AN INNOVATIVE ERGONOMIC DESIGN OF CLASSROOM DESKTOP-CHAIR AND ITS ANALYSIS BASED ON ANTHROPOMETRIC MEASUREMENTS AT TERTIARY INSTITUTIONS.
CASE STUDY: UASIN-GISHU COUNTY, KENYA

BY

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DECLARATION

Declaration by the Candidate

This thesis is my original work and has not been presented for a degree in any other University. No part of this thesis may be reproduced without the prior written permission of the author and/or Moi University.

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DEDICATION

To

my father who ensured that I excelled in education,

Mr. Elnour Ahmed

my brothers and sisters (Mr. Adam, Mr. Ahmed, Mrs. Mona, and Mrs. Rabha)

For the continual love, support & encouragement.

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ABSTRACT

The design of classroom desktop-chairs (one size fits all) in many institutions is usually done with no consideration of anthropometric. This may cause musculoskeletal disorders and affect learning effectiveness due to sitting for a long time in awkward position. The main objective of this research was to use the concept of innovative ergonomics to design and analyse a classroom desktop-chair for students in Uasin-Gishu County. The specific objectives were: to collect anthropometric data for students from four selected tertiary institutions; to design a desktop-chair using the collected anthropometric measurements and to analyse the desktop-chair design using RULA ergonomic analytical tool. The sample size of 382 was determined according to Homkhiew et al. (2012). Anthropometric data was collected from a total of 382 students of both genders from four selected institutions within Uasin-Gishu County. The selected institutions for the survey were Moi University (MU), University of Eldoret (UoE), Rift Valley Technical Training Institute (RVTTI) and The Eldoret National Polytechnic (TENP). All fourteen (14) anthropometric measurements were taken (stature, sitting height, shoulder height, popliteal height, hip breadth, elbow height, buttock popliteal length, buttock knee length, thigh clearance, eye height, shoulder breadth, knee height, body mass and forearm fingertip length) from students with the help of anthropometric tools. The research applied fundamental engineering principles of product design and was carried out in compliance with ISO 7250-1:2017. The anthropometric data from four subject institutions were compared using one-way ANOVA analysis. The data obtained was analysed using Minitab 17.0 statistical package, to get the mean, standard deviation, minimum, maximum, 5^{th}, 50^{th} and 95^{th} percentiles. Using the collected anthropometric data, a students' desktop-chair was proposed. The engineering design software, SolidWorks 2019, was used to develop four different conceptual designs of the desktop-chair from which one option was selected through Concept Scoring Method (CSM). To select the best option, relevant data was collected from students through a survey. The best selected desktop-chair concept was analysed using ergonomic software, Computer-Aided Three-dimensional Interactive Application (CATIA) based on Rapid Upper Limb Analysis (RULA). The tests results were failed to reject the null hypothesis (e.g., popliteal height $p = 0.39$), which meant that there was no significant difference among the anthropometric data sets. The analysed anthropometric data set was used to design, an innovative ergonomically suitable classroom desktop-chair. The results show that the proposed desktop-chair design gave better result where the final score was reduced from 4 to 1, which meant the chances of musculoskeletal disorders could be reduced. In conclusion, one type of ergonomically suitable classroom desktop-chair design was proposed to improve the match between classroom desktop-chairs dimensions and students' anthropometric characteristics. Further work on prototyping, usability and durability testing should be carried out.

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DEFINITION OF TERMS

Anthropometry: The dimensions of the human body and how these are measured. It covers the size and proportions of people, the length and range of movement of their limbs, head and trunk.

Biomechanics: The application of physics to the analysis of posture and human movement. It deals with the levers and arches of the skeletal system and the forces applied to them by the muscles and gravity.

End-user: A person who uses a product rather than one who makes or sells, especially a person who uses a product connected with computers.

Ergonomics: The study of working conditions, specifically the design of equipment and furniture, in order to help people, work more professionally.

Fatigue: A state of impairment that can include physical and/or mental elements, associated with lowered alertness and reduced performance.

Injury: Damage to the body caused by exposure to a hazard.

Musculoskeletal disorders: Are conditions that affect the body's muscles, joints, ligaments and nerves.

Occupational ergonomics: Ergonomics as is applied at work to the design of the workplace, equipment, tasks and work organizations.

Risk Assessment: Process used to determine the likelihood of people being exposed to injury, illness or disease in any situation identified during the hazard identification process; and also, the severity of the illness, injury or disease.

Standards: These are issued by the Standard setting body in each country and provide guidelines relating to the design, operation and maintenance of equipment and systems. All Standards have a specific number and date.

ABBREVIATIONS AND ACRONYMS

CATIA:	Computer-Aided Three-dimensional Interactive Application
RULA:	Rapid Upper Limb Analysis
MSDs:	Musculoskeletal disorders
KEBS:	Kenya Bureau of Standard.
ANOVA:	Analysis of Variance
Ae:	Aesthetic
Av:	Availability
BKL:	Buttock knee length
BM:	Body mass (weight)
BPL:	Buttock popliteal length (seat depth)
D:	Durability
DH:	Desktop height
DL:	Desktop length
DW:	Desktop width
EAS:	Ergonomics and safety
EH:	Elbow height
EHS:	Eye height, sitting
EOM:	Ease of manufacture
ES:	Environmental soundness
EV:	Economic value
FFL:	Forearm fingertip length
(a):	Foldable desktop with book holder at the back
(b):	Desktop-chair and bag/book holder at lower desk
(c):	Foldable but fixed height desktop

(d): Fixed height desktop and book holder at the back

HAA: Human action analysis model

HBM: Human builder model

HBS: Hip breadth, sitting

HME: Human measurement editor model

HPA: Human posture analysis model

KH: Knee height sitting

LCC: Life cycle cost

M: Maintainability

Max: Maximum

Min: Minimum

PHS: Popliteal height, sitting

R: Reliability

S: Stature (body height)

SA: Social appeal

SB: Shoulder (bideltoid) breadth

SD: Seat depth

***St. Dev*:** Standard deviation.

SH: Seat height

SH: Sitting height (erect)

SHS: Shoulder height, Sitting

SOU: Ease of use

SSA: Seat slope angle for chair

SSA: Seat slope angle for table

SW: Seat width

TC: Thigh clearance

UAF: Utility and function

MU: Moi University

UoE: University of Eldoret

RVTTI: Rift Valley Technical Training Institute

TENP: The Eldoret National Polytechnic

CHAPTER ONE: INTRODUCTION

1.0 Introduction

This chapter covers the general background information of the research. It also explains the research problem, justification of the research, the research objectives, scope of the research, purpose of the research and the significance of the research.

1.1 Background of the Research

Uasin-Gishu County is situated in the mid-west of Kenya's Rift-Valley; its name comes from the *Illwuasin-Kishu Mausai*. The education facilities in Uasin-Gishu are fairly developed with many institutions such as; (i) Moi university (MU) which is located in Kesses, (ii) University of Eldoret (UoE), (iii) Rift Valley Technical Training Institute (RVTTI) and (iv) The Eldoret National Polytechnic (TENP) all located in Eldoret town (Forest & Kali, 2009). A map of these institutions is presented in appendix VII.

The basic philosophy of ergonomics is to make any design that fits the people who use them, thus leading to comfortability. Ergonomics is a profession that applies theory, principles, data and methods for understanding the interaction between humans and other elements associated with the system, scientific discipline, personal happiness and optimize the performance of the entire system (Kurban et al., 2015; Taifa & Desai, 2017).

Anthropometry is one of the most important parts of ergonomics. It is necessary to consider the anthropometric measurements as well as to follow the ergonomic guidelines in planning any design of furniture in which people perform their regular activities (Bhuiyan & Hossain, 2015).

Anthropometric dimensions whenever considered for designing helps students in achieving comfortability, reducing musculoskeletal disorders (MSDs) and improves the performance of students in terms of attentiveness while professors or instructors are teaching them (Taifa & Desai, 2017; Qutubuddin S.Ma, 2015).

Anthropometric data is a collection of the dimensions of the human body and is useful for apparel sizing, forensics, physical anthropometry and ergonomic design of the workplace. Similarly, some authors have defined anthropometric data as that used in ergonomics to specify the physical dimensions of workplace, equipment, furniture and clothing (Castellucci et al., 2014).

Anthropometry has also been defined as "the science of measurement and the art of application that establishes the physical geometry, mass properties and strength capabilities of the human body" (Taifa & Desai, 2017).

In simple meaning, anthropometry can be defined as the study which deals with body dimensions i.e. body size, shape, strength and working capacity for design purposes and body composition (Taifa & Desai, 2017). People should be able to use comfortably their bodies during the day. This comfort in the workplace as people use tools, equipment and elements of decoration is possible for the human anthropometry.

School furniture is one of the most important physical facilities provided in a classroom environment where the students spend most of their time. The functional utility of the student's classroom furniture is a result of its physical design in relationship to the physical structure and biomechanics of the human body.

Body size has become a matter of practical interest to designers and engineers. In ergonomics, anthropometric data is widely used to specify the physical dimension of workplace, equipment, furniture and clothing. This is especially true for school children, who spend most of their time sitting at their chairs and desks and ought to be able to adopt comfortable body postures (Dursun et al., 2003; Qutubuddin S.Ma, 2015).

It can be observed that there is an increased attention/care on school classrooms, in particular about their design to be suitable to the needs of the students and with appropriate dimensions according to the students' anthropometric characteristics (I. Castellucci, Arezes, et al., 2014).

When designing school classrooms, it is necessary to know the potential height of the student's body and applying ergonomics principles (Al-saleh et al., 2013).

The design of classroom desktop-chairs (one size fits all) in many institutions is usually done with no consideration of ergonomics. Therefore, there is a mismatch between classroom desktop-chair dimensions and students' anthropometric characteristics. This may cause musculoskeletal disorders and affect learning effectiveness due to sitting for a long time in an awkward position. Ergonomically designed furniture is known to reduce musculoskeletal disorders and most probably improve the attentiveness of students in the classroom environment.

Classroom chair is considered as an important element for students to improve comfort and concentration in the study environment. Ergonomic chair design and engineering are, therefore, considered very important for its usability and comfort point of views for the students (S & M, 2019).

