UNIVERSITI PUTRA MALAYSIA

# *DEVELOPMENT OF A MODEL TO ASSESS WORK EFFICIENCY BASED ON ACTIVITY ENERGY EXPENDITURE AND ACTIVITY WASTED ENERGY IN HORIZONTAL DRILLING TASK*

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By

**ALI AHMED MANSOUR SHOKSHK**


**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

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Despite robotics and mechanisation becoming more common in the industry, hand drilling is still widely used in furniture manufacturing, household work, construction work, aircraft manufacturing, and aerospace. MSDs that are caused by non-neutral postures of the wrist, back, and shoulder, and high forces applied during drilling have affected operators. Measuring worker efficiency offers a chance to understand the things that work well and whether further changes are needed. Work efficiency models in literature are few and done in different tasks and simulations. Factors affecting work efficiency in drilling are the tool weight, repetitive movements, awkward posture, and anthropometry. The ideal weight of the hand tool has been conflicted in literature. Preliminary study in this research found that repetitive movement was necessary to continue drilling without any tiredness. Criticism has been raised recently on the posture assessment methods as they do not focus on load and coordinated postures. The effects of weight and Maximum Grip Strength (MGS) on Activity Energy Expenditure (AEE) also differ in the literature. Therefore, the aim of this study was to develop a working efficiency model in horizontal drilling tasks based on AEE and Wasted Energy Activity (AWE). Ideal tool weight, ideal repeated cycle time (RCT), and 12 coordinated postures were investigated. This model also served to validate the AEE data through Rating Perceived Exertion (RPE) and Accomplishment Time (AT), and finally, to investigate the effects of anthropometry on AEE and work efficiency. AnyBody modelling system using Maximum Muscle Activity (MMA) was used to investigate the weight of the tool. AEE using Actiheart was used to find the ideal RCT and investigate the 12 coordinated postures. RPE using Borg scale and AT using stopwatch were used to validate the AEE data. Differences in means and repeated measures ANOVA were used to analyse the data. Results showed that a tool mass of 2 kg or less, and a 4-sec RCT were optimum. Working with shoulder flexion of 90° and trunk bent forward of 20° was the most awkward posture. Leg support provided more comfort to all postures. From the 12 coordinated postures, 6 were between light and moderate awkward postures. The rest of the postures were between hard and very hard. The correlations between AEE with RPE and AT were strong which are 0.923; $P < 0.01$ and -0.827; $P < 0.01$ respectively. Furthermore, AEE declined with the increase in the subject's weight and MGS with $R^2 = 0.62$ and 0.12 respectively. Individuals with more weight (fat free) and high MGS consume less AEE and are considered more efficient. Finally, posture work efficiency model was also developed. The 12 coordinated postures had different efficiencies from low to very high. This model can serve as a basis for a new method to assess posture based on physiological assessment. Furthermore, this finding is useful to save up the individual's energy to work for a longer duration with less fatigue.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PEMBANGUNAN MODEL UNTUK MENILAI KECEKAPAN KERJA BERDASARKAN AKTIVITI PERBELANJAAN TENAGA DAN AKTIVITI PEMBAZIRAN TENAGA DALAM TUGAS PENGGERUDIAN MENDATAR**

