



**CONCEPTUAL DESIGN OF SMART PASSIVE EXOSKELETON FOR  
MONITORING LOCALIZED PRESSURE AND POSTURAL ANGLE DURING  
SITTING/STANDING TASKS**

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)



by

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## APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Bachelor Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:



## ABSTRAK

Dalam industri pembuatan, ramai pekerja melaksanakan proses tugas mereka dalam keadaan berdiri yang terlalu lama. Akibat berdiri terlalu lama, pekerja mengalami ketidakselesaan dan keletihan otot di bahagian bawah badan seperti belakang dan kaki. Kawalan kejuruteraan yang dikaitkan dengan exoskeleton duduk dan berdiri boleh dicadangkan untuk menangani masalah isu ergonomik ini. Exoskeleton duduk berdiri komersial semasa adalah terhad kerana dia tidak boleh memanjang secara automatik apabila diperlukan disebabkan tapak tempat duduk tidak stabil untuk menstabilkan kedudukan badan untuk kegunaan jangka masa panjang, dan kekurangan sistem maklum balas ergonomik untuk memaklumkan pengguna tentang perubahan dalam kedudukan dari duduk dan berdiri, begitu juga sebaliknya. Objektif kajian ini adalah untuk menentukan keperluan pengguna dan keperluan reka bentuk exoskeleton duduk-berdiri, mencipta dan menilai kesan exoskeleton duduk dan berdiri yang dihasilkan pada aktiviti otot dan tekanan sentuhan, dan mengintegrasikan exoskeleton duduk dan berdiri dengan sensor tekanan dalam keadaan berdiri dan duduk secara berselang-seli. Tinjauan dalam talian menggunakan borang Google akan dijalankan untuk mengetahui keperluan pekerja industri berkenaan reka bentuk eksoskeleton duduk dan berdiri. Sepuluh orang dewasa muda Malaysia yang sihat berumur 21 – 30 tahun akan dipilih untuk mengkaji kesan exoskeleton berdiri duduk pada aktiviti otot dan tekanan di bahagian punggung. Alat elektromiografi (EMG) (Delsys, USA) akan digunakan untuk mendapatkan isyarat EMG pada otot tibialis anterior, vastus lateralis dan gastrocnemius. Sementara itu, Tikar Tekanan Badan (CONFORMat, USA) akan digunakan untuk menganalisis tekanan sentuhan antara punggung dan tempat duduk eksoskeleton. Hasil kajian, rumusan soal selidik mendapati pekerja industri mengalami gangguan muskuloskeletal akibat berdiri lama. Pekerja industri mengemukakan ciri berikut bagi eksoskeleton duduk berdiri masa hadapan: mudah alih, selesa, kos rendah, stabil, boleh laras, ringan, pergerakan kurang terhad, tampan, mudah digunakan, maklum balas

ergonomik boleh mengingatkan mereka supaya mereka boleh Duduk bergantian atau berdiri semasa anda bekerja. Keputusan EMG menunjukkan bahawa exoskeleton duduk berdiri yang dibangunkan dalam kajian ini mampu mengurangkan pengecutan otot sebanyak 75 peratus, yang mencukupi untuk mengurangkan keletihan otot. Berdasarkan keputusan, kajian ini menyimpulkan bahawa exoskeleton duduk-diri yang dibangunkan dalam kajian ini menunjukkan potensi besar dalam mengurangkan ketidakselesaan subjektif dan keletihan otot yang disebabkan oleh berdiri berpanjangan. Faedah penyelidikan ini ialah ia membuat hipotesis bahawa prototaip exoskeleton duduk akan dapat membantu jurutera industri mengurangkan risiko ergonomik yang berkaitan dengan kedudukan berpanjangan di tempat kerja.



