

ACKNOWLEDGEMENTS

Praised belongs to Allah (SWT) who has bestowed upon me the strength and will to complete this thesis. Peace and blessings of Allah are due to His messenger, the Prophet Muhammad (SAW) and his family.

I would like to express my sincere thanks and profound appreciation to those individuals who have contributed towards the completion and submission of this thesis. Among those that I take pleasure to mention included:

- i) Associate Professor Dr. Siti Zawiah Md. Dawal my supervisor for her advices, supervision and cooperation throughout the preparation of this thesis.
- ii) Professor Dr. Zahari Taha, my ex-supervisor for his guidance and advice during the early course of the research.
- iii) Dean of Graduate Studies, Dean of the Faculty of Engineering, Deputy Dean of Post Graduate Study, Head of Department and all staff members from the Department of Engineering Design and Manufacture and also to my friends who have assisted me during this research at the University of Malaya.
- iv) Professor Dr. Tengku Aizan Abdul Hamid, Director of Institute of Gerontology, University Putra Malaysia and Associate Professor Dr Ar.

Azizah Salim from the Department of Architecture, University Putra Malaysia for their guidance and encouragement in elderly research projects.

- v) Department of Social Welfare under the Ministry of Women, Family and Community Development Malaysia for his permission and support to make data collection possible.
- vi) To all participants involved in this research.
- vii) Finally, my dear wife Farida Abdul Matheen who showered me with support, encouragement, confidence, suggestion and for her constantly prayed throughout the years. Last but not least, my children Faruq Arrasyid, Fatin Fasehhah, Fakhrul Anwar and Fayyadh Aslam who constantly prayed and bore the strain of the work throughout the years.

May Allah reward His blessing on them for their sincere corporation and may Allah accept this little effort in seeking His pleasure.

Special thanks to University of Malaya, Kuala Lumpur for funding this research under Research Grant No. IPPP/UPPiT/Geran(RU/PPP) PS040/2008A.

ABSTRACT

Malaysia is expected to become an aged society by year 2020, hence there is a need to prolong the independency of its senior citizens by improving their residential environment. This thesis aimed to increase elderly independency and their quality of life by ergonomic means to let them live independently as long as possible.

The main research question is; what is the role of ergonomics in enhancing comfort perception for improving residential built environment for the Malaysian elderly population? Besides this main research question, there are four sub-research questions in this study namely; what is the present state of living among elderly population in Malaysia, which ergonomic factors are affecting task performance of elderly population in their homes, what are the significant factors for enhancing comfort perception among elderly person when they perform their tasks, and what are the recommendations for ergonomic interventions that could enhance comfort perception for improving residential built environment for the elderly population.

From these research questions some construct descriptions were identified. They are elderly population, ergonomics, enhanced comfort perception, and improved residential built environment. From these constructs four research objectives were structured. They are; to understand the present state of living among elderly population in Malaysia, to identify significant ergonomic factors that affecting task performance of elderly population in their homes, to determine significant anthropometric dimensions that could enhanced comfort perception among elderly person when performing their task in the kitchen, and to develop anthropometric workstation design model that could enhance comfort perception for elderly in the kitchen. The main hypothesis was 'Comfort Perception improved (when) Postural Measurement and Physiological Limitation matched with acceptable range during task performance'.

Chapter 1 is the introduction of the thesis. It consists of background study, issues relating to elderly in Malaysia, problem statements, research questions, research objectives, theoretical framework, inquiry strategy, expected findings, scope and limitation, significance of study, expected contribution and explains the organization of the thesis. Chapter 2 presents the literature review on ergonomics, enhance elderly comfort perception, task performance and improving residential built environment. Chapter 3 presents the method used, the subjects, apparatus and type of data. The eagle table research framework provides explicit information regarding the whole methodology of this study. This includes general survey, elderly critical task, major data acquisition, and validating elderly comfort perception. Chapter 4 explains the result of the study includes selection of subjects, elderly demography, results from the survey. It also presents the result of affecting factors against activity of frying such as postural assessment, physiology, anthropometry, kitchen environment and kitchen triangle distance. Chapter 5 explains the prototype fabrication and testing, setting-up the experiment, results of postural assessment and Rapid Entire Body Assessment (REBA), formulation to predict custom stove height and discussion on experiment. Chapter 6 explains ergonomic design criteria, proposed ergonomics design model, discussed on guidelines and challenges in elderly research. Chapter 7 summarizes the output and knowledge contribution of the study. This includes the key findings, limitation of the research and major contribution. Finally suggests what could be done for future work.