1.2 Statement of the Problem

Based on data from Asia (4.4m students were studying in Iran), therefore, lack of standard desks and chairs can influence the health of this stratum (Ansari et al., 2018). However, in Finland, limited researches have been conducted so far on the chair design and engineering considering the absolute needs and expectations from the students in the furniture environment (Al-Hinai et al., 2018). According to European educational furniture standard a number of studies shown that most of the physical problems in the classroom environment are due to the mismatch between anthropometric dimensions of the students at different ages and dimensions and also closely related to incorrect sitting posture (Macedo et al., 2015). Majority of people in India have a culture of sitting in an awkward posture for a long time on the floor or any furniture provided. In the long run, such habit has a great chance of causing some ergonomic problems including musculoskeletal disorder (MSDs), student's dissatisfaction and all ergonomic problems due to un-ergonomic furniture (Taifa & Desai, 2017). Also, research done in Nigeria by (Musa et al., (2011), confirmed that 93.75 % of students in three selected tertiary institutions complained of neck, shoulder, upper and lower back pains that they attributed to the furniture they used. Students run the risk of negative effects from poorly designed and ill-fitting furniture, due to prolonged periods of sitting during school (Igbokwe et al., 2019). Also, seats that are poorly designed, especially those that do not consider the anthropometric data of its users, have negative health implications (Tunay & Melemez, 2008). This is also buttressed by a study carried out on the anthropometric match in South Africa which stated that an incorrect body alignment reduces the ability of antigravity muscles to generate torque (Igbokwe et al., 2019b). The purpose of the study done by Waleed, (2018), was to fill the gap of not having enough anthropometric data for young males in Saudi Arabia. The variation between anthropometry and the actual measurement poses problems to the feet, ankles and thighs of the student. The basic philosophy of ergonomics is to make any product design comfortable. Students require well designed classroom desktop-chairs for their comfortability in the learning context. This requires that in designing classroom desktop-chairs, designers should include Anthropometric sciences. According to some estimations, about 44 million workers in Europe suffered from the occupational musculoskeletal disorder (MSDs) (Yusop et al., 2018). This shows that the ergonomics problem is a major issue that needs to be solved to avoid further suffering in the future. Therefore, there is need for ergonomists to treat the issue of furniture design for students as a necessity. The design of classroom desktop-chairs (one size fits all) in many institutions is usually done with no consideration of ergonomics. Therefore, there is a mismatch between classroom desktop-chairs dimensions and students' anthropometric characteristics. This may cause musculoskeletal disorders and affect learning effectiveness due to sitting for a long time in an awkward position. This present research is of paramount importance because it expends current knowledge in the field of anthropometry to provide a database for future research and it is potentially beneficial to all future student’s fraternity. This research, therefore, seeks to use anthropometric data for the design of classroom desktop-chairs for students in Kenya based on anthropometric measurements collected from students at four selected tertiary institutions in Uasin-Gishu County in order to improve physical responses and their performance.

1.3 Justification of the Research

Collecting and analysing anthropometric measurements from students will provide a basis for the alternative solution to reduce musculoskeletal disorders (MSDs), improve performance of students in terms of attentiveness while professors or instructors are teaching them, increase the efficiency of the students, improve the design of classroom desktop-chairs and increase physical health. The mental and physical comfort of students will contribute to be a successful individual. This research, therefore, aims to reduce the discomfort in students, in the long run.

1.4 Objectives of the Research

1.4.1 Main Objective

The main objective of this research is to use the concept of innovative ergonomics to design and analyse a classroom desktop-chair for students in Uasin-Gishu County.

1.4.2 Specific Objectives

The specific objectives of this research are to:

i. Collect anthropometric data for students from four selected tertiary institutions namely: MU, UoE, RVTTI and TENP.
ii. Design a desktop-chair using the collected anthropometric measurements.
iii. Analyse the desktop-chair design using RULA ergonomic analytical tool.

1.5 Scope of the Research

This research, therefore, was used standard procedures for anthropometric measurements from Kenyan students at four selected tertiary institutions in Uasin-Gishu County. It was limited to designing and analysing a desktop-chair for students in Kenya based on anthropometric measurements collected from students at four selected tertiary institutions in Uasin-Gishu County. This research, therefore, was focused on designing and analysing a desktop-chair that meets the needs of students' physical dimensions based on ergonomic criteria.

1.6 Purpose of the Research

This research, therefore, aimed to use the concept of innovative ergonomics to design and analyse a classroom desktop-chair for students in Kenya based on anthropometric measurements collected from students at four selected tertiary institutions in Uasin-Gishu County.

1.7 Significance of the Research

The success of the present research will benefit future students by establishing an anthropometric database for classroom desktop-chairs for students at four selected tertiary institutions in the long run. The present research will utilize anthropometry (a branch of human factors engineering/ergonomics), as one of the research tools, for redesign/analysis of classroom desktop-chairs, to be used by students, and it seeks to improve students' physical posture, comfort and hence, overall performance. This research, therefore, aims to reduce, in the long run, the discomfort in students and musculoskeletal disorders (MSDs), during a long time sitting at the class lecture. It will be suitable for a large number of students at tertiary institutions in Kenya. The present research will provide a database for future research and it is potentially beneficial to all future student’s fraternity. This research, therefore, would hopefully be a reference point for scholars in the future within this field.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter gives an overview of important literature that is important to the research. It reviews in seventeen sections: (1) Ergonomics: background and objectives of ergonomics, ergonomic chair, the advantage of ergonomics, application of ergonomics, ergonomics standards, the effect of un-ergonomically classroom furniture, ergonomics of the classroom furniture, ergonomic principles that contribute to good classroom design, ergonomics as the points to remember, ergonomics for occupational health practice, ergonomic evaluation of design, ergonomic furniture design, and ergonomic model; (2) Anthropometry: background, definition and history, procedures in anthropometric measurements, types of anthropometric measurements, advantages and disadvantages of anthropometrics, application of anthropometrics, Principles in application of anthropometric data, anthropometric fit, quality control for anthropometry, anthropometry (body size), and relationships between school furniture dimensions and body dimensions; (3) Percentile; (4) Normal distribution; (5) Classroom furniture; (6) Musculoskeletal disorders (MSDs); (7) Basic student's body dimensions and their Importance; (8) Workstation design; (9) Conceptual designs; (10) Concept scoring; (11) Digital human modelling (DHM); (12) School furniture design; (13) Overview of design challenges; (14) Engineering design and general design considerations; (15) Industrial design; (16) Design thinking, and (17) Research gaps.

The literature reviewed is mainly guided by the objectives of the research, problem statement and justification of the research.

2.1 Ergonomics

2.1.1 Background

Ergonomics is the application of scientific principles, methods and data drawn from various disciplines to the development of the engineering systems in which people perform a significant role. Among the basic disciplines are psychology, cognitive science, physiology, biomechanics, applied physical anthropometry and industrial systems engineering (Shamsuddin et al., 2015). Ergonomics is a scientific area concerned with multidisciplinary studies of technology, technique, and environment on the human body. It attempts to resolve the relationships in the human job system to improve the workplace (Sarı & Şahin, 2019). “Ergonomics concerns information about anthropological behaviour, abilities, limits and other characteristics to the design of machines, tools, jobs, tasks, and environments for productive, healthy, safe, comfortable and effective human use” (Wang & Chen, 2012). The results of scientific work in the human sciences are applied by ergonomists in the solution of practical problems in the design and manufacture of products and systems (Zhang & Zhang, 2005). The domains of specialization within the discipline of ergonomics can broadly be distinguished as follows in figure 2.1.

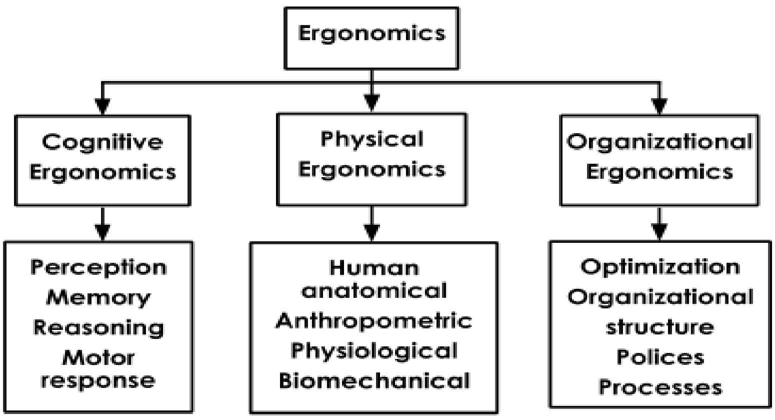


Figure 2.1: Classification of the sub-fields of ergonomics

Source: *(Zhang & Zhang, 2005).*

Some clarification on the sub-fields of ergonomics are provided (Zhang & Zhang, 2005):

1. Physical ergonomics is concerned with human anatomical, anthropometric, physiological, and biomechanical characteristics as they relate to physical activity (relevant topics include working postures, materials handling, repetitive movements, work-related musculoskeletal disorders, workplace layout, safety and health).
2. Cognitive ergonomics is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system (relevant topics include mental workload, decision-making, skilled performance, human-computer interaction, human reliability, work stress and training as these may relate to human-system design).
3. Organizational ergonomics is concerned with the optimization of socio-technical systems, including their organizational structures, policies, and processes (relevant topics include communication, crew resource management, work design, design of working times, teamwork, participatory design, community ergonomics, cooperative work, new work paradigms, virtual organizations, telework and remote connectivity and quality management).

2.1.2 Objectives of Human Engineering (Ergonomics)

Human engineering (ergonomics) has two broader objectives such as (Chandra et al., 2015):

:

1. To enhance the efficiency and effectiveness with which the activities (work) is carried out to increase the convenience of use, reduced errors and increase in production; and
2. To enhance certain desirable human values including safety, reduced stress and fatigue and improved quality life. Thus, in general the scope and objective of ergonomics are “designing for human use and optimizing working and living conditions”. Thus, human factor discovers and applies information about human behaviour, abilities and limitation and other characteristics to the design of tools, machines, systems, tasks, jobs and environment for productive, safe, comfortable and effective human use.

2.1.3 Definition and History

The word “ergonomic” was derived from the Greek word, ergon, meaning work, and nomos, meaning law or usage. The literature suggests that the word “Ergonomics” was independently used in 1949 by a British scientist (Deros et al., 2009).