## **ABSTRACT**

In manufacturing industry, many workers perform their task processes in prolonged standing. Due to prolonged standing, workers experienced discomfort and muscle fatigue in the lower body parts such as back and legs. Engineering controls associated with sit-stand exoskeleton can be proposed to resolve these ergonomics issues. The limitations of the current commercial sit-stand exoskeletons are the stand is unable to extend automatically when needed, the base of the stand is not stable to stabilize the body posture for prolonged use, and lack of ergonomics feedback system to alert users in changing positions from sitting and standing, vice-versa. The objectives of this study are to determine users' needs and design requirements of sit-stand exoskeleton, fabricate and evaluate the effects of the fabricated sit-stand exoskeleton on muscle activity and contact pressure, and integrate the sit-stand exoskeleton with a pressure sensor for alternating standing and sitting postures. An online survey using Google form was performed to determine the needs of industrial workers regarding design of the sit-stand exoskeleton. Ten healthy Malaysian young adults aged 21 – 30 years old were selected to study the effects of the sit-stand exoskeleton prototype on the muscle activity and the contact pressure in the buttock. Surface electromyography (EMG) instrument (Delsys, USA) was used to measured and analyzed EMG signals in the tibialis anterior, vastus lateralis, and gastrocnemius muscles. Meanwhile, Body Pressure Mat instrument (CONFORMat, USA) was applied to analyse the contact pressure between the buttock and the exoskeleton seat. As the outcome of the study, the questionnaire survey found that industrial workers suffered from musculoskeletal disorders due to prolonged standing. The industrial workers proposed the following features in the future sit-stand exoskeleton: portable, comfortable, low cost, stable, adjustable, lightweight, low movement restriction, good appearance, easy to use and having ergonomics feedback that can alert them so that they can alternately sit or stand while working. The EMG results showed that the sit-stand exoskeleton developed by this study was able to minimize muscle contraction up to 75 percent which is good

enough for reducing muscle fatigue. Based on the results, this study concluded that the sit-stand exoskeleton developed by this study has shown a great potential to reduce the subjective discomfort and muscle fatigue caused by prolonged standing. The benefit of this study is that study hypothesized that the sit-stand exoskeleton prototype would be able to assist industrial engineers to alleviate the ergonomics risk associated with prolonged standing at workplace.





## DEDICATION

Special dedication my beloved mother, Roslina Binti Abd Malik  
my father and my sister, Ir. Ahmad Apandi Bin Lakin and Aini Ardina Binti Ahmad  
Apandi for giving me moral support, encouragement and also understandings  
Thank You So Much & Love You All Forever



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# Table of Contents

<b>DECLARATION</b>	I
<b>APPROVAL</b>	II
<b>ABSTRACT</b>	III
<b>ABSTRAK</b>	IV
<b>DEDICATION</b>	VI
<b>ACKNOWLEDGEMENT</b>	VII
<b>CHAPTER 1</b>	1
<b>INTRODUCTION</b>	1
1.1 Background of Study	1
1.2 Problem Statement	3
1.2.1 Limitations of the design prototype and commercial sit-stand exoskeletons	3
1.2.2 Lacking ergonomics feedback system to alert users in changing positions from sitting and standing, vice-versa	5
1.3 Objectives	6
1.3.1 Relationship Between Problem Statement and Objective	6
1.4 Scope	7
1.5 Significance/Importance of Study	8
1.6 Organization of the Report	8
1.7 Summary	9
<b>CHAPTER 2</b>	10
<b>LITERATURE REVIEW</b>	10
2.1 Ergonomics Issues Related to Prolonged Standing	10