There are 30 subjects taking part in this study. They are aged between 60 to 83 years with the mean of age at 67.1 year. From the survey, frying was identified as most important and most tiring task. It was then selected to be the case study. Three environmental parameters obtained from the study were temperature (26.0°C), light (800 lux) and relative humidity (70.0%RH). Based on the findings ten kitchen triangle distances were exceeded 792cm (26') of the National Kitchen and Bath Association (NKBA) guidelines. Volume of Oxygen (VO₂)

was used to measure physiological limitation. Based on the results, severity of five minutes frying task for Malaysian elderly could be classified as “Light Work”. However, eight elderly were found having higher volume of oxygen consumption. The anthropometry measurements were applied to estimate frying task envelope. The elbow height and elbow-thumb-tip length were used with the equation to predict individual stove height. Postural measurements were applied to evaluate armpit angle and elbow angle whilst performing frying task. It proved that many elderly having the wrong stove height that could cause fatigue. REBA score was done twice; observation on actual frying task in elderly’s kitchen (90% at medium risk) and observation on frying task using the adjustable table-top with their preferable height (0.07% at low risk and 99.93% safe). It proved by improving the elderly comfort perception could improve the frying task and increased their quality of life. Cornell body parts diagram was used with questionnaire to evaluate strain, pain and fatigue among the elderly upon frying. It was found upper arm, shoulder, neck and upper back, and lower back rated at ‘very fatigue’.

Results from this study shows that the most significant comfort perception factor was the stove height. It has relationships with anthropometry, task performance, strain and fatigue, physiological limitation and postural measurement. An adjustable table-top was designed and fabricated to test and validate the equations for setting individual stove height based on his/her anthropometry. It was found that the elderly preferable stove height were within the range of what was calculated by the equation. Therefore the equation could be used to predict individual stove height.

In conclusion, the increase in the aging population in Malaysia is inevitable. The aged population has its own unique problems and will generate new challenges and demands to designers, engineers and ergonomists. We will all age and we later on become independent and require the services for the aged at some point in time.

ABSTRAK

Malaysia dijangka akan menjadi negara tua pada tahun 2020, oleh itu terdapat keperluan untuk memanjangkan keupayaan berdikari di kalangan warga tua dengan meningkatkan kualiti persekitaran kediaman mereka. Tesis ini bertujuan untuk meningkatkan keupayaan berdikari di kalangan warga tua dan memperbaiki kualiti hidup mereka dengan pendekatan ergonomik untuk membolehkan mereka hidup berdikari selama mungkin.

Persoalan utama kajian adalah; apakah peranan ergonomik dalam meningkatkan persepsi keselesaan untuk meningkatkan persekitaran binaan bangunan bagi penduduk warga tua di Malaysia? Di samping persoalan utama kajian, terdapat empat sub-persoalan kajian dalam kajian ini iaitu; apakah taraf kehidupan semasa di kalangan penduduk warga tua di Malaysia, apakah faktor ergonomik yang boleh menjejaskan prestasi tugas penduduk warga tua di rumah mereka, apakah faktor-faktor yang penting bagi meningkatkan persepsi keselesaan di kalangan warga tua apabila mereka melaksanakan tugas-tugas harian, dan apakah cadangan pendekatan ergonomik yang boleh meningkatkan persepsi keselesaan untuk menambah baik persekitaran binaan kediaman untuk mereka.