Ergonomics came about as a consequence of the design and operational problems presented by technological advances in the last century. It owes it developments to the same historical processes that gave rise to other disciplines such as industrial engineering and occupational medicine. Ergonomic is the use of scientific information concerning humans to the design of objects and systems used by humans (Sepehri et al., 2013).

Ergonomics is one of the key components of furniture in many areas. Often, the lack of in depth analyses for the ergonomics aspect of furniture design results in problems such as negative customer feedback, erosion in brand image and decreased profits (Efe et al., 2017).

Most of the available ergonomics studies depend on qualitative methods like surveys, which bring some uncertainty in ergonomics assessments due to lack of controlled measurements (Gupta, 2014). Nowadays, sitting in furniture has become a more integral part of human life.

More people spend their days sitting rather than performing activities whether at home, at work, at school, at the train, at the office etc. There are studies which have been performed about the comfort of sitting in trains, offices, schools and sports centers etc. Research done by Adekunle et al., (2011), shows that students spend about 80% of their time in the classroom performing various activities like reading, writing, drawing and other related activities, which requires them to sit continuously for a long hours.

Ergonomics is a way to work smarter, not harder by designing tools, equipment, workplaces and tasks to fit the job to the worker not the worker to the job (Al-Hinai et al., 2018a). Ergonomics is a profession that applies theory, principles, data and for understanding the interaction between humans and other elements associated with the system, scientific discipline, personal happiness and optimized performance of the entire system (Kurban et al., 2015).

2.1.4 Ergonomic chair

Literature shows that providing an optimal solution with sufficient comfort is an extremely difficult task when a fixed type of chair is used (Igbokwe et al., 2019b).

An ergonomics chair used in the classroom environment should contribute towards the students (S & M, 2019; Al-Hinai et al., 2018a).

In addition to aesthetic point of views, an ergonomically designed chair should have additional features related to ease of use, ease of maintenance, durability, availability etc. there are many problems in the classroom due to un-ergonomically designed chair for students, which results in abnormal posture. This causes increased physical stress, generates muscular back, neck and head pains, loss of concentration and restlessness in an attempt to find a better position (Al-Hinai et al., 2018a).

2.1.5 Advantage of Ergonomics

Ergonomics can have a strong impact on any organization, the benefits are as follows (Burak & Veljović, 2019):

1. Reduced cost by decreasing injuries occurrence of the workers,
2. Improved productivity is the result of the better designed workplace, which ensures good posture, less exertion and fewer motions of the workplace,
3. Better quality because poor ergonomics leads to frustrated and fatigued workers that do not do their best at work,
4. If an employee does not experience fatigue and discomfort during their workday, this can result in a decrease of absenteeism, improved morale and increased employee involvement,
5. Better human performance because of safety and health culture created in the organization.

2.1.6 Application of Ergonomics

The purpose of ergonomics is to enable the work system to function better by improving the interactions between users and machines. Better functioning can be defined more closely, for example, the more output from fewer inputs to the system (greater productivity) or increased reliability and efficiency (a lower possibility of inappropriate interactions between the system components). The specific definition of better working depends on the context (Woo et al., 2016).

2.1.7 Ergonomics Standards

Ergonomics principles have developed from national standards to international criteria and regulations. While Europe was and remains to be a leader in standardization of the ergonomics requirements and office workplace. Further nation, such as: United States, Australia and Canada (Woo et al., 2016). See appendix VIII as presents some ISO standard for ergonomics.

2.1.8 Effect of Un-ergonomically Classroom Furniture

According to Taifa & Desai, (2017), all ergonomic problems are due to un-ergonomic classroom furniture. Parcells et al., (1999), found that most students use chairs which are too high or too deep. It is for these reasons that public health concerns over the effects of bad posture need to be focused on the design of classroom furniture.

Un-ergonomically designed classroom furniture is frequently considered one of the major causes of severe posture problems in adulthood. Most schoolroom activities involve sitting for long periods, with little or no breaks. The use of poorly designed furniture, specifically school furniture, that do not match anthropometric characteristics of its users has a negative influence on human health (Kurban et al., 2015).

Research done by A. I Musa et al., (2011), shows numerous medical problems that have resulted because of the use of classroom furniture that does not match the anthropometric measurements of the school students. Table 2.1 shows the variability of lower back pain (LBP) issues among students in different countries (Ismaila et al., 2013b; Murphy et al., 2004).

Table 2.1: Students having lower back pain in the selected countries.

Country	Lower Back Pain (LBP) (%)
Nigeria	93.75
Switzerland	51
USA	36
Canada	33
England	26
UK	25
Finland	20

Source: *(Ismaila et al., 2013b**;** Murphy et al., 2004).*

2.1.9 Ergonomics of the Classroom

A school is a place of work (Geiger-Brown et al., 2004). Different types of work are performed in the classroom and an appropriate workplace must be offered for each type of work (Rasmussen, 1996). Therefore, there is need for ergonomics to be considered in school furniture design as an obligation. Thus, educational institutions/universities should treat the selection of right kind of classroom furniture as social responsibility towards the students' community.

2.1.10 Ergonomic Principles that Contribute to Good Classroom Design

Ergonomics derives from two Greek words: ergon, meaning work and nomoi, meaning natural laws. Combined, they create a word that means the science of work and a person’s relationship to that work. In the application of ergonomics is a discipline focused on making products and tasks that are comfortable and efficient for the user (Wang & Chen, 2012). The goal for the design of the classroom is to design for as many students as possible and to have an understanding of the ergonomic principles of posture and movement, which play a central role in the provision of a safe, healthy and comfortable work environment. Posture and movement at work will be dictated by the task and workplace. The body's muscles, tendons and joints are involved in adopting posture, carrying out a movement and applying a force. The muscles provide the force necessary to adopt a posture or make a movement. Poor posture and movement can contribute to local mechanical stress on the muscles, ligament and joints leading to problems of the neck, back, shoulder, wrist and other parts of the musculoskeletal system (Chandra V et al., 2015).

2.1.11 Ergonomics: Points to Remember

The main points to remember in ergonomics design, holders of at least (Chandra et al., 2015):

1. Ergonomics applies information about human behaviour, abilities and other characteristics to the design of tools, machines, tasks, jobs and environments.
2. The goal for the design of workplace is to design for as many people as possible and to have an understanding of the ergonomic principles of posture and movement, which play a central role in the provision of safe, healthy and comfortable work environment.
3. Risk assessment of manual handling activities and display screen equipment workplaces should always take account of ergonomic principles.

2.1.12 Ergonomics for Occupational Health Practice

It is often referred to as occupational ergonomics as it is an important part of occupational health and safety. As such, it aims to promote health, efficiency and well-being in employees by designing for safe, satisfying and productive work. Ergonomics can play an important role in occupational health and safety management where the primary aim is to reduce risks of injury or disease, while enhancing the quality of working life. In occupational ergonomics, it is necessary to examine not only the physical design aspect of work but also other areas, such as work organisations and task design. The social and managerial environment is important. Usually, these aspects require ergonomics to be integrated into the broader work systems (Phee et al., 2009).

2.1.13 Ergonomic Evaluation of Design

The main objective of the ergonomic evaluation is to find ways to improve the final product design and to prove the proposed design has human conformance and effectiveness (Muthukumar et al., 2015).

2.1.14 Ergonomic Furniture Design

Furniture design and user anthropometry have become a major concern in designing ergonomically proper furniture. Appropriate furniture design helps to reduce user fatigue and discomfort. Various guidelines and design standards have been developed and recommended to improve school furniture, including European standards for classroom furniture (Esmaeel & Order, 2017), The ergonomic design defines the dimensions and characteristics for school furniture. Thus, anthropometric dimensions are required to determine classroom furniture dimensions. The relevant anthropometric measurements include; popliteal height, buttock popliteal length, knee height and elbow height, etc. (Castellucci, et al., 2014).

2.1.15 Ergonomics Model

In ergonomics and human factor engineering, the term model is often defined as a mathematical or physical system that obeys specific rules and conditions and whose behavior is used to understand a real (physical, biological human technical, etc.) system to which it is analogous in certain respects to the real system (Shamsuddin et al., 2015).

The ergonomics design is related to the product and process where is important to analyse and optimize the user interface. Nowadays the ergonomics design process is the computer-aided by using different specialized software attached to CAD or CAM products. This is the case of CATIA V5, software. Furthermore, CATIA V5 is a combined suite of computer-aided design (CAD) and computer-aided manufacturing (CAM), applications for digital product simulation and meaning (CULDA et al., 2013). CATIA V5 software offers ergonomic aspects of manual operations during early stages of designing products and manufacturing processes by providing safety, efficiency and comfort of the workplace environment using digital human models (DHM) (Sarı & Şahin, 2019).

2.2 Anthropometry

2.2.1 Background

One of the most significant sub-fields of physical ergonomics is anthropometry (Zhang & Zhang, 2005). This research aimed to use the concept of innovative ergonomics to design and analyse a classroom desktop-chair for students in Kenya based on anthropometric measurements collected from students at four selected tertiary institutions in Uasin-Gishu County. These institutions were (i) Moi university (MU), (ii) University of Eldoret (UoE), (iii) Rift Valley Technical Training Institute (RVTTI) and (iv) The Eldoret National Polytechnic (TENP).

Anthropometry is the study of the measurement of the human body in terms of the dimensions of bone, muscle and adipose (fat) tissue. Measures of subcutaneous adipose tissue are important, because individuals with large values are reported to be at increased risks for hypertension, adult-onset diabetes mellitus, cardiovascular disease, gallstones, arthritis and other diseases. Anthropometry is essential and critical information needed to assist in describing the data collected from students (Todd et al., 2007). The purpose of anthropometry is to collect high-quality body measurement data using standardized procedures and calibrated equipment. Accurate data are fundamental to the evaluation of anthropometric trends over time.

Anthropometry meaning "measurement of a human's body", in physical anthropology, refers to the measurement of the human individual to understand human physical variation. Nowadays, anthropometry plays an important role in industrial design and clothing design. Changes in lifestyles, nutrition and ethnic composition of populations lead to changes in the distribution of body dimensions and require regular updating of anthropometric data collections (Yusop et al., 2018).