2.2	Evidence of Negative Health Outcome	11
2.2.1	Cardiovascular Disease	11
2.2.2	Fatigue / Discomfort	12
2.2.3	Low Back Pain	14
2.3	Explanation of Passive Exoskeleton	15
2.3.1	The Chair-Less Chair	15
2.3.2	The Lower Hip Region Support	16
2.3.3	The Thigh Region Support	16
2.3.4	The Calf Region Support	17
2.3.5	The Hydraulic Piston	17
2.3.6	The Shoe and Strap	18
2.4	Exoskeleton for Standing at Workplace	18
2.5	Existing Design of Exoskeleton For Prolonged Standing	19
2.5.1	Design and Preliminary Experimentation of Passive Weight-Support Exoskeleton	19
2.5.2	Effect of Wearable Exoskeleton Chair Based On Muscle Activities	20
2.5.3	Chair-Less Chair for Lumbar Pain Reduction	21
2.6	Description Mechanism and Function Of Existing Design	22
2.6.1	Chair X	22
2.6.2	Chair-less chair for lumbar pain	22
2.6.3	PEXER IV	23
2.7	Advantages and Disadvantages of Existing Design	23
2.8	Malaysian Anthropometry	24
2.9	Difference Between Previous Studies and Current Study	26
2.10	Design on Ergonomic Passive Sit And Stand Exoskeleton	28
2.10.1	Determination of user needs through Questionnaire Form	29
2.10.2	House of Quality	29
2.10.3	Conceptual Design	31
2.10.4	Pugh Concept Selection	32
2.10.5	Concept of Scoring	33
2.11	Analysis and Synthesis of Literature Review	33
2.12	Summary	35

<b>CHAPTER 3</b>	36
<b>METHODOLOGY</b>	36
3.1 Design Requirement of Passive Sit and Stand Exoskeleton	36
3.1.1 Online questionnaire survey	36
3.1.1.1 Flow chart of questionnaire survey	37
3.1.2 House of Quality (HOQ)	38
3.2 Design and Fabricate Passive Sit-stand Exoskeleton	40
3.2.1 Conceptual design	41
3.2.2 Pugh Concept Selection	43
3.2.3 Concept of Scoring	44
3.2.4 Bill of material	45
3.2.5 Fabrication of Passive Sit and Exoskeleton Stand	46
3.2.5.1 Cutting	46
3.2.5.2 Drilling	47
3.3 Evaluating Sit-Stand Exoskeleton on Muscle Activity and Contact Pressure	47
3.3.1 Electromyography (EMG)	48
3.3.2 CONFORMat	52
3.3.3 Compression Test	53
3.3.4 Experimental Procedures	54
<b>CHAPTER 4</b>	56
<b>RESULTS AND DISCUSSION</b>	56
4.1 Design Requirements of Sit-Stand Exoskeleton	56
4.1.1 Questionnaire Survey	56
4.1.2 Quality Function Deployment (QFD)	67
4.1.3 Conceptual Design	70
4.1.4 Pugh Concept Selection	71
4.1.5 Concept Scoring	72
4.1.6 Detail Design	73
4.1.7 Design of 3D with Bill of Material (BOM)	76
4.1.8 Design of Assembly View	77
4.2 Evaluate the Effects of the Fabricated Sit-Stand Exoskeleton	

on Muscle Activity and Contact Pressure	78
4.2.1 Mechanical Compression Test	79
4.2.2 Experimental Results	80
4.3 Integrate The Sit-Stand Exoskeleton with Pressure and Postural Angle Sensors for a Conceptual Smart System of Alternating Standing and Sitting Postures.	98
4.3.1 Pressure Sensor IoT	98
4.3.2 Postural Sensor IoT	103
4.4 Summary	106
<b>CHAPTER 5</b>	108
<b>CONCLUSION AND RECOMMENDATION</b>	108
5.1 Design Requirements of Sit-Stand Exoskeleton	108
5.2 Evaluate the Effects of the Fabricated Sit-Stand Exoskeleton on Muscle Activity and Contact Pressure.	108
5.3 Integrate The Sit-Stand Exoskeleton with Pressure and Postural Angle Sensors for a Conceptual Smart System of Alternating Standing and Sitting Postures.	109
5.4 Recommendation for Future Study	109
5.5 Sustainable Design and Development	109
5.6 Complexity	110
5.6 Life-long Learning	110
<b>APPENDIX</b>	111
<b>REFERENCES</b>	142