Daripada soalan-soalan penyelidikan, beberapa penerangan konstruktif telah dikenal pasti. Ia adalah penduduk warga tua, ergonomik, meningkatkan persepsi keselesaan, dan memperbaiki persekitaran binaan kediaman. Dari situ, empat objektif kajian telah dibina. Objektif tersebut adalah; untuk memahami taraf hidup semasa di kalangan penduduk warga tua di Malaysia, untuk mengenal pasti faktor-faktor penting ergonomik yang menjejaskan prestasi tugas penduduk warga tua di rumah mereka, untuk menentukan dimensi utama antropometri yang boleh mempertingkatkan persepsi keselesaan di kalangan warga tua apabila melaksanakan tugas mereka di dapur, dan untuk membangunkan reka bentuk mejakerja berpandukan model

antropometri yang boleh meningkatkan persepsi keselesaan di kalangan mereka ketika bekerja di dapur.

Hipotesis utama dalam kajian ini ialah; Persepsi Keselesaan meningkat (apabila) pengukuran postur dan had fisiologi sepadan dengan julat yang boleh diterima ketika melaksanakan tugas.

Bab 1 merupakan pengenalan tesis. Ia terdiri daripada kajian latar belakang, isu-isu yang berkaitan dengan warga tua di Malaysia, pernyataan masalah, soalan kajian, objektif kajian, kerangka teori, strategi inkuiri, penemuan yang dijangkakan, skop dan had, kepentingan kajian, jangkaan sumbangan dan menerangkan organisasi tesis. Bab 2 membentangkan kesusasteraan tentang ergonomik, meningkatkan persepsi keselesaan warga tua, prestasi tugas dan menambah baik persekitaran binaan kediaman. Bab 3 membentangkan kaedah yang digunakan, peserta kajian, alat dan jenis data. 'Eagle table research framework' menyediakan maklumat jelas mengenai keseluruhan metodologi kajian ini. Ia termasuk kajian umum, tugas kritikal warga tua, pemerolehan data utama, dan mengesahkan persepsi keselesaan warga tua. Bab 4 menerangkan hasil kajian ini termasuk pemilihan peserta kajian dan demografi warga tua. Ia juga membentangkan hasil daripada faktor-faktor yang memberi kesan terhadap aktiviti menggoreng seperti penilaian postur, fisiologi, antropometri, persekitaran dapur dan jarak segitiga dapur. Bab 5 menjelaskan fabrikasi prototaip dan ujian, mengadakan ujian, keputusan penilaian postur dan REBA, penggunaan formula untuk meramalkan ketinggian dapur dan perbincangan mengenai eksperimen. Bab 6 menerangkan kriteria reka bentuk ergonomik, cadangan reka bentuk model ergonomik, membincangkan garis panduan dan cabaran dalam penyelidikan. Bab 7 adalah ringkasan sumbangan kepada ilmu pengetahuan. Ini termasuk penemuan penting, had penyelidikan dan sumbangan utama. Akhirnya mencadangkan apa yang boleh dilakukan untuk kerja-kerja akan datang. Seramai 30 orang warga tua telah mengambil bahagian dalam kajian ini. Mereka berusia antara 60 hingga 83 tahun dengan min umur pada 67.1 tahun.

Daripada kajian itu, menggoreng telah dikenalpasti sebagai tugas yang paling penting dan yang paling memעותkan. Ia kemudian dipilih menjadi kajian kes. Tiga parameter persekitaran yang diperoleh daripada kajian ini ialah suhu (26.0 ° C), cahaya (800 lux) dan kelembapan (70.0% RH). Berdasarkan dapatan jarak sepuluh segitiga dapur telah melebihi 792 sm (26') berbanding garis panduan yang dikeluarkan oleh NKBA.