Anthropometric data are used in ergonomics to specify the physical dimensions of workspaces, equipment, furniture and clothing. Appropriate use of anthropometry in design may improve the well-being, health, comfort and safety of a product's users. Anthropometric data is one of essential factors in designing machines and devices. Incorporating such information would yield more effective designs, ones that are more user friendly, safer and enable higher performance and productivity (Bhattacharya et al., 2019).

2.2.2 Definition and History

The term 'Anthropometry' is derived from a combination of Greek words anthrop (meaning human) and metrics (meaning measurement). It refers to the scientific measurement and collection of data about human physical characteristics such as body dimensions, body volumes, masses of body segments, center of gravity and inertial properties (Gupta, (2014). Similarly, some authors defined anthropometric data as that used in ergonomics to specify the physical dimensions of the workplace, equipment, furniture and clothing (Ismaila et al., 2013b).

Anthropometry is the essential and critical information needed to assist in describing the data collected from people (Baharampour et al., 2013). Anthropometry is the study of the measurement of the human body in terms of the dimensions of the bone, muscle, etc. A lot of managers in developed countries realised the importance of well-designed workplace and equipment in enhancing the productivity and lowering of worker fatigue. Anthropometry is aimed at providing the correct body dimensions required to provide a good fit of the product to the user. Also, it helps the designer to understand and appreciate the variability that exists in the human body dimension (Johan & Renate, 2005).

According to Deros et al., (2009), anthropometry has been considered as the very basic core of ergonomics in an attempt to resolve the dilemma of "fitting users to machines".

Anthropometry has three major principles, which are mainly being followed in designing various products depending on the type of the product (Taifa & Desai, 2017). The first principle is ‘‘design for extreme individual" which can be either design for the maximum population normally referred to as the 95^{th} percentile male or design for the minimum population commonly referred to as the 5^{th} percentile female. The second principle is "designing for an adjustable range" which puts consideration of both 5^{th} percentile female and 95^{th} percentile male in order to accommodate 90% of the population. Therefore, the adjustability principle has been much suggested by many researchers as the main ergonomics principles to be followed in designing furniture. The last principle is ‘‘designing for the average" which is mostly being used whenever the use of adjustability is impractical. There are so many designs specifically for the average but fewer designs are based on the design for adjustability especially for government colleges.

Anthropometric measurements vary from country to country at least with small variation. Due to such variation, there is need of having a good database of anthropometric measurements in state wise if possible, thus, as such data could be used for the current time and future time in designing classroom furniture.

Analysis of anthropometric data can be used to extract important information about (Abidi et al., 2013):

1. The body sizes and shapes existing in a particular population,
2. The important key body dimensions,
3. Clusters with similar key body dimensions,
4. What size designation can be used for better fitting choice.

2.2.3 Procedures in Anthropometric Measurements

Anthropometric measurement procedures are (Johan & Renate, 2005):

First; before starting the anthropometric measurements, there are some activities should be done such as:

1. Identifying the target of the people.
2. Defining the sample-size of the people.
3. Determining the anthropometric data.
4. Preparing the assessment team(s).
5. Obtaining approval from the ethics committee (Appendix I and II).
6. Permission letter to conduct this present research must be got from the headmaster for each of the selected institutions to be considered (Appendix III).

Second; during the anthropometric measurements, it is important to follow a standard procedure, where the measures are collected from the right side of the subjects while they are sitting and standing position, without shoes and using light clothes in order to take quick and accurate measurements of the human body as shown in figure 2.2 and 3.7 as well as Appendix XV.

Third; After collecting the anthropometric measurements, it is important to check the data by using observation of mean, standard deviation (***St. Dev***), minimum (min), maximum (max), 5th, 50th and 95th percentile. (Castellucci et al., 2014).

Figure 2.2: Sitting in a standing position.
Source: *(https://retrohound.org/2019/08/10/corvette-news-aug)*

2.2.4 Types of the Anthropometry Measurements

There are two types of anthropometry measurements, which are static and dynamic (Man, 2011):

2.2.4.1 Static (Structural) Anthropometry

Static is a skeletal dimensions measures distance of bones between joint centers includes some soft tissue measures in contour dimensions (e.g., wobbly staff that covers bodies muscle, fat, skin and bulk).

2.2.4.2 Dynamic (Functional) Anthropometry

Dynamic is the distance was measured when the body is in motion or involved in physical activity, includes; reach (e.g. could be arm plus extended torso), clearance (e.g. two people through a doorway), volumetric data (the effective space for a given task, kinetochore).

2.2.5 Advantages of Anthropometrics

The advantages of anthropometrics are (Bhattacharya et al., 2019):

1. Better comfort
2. Reduce fatigue.
3. Increase accuracy.
4. Increase productivity.
5. Noninvasive and relatively economical to obtain.
6. Objective.
7. Comprehensible to communities at large.
8. Reduction of musculoskeletal disorders (MSDs).

So, if the worker is performing the task in the best possible manner as per the capability of the human body.

2.2.6 Application of Anthropometrics

The application of anthropometrics are described (Gupta, 2014):

1. For designing and industrial workstation, it is necessary to obtain relevant information on task performance, equipment, working posture and environment. In cases where a new workstation design, it is advantageous to obtain such information from a similar task situation.
2. Several methods, such as direct observation, one to one interview with experienced operators, videotaping and questionnaires can be used for this purpose.
3. Before designing a workstation in industry, it is desirable to conduct a worker survey through appropriate questionnaires to determine the effect of the existing equipment or system design on employee comfort, health, easy for use and ease of maintenance.
4. The objectives of such a survey should be documented or recorded:

   (a) The general rating of various equipment/system design and environmental (noise, temperature, light and workspace) factors.

   (b) The current level of physical, mental and visual fatigue induced by the job to the operators.

   (c) The changes in postural discomfort in specific anatomical regions, during the day.

2.2.7 Principles in Application of Anthropometric Data

There are many principles in the application of anthropometric data as described (Chandra, et al., 2015):

1. Design for extreme individuals: designing for maximum population value is the recommended strategy if a given maximum value of some design feature should accommodate doors.
2. Designing for adjustable range: in the design features for equipment or facilities the provision for adjustment should be there for the individual who use them.
3. Designing for average: there is average individual and a person may be average on one or two sizes.
4. Designers often design for average as a compromise as they do not have to deal with anthropometric data.

2.2.8 Disadvantages of Anthropometrics

The disadvantages of anthropometrics are lie in (Brolin, 2016):

1. The significant potential for measurement inaccuracies.
2. The need for precise age data in young children for construction of most indices.
3. Limited diagnostic relevance.
4. A debate over selection of appropriate reference data and cut off points to determine conditions of abnormality.

2.2.9 Anthropometric Fit

For all types of clothing and body worn technologies, it is important to consider how they integrate and interact with the complex shapes from the unique profile of the human body. If particular furniture is designed by considering dimensions of the children from 12 years to 17 years, it will also not suit the children of all age groups

(Adekunle et al., 2014). On the other hand, any product (whether it is a workstation or clothing) has to fit the user population. Usually, and this design included, the user population varies in size and the designer should account for this range of sizes.

There are three ways; in which design will fit the user such as (Starovoytova, 2018):

1. Single size, that for all.
2. An adjustment design; the design can incorporate adjustment compatibility, to accommodate several, but not all sizes and the most expensive option.
3. Several sizes. And therefore, this research should be used as an adjustment average option, to cater to different sizes.

Anthropometric knowledge is most frequently used by designers and product evaluators in the form of one-dimensional data to verify whether the product dimension is fitting the human dimension.

There are several ways of how anthropometric data are used such as (Johan & Renate, 2005):

1. Ego design: body dimensions as a guide.
2. Average design: body dimensions of the average as a guide.
3. Design for P5: body dimensions of the smallest person as a guide.
4. Design for P95: body dimensions of the largest person as a guide.
5. Design for P5-P95: body dimensions of the smallest and largest person as a guide. This type is used most commonly and means that excluding 10% is acceptable.

2.2.10 Quality Control for Anthropometry

Quality control procedures ensure the collection and documentation of accurate and reliable data. The anthropometry data are among the most widely used data collected in the research. The anthropometry protocol requires the examiner and recorder to work together as a team. In anthropometrics, the most common errors involve body positioning, locating and marking body landmarks. In addition, to the standardized measurement protocol, the anthropometry component incorporates specific quality control procedures by using a standard (Centres for disease control and prevention, 2007).

2.2.11 Anthropometry (Body Size)

The anthropometry (body size) to ensure has the following criteria (Phee et al., 2009):

1. Consider differences in users, body size in the design of the workplace.
2. Decide beforehand if needs to accommodate people in the extremes of the body size range and make special provision for these people in the design of the workplace.
3. Commercially available anthropometric tables are useful as a guide when designing workplaces and equipment but they should be interpreted with care bearing in mind the worker population.

These are some of the dimensions that are important in different types of work as shown in figure 2.3.