## LIST OF FIGURES

Figure 1.1: A worker operating a lathe machine in standing posture	1
Figure 1.2: Muscular aches in the leg due to prolonged standing	2
Figure 1.3: Example Example of discomfort and muscle pain caused by standing for long period of time	3
Figure 1.4: Framework of study	8
Figure 2.1: Design exoskeleton chair-less chair (Malode et al., 2021)	15
Figure 2.2: Thigh region support (Delicia et al., 2020)	16
Figure 2.3: The Hydraulic Piston (Delicia et al., 2020)	17
Figure 2.4: Shoe and strap (Delicia et al., 2020)	18
Figure 2.5: PEXER IV (Hasegawa & Ogura, 2013)	19
Figure 2.6: A wearable exoskeleton chair X (Li et al., 2019)	20
Figure 2.7: Chair-less for lumbar pain reduction (Delicia et al., 2020)	21
Figure 2.8: Design 1, a wearable exoskeleton chair X (Li et al., 2019)	22
Figure 2.9: Design 2, the chair-less for lumbar pain reduction (Delicia et al., 2020)	22
Figure 2.10: Design 3, PEXER IV (Hasegawa & Ogura, 2013)	23
Figure 2.11: The illustration of the measured anthropometric (Karmegam et al., 2011)	24
Figure 2.12: House of Quality (HOQ)	30
Figure 3.1: Flow Chart	37
Figure 3.2: House of Quality (HOQ)	38
Figure 3.3: Flow chart design and fabricate exoskeleton	40
Figure 3.4: Flow chart experimenting the design product	47
Figure 3.5: EMG sensor	48
Figure 3.6: DELSYS EMGworks	48
Figure 3.7: Example of EMG signal	48
Figure 3.8: Pressure Mat	49
Figure 3.9: Software CONFORMat	49
Figure 3.10: Autograph AG-1 100kN	50

Figure 3.11: Design exoskeleton - Foot pressure test (sitting)	52
Figure 3.12: Design exoskeleton - Foot pressure test (standing)	53
Figure 3.13: Commercial exoskeleton - Foot pressure test (sitting)	53
Figure 3.14: Design exoskeleton - Foot pressure test (standing)	54
Figure 3.15: MVC (L) Gastro	54
Figure 3.16: MVC (L) Tibialis	55
Figure 3.17: MVC (L) Vastus	55
Figure 3.18: MVC (R) Gastro	56
Figure 3.19: MVC (R) Tibialis	56
Figure 3.20: MVC (R) Vastus	57
Figure 3.21: (L) Gastro – standing still	57
Figure 3.22: (L) Tibialis – standing still	58
Figure 3.23: (L) Vastus – standing still	58
Figure 3.24: (R) Gastro – standing still	59
Figure 3.25: (R) Tibialis – standing still	59
Figure 3.26: (R) Vastus – standing still	60
Figure 3.27: Design exoskeleton (L) Gastro – sitting	60
Figure 3.28: Design exoskeleton (L) Tibialis - sitting	61
Figure 3.29: Design exoskeleton (L) Vastus - sitting	61
Figure 3.30: Design exoskeleton (R) Gastro - sitting	62
Figure 3.31: Design exoskeleton (R) Tibialis – sitting	62
Figure 3.32: Design exoskeleton (R) Vastus – sitting	63
Figure 3.33: Design exoskeleton (L) Gastro – standing	63
Figure 3.34: Design exoskeleton (L) Tibialis – standing	64
Figure 3.35: Design exoskeleton (L) Vastus – standing	64
Figure 3.36: Design exoskeleton (R) Gastro – standing	65
Figure 3.37: Design exoskeleton (R) Tibialis – standing	65
Figure 3.38: Design exoskeleton (R) Vastus – standing	66
Figure 3.39: Commercial exoskeleton (L) Gastro – sitting	66
Figure 3.40: Commercial exoskeleton (L) Tibialis – sitting	67
Figure 3.41: Commercial exoskeleton (L) Vastus – sitting	67
Figure 3.42: Commercial exoskeleton (R) Gastro – sitting	68
Figure 3.43: Commercial exoskeleton (R) Tibialis – sitting	68