Bagi mengukur had fisiologi warga tua ketika memasak, kandungan oksigen (VO₂) dalam pernafasan digunakan. Berpandukan keputusan kajian, tahap keterukan beban kerja untuk melaksanakan tugas menggoreng selama 5 minit di kalangan warga tua Malaysia boleh diklasifikasikan sebagai “Tugas Ringan”. Namun terdapat 8 orang warga tua yang mengambil kadar oksigen yang tinggi berbanding dengan yang lain.

Pengukuran antropometri telah digunakan untuk menganggar saiz ruang kerja ketika menggoreng. Ketinggian siku dan panjang siku ke hujung jari digunakan dengan ‘equation’ untuk meramalkan ketinggian dapur individu. Ukuran postur telah digunakan untuk menilai sudut ketiak dan sudut siku semasa menggoreng. Ia membuktikan bahawa ramai warga tua mempunyai ketinggian dapur yang salah di mana ia boleh meningkatkan tahap keletihan.

Skor REBA dilakukan sebanyak dua kali; iaitu pemerhatian sebenar ketika tugas menggoreng di dapur asal (90% berisiko sederhana) dan pemerhatian ketika tugas menggoreng menggunakan meja bolehlaras dengan ketinggian mereka (0.07% risiko terendah dan 99.93% memasak dengan tahap selamat). Ia terbukti dengan meningkatkan persepsi keselesaan warga tua boleh meningkatkan tugas menggoreng dan peningkatan kualiti hidup mereka. Rajah bahagian tubuh Cornell digunakan bersama soal selidik untuk menilai ketegangan, sakit dan keletihan di kalangan warga tua ketika menggoreng. Adalah didapati lengan, bahu, leher dan bahagian atas belakang dan bawah belakang dinilai sebagai 'sangat meletihkan'. Hasil daripada kajian ini menunjukkan bahawa faktor persepsi keselesaan yang paling penting ialah

ketinggian dapur. Ia mempunyai hubungan dengan antropometri, prestasi kerja, tekanan dan keletihan, had fisiologi dan pengukuran postur tubuh.

Satu meja bolehlaras telah direkabentuk dan dibina untuk menguji dan mengesahkan 'equation' penetapan keselesaan ketinggian dapur individu berdasarkan antropometri mereka. Adalah didapati bahawa keselesaan ketinggian dapur yang dipilih berada dalam julat yang sama dengan yang dikira menggunakan 'equation'. Oleh itu 'equation' ini boleh digunakan untuk meramal ketinggian dapur individu.

TABLE OF CONTENTS

| | |
|--|-------|
| ACKNOWLEDGEMENTS..... | i |
| ABSTRACT..... | iii |
| ABSTRAK..... | vi |
| TABLE OF CONTENTS..... | x |
| LIST OF FIGURES..... | xvi |
| LIST OF TABLES..... | xvii |
| NOMENCLATURE..... | xviii |
| List of equations..... | xviii |
| LIST OF ABBRIVIATIONS..... | xix |
| | |
| CHAPTER 1 INTRODUCTION..... | 1 |
| 1.1 Introduction..... | 1 |
| 1.2 Context and Background of Study..... | 1 |
| 1.3 Delay Issues Relating to Elderly Population in Malaysia..... | 4 |
| 1.4 Problem Statement..... | 8 |
| 1.5 Research Questions..... | 11 |
| 1.6 Research Aims and Objectives..... | 11 |
| 1.7 Theoretical Framework..... | 12 |
| 1.8 Inquiry Strategy..... | 13 |
| 1.9 Expected Findings..... | 14 |
| 1.10 Scope and Limitations..... | 16 |
| 1.11 Significance of the Study..... | 17 |
| 1.12 Expected Contributions..... | 17 |
| 1.13 Organisation of the Thesis..... | 18 |
| | |
| CHAPTER 2 LITERATURE REVIEW..... | 21 |
| 2.1 Introduction..... | 21 |
| 2.2 Ergonomics..... | 21 |
| 2.2.1 Definition of Ergonomics..... | 21 |
| 2.2.2 General Introduction to Ergonomics..... | 22 |
| 2.3 Enhance Comfort Perception..... | 23 |
| 2.3.1 Definition of Comfort Perception..... | 23 |
| 2.3.2 General Introduction to Comfort Perceptions..... | 23 |