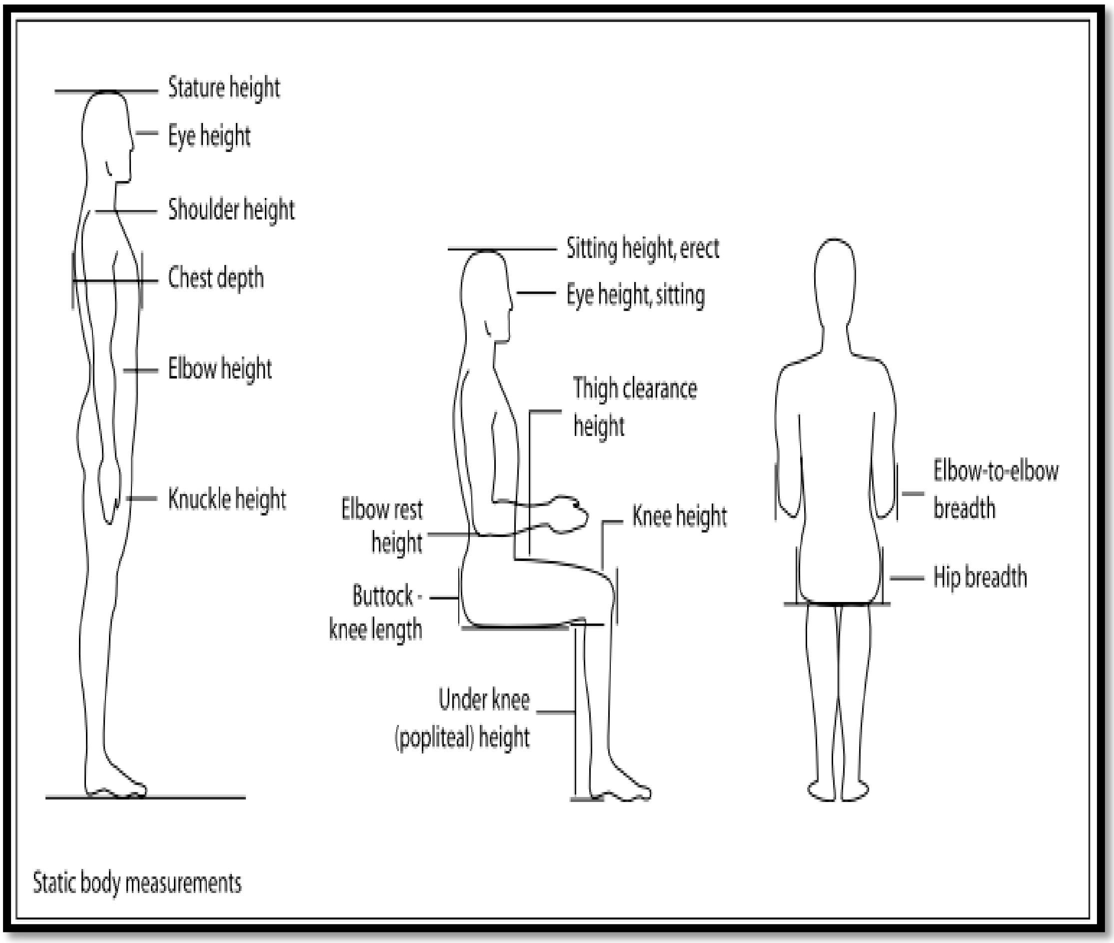


Figure 2.3: Consider differences in body size when designing workplaces and tasks
Source: *(Phee et al., 2009).*

2.2.12 Relationships Between School Furniture Dimensions and Body Dimensions

Previous research found that most furniture used in the classroom did not fit the bodies of students (Phee et al., 2009). According to Wutthisrisatienkul & Puttapanom, (2019), examined this issue and found that students who used unsuitable desks and chairs in school suffered from muscle aches, headaches, neck and back pain. There have been some equations, to investigate the mismatch between classroom chairs and anthropometric dimensions of students. See tables 2.2 and 2.3.

2.2.12.1 Seat height (SH) and Popliteal Height (PH)

Based on the references, the seat height should be adjusted according to the popliteal height (Baharampour et al., 2013). Besides, the knee angle into the vertical axes should be up to 300 (Molenbroek et al., 2003). But the minimum of the same angle was 50. So, the design could be done by following Equation (1):

$(PH + 2) \cos 300 \leq SH \leq (PH + 2) \cos 50$ ……………………………......................(1)

Where SH is seat height and PH is popliteal height.

2.2.12.2 Seat Width (SW) and Buttock Width (BW)

According to Molenbroek et al., (2003); and Baharampour et al., (2013), the seat width should be designed based on largest buttock width. The minimum number for seat width is obtained from the multiplication of 1.1 by the buttock width and for the maximum, the coefficient is 1.3. So, to determine the seat width of the classroom furniture is shown in Equation (2):

$110\% \; BW \leq SW \leq 1130\% \; BW$…………………………………………………… (2)

Where BW is buttock width and SW is seat width.

2.2.12.3 Seat Depth (SD) and Buttock Popliteal Length (BPL)

It is believed that the seat depth should be designed for the 5^{th} percentile of the BPL distribution (Ansari et al., 2018). Some other studies (Baharampour et al., 2013), confirmed that the SD it should be at least 2 inches shorter than the BPL. However, the most famous reference that upheld a mismatch for seat depth has been defined as all the numbers, which exist in Equation (3):

$0.8 \; BPL \leq SD \leq 0.95 \; BPL$………………………………………………………. (3)

Where SD is the seat depth and BPL is buttock popliteal height.

2.2.12.4 Backrest Height (BH) and Shoulder Height (SH)

For facilitating the mobility of the torso and arms towards the lower body, it is better to design the backrest height up to the sub-scapula height (Castellucci et al., 2014; Gouvali & Boudolos, 2006). So, to determine the backrest height of the classroom furniture is shown in Equation (4):

$0.6\ SH \leq BH \leq 0.8\ SH$……………………………………………………………. (4)

Where SH is shoulder height and BH is backrest height.

2.2.12.5 Desktop Height (DH) and Sitting Elbow Height (SELH):

The elbow height is recommended as the original determination for desktop height. Some researchers (Castellucci, et al., 2014; Gouvali & Boudolos, 2006), suggested that the desktop height would be 3 to 5 cm higher than the sitting elbow height. So, to determine the desktop height of the classroom furniture is shown in Equation (4):

$SELH \leq DH \leq SELH + 5$……………………………………………………………… (5)

Where SELH is sitting elbow height and DH is desktop height.

2.2.12.6 Distance Between Armrests and Distance Between Elbows

According to Baharampour et al., (2013), the distance between armrests should be 18 inches (BIFMI Guideline) or maybe 16.5 to 19 inches in some other guides. This research proposed a new interval, equivalent to seat width equation (6), defining the minimum and maximum distance between armrests.

$110\%\ ELELD \leq AD \leq 1130\%$...(6)

Where ELELD is the distance between elbows and AD is the distance between arm-rests.

2.2.12.7 Thigh Clearance (TC) and Seat to Desk Clearance (SDC)

The appropriate SDC needs to be higher than thigh clearance (TC) to provide leg movement. The optimum SDC should be 2 cm higher than knee height. Thus, a match criterion is established according to equation (7).

$$(TC+2) < SDC \quad (7)$$

Where SDC is seat to desk clearance and TC is thigh clearance.

Table 2.2: Anthropometric dimensions and their description

Dimensions	Description
Sitting elbow height from the seat	The vertical distance from the seat-surface to the bottom of the elbow.
Buttock knee length	The horizontal distance from the back of the uncompressed buttock to the front of the kneecap.
Buttock popliteal length	The horizontal distance from the back of the uncompressed buttocks to the popliteal angle, at the back of the knee, where the back of the lower legs meets the bottom of the thigh.
Buttock height	The vertical distance from the floor to the popliteal angle at the bottom of the knee where the tendon of the biceps femora's muscle inserts into the lower leg.
Buttock width	The maximum horizontal distance across the hips in the sitting place.
Sitting shoulder height	The vertical distance from the seat-surface to the acromion.
Distance between elbows	The horizontal distance between the end bony point of one of the elbows to the same part of the other one.

Source: *(Baharampour et al., 2013; Esmaeel & Order, 2017)*

Table 2.3: Components of chair dimensions and its description

Dimension	**Description**
Seat height	The vertical distance from the highest point on the front of the chair to the floor
Seat width	The horizontal distance between the lateral edges of the seat.
Seat depth	The vertical distance from the back of the seat.
Backrest height	The vertical distance from the sitting surface to the top edge of the backrest of the seat.
The distance between the armrests of the chair	The vertical distance between two internal edges of the armrests of the seat.
Desktop seat height	The vertical distance from the sitting surface to the upper edge of the desktop.

Source: *(Baharampour et al., 2013).*

2.3 Percentile

The percentile indicates the location of z-score in a distribution as shown in table 2.4. Percentile range from 1 to 99 Anthropometric dimensions for each population are generally ranked by size and defined as percentile (Hse, 2005). The percentile is shown in figure 2.4 and can be selected from 0.01 to 99.99 (Process & Data, 2019).

Table 2.4: Z-values for commonly used percentiles

Percentile	*Z-values*
1st	-2.326
2.5th	-1.960
5th	-1.645
10th	-1.282
25th	-0.675
50th	0
75th	0.675
90th	1.282
95th	1.645
97th	1.960
99th	2.326

Source:(http://sphweb.bumc.bu.edu/otlt/MPHModules/BS/BS704_Probability/BS704_Probability10.html)

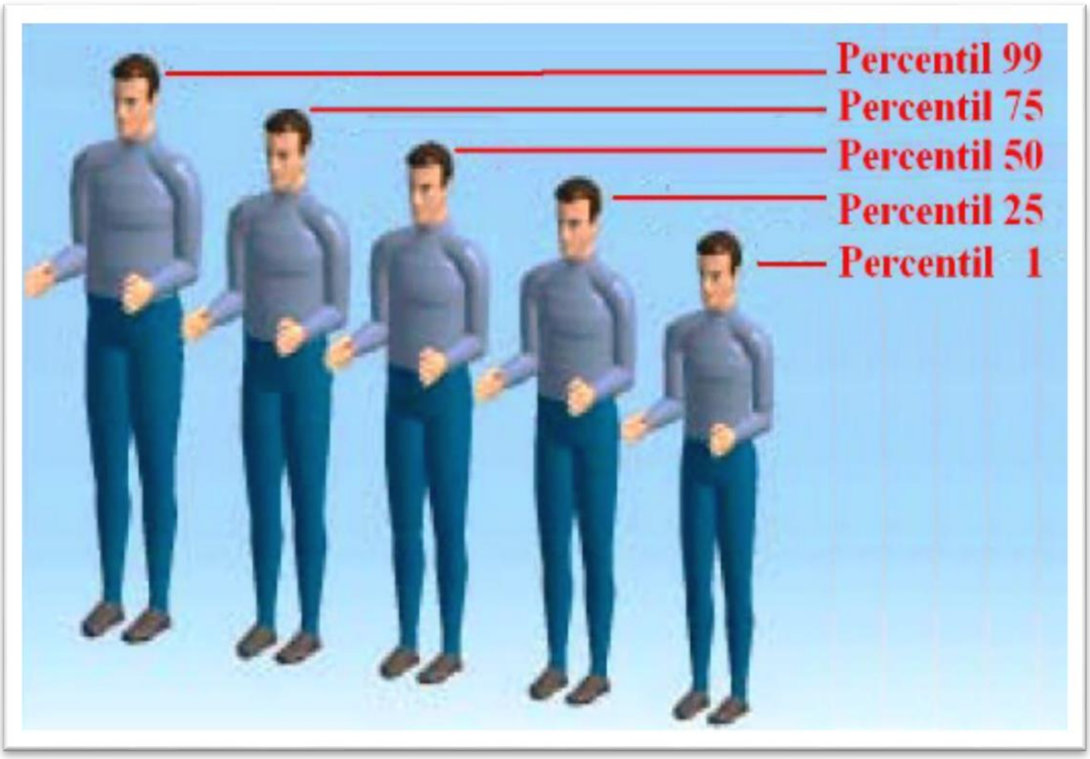


Figure 2.4: Percentiles illustration

Source: *(Process & data, 2019).*

2.4 Normal Distribution

According to Deros et al., (2009), refer to an observed frequency distribution, which is referred to a continuous value, real number distribution like the normal distribution. The calculations for the 5th, 50th and 95th percentiles by using normal distribution are shown in formulas 1, 2 and 3:

For 5th percentile $= \mu - 1.65\ \alpha$……………………………………………………… (1)

For 50th percentile $= \mu + z\ \alpha$……………………………………...……………..…. (2)

For 95th percentile $= \mu + 1.65\ \alpha$……………………………………………………… (3)

Where α is the standard deviation, μ is mean, and z is the score. For further understanding, a basic normal distribution graph is shown in figure 2.5, with a clear description of the 90% of the distribution (Deros et al., 2009). Also, z-score was shown in table 2.4.

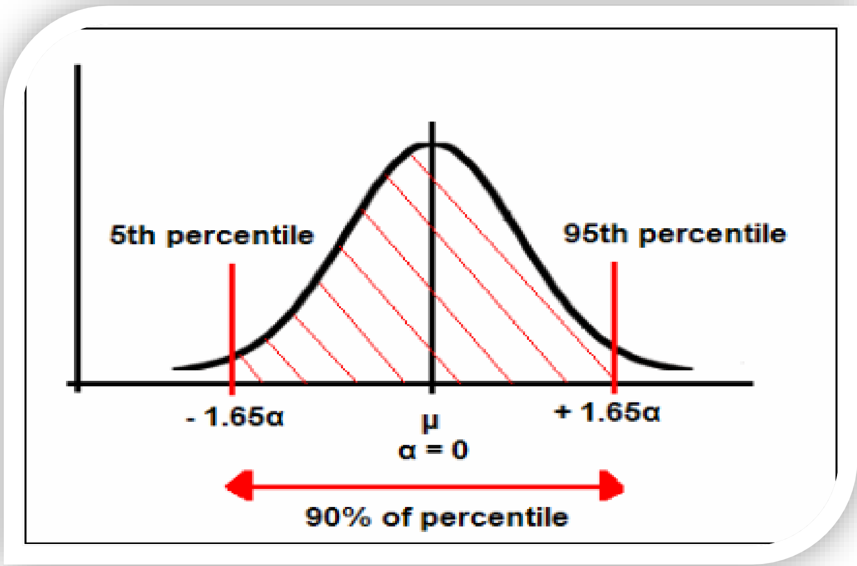


Figure 2.5: The normal distribution graph
Source: *(Deros et al., 2009).*

2.5 Classroom Furniture

Students spend around 80% of their school time in the classroom performing various activities like reading, writing, drawing and other related activities, which requests them to sit continuously for long hours (Adekunle et al., 2014; Adekunle et al., 2011). Based on the data from case studies at the four selected tertiary institutions. therefore, there are various designs of classroom furniture for students in the four selected tertiary institutions as shown in figures 2.6 and 2.7. This variation will pose problems to the feet, ankles and thighs of the students. Figure 2.8, shows, some of the existing furniture used by students in the classroom environment which maybe not comfortable for them during reading and writing activities.

Figure 2.6: Various design of classroom furniture
Source: *(Classroom at MU, UoE, RVTTI and TENP)*

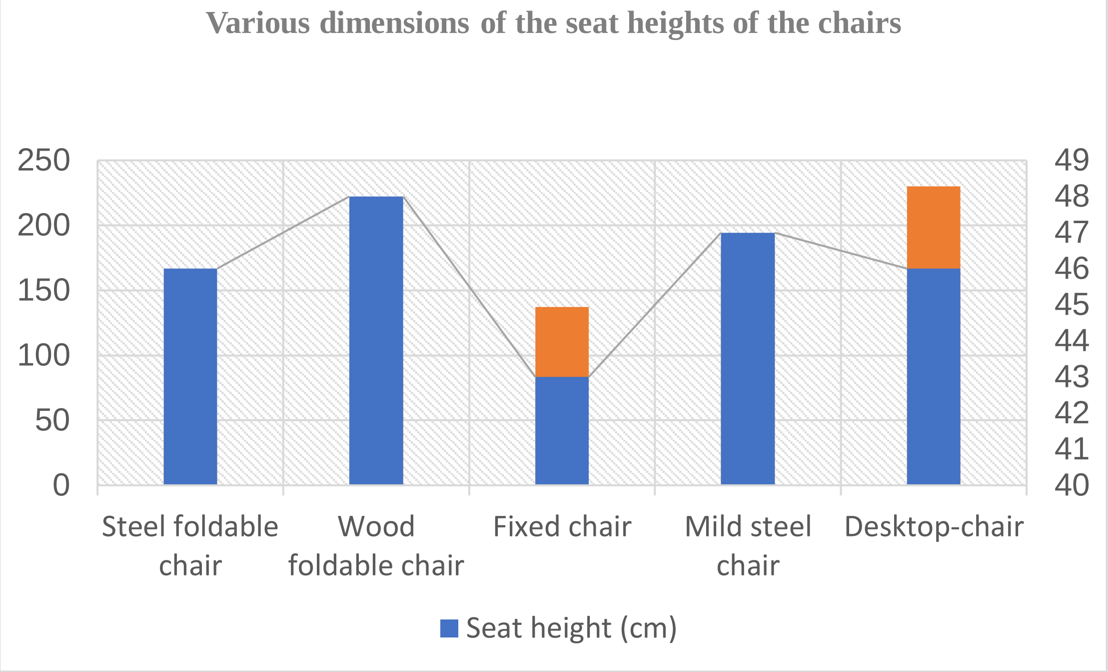


Figure 2.7: Various dimensions of seat height of the existing classroom chairs

Figure 2.8: Some of the existing furniture used by students in the classroom.
Source: *(Classroom at MU, UoE, and TENP)*

Otherwise, several global studies have shown a mismatch between the physical dimensions of students and classroom furniture (Optaha & Normalisation, 2015). Research done by Adekunle in (2011) and (2014), shows that the school furniture did not matches up with the school children anthropometric measurements. The compatibility between classroom furniture dimensions and students' anthropometric characteristics was identified as a key aspect for improving some students' physical-responses (Castellucci et al., 2017). However, furniture has a significant effect on human health. So, it is necessary to use anthropometric data to design the school furniture (Biswas et al., 2014).

2.6 Musculoskeletal Disorders (MSDs)

Musculoskeletal disorders (MSDs) are the injuries and disorders of the soft tissues such as (muscles, ligaments, sinews, joints and tendon) and nervous system. They may affect virtually all tissues, including the concerns and tendon sheaths and most commonly involve the back, arms, occupational safety, well-being and health professionals have called these disorders a variety of names, including cumulative trauma disorders (CTD), repetitive stress injuries, repeated trauma and occupational overexertion disease. Some potential causes of musculoskeletal injuries are related to biological and lifestyle characteristics of individuals and are therefore difficult to anticipate or do anything about using design. However, work related musculoskeletal disorders (MSD) causes are possible for an engineer to avoid and are therefore the most interesting ones to identify quickly. Engineers with knowledge of ergonomics should design work and workplaces to minimize the adverse risks of the following (Journal, 2015):

1. Forced working postures.
2. Load weight.
3. Static work.

4. Continuous loading of tissue structures.
5. Repetitive working tasks.
6. Time pressure/lack of recovery time.
7. Working technique.
8. Working attitude.
9. Demotivation, stress.
10. Organization.

2.7 Basic Student's Body Dimensions and Their Importance

The literature review shows that anthropometric parameters are one of the most important factors in deriving classroom dimensions and in designing comfortable furniture for the students (Mohamed et al., 2010; Baharampour et al., 2013). As shown in Appendix IX.

2.8 Workstation Design

As highlighted above, ergonomics deals with the engineering of machines for human use and with the engineering of human tasks for operating machines. It is concerned with the ways of designing equipment, machines facilities and work environments. So, that they match human capabilities and limitations. The objectives of ergonomics are to increase the efficiency of the worker, to promote worker health and to satisfaction of the worker (Journal, 2015).

2.9 Conceptual Designs

The very important step in the product development process is so called conceptual design. It is the art of the designer, thinking about the problem in the existing design comes out with different ideas which are recorded in turn through conceptual sketches, the steps involved in the conceptual design stages are (Muthukumar et al., 2015):

1. Identifying the sub function.
2. Generation of types of sub function.
3. Building a morphological matrix.
4. Concept generation.
5. Concept selection for proposed design.

2.10 Concept Scoring

The objective of concept scoring method is to select the best conceptual design (Al-Hinai et al., 2018a). The appropriate selection of design concepts has a strong influence. Concept selection is the decision making phase of concept design (Ye, et al., 2013).

2.11 Digital Human Modelling (DHM)

Digital human modelling (DHM) is the tools that are used in to order to reduce the need for physical tests and to facilitate proactive consideration of ergonomics in virtual product and production development processes. Digital human modelling (DHM) tools provide and facilitate simulations, visualizations and analyses in the design process when seeking feasible solutions on how the design can meet set ergonomics requirements (Brolin, 2016).

2.12 School Furniture Design

Several research studies have shown that students often remain seated in classroom for a considerable amount of time. Prolonged sitting and a static posture in a forward bending manner were found to be the main cause for low back pain. School furniture plays a very important role in the maintenance of good sitting posture. Moreover, bad sitting habits that develop during childhood are not easy to change in later years (Wutthisrisatienkul & Puttapanom, 2019).