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Walaupun robotik dan mekanisasi menjadi lebih biasa dalam industri, penggerudian tangan masih digunakan secara meluas dalam pembuatan perabot, kerja rumah, kerja pembinaan, pembuatan pesawat, dan aeroangkasa. MSDs yang disebabkan oleh postur pergelangan tangan, belakang, dan bahu yang tidak neutral, dan daya tinggi yang digunakan semasa penggerudian telah mempengaruhi pengendali. Mengukur kecekapan kerja menawarkan peluang untuk memahami perkara-perkara yang berfungsi dengan baik dan apakah perubahan selanjutnya diperlukan. Model kecekapan kerja dalam kesusasteraan adalah sedikit dan dilakukan dalam pelbagai tugas dan simulasi. Faktor-faktor yang mempengaruhi kecekapan kerja dalam penggerudian adalah berat alat, pergerakan berulang, postur janggal, dan antropometri. Berat badan yang ideal alat tangan telah bertentangan dengan kesusasteraan. Kajian awal dalam kajian ini mendapati pergerakan berulang diperlukan untuk meneruskan penggerudian tanpa sebarang keletihan.Kritikan telah dibangkitkan baru-baru ini mengenai kaedah penilaian postur kerana mereka tidak memberi tumpuan kepada postur dan beban yang diselaraskan. Kesan berat dan Kekuatan Cengkaman Maksimum (MGS) untuk Aktiviti Perbelanjaan Tenaga (AEE) juga berbeza dalam kesusasteraan. Oleh itu, matlamat kajian ini adalah untuk membangunkan model kecekapan kerja dalam tugas penggerudian mendatar berdasarkan AEE dan Aktiviti Tenaga Hilang (AWE). Berat alat yang ideal, masa kitaran berulang yang ideal (RCT), dan 12 postur yang diselaraskan telah disiasat. Model ini juga berfungsi untuk mengesahkan data AEE melalui pengukuran kerja keras yang dirasai (RPE) dan Waktu Pencapaian (AT), dan akhirnya, untuk mengkaji kesan antropometri pada AEE dan kecekapan kerja. Sistem pemodelan AnyBody menggunakan Kegiatan Otot Maksimum (MMA) digunakan untuk menyiasat berat alat tersebut. AEE menggunakan Actiheart telah digunakan untuk mencari RCT yang ideal dan menyiasat 12 postur yang diselaraskan. RPE menggunakan skala Borg dan AT menggunakan jam randik digunakan untuk mengesahkan data AEE. Perbezaan cara dan langkah berulang ANOVA digunakan untuk menganalisis data. Keputusan menunjukkan bahawa 2 kg atau kurang berat alat dan 4 saat RCT adalah optimum. Bekerja dengan lekukan bahu 90° dan badan membongkok ke depan 20° adalah postur yang paling janggal. Sokongan kaki memberikan keselesaan kepada semua postur. Dari 12 postur yang diselaraskan, 6 adalah antara postur ringan dan mudah. Selebihnya adalah antara postur keras dan sangat keras. Hubungan antara AEE dengan RPE dan AT adalah kukuh iaitu masing - masing 0.923; P <0.01 dan -0.827; P <0.01. Tambahan pula, AEE menurun dengan peningkatan berat subjek dan MGS iaitu masing - masing $R^2$ = 0.62 dan 0.12. Individu yang mempunyai berat badan (bebas lemak) dan tinggi MGS menggunakan kurang AEE dan dianggap lebih cekap. Akhirnya, model kecekapan postur kerja juga dibangunkan. Dua belas postur yang diselaraskan mempunyai kecekapan yang berbeza dari rendah ke sangat tinggi. Model ini boleh menjadi asas bagi kaedah baru untuk menilai postur berdasarkan penilaian fisiologi. Tambahan pula, penemuan ini berguna untuk menjimatkan tenaga individu untuk bekerja bagi tempoh yang lebih lama dengan kurang keletihan.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| AEE | Activity Energy Expenditure |
| ANOVA | Analysis of Variance |
| AT | Accomplishment Time |
| AWE | Activity Wasted Energy |
| BH | Body Height |
| BMI | Body Mass Index |
| bpm | Beats Per Minute |
| BW | Body Weight |
| DIT | Diet-Induced Thermogenesis |
| DIY | Do-It-Yourself |
| DLW | Doubly Labelled Water |
| ECG | Electrocardiography |
| EMG | Electromyography |
| IBI | Inter-Beat-Interval |
| KCAL | Kilocalorie |
| LBM | Lean Body Mass |
| LBP | Low Back Pain |
| MAP | Maximum Aerobic Power |
| MGS | Maximum Grip Strength |
| MHR | Maximum Heart Rate |
| MMA | Maximum Muscle Activity |
| MSDs | Musculoskeletal Disorders |
| MVC | Maximum Voluntary Contraction |

| | |
|---|---|
| OWAS | Ovako Working Posture Analysing |
| RCT | Repetitive Cycle Time |
| REBA | Rapid Entire Body Assessment |
| REE | Rest Energy Expenditure |
| RPE | Rating Perceived Exertion |
| RULA | Rapid Upper Limb Assessment |
| SHR | Sleeping Heart Rate |
| SPSS | Statistical Package For The Social Sciences |
| TEE | Total Daily Energy Expenditure |
| ULP | Upper Limb Pain |
| VDU | Visual Display Unit |