Figure 3.44: Commercial exoskeleton (R) Vastus – sitting	69
Figure 3.45: Commercial exoskeleton (L) Gastro – standing	69
Figure 3.46: Commercial exoskeleton (L) Tibialis – standing	70
Figure 3.47: Commercial exoskeleton (L) Vastus – standing	70
Figure 3.48: Commercial exoskeleton (R) Gastro – standing	71
Figure 3.49: Commercial exoskeleton (R) Tibialis – standing	71
Figure 3.50: Commercial exoskeleton (R) Vastus – standing	72



## LIST OF TABLES

Table 1.1: The stand is unable to extend automatically.	4
Table 1.2: The base of the stand is not stable.	4
Table 1.3: Lack of ergonomic feedback.	5
Table 1.4: Relationship of problem statement and objective	7
Table 2.1: Studies examining prolonged standing and cardiovascular	11
Table 2.2: Studies examining prolonged standing, fatigue & discomfort	12
Table 2.3: Studies examining prolonged standing and LBP	14
Table 2.4: Advantages and Disadvantages of Existing Design	23
Table 2.5: Table of measurement of body and labelled number (Karegam et al., 2011)	25
Table 2.6: Anthropometric of Malay's male (Karmegam et al., 2011)	25
Table 2.7: Anthropometric of Malay's female (Karmegam et al., 2011)	26
Table 2.8: Representative symbol for interrelationship matrix	30
Table 2.9: Representative symbol for co-relationship matrix	30
Table 2.10: Concept Design	31
Table 2.11: Pugh Concept Screening	32
Table 2.12: Rating used for concept comparison and evaluation	32
Table 2.13: Concept Scoring	33
Table 2.14: The differences between past study and current study	34
Table 3.1: Representative symbol for interrelationship matrix	39
Table 3.2: Conceptual Design	41
Table 3.3: Pugh Concept Screening	43
Table 3.4: Rating used for concept comparison and evaluation	43
Table 3.5: Concept Scoring	44
Table 3.6: Steps in operating the EMG	48
Table 3.7: step in operating MVC experiment	49
Table 3.8: step in operating the pressure test	50
Table 3.9: step in operating the compression test	50
Table 3.10: Experimental procedures for EMG test and pressure Test	51

# CHAPTER 1

## INTRODUCTION

In this first chapter explains about background of study, problem statement, objective, scope of the study, the significance of the study, and the organization of the report. The background of study elaborates how the exoskeleton will benefit to the manufacturing industry. The problem statements define the issue that frequently happens in the manufacturing industry that would encourage to design of the sit-stand exoskeleton. Additionally, the problem statement highlights the limitations of the existing prototype and commercial sit-stand exoskeletons. An objective is a clear statement of the project goal to accomplish design prototype. The scope explains the focus and limitation of the study. The significance of this study shows how the exoskeleton prototype will overcome ergonomics issues on prolonged standing at the manufacturing industry. Lastly, the organization of the report demonstrates how this report is carried out in total.

### 1.1 Background of Study

In manufacturing industry, the workers usually practices the action of prolonged standing for their daily jobs. They did not have a choice because the working area would not allow them to rest in a short period of time because of the hazardous environment and to work right beside the machine. Due to prolonged standing, many workers have taken medical leave because of common health injuries. Thus, this can affect the company production process and their performance. Figure 1.1 shows a worker operating a lathe machine for prolong hours in standing posture.