2.13 Overview of Design Challenges

In designing any products there are some design challenges which need to be addressed to achieve major objectives of collecting anthropometric measurements. Some of the design challenges are as follows (Taifa & Desai, 2017):

1. Design for all; this means the strategy to try to exclude as less as possible, so as all people can be able to use the designed product.
2. Design one size which fits all; for example, a public outdoor chair should be designed in such way that there is mostly only one size which fits all.
3. Made to measure; for example, an astronaut, their suits are made to fit their body size and shape.
4. Design for average; this is almost the same as one size fits all. Many people are excluded from comfortable usage. This is due to the reality that there is no body who is average. In case, a person has an average body height (stature).

2.14 Engineering Design and General Design Considerations

Design is the part of a human problem-solving activity beginning with a perception of a gap in a user experience, leading to a plan for a new artifact and resulting in the production of that artifact. Product design is conceiving and giving form to goods and services that address needs.

The following factors are considered during the design process such as (Madara et al., 2016):

1. Simplicity.
2. Ergonomics and safety.
3. Ease of use.
4. Aesthetics.

5. Ease of manufacture.
6. Availability of material and labor.
7. Reliability.
8. Operational and maintenance costs.
9. Weight and size.
10. Efficiency.
11. Durability.
12. Environmental soundness.
13. Utility and function.
14. Life cycle cost.

Table 2.5 shows the elements of the product design as an example for the Ducati monster motorcycle, a highly successful artifact introduced in 1993.

Table 2.5: The elements of product design.

What are the user needs?	*The motorcycle sounds powerful*
What are the target values of the product attributes?	0-100 km/hr. acceleration time < 4.0 seconds, etc.
What is the core product concept?	A naked bike as a raw counterpoint to the faired sport-bikes in the market.
What will be the overall physical form and appearance of the product?	Typically, the form is initially represented with a sketch and eventually in represented by a 3D computer model.
What is the product architecture?	Welded tubular frame; Ducati L-Twin engine/transmission hung from frame at four points; chain derive; rear swing arm suspended from transmission casing, etc.
What variants of the product will be offered?	M900 initial, to be followed by M400, M600 and M750 (differing primarily in engine displacement).
Which components will be shared across which variants of the product?	Most components except engine shared across all models.
What are the values of the key product parameters?	90cc engine displacement; 1440mm wheelbase; 14-liter fuel capacity.
What is the detailed design of the components?	Usually, the detailed design of components is represented with 3D computer models plus annotations for finishes, materials, and other attributes.

Source: *(Madara et al., 2016; Starovoytova, 2019).*

2.15 Industrial Design

In some industrial product design, the designers should keep in mind that the industrialized products should fulfil the clients and expectations. In general, it is also expected that the industrialized product should satisfy the predefined specifications and functionalities to support both the users and producers. There are two design characteristics were reflected in any product design such as (Al-Hinai et al., 2018b; Nayak, 2015):

1. Ergonomics; is a way to work smarter not harder by designing tools, equipment, workplaces and tasks to fit the job to the worker, not the worker to the job. That is why various ergonomics criterions are considered as the most important criteria during product design phase. In the proposed chair design several ergonomics issues such as ease of use, ease of writing on the desk, interaction between the chair and the user, etc.
2. Aesthetics; Another important criterion in any product design is to consider the looking of the product itself, which is known as the aesthetics of the product design. This product's aesthetic contributes substantially to satisfy the customer needs.

Therefore, the product designer and manufacturer need to use anthropometric measurements and ergonomic information in deciding on designing technologies, equipment, machines, products and systems.

2.16 Design Thinking

Design thinking can be described as a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity (Pusca & Northwood, 2018). Thus, in essence it is a fully participatory design method, employing multidisciplinary actions not only in the developmental stages of the product design process. It goes further to post occupational evaluation by professionals and end users themselves. After all, when it comes to designing workspaces, the workers will be at the same time the most affected by product results and the ones most likely to contribute with important insights about whatever is being designed for them. Design thinking is considered a natural evolution of design as an applied social science. Traditionally, designers focused their attention on improving looks and functionality of products. In recent years they have broadened their approach, creating entire systems around products and services they work at (Soares, 2014).

Design thinking is a procedure of design used as an innovative instrument that applies design procedures to achieve the best consequences. It is focused on discovering the best solutions for the problems and discovers different ways to solve them. It is completed up from dissimilar activities. These activities are mostly divided into several stages (Foster, 2019; Soares, 2014 and Starovoytova, (2018):

1. Empathize; This first stage consists of understanding how a person do things and why does they do it in that way, their opinions and needs. This is an actual important step since the problems that designers attempt to solve are essentially other people's problems.
2. Define; The main aim of this stage is to explain and focus on the problem to start observing for possible solutions. It is a way of arranging all the evidence gathered in the first stage.
3. Ideate; Ideation is the generating different thoughts or ideas in order to solve the problem that the report contains. It is finding the greatest ideas possible so the designer may select the best one then works on it.
4. Prototype; This step is based on generating different objects that help the designer to take the greatest decisions while designing the final idea. There are several ways of prototyping however all of them have in the common that they are used to communicate and interact with the last user.
5. Test; All the prototypes that designers make during the prototype phase, designers solicit feedback from the last user to work again on their identification and understand them a little bit further and find novel solutions or possible

problems. To be strong, it makes a better product design. It could be made by testing with a physical item or simulating a real context of the user's life.

2.17 Research Gaps

Limited to the above literature review; Al-Hinai et al., (2018a), Recommended that the compatibility between classroom furniture dimensions and the students anthropometric characteristics has been identified as a key factor for improving some students' physical responses. Besides, there is many researches worldwide (Castellucci et al., 2010; Chung & Wong, 2007; Milanese & Grimmer, 2004; Saarni et al., 2007), confirmed a clear mismatch between students' anthropometric characteristics and the dimensions of classroom furniture. However, the design of classroom desktop-chairs (one size fits all) in many institutions is usually done with no consideration of ergonomics. Therefore, there is a mismatch between classroom desktop-chairs dimensions and students' anthropometric characteristics. This may cause musculoskeletal disorders and affect learning effectiveness due to sitting for a long time in an awkward position. Ergonomically designed furniture is known to reduce musculoskeletal disorders and improve the attentiveness of students in the classroom environment. This research, therefore, will fill the research gaps by providing an innovative ergonomic design of classroom desktop-chair and its analysis based on anthropometric measurements at tertiary institutions in Uasin-Gishu County, Kenya. This will ensure safety, comfort, adaptability, suitability and ultimately guarantee user satisfaction as well as result in the reduction of musculoskeletal disorders (MSDs). The research gaps, therefore, were identified based on specific objectives are summarised in table 2.6.

Table 2.6: Summary of objectives, authors and years, issues researched and gaps identified.

S/No	Objectives	Authors and years	Issues researched	Gaps identified
1.	To conduct anthropometric measurements for students.	(Ismaila et al., 2013)	Anthropometric design of furniture for use in tertiary institutions, Nigeria.	Therefore, no anthropometric design is done for institutions, Kenya.
		(Al-Hinai et al., 2018).	An ergonomic student furniture design and engineering for school-furniture.	Thus, no design based on actual anthropometric measurements was done.
		(Harvey & Kenyon, 2013).	Classroom chair considerations for students in urban higher education.	Therefore, there are no anthropometric measurements was done.
2.	To design a desktop-chair.	Taifa & Desai, (2017).	Anthropometric dimensions for an ergonomic design for students, India.	Therefore, there is no design and analysis were done.
		(Diniardi & Ramadhan, 2015).	Chair design analysis of work to MSDs using anthropometry method, Indonesia.	Thus, there is no design was done.
		(Castellucci et al., 2014).	Applied anthropometrics in school furniture design, Netherlands.	Therefore, there is no design and analysis were done.
3.	To analyse the desktop-chair using RULA.	(Bhuiyan & Hossain, 2015).	University hall furniture based on anthropometry, Bangladesh.	Thus, there is no design and analysis were done.
		(Igbokwe et al., 2019).	Considerations of anthropometrics in the design of lecture furniture, Nigeria.	Therefore, there is no analysis was done.
		(Ansari et al., 2018).	Design of ergonomic-chair for students in an educational setting, Iran.	Thus, there is no analysis by RULA ergonomic analytical tool was done.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction

This chapter covers the methods used towards the achievements of the present research's objectives. It has been sectioned according to the specific objectives. It begins with the collection of anthropometric details of the students which cover sample determination, body dimensions, measurement procedure, measuring instruments and materials, data acquisition and furniture measurement. The second section deals with the design of concept desktop-chair which entails with the sketches of the proposed designs, concept generation, concept selection of the best selected desktop-chair design and complete model of the best selected product design using professional edition (SolidWorks 2019, engineering software). The third section of this chapter covers the analysis of the best selected desktop-chair design using Computer-Aided Three-Dimensional Interactive Application (CATIA) based on Rapid Upper Limb Analysis (RULA). And the last sections cover the methods of the data analysis to be employed for the data collected.

The experimental part can be subdivided according to the specific objectives into the following sub-sections:

1. Collect anthropometric data for students from four selected tertiary institutions namely: MU, UoE, RVTTI and TENP.
2. Design of a desktop-chair using the collected anthropometric measurements.
3. Analysis of the desktop-chair design using RULA ergonomic analytical tool.

3.1 Collect Anthropometric Data for Students from Four Selected Tertiary Institutions Namely: MU, UoE, RVTTI and TENP

3.1.1 Introduction

To conduct anthropometric measurements for students from four selected tertiary institutions in Uasin-Gishu County, namely: Moi University (MU), University of Eldoret (UoE), Rift Valley Technical Training Institute (RVTTI) and The Eldoret National Polytechnics (TENP), is the first objective of the research.

Anthropometric data was collected from a total of three hundred and eighty-two (382) students of both genders. Fourteen (14) anthropometric measurements (stature, sitting height, shoulder height, popliteal height, hip breadth, elbow height, buttock popliteal length, buttock knee length, thigh clearance, eye height, shoulder breadth, knee height, body mass and forearm fingertip length) were taken from students with the help of anthropometric tools. The research applied fundamental engineering principles of product design and was carried out in compliance with ISO 7250-1:2017 (Basic human body measurements for technological design part 1: Body measurement definitions and landmarks). The anthropometric data from the four (4) subject institutions were compared using one-way ANOVA analysis. The data obtained was analysed using Minitab 17.0 statistical package, to get the mean, standard deviation, minimum, maximum, 5^{th}, 50^{th} and 95^{th} percentiles.