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Measuring worker efficiency offers a chance to understand the things that work well and whether further changes are needed (Rao, 2014; Wei & Taormina, 2011). Rao (2014) revealed that high work efficiency is to perform work correctly in the presence of physical and cognitive body health; it is one of the foremost current management concerns. In addition, work efficiency is the quality of work done (Meena et al., 2014). In a more general sense, it is the ability to do things well, successfully, and without waste (e.g., energy or time) (Wei & Taormina, 2011). A large and growing body of literature has focused on the study of efficiency in sports and movement. However, work efficiency of hand tool tasks such as drilling has received little attention.

Manual handling tools are widely used in maintenance, power engineering, automobile assembly, electricity works, construction, healthcare, and farming industries (Chung et al., 2001; Hamed et al., 2018; Lee, 2017; Li et al., 2009; Singh & Khan, 2012). Musculoskeletal disorders (MSDs) such as upper limb pain (ULP) and low back pain (LBP) are the most common work-related injuries in manual handling tasks (Finneran & O'Sullivan, 2010; Phelan & O'Sullivan, 2014; Rasool et al., 2017; Yu et al., 2018). Such diseases are mainly caused by over-exertion, repetitive movements, or prolonged working postures during performing tasks (Alzuheri et al., 2010; Srinivasan et al., 2015). USA companies have spent untold billions of dollars on loss productivity due to the MSDs of workers. Work MSDs reached about 365,000 cases in the USA in 2014 (Alabdulkarim et al., 2016). The spending can be expressed through the demands of worker compensations, insurance bills, lawsuits, and disabilities as well as hiring and training of new staff (Alzuheri et al., 2010).

A survey was carried out by Zein et al. (2015) on the posture practices by Malaysian industrial workers. It was found that over 93.1% of the workers faced physical fatigue and 94.2% experienced mental fatigue while working. For the working postures, shoulder at chest level (30.1%), trunk moderately bent forward (90.8%), and heavy load lifting of 1 to 5 kg (80.5%) were the major work postures practised by most of the industrial workers in Malaysia. Table 1.1 shows the Social Security Organisation of Malaysia (SOCSO) report in 2017 regarding Malaysian industrial workers' injuries (SOCSO, 2017). There were still a high number of injuries on trunk, shoulder, leg, and over-exertion in handling.

**Table 1.1 : Statistics of Malaysian workers' injuries**

| | Statistics | | |
|---|---|---|---|
| | **Male** | **Female** | **Total** |
| Back | 1605 | 437 | 2042 |
| Shoulder | 2328 | 452 | 2780 |
| Upper arm | 83 | 26 | 109 |
| Over-exertion in lifting objects | 684 | 150 | 834 |
| Over-exertion in handling or throwing objects | 3511 | 477 | 3988 |
| Wrist | 1009 | 420 | 1429 |
| Leg | 4733 | 1494 | 6227 |

(SOCSO, 2017)

A report published in the USA revealed that 4.39% of work-related injuries were caused by hand tools (Aghazadeh & Mital, 1987; Venkata & Bhogaraju, 2006). Table 1.2 shows the cases with the numbers and percentages of fatigue caused by hand tools (Aghazadeh & Mital, 1987; Venkata & Bhogaraju, 2006). The total number of cases was 18,140 for powered hand tools and 68,118 for non-powered hand tools. Although non-powered hand tools lead to more injuries than powered tools, the harshness of injuries caused by powered hand tools is more severe. The drilling tool showed high injury cases with 17.6%.