Figure 1.1: A worker operating a lathe machine in standing posture

Prolonged standing is also common in the service sector: sales clerks, food service employees, salons employees, grocery clerks, customer service representatives, flight attendants, receptionists, and security guards. Standing for most of the working day is bad for the lower limbs; it can damage joints, cause muscular aches, and cause foot issues such as heel spurs and flat feet. The most frequent symptom of operating on feet, and generally the first to begin, is leg pain and exhaustion. Standing for two hours causes EMG signs of muscle exhaustion, severe soreness in the lower back, and edema build-up in the feet. Figure 1.2 shows the muscular aches in the leg due to prolonged standing.

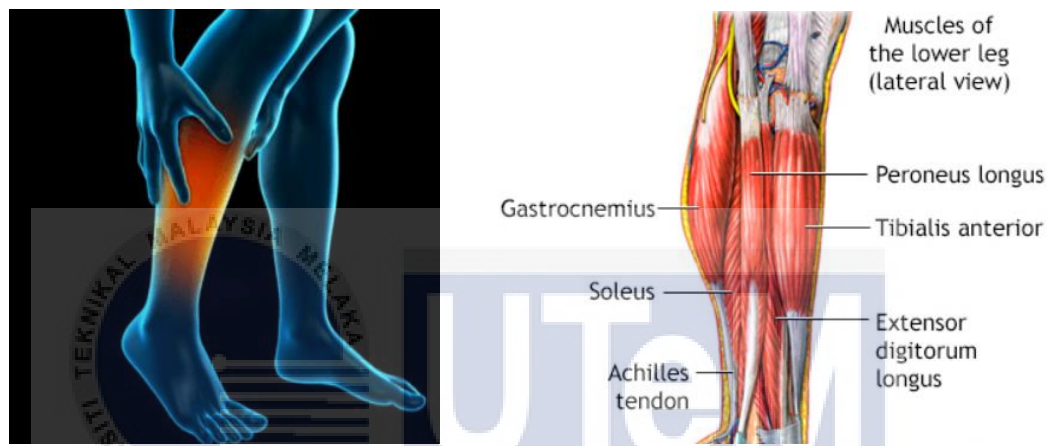


Figure 1.2: Muscular aches in the leg due to prolonged standing

Due to above mentioned issue, the primary goal of this study is to develop a device called passive sit-stand exoskeleton for workers who perform the job in prolonged standing. This passive sit stand exoskeleton can benefit them for preventing muscular aches due to prolonged standing.

## 1.2 Problem Statement

Prolonged standing can cause occupational injuries and physiological discomfort, muscle fatigue, pain and could also contribute to the development of severe health hazards such as Musculoskeletal Disorders (MSDs). MSDs include discomfort and pain in the back, leg, and feet. Figure 1.3 shows discomfort and muscle pain caused by standing for long period of time.



Figure 1.3: Example of discomfort and muscle pain caused by standing for long period of time

To be specific, this study identified several limitations and constraints of the existing prototype and commercial sit-stand exoskeletons through direct observation and literature review, summarized as follow:

### 1.2.1 Limitations of the design prototype and commercial sit-stand exoskeletons

1. The stand is unable to extend automatically when needed:

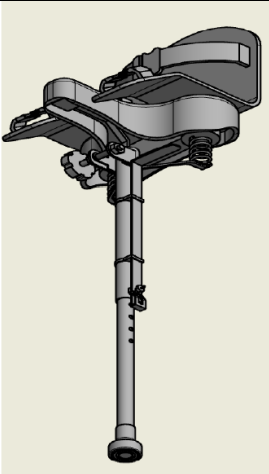

Both existing and commercial exoskeleton can adjust the height by just going down, but it cannot increase the height automatically; thus the user needs to bend to increase the height; this will put the user in the discomfort posture.

Table 1.1: The stand is unable to extend automatically.