| | | |
|-----------------------------|---|----|
| 2.3.3 | Theories on Comfort Perception | 24 |
| 2.3.4 | Gap Analysis of Comfort Perception | 24 |
| 2.3.5 | Factors Enhancing Comfort Perception among Elderly | 24 |
| 2.3.6 | Comfort Perception Factors that could Support Task Performance by Elderly..... | 25 |
| 2.4 | Task Performance | 25 |
| 2.4.1 | Definition of Task and Task Performance..... | 25 |
| 2.4.2 | Selection of IADL task..... | 25 |
| 2.4.3 | Factors Affecting Frying among the Elderly..... | 26 |
| 2.4.4 | Physiological Capabilities..... | 26 |
| 2.4.5 | User's Anthropometry towards Task and Space Setting..... | 27 |
| 2.4.6 | Working Posture..... | 28 |
| 2.4.7 | Working Space Environmental Factors..... | 32 |
| 2.4.8 | Kitchen Design and Triangle Distance..... | 34 |
| 2.5 | Improving Residential Built Environment through Ergonomics..... | 37 |
| 2.5.1 | Current Design Guidelines for Elderly Residential..... | 37 |
| 2.5.2 | Ergonomic Intervention that could Enhance Comfort Perception for Improving Residential Built Environment for the Elderly Population.... | 38 |
| 2.5.3 | Improving Task Performance by Ergonomic Means..... | 38 |
| 2.5.4 | Developing Anthropometric Workstation Design Model for Elderly in the Kitchen..... | 39 |
| 2.5.5 | Prototype of Adjustable Working Table..... | 39 |
| 2.6 | Summary..... | 40 |
| CHAPTER 3 METHODOLOGY | | 41 |
| 3.1 | Introduction..... | 41 |
| 3.2 | Eagle Table Research Framework | 43 |
| 3.3 | General Survey..... | 43 |
| 3.3.1 | Elderly Demography | 44 |
| 3.3.2 | Gender and Age | 45 |
| 3.3.3 | Health Condition..... | 45 |
| 3.3.4 | Sample Size..... | 46 |
| 3.4 | Elderly's Critical Task | 46 |
| 3.5 | Major Data Acquisitions | 47 |
| 3.5.1 | Postural Measurement..... | 47 |
| 3.5.2 | Physiological Measurement..... | 49 |

| | | |
|-------|---|-----------|
| 3.5.3 | Anthropometrics Measurement..... | 50 |
| 3.5.4 | Environmental Measurement | 51 |
| 3.5.5 | Kitchen Triangle Distance | 53 |
| 3.6 | Questionnaires..... | 54 |
| 3.6.1 | Measuring the Most Important IADL | 54 |
| 3.6.2 | Measuring the Most Tiring IADL..... | 55 |
| 3.6.3 | Rapid Entire Body Assessment (REBA) | 55 |
| 3.7 | Data Analysis | 56 |
| 3.7.1 | Anthropometry..... | 56 |
| 3.7.2 | Task Performance..... | 57 |
| 3.7.3 | Strain and Fatigue..... | 57 |
| 3.7.4 | Physiological Limitation..... | 57 |
| 3.7.5 | Postural Measurement..... | 57 |
| 3.7.6 | Comfort Perception on Environment (light, temperature and humidity)..... | 57 |
| 3.7.7 | Comfort Perception on Environment (kitchen triangle distance)..... | 58 |
| 3.7.8 | Comfort Perception on Environment (stove height)..... | 58 |
| 3.8 | Validation of Elderly Comfort Perception..... | 58 |
| 3.8.1 | Comfort perception on anthropometry..... | 58 |
| 3.8.2 | Comfort perception on postural measurement..... | 58 |
| 3.8.3 | Comfort perception on kitchen environment..... | 58 |
| 3.8.4 | Comfort perception on kitchen triangle distance..... | 59 |
| 3.8.5 | Comfort perception on physiological limitation..... | 59 |
| 3.9 | Summary | 59 |
| | CHAPTER 4 RESULTS | 60 |
| 4.1 | Introduction..... | 60 |
| 4.2 | Selection of Subjects..... | 60 |
| 4.3 | Elderly Demography..... | 61 |
| 4.4 | Results of IADL tasks from Preliminary Survey | 63 |
| 4.4.1 | Measuring most important task..... | 65 |
| 4.4.2 | Measuring most tiring task..... | 66 |
| 4.4.3 | Correlations between meal preparation and house-keeping..... | 67 |
| 4.5 | Results of All Factors..... | 67 |
| 4.5.1 | Physiological Factor..... | 67 |
| 4.5.2 | Anthropometrical Factor | 70 |

