2012).

Normalizing the EMG value was necessary to overcome the uncertain character of microvolt between some variables, such as electrode sites and subjects (Konrad, 2005). Maximum voluntary contraction (MVC) is one of the ways to normalize the signal by rescaling the microvolt units to percentage of maximum innervation capacity. The %MVC value can be obtained by divided the processed EMG signal by the MVC (Oikawa et al., 2011; Safee et al., 2014).

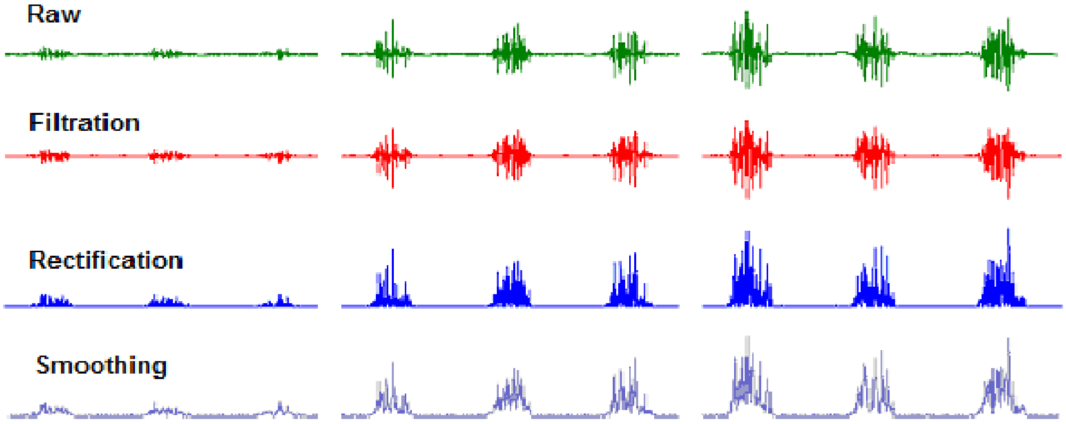

Figure 2.5. Converted EMG Signal

Preparation before electrode installment is necessary to perform due to its influence on the quality of EMG measurement. Before positioning the electrode, skin surface must be cleaned by removing the hair if necessary and clean the skin to remove dead skin cells, clean dirt and sweat by following options (Konrad, 2005);

1) Using special abrasive and conductive cleaning pastes.
2) Sweep skin for 3 or 4 times using sand paper softly.
3) Gently rub the skin with alcohol, this method may be sufficient for static muscle function tests in easy conditions

According to The European Recommendations for Surface Electromyography from Konrad (2005), silver chloride pre-gelled electrodes are recommended for general use since it is easy and quick handling, also hygiene. After the skin are cleaned, disposable electrodes will be attached to the muscle. The following guideline are some of the general guidelines which will be applied in the study (Konrad, 2005);

1) The general recommendation for inter-electrode distance is 2 cm, from one center point to another center point
2) Wet gel electrodes have the best skin impedance values
3) Apply electrodes in parallel to the muscle fiber direction to maximize sensitivity and selectivity

2.2.8. Non-Parametric Statistical Test

Non-parametric statistical test is the alternative statistical test in certain conditions where the data has small sample size and not normal distributed (Larose, 2015). The guideline flow to determine the required statistics tests shown in figure 2.6 (Sari & Wardani, 2016).

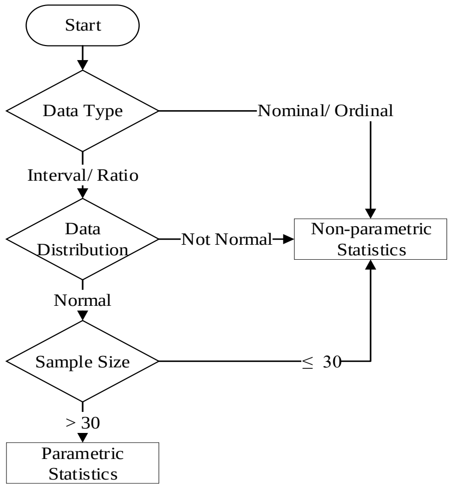

Figure 2. 6. Guidelines for Using Non-parametric Statistics

Some non-parametric statistical tests done as the alternatives from parametric statistical test in the same situation. Larose (2015) determined and summarized the efficiency of non-parametric statistical test compared with parametric test in the same situation as shown in table 2.3 below.

Table 2. 3. Parametric and Non-parametric Test

Situation	Parametric Test	Non-parametric Test	Efficiency
Matched pairs	*T* test or *Z* test	Sign test	0.63
Matched pairs (Dependent sample)	*T* test or *Z* test	Wilcoxon signed rank test	0.95
Two independent samples	*T* test or *Z* test	Wilcoxon rank sum test or Mann Whitney *U* Test	0.95
Several independent samples	Analysis of variance (*f* test)	Kruskal-Wallis test	0.95
Correlation	Linear Correlation	Rank correlation test	0.91

This study will use Kruskal-Wallis and Mann Whitney U to test the hypothesis. Hypothesis is a tentative statement which is a presumption of observation and one of its functions is to test the validity of a theory (Nasution, 2000). Thus, the purpose of testing hypothesis is to produce a decision about the difference between the sample statistical value and the hypothesis value.

a. Kruskal-Wallis Test

Kruskal-Wallis test is a test that is used to find out the independent sample of test k comes from a different population or not (Spiegel, 1961). The hypotheses used for the Kruskal-Wallis test are:

H0 : There were no significant differences between the test group data k

H1 : There is a significant difference in the difference between k test group data.