**Table 1.2 : Number and Percentage distribution of cases**

| Non-Powered hand tools | | | Powered Hand Tools | | |
|---|---|---|---|---|---|
| Hand Tool Type | Cases | Percent (%) | Hand Tool Type | Cases | Percent (%) |
| Axe | 517 | 0.8 | Grinder | 1502 | 8.3 |
| Blow torch | 187 | 0.3 | Buffer | 377 | 2.1 |
| Chisel | 476 | 0.7 | Chisel | 38 | 0.2 |
| Crowbar | 2047 | 3.0 | Drill | 3192 | 17.6 |
| File | 143 | 0.2 | Hammer | 1458 | 8.0 |
| Fork | 328 | 0.5 | Ironer | 9 | .0 |
| Hammer | 6838 | 10.0 | Knife | 272 | 1.5 |
| Hatchet | 94 | 0.1 | Power activated tools | 107 | 0.6 |
| Knife | 30163 | 44.3 | Riveter | 178 | 1.0 |
| Pick | 373 | 0.5 | Screwdriver | 248 | 1.4 |
| Plane | 31 | 0.0 | Sandblaster | 94 | 0.5 |
| Pliers, Tongs | 676 | 1.0 | Saw | 6088 | 33.6 |
| Punch | 92 | 0.1 | Welding tools | 763 | 4.2 |
| Rope, chain | 2290 | 3.4 | Hand tools, powered, NEC | 3814 | 21.0 |
| Saw | 940 | 1.4 | - | - | - |
| Scissors | 1654 | 2.4 | - | - | - |
| Screwdriver | 1420 | 2.1 | - | - | - |
| Shovel | 3850 | 5.7 | - | - | - |
| Wrench | 6072 | 8.9 | - | - | - |
| Hand tool, not powered, NEC | 9927 | 14.6 | - | - | - |
| **Total** | **68118** | **100** | **Total** | **18140** | **100** |

**NEC - Not elsewhere classified**

Drilling is one of the important hand tool tasks in the industrial sectors and one of the most adaptable hardware tools used at homes, workshops, and factories (Sasikumar & Lenin, 2017; Singh & Khan, 2012). Sasikumar and Lenin (2017) found that hand drilling, being an essential component in many fields, is important to diminish MSDs. Rasool et al. (2017) concluded that drilling is associated with MSDs on the forearm, wrist, back, and shoulder with increased osteoarthritis in those workers who are predisposed to the illness. The high contact forces in drilling exerts severe pressure on the functional structure of the hand, which may be strongly influenced by several factors, such as tool weight, working posture, grip and push forces, individual work habits, handle size, and hand pressure interface (Singh & Khan, 2012).

Many MSDs directly and indirectly affect operators in drilling operations (Mathesan & Mohan, 2015; Rempel et al., 2010). Repeated drilling is often boring, monotonous, and fatiguing which causes MSDs at the wrist, forearm, shoulder, and back among hand-drilling workers (Das et al., 2007; Rasool et al., 2017). Mehta and Agnew (2010) discovered that shoulder fatigue on task performance and muscular responses of a drilling task are commonly observed within the construction industry. There are a number of occupational factors of hand tool tasks such as repetitive movements, strong exertions, awkward postures, and local mechanical pressures that can lead to increased MSDs (Dianat et al., 2015). Sasikumar and Lenin (2017) indicated that there is a research gap related to the driller's posture and the corresponding mechanical reactions during the process. Vidyasagar et al. (2014) revealed the postural awkwardness practised by miners while performing face drilling which becomes the keystone for mining works.

One of the aims of ergonomics is to reach maximum performance and work safety with fewer MSDs and less consumed energy of particular physical tasks (Shaik, 2015; Shephard & Aoyagi, 2012). The increase in the level of physical effort is accompanied by an increase in energy expenditure (Kahya, 2007). Human energy expenditure assessment for work is an important factor to determine the physiological impact and work efficiency of workers (Eminoğlu et al., 2010). In some tasks, energy is wasted because of unproductive activities. For example, static exertion, awkward postures, lack of work breaks, and inefficient usage of equipment or methods lead to the increase in Activity Energy Expenditure (AEE) which leads to the decrease in work efficiency and productivity (Kahya, 2007). The concerns which have been raised recently that working in an uncomfortable posture, high work pace, or anthropometry contributes not only to the development of MSDs but also leads to the loss of body energy and work efficiency.