| | | |
|--|---|-----|
| 4.5.3 | Environmental Factor..... | 72 |
| 4.5.4 | Kitchen Triangle Distance Factor | 74 |
| 4.5.5 | Postural Factor | 76 |
| 4.5.6 | Strain, Pain and Fatigue | 79 |
| 4.6 | Summary..... | 83 |
| CHAPTER 5 PROTOTYPE FABRICATION AND TESTING..... | | 86 |
| 5.1 | Introduction..... | 86 |
| 5.2 | Fabrication of an Adjustable Table-top | 86 |
| 5.3 | Setting-up the Experiment | 88 |
| 5.4 | Results..... | 89 |
| 5.4.1 | Postural measurement..... | 89 |
| 5.4.2 | Rapid Entire Body Assessment (REBA)..... | 90 |
| 5.5 | Prediction of Custom Stove Table-top Height using Equation..... | 90 |
| 5.6 | Discussions..... | 93 |
| 5.7 | Summary..... | 93 |
| CHAPTER 6 DISCUSSION | | 95 |
| 6.1 | Introduction..... | 95 |
| 6.2 | Ergonomic design criteria of the elderly kitchen..... | 95 |
| 6.2.1 | Anthropometry..... | 95 |
| 6.2.2 | Postural Measurement and REBA..... | 96 |
| 6.2.3 | Physiology..... | 96 |
| 6.2.4 | Kitchen Environment..... | 97 |
| 6.2.5 | Kitchen Triangle Distance..... | 97 |
| 6.3 | Review of the Proposed Ergonomic Design Model..... | 98 |
| 6.4 | Challengers in elderly research..... | 99 |
| 6.4.1 | Getting the participants | 99 |
| 6.4.2 | Entering kitchens for data collection | 99 |
| 6.4.3 | Environmental data collection | 100 |

| | | |
|-----------|---|-----|
| 6.5 | Current and Proposed Guidelines | 101 |
| 6.6 | Summary | 101 |
| CHAPTER 7 | CONCLUSIONS AND FUTURE WORK | 102 |
| 7.1 | Introduction..... | 102 |
| 7.2 | Key Findings and Output of the Study | 103 |
| 7.3 | Limitations of the Study..... | 103 |
| 7.4 | Major Contributions..... | 104 |
| 7.4.1 | Develop and Propose Anthropometric Workstation Design Model for the Elderly in the Kitchen..... | 104 |
| 7.4.2 | Develop Equation for Custom Table-top Height Setting..... | 104 |
| 7.4.3 | Propose Ergonomic Solution by Fabricating and Testing Stove Table-top Prototype..... | 104 |
| 7.4.4 | Propose Kitchen Environment Design Guidelines | 105 |
| 7.4.5 | Promoting ‘living-in-place’ for Malaysian Elderly Population..... | 105 |
| 7.5 | Recommendation for Future Work | 105 |
| | REFERENCES..... | 107 |
| | APPENDIX A..... | 115 |
| | APPENDIX B..... | 117 |
| | APPENDIX C..... | 118 |
| | APPENDIX D..... | 119 |
| | APPENDIX E..... | 120 |
| | APPENDIX F..... | 121 |
| | APPENDIX G..... | 122 |
| | APPENDIX H..... | 123 |
| | APPENDIX I..... | 124 |
| | APPENDIX J..... | 139 |
| | APPENDIX K..... | 143 |
| | APPENDIX L..... | 144 |
| | APPENDIX M | 146 |