The decision making is based on a hypothesis seen from the significance value. If significance value ≥ 0.05 then H0 is accepted which means there is no significant difference. Otherwise, if the significance value is <0.05, H0 is rejected, which means that there is a significant difference between the test group data.

The procedure of this test started by ranking all of the data from group data 1 to group data n, followed by sum the rank which will become R_1, R_2, until R_n variable. The following formula used to calculate the H value (Spiegel, 1961; Diyono 2014).

$$H = \frac{12}{N\,(N+1)}\left(\frac{R1^2}{n1} + \frac{R2^2}{n2} + \frac{Rn^2}{Rn}\right) - 3(N+1) \qquad (2.1)$$

H value was calculated where n symbolize the sample size and R the sum of the ranks. If the distribution sample (k) equals to 3 and n1, n2, and n3 ≤ 5, table O was used to obtain H-table. Otherwise, Chi Square table will be used with the degree of freedom = k-1.

b. Mann Whitney U Test

Mann Whitney test is a non-parametric different test by calculating the difference between medians from two data independent groups (Diyono, 2014). The hypothesis used in the Mann Whitney test is:

H0 : There is no significant differences between two data groups

H1 : There is a significant difference in between two data groups

The decision making is based on a hypothesis seen from the significance value. If significance value ≥ 0.05 then H0 is accepted which means that there is no significant difference. Otherwise, if the significance value is <0.05, H0 is rejected, which means that there is a significant difference between the test group data.

The procedure of this test started by ranking all of the data and separate the rank from one group to another, followed by sum the rank which will become $\sum Rx$ and $\sum Ry$ variable. The following formula is used to calculate the U value (Diyono, 2014).

$$Ux = (nx\ x\ ny) + \frac{(nx+1)x\ nx}{2} - \sum Rx \tag{2.2}$$

$$Uy = (nx\ x\ ny) + \frac{(ny+1)x\ ny}{2} - \sum Ry \tag{2.3}$$

U value was calculated where n symbolizes the sample size and R the sum of the ranks. The least u value was used as U-count and will be compared with U-table. H0 will be accepted if U-count ≥ U-table. Otherwise, it will be rejected if U-count < U-table. The critical value of Mann-Whitney U Table in two tailed testing shown in table 2.4 Below.

Table 2. 4. Critical Value of Mann-Whitney U Table (2-tailed)

n_2	α	n_1																	
		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
3	.05	--	0	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
	.01	--	0	0	0	0	0	0	0	0	1	1	1	2	2	2	2	3	3
4	.05	--	0	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	14
	.01	--	--	0	0	0	1	1	2	2	3	3	4	5	5	6	6	7	8
5	.05	0	1	2	3	5	6	7	8	9	11	12	13	14	15	17	18	19	20
	.01	--	--	0	1	1	2	3	4	5	6	7	7	8	9	10	11	12	13
6	.05	1	2	3	5	6	8	10	11	13	14	16	17	19	21	22	24	25	27
	.01	--	0	1	2	3	4	5	6	7	9	10	11	12	13	15	16	17	18
7	.05	1	3	5	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
	.01	--	0	1	3	4	6	7	9	10	12	13	15	16	18	19	21	22	24
8	.05	2	4	6	8	10	13	15	17	19	22	24	26	29	31	34	36	38	41
	.01	--	1	2	4	6	7	9	11	13	15	17	18	20	22	24	26	28	30
9	.05	2	4	7	10	12	15	17	20	23	26	28	31	34	37	39	42	45	48
	.01	0	1	3	5	7	9	11	13	16	18	20	22	24	27	29	31	33	36
10	.05	3	5	8	11	14	17	20	23	26	29	33	36	39	42	45	48	52	55
	.01	0	2	4	6	9	11	13	16	18	21	24	26	29	31	34	37	39	42
11	.05	3	6	9	13	16	19	23	26	30	33	37	40	44	47	51	55	58	62
	.01	0	2	5	7	10	13	16	18	21	24	27	30	33	36	39	42	45	48
12	.05	4	7	11	14	18	22	26	29	33	37	41	45	49	53	57	61	65	69
	.01	1	3	6	9	12	15	18	21	24	27	31	34	37	41	44	47	51	54
13	.05	4	8	12	16	20	24	28	33	37	41	45	50	54	59	63	67	72	76
	.01	1	3	7	10	13	17	20	24	27	31	34	38	42	45	49	53	56	60
14	.05	5	9	13	17	22	26	31	36	40	45	50	55	59	64	67	74	78	83
	.01	1	4	7	11	15	18	22	26	30	34	38	42	46	50	54	58	63	67
15	.05	5	10	14	19	24	29	34	39	44	49	54	59	64	70	75	80	85	90
	.01	2	5	8	12	16	20	24	29	33	37	42	46	51	55	60	64	69	73
16	.05	6	11	15	21	26	31	37	42	47	53	59	64	70	75	81	86	92	98
	.01	2	5	9	13	18	22	27	31	36	41	45	50	55	60	65	70	74	79
17	.05	6	11	17	22	28	34	39	45	51	57	63	67	75	81	87	93	99	105
	.01	2	6	10	15	19	24	29	34	39	44	49	54	60	65	70	75	81	86
18	.05	7	12	18	24	30	36	42	48	55	61	67	74	80	86	93	99	106	112
	.01	2	6	11	16	21	26	31	37	42	47	53	58	64	70	75	81	87	92
19	.05	7	13	19	25	32	38	45	52	58	65	72	78	85	92	99	106	113	119
	.01	3	7	12	17	22	28	33	39	45	51	56	63	69	74	81	87	93	99
20	.05	8	14	20	27	34	41	48	55	62	69	76	83	90	98	105	112	119	127
	.01	3	8	13	18	24	30	36	42	48	54	60	67	73	79	86	92	99	105