## 1.2 Problem Statement

Despite the prevalence of robotics and mechanisation in the industry, hand drills are still used in many tasks such as furniture manufacturing, household work, construction work (electricity and plumbing), mining industry, aircraft manufacturing, and aerospace. Hambali et al. (2019) investigated working posture in mechanical assembly department at ABC Company Sdn. Bhd in Malaysia. The results showed that the highest ergonomic risk happened in the department of drilling. Khan & Muzammil (2018) revealed that drilling task is dull and repetitive in nature, with numerous health- and safety-related concerns such as repetitive strain injury and MSD. Yu et al.(2018) revealed that most of China's furniture drilling tasks are in semi-mechanised state. Mondal and Ray (2017) also discovered that the face (horizontal) drilling process is the most prevalent task in underground mines of India. Furthermore, Vidyasagar et al. (2014) concluded that awkward postures experienced by miners became high while doing face drilling. Therefore, work efficiency study in horizontal drilling task is necessary to reduce related MSDs in different drilling tasks and determine actions to avoid wasting energy in unproductive activities such as a high tool weight (increase in a tool weight more than the ideal without using supporting tools), awkward postures, and unsuitable repetitive movements.

Few studies are found relating to work efficiency in the workplace. Zhao et al. (2010) proposed a model to predict the work efficiency of posture. This model was based on predicted practical data. Shirouyehzad et al. (2012) established a work efficiency model based on psychological factors that did not include posture. Mohod and Mahalle (2018) developed a mathematical model of energy consumption of female operators performing drilling task. Posture is one of the factors in this model. Chang et al. (2019) developed a model of overhead drilling task based on posture. All those aforementioned models were based on simulation, not on experimental assessments.

Recent literature have recently raised the main factors which affect worker efficiency in drilling tasks. These factors are the weight of tool, repetitive movements, coordinated postures, and anthropometry. A study by Maurice (2015) found that the weight of tool results in a significant decrease in productivity. In the same context, Hu et al. (2011) concluded that the weight of tool may also have internal physiological and biomechanical effects on the worker such as tissue deformity in the nervous system. However, the ideal tool weight has been conflicted in literature. Mital and Kilbom (1992) revealed that the optimum tool mass is 2.3 kg or lower. Hu et al. (2011) concluded that a tool mass of 1.5 kg and above is the most conducive for MSDs among workers. More investigation on ideal hand tool weight are needed. Recent literature have also been concerned about repetitive movements. Srinivasan et al. (2015) and Zadry et al. (2009) found that repetitive movement tasks is one of the factors that can cause MSDs among workers. This will affect work efficiency where human energy consumption can be the parameter to detect MSDs (Mohod & Mahalle, 2018; Nur et al., 2015b). Freivalds (2004) concluded that muscle fatigue is a failure to sustain the desired or expected strength to finish work and is related to physically repetitive work. In a preliminary experiment of horizontal drilling task which was conducted before this study, repetitive hand movement is necessary to continue drilling without any tiredness. Therefore, investigating the ideal Repetitive Cycle Time (RCT) is crucial to reduce AEE and increase work efficiency in horizontal drilling task.

There has been a recent debate on posture assessment. Budnick (2013) criticised the most popular method, Rapid Upper Limb Assessment (RULA) which has a powerful concentricity on posture, but low concentration on load, repetition, and duration. Literature have also been concerned about the possibility of under- or over-estimation to evaluate body postures due to upper limb combinations (Khan et al., 2013; Lim et al., 2011). Brookham et al. (2010) investigated the effects of a light hand tool task effort on the activity of shoulder muscle during different postures of humeral rotation and shoulder flexion. They found that 60° shoulder flexion with -45° internal rotation of forearm as an excellent posture. Farooq and Khan (2014) investigated the combination of shoulder/elbow postures for a repetitive task. They found that 45° elbow flexion angle with -45° shoulder extension as the most awkward posture. The coordinated postures of the shoulder, trunk, and leg in horizontal drilling task were not considered. Therefore, an investigation of the coordinated postures of the shoulder, trunk, and leg in horizontal drilling task as an interaction effect between those postures is beneficial to classify them from light, moderate, hard, to very hard awkward postures.

Furthermore, literature have been concerned about the effects of anthropometry on physiological responses of an individual. Goldsmith et al. (2009) and Rosenbaum et al. (2003) concluded that extra weight of an individual in the form of fat increases the workload on muscles, leading to a higher heart rate during physical activities. Hellesvig-Gaskell (2017) found that when bodyweight is mostly composed of muscles, the load of work is reduced because the ability to do mechanical work increases with muscle mass. However, these results contradict those from Hills et al. (2014) who concluded that bigger individuals need more energy requirement than smaller ones. These conflicting results have triggered more investigation in relation to the weight of individuals and AEE in different loads such as coordinated postures in horizontal drilling task. Furthermore, recent studies have debated on hand strength in adults. For example, Jürimäe et al. (2009) found that the larger the hand size, the stronger the hand. This result is consistent with the study of Nicolay & Walker (2005) who noted that hand and arm sizes generally function as a better predictor of grip strength than body mass and body height. All these research studied the effects of body composition and anthropometric variables on hand strength. However, the reverse effect of Maximum Grip Strength (MGS) on AEE and work efficiency has not been considered.