LIST OF FIGURES

| | |
|--|----|
| Figure 2.1 The table-top is higher than the waist height. | 29 |
| Figure 2.2 The stove is too high compared to the her anthropometry..... | 30 |
| Figure 2.3 Low table-top height | 30 |
| Figure 2.4 Neck Extension (A) and Flexion (B) | 31 |
| Figure 2.5 Gallery-type kitchen triangle | 36 |
| Figure 2.6 L-type kitchen triangle | 36 |
| Figure 2.7 U-type kitchen triangle | 37 |
| Figure 3.1 The red mark 'A' is the location of Sungai Merab..... | 44 |
| Figure 3.2 Site location of Sungai Merab (2° 95' N, 101° 79' E)..... | 45 |
| Figure 3.3 Panasonic video camera Model AG-DVX102BE | 48 |
| Figure 3.4 Reflective markers available in the market | 48 |
| Figure 3.5 Strobe light is used to increase markers reflectiveness | 48 |
| Figure 3.6 Vernier LabPro Data Logger | 50 |
| Figure 3.7 Vernier Oxygen Gas Sensor..... | 50 |
| Figure 3.8 Anthropometer used to measure elderly person's physical dimensions..... | 51 |
| Figure 3.9 Equipment for environmental measurement (EXTECH 45170)..... | 53 |
| Figure 3.10 Standard 8 meter measuring tape..... | 54 |
| Figure 3.11 Example of a REBA Score Sheet (Hignett and McAtamney)..... | 56 |
| Figure 4.1 Graph shows oxygen readings generated by the software | 67 |
| Figure 4.2 Results of VO ₂ (n=30) | 68 |
| Figure 4.3 Cornell body parts diagram | 80 |
| Figure 5.1 CAD Drawing of the adjustable table-top height..... | 87 |
| Figure 5.2 Prototype of the adjustable table-top height..... | 87 |
| Figure 5.3 Image shows height lock, hydraulic bottle jack and a steel ruler | 88 |
| Figure 5.4 Earlier data on armpit and elbow angles | 89 |
| Figure 5.5 Improved armpit and elbow angles..... | 89 |
| Figure 5.6 Dimensions used in the formulae to obtain 'X' measurement | 91 |