Existing prototype of sit-stand exoskeleton	Commercial sit-stand exoskeleton
 <p data-bbox="432 819 612 853">Solehin, 2021</p>	 <p data-bbox="956 826 1299 860">Source: <a href="http://www.noonee.com">www.noonee.com</a></p>

2. The base of the stand is not stable to stabilize the body posture for prolonged use:  
 The bottom platform in the existing exoskeleton is too small same goes with the commercial exoskeleton, but the commercial has two small bottom platforms. When the base is small, it can discomfort the user because it is not stable; thus the user needs to use their leg to steady their position when used. Also, a small base has the potential to tilt backwards, and this would lead the user to fall backward.

Table 1.2: The base of the stand is not stable.

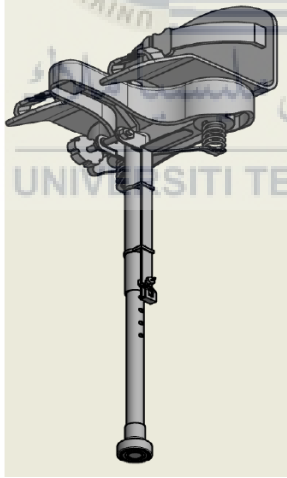

Existing prototype of sit-stand exoskeleton	Commercial sit-stand exoskeleton
 <p data-bbox="432 1924 612 1957">Solehin, 2021</p>	 <p data-bbox="920 1921 1331 1955">Source: <a href="http://www.lexbyastride.com">www.lexbyastride.com</a></p>

**1.2.2 Lacking of ergonomics feedback system to alert users in changing positions from sitting and standing, vice-versa.**

Abundant published literature highlighted that ergonomics interventions using a wearable sit-stand exoskeleton are helpful to minimize muscle fatigue associated with prolonged standing. However, far too little attention has been paid to studying and visualizing the trend/ pattern of data such as force and contact pressure in contact areas such as buttock and feet. Yet, information of force, contact pressure, and time workers start to feel discomfort/ numbness (onset of fatigue) is still unknown.

There are commercial products and prototypes of wearable sit-stand exoskeleton developed by manufacturers and past researchers; however, an exoskeleton that can alert the users (workers) to alternate sit/stand based on quantitative data (postural angle, contact pressure, and time) requires a further study.

Table 1.3: Lack of ergonomic feedback.

Existing prototype of sit-stand exoskeleton	Commercial sit-stand exoskeleton
 <p data-bbox="432 1641 612 1675">Solehin, 2021</p>	 <p data-bbox="954 1641 1302 1675">Source: <a href="http://www.archelis.com">www.archelis.com</a></p>

### 1.3 Objectives

- a) To determine users' needs and design requirements of sit-stand exoskeleton from Malaysian industrial workers.
- b) To evaluate the effects of the fabricated sit-stand exoskeleton on muscle activity and contact pressure of the users.
- c) To integrate the sit-stand exoskeleton with pressure and postural angle sensors for a conceptual smart system of alternating standing and sitting postures.

#### 1.3.1 Relationship between Problem Statement and Objective

A problem statement is a statement of a current issue or a flaw that needs to be repaired and improves. In design 1, the stand is unable to extend automatically, the user needs to bend to increase the height; this will put the user in the discomfort posture. Design 2, the base of the stand is not stable, it can discomfort the user because it is not stable; thus the users' needs to use their leg to steady their position when used. Design 3, it lack of ergonomics feedback, this is a feature must have because it can inform the worker of what positios there in. An objective is a clear statement of the project goal to accomplish design prototype. The first objective is to determine user needs, where is this study a survey would be conducted and evaluate the feedback. The second objective is to evaluate the fabricated sit-stand exoskeleton, where in this study an exoskeleton is being design and fabricated base on collected feedback. The third objective is to integrate the exoskeleton with pressure sensor, where in this study the product and its features is being testes where it would meet user expectation. Table 1.4 shows the relationship of problem statement and objective.