## 1.3 Objectives of Research

1. To develop a posture work efficiency model based on AEE and Activity Wasted Energy (AWE) in horizontal drilling task.
   - 1.1. To investigate the ideal weight of hand tool.
   - 1.2. To find the optimal RCT.
   - 1.3. To determine the effects of coordinated postures of shoulder, trunk, and leg on AEE.
   - 1.4. To validate the data of AEE with Rating Perceived Exertion (RPE) and Accomplishment Time (AT).
2. To analyse the effects of anthropometry in terms of subject's weight and MGS on AEE and work efficiency.

## 1.4 Scope of Study

The task was a horizontal drilling task. The independent variables were 12 coordinated postures of the shoulder, trunk, and leg; an external load of 0, 2, 4, until 20 kg; RCT of 2, 4, and 6 sec; and anthropometry. The dependent variables were Maximum Muscle Activity (MMA), AEE, RPE, and AT. All other factors were controlled. The subjects were Malaysian men with good health with age range 22–25.

## 1.5 Organisation of Thesis

The thesis consists of five chapters. The first chapter provides a general introduction, problem statement, objectives, and scope. Chapter 2 of the thesis reviews the previous literature on work efficiency, metabolic energy and physical work, MSDs, hand tools that involve drilling task, weight of hand tool, AnyBody modelling system, MMA, and RCT. This chapter also discusses awkward posture including subjective assessment, coordinated postures, AEE, and AT. This chapter reviews anthropometry in terms of individual weight and grip strength as well. Finally, the knowledge gap is discussed.

Chapter 3 defines the methodology used in the research. The chapter focuses on the experimental design of three experiments which comprise investigation of the weight of tool, RCT, and awkward postures in horizontal drilling task. The methodology of the validation of AEE data, posture work efficiency, the effects of anthropometry on AEE and work efficiency are also discussed. This chapter describes variable identifications, selection of equipment and tools, and subject selection too. Finally, a statistical analysis is detailed.

Chapter 4 provides the empirical results and their interpretation. The effect of the tool weight on MMA is discussed. The effects of RCT and 12 coordinated postures of the shoulder, trunk, and leg on AEE are interpreted. Furthermore, data validation of AEE with RPE and AT is investigated. Then, posture work efficiency model based on AEE is developed. The effects of anthropometry in terms of subject's weight and MGS on AEE and work efficiency are also discussed. Finally, Chapter 5 covers conclusion, limitations, and recommendations for future research.

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## BIODATA OF STUDENT

Ali Ahmed Shokshk was born on 5th May 1969 at Zliten city of Libya. He completed his primary education at Esraa School of Alsabaa in 1983 and completed his secondary school at Secondary Zliten School in 1986. He has got BSc. from Computer and Electronic Engineering, Faculty of Industrial Technology, Misrata, Libya in 1995. Also, he got MSc. in Engineering Management in Faculty of Industrial Technology, Misrata, Libya in 2002. He worked at Higher Polytechnic Institute of Zliten from 2004 to 2013 as a lecturer. Furthermore, he was employed as a head of the departments of Electric/Electronic Engineering, and quality office. In addition, during his carrier, he had supervised many projects in Higher Polytechnic Institute of Zliten and Computer Department in Scientist Faculty, Almurgeb University, Zliten. From 2015 up to now he is carrying out a research of PhD in Industrial Engineering at Faculty of Engineering, Universiti Putra Malaysia.

## LIST OF PUBLICATIONS

### Journals

Ali Ahmed Shokshk, Rosnah Mohd Yusuff, Siti Azfanizam Ahmad, Hazreen Haizi Harith, Azizul Rahman Abd Aziz. 2017. The Effect of Load on Whole Body Muscle Activity during Neutral Posture for Malaysian Population. *International Journal of Engineering and Technology*. 14(2), 62-67, FEIIC.

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