LIST OF TABLES

| | |
|--|----|
| Table 1.0 Eagle Research Design Table | 9 |
| Table 3.0 Eagle Table Research Framework..... | 41 |
| Table 4.1 Statistics on Age | 61 |
| Table 4.2 Overall statistics on Age, Gender, Ethnic and Religion..... | 62 |
| Table 4.3 Statistics on Gender..... | 62 |
| Table 4.4 Statistics on Ethnic | 62 |
| Table 4.5 Statistics on Religion | 63 |
| Table 4.6 Descriptive Statistics on House Keeping and Meal Preparation | 63 |
| Table 4.7 Statistics on House Keeping and Meal Preparation | 64 |
| Table 4.8 Statistics on house-keeping importance level | 64 |
| Table 4.9 Statistics on meal preparation importance level | 64 |
| Table 4.10 Statistics on house-keeping tiredness level | 65 |
| Table 4.11 Statistics on meal preparation tiredness level | 65 |
| Table 4.12 Correlation between meal preparation and house-keeping..... | 66 |
| Table 4.13 Severity of work in terms of volume of oxygen consumption (VO ₂)..... | 69 |
| Table 4.14 Statistics on volume of oxygen consumption (VO ₂)..... | 69 |
| Table 4.15 Statistics on stature height..... | 70 |
| Table 4.16 Statistics on waist height..... | 71 |
| Table 4.17 Statistics on arm reach forward..... | 71 |
| Table 4.18 Statistics on arm span..... | 71 |
| Table 4.19 Statistics on shoulder height..... | 71 |
| Table 4.20 Descriptive statistics on light, temperature and humidity..... | 72 |
| Table 4.21 Descriptive statistics show the frequency of elderly comfort perception on kitchen temperature..... | 73 |
| Table 4.22 Descriptive statistics show the frequency of elderly comfort perception on kitchen brightness level..... | 74 |
| Table 4.23 Descriptive statistics of kitchen triangle distances..... | 75 |
| Table 4.24 Walking and leg fatigue or pain level..... | 75 |
| Table 4.25 Angles related to frying task performed at elderly kitchens..... | 77 |
| Table 4.26 Angles related to frying using adjustable stove table-top..... | 78 |
| Table 4.27 REBA score based on actual elderly stove table-top height..... | 79 |
| Table 4.28 REBA score based on the elderly comfort perception using the adjustable stove table-top height..... | 79 |
| Table 4.29 Descriptive statistics on fatigue level of foot..... | 81 |
| Table 4.30 Descriptive statistics on fatigue level of shank/lower leg..... | 81 |
| Table 4.31 Descriptive statistics on fatigue level of thighs..... | 81 |
| Table 4.32 Descriptive statistics on fatigue level of forearm..... | 82 |
| Table 4.33 Descriptive statistics on fatigue level of upper arm..... | 82 |
| Table 4.34 Descriptive statistics on fatigue level of lower back..... | 82 |
| Table 4.35 Descriptive statistics on fatigue level of upper back..... | 82 |

| | |
|---|----|
| Table 4.36 Descriptive statistics on fatigue level of shoulder..... | 82 |
| Table 4.37 Descriptive statistics on fatigue level of neck..... | 83 |
| Table 4.38 Relationship between Comfort Perception Variables..... | 83 |
| Table 4.39 Most Significant Comfort Perception Factor..... | 84 |
| Table 5.1 REBA score of the tested group..... | 90 |
| Table 5.2 Range of stove table-top height (n=12)..... | 92 |

NOMENCLATURE

| | |
|----------|---------------------------|
| α | Cronbach alpha |
| bpm | beat per minute |
| °C | Temperature in Celsius |
| °F | Temperature in Fahrenheit |
| Fc | Footcandles |
| K | Kelvin |
| Lux | Unit of luminance (lux) |
| n | Sample size |

LIST OF EQUATIONS

| | |
|------------|--|
| Equation 1 | General equation to measuring the stove table-top height |
| Equation 2 | Measuring stove table-top height when the angle is 20° |
| Equation 3 | Measuring stove table-top height when the angle is 15° |
| Equation 4 | Measuring stove table-top height when the angle is 10° |
| Equation 5 | Measuring stove table-top height when the angle is 5° |

LIST OF ABBRIVIATIONS

| | |
|-----------------|--|
| AARP | American Association of Retired Person |
| ADL | Activities of Daily Living |
| ASHRAE | American Society of Heating and Refrigerating Engineers |
| BADL | Basic Activities of Daily Living |
| CAD | Computer Aided Design |
| DHM | Digital Human Models |
| DVT | Digital Video Tape |
| EKG | Electrocardiogram (ECG) |
| HDD | Hard Disk Drivers |
| IADL | Instrumental Activities of Daily Living |
| IEA | International Ergonomics Association |
| NASA | National Aeronautics and Space Administration of America |
| NKBA | National Kitchen & Bath Association |
| O ₂ | Oxygen |
| OCD | Occupational Cervicobrachial Disorder |
| REBA | Rapid Entire Body Assessment |
| RH | Relative Humidity |
| RULA | Rapid Upper Limb Assessment |
| ULD | Upper Limb Disorder |
| VO ₂ | Volume of Oxygen |
| WRMSD | Work Related Musculoskeletal Disorder |