To achieve the first objective, therefore, entire methodology can be achieved by using the following procedure in figure 3.1.

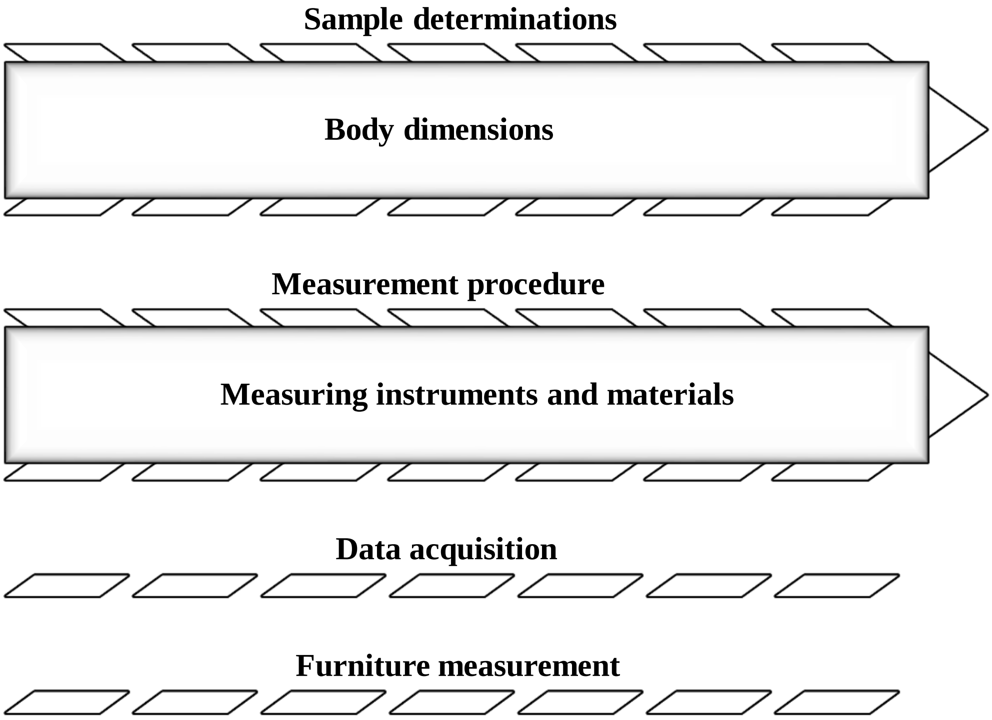


Figure 3.1: Main steps of the measurements.

3.1.2 Sample Determinations

Four higher selected institutions in Uasin-Gishu County, Kenya, namely: (i) Moi University (MU), (ii) University of Eldoret (UoE), (iii) Rift Valley Technical Training Institute (RVTTI) and (iv) The Eldoret National Polytechnic (TENP) were selected to participate in the research (Appendix VII). In addition, these institutions were selected because they represent different types of tertiary institutions in Uasin-Gishu County, Kenya. Also, they were quite interested in the research especially since it is basically on students' comfortability in their classroom's environment. The total number of students considered for the present research was fifty five thousand and four hundred thirty one (55,431), through the use of Eq. (1) given by Homkhiew et al., (2012), whereby the students sample involved in the present research were three hundred and eighty-two (382), through use of Eq. (2) given by Madara, (2016).

The sample size for this present research was determined by using equations-(1).

Sample-size = $\dfrac{\frac{Z^2 * P\,(1-P)}{e^2}}{1+\frac{Z^2 * P\,(1-P)}{e^2\,N}}$ ………………………………………………………... (1)

Whereby:

N is total number of students,

Z is standard normal deviation for 95% confidence level (Z-score of 95% is 1.96),

p is the proportion in the target population estimated to have a particular characteristic i.e., p considered at 50%,

(1-p) is the proportion in the target population not having the particular characteristics,

e is the margin of error (degree of accuracy) required which usually is being set at 5% level as established by Homkhiew et al., (2012).

To find the right z-score to use the table 3.1 as well as figure 3.2.

Table 3.1: Z-score based on the desired confidence level.

Desired confidence level (%)	**Z-score**
80	1.28
85	1.44
90	1.65
95	1.96
99	2.58

Source: *(Erickson et al., 1867)*.

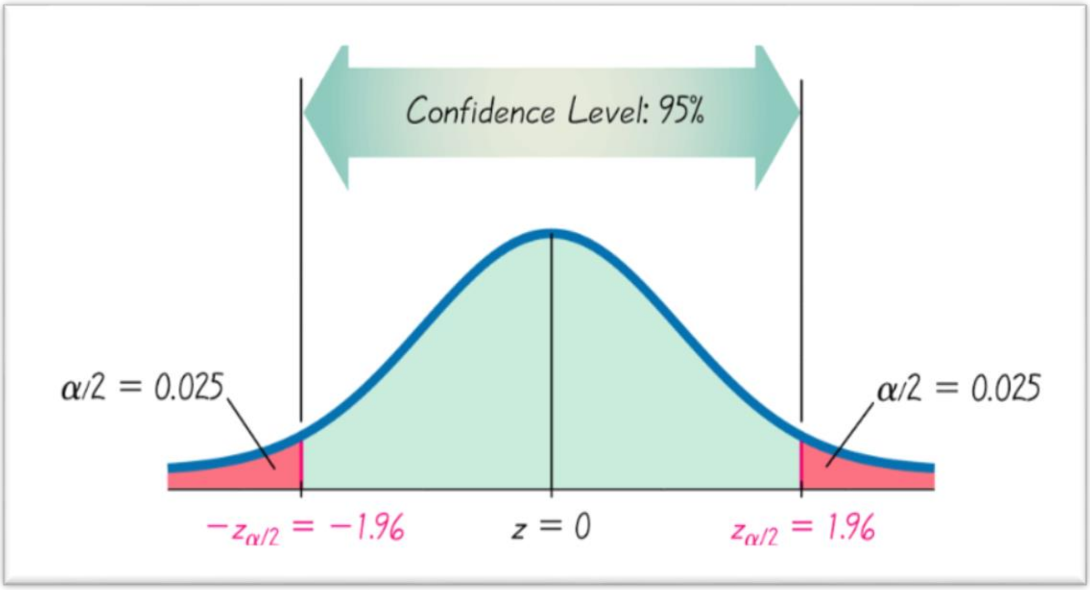


Figure 3.2: Confidence level of 95%

Source: (*Erickson* et al., 1867)**.**

The sample size, in this research was = $\dfrac{\dfrac{(1.96)^2 * 0.5(1-0.5)}{(0.05)^2}}{\dfrac{(1+(1.96)^2 * 0.5(1-0.5)}{(0.05)^2 * 55431}} = 382$

The students' sample for this research also, was calculated by using equations-(2).

Students sample = $\frac{Students\ per\ institutions}{Total-number\ of\ students\ in\ institutions} * Sample\ size$............ (2)

The students' sample for each institution was determined using the equation-2 as shown:

MU = $\frac{24574}{55431} * 832 = 171$

UoE = $\frac{20000}{55431} * 832 = 139$

RVTTI = $\frac{5300}{55431} * 832 = 37$

TENP = $\frac{5057}{55431} * 832 = 35$

The total sample size in this research, therefore, was 171 + 139 + 37 + 35 = 382. As shown in table 3.2 as well as in figure 3.3.

Table 3.2 Summary of sample size distribution.

Institutions	Number of students	Students sample	References
MU	24,574	171	https://www.mu.ac.ke
UoE	20,000	139	https://www.uoeld.ac.ke
RVTTI	5,300	37	https://www.rvti.ac.ke
TENP	5,057	35	https://www.tenp.ke
Total	**55,431**	**382**	

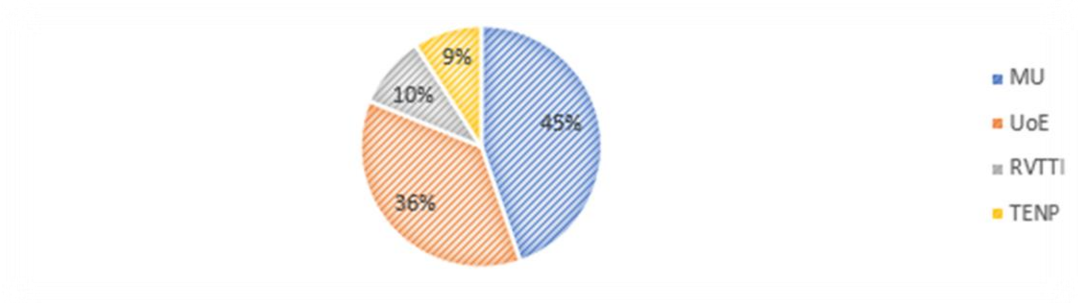


Figure 3.3: Summary of sample size distribution (%)

3.1.3 Body Dimensions

Designing of the standard desktop-chairs needs direct involvement of anthropometric measurements. Various researchers Igbokwe et al., (2019b), suggested body dimensions which are essential in designing furniture, specifically for students. Figure 3.10 shows all twelve (12) body dimensions which were selected for this research with additional of weight and Forearm fingertip length as the fourteenth (14^{th}) body measurement. Two dimensions were collected while a participant in the standing position, the remaining twelfth (12^{th}) dimensions were taken while the participant remained seated. All anthropometric data collected were based on ISO 7250-1:2017 (Basic human body measurements for technological design part 1: Body measurement definitions and landmarks) (Esmaeel & Order, 2017). However, actual chair dimensions are determined by measurements of the human body (anthropometric measurements). The two most relevant anthropometric measurement for chair design is the popliteal height and buttock popliteal length. The popliteal height is the distance from the underside of the foot to the underside of the thigh at the knees. It is sometimes called the "stool height". The term "sitting height" is reserved for the height to the top of the head when seated. The popliteal height, after adjusting for heels, clothing and other issues, is used to determine the height of the chair seat. The buttock popliteal length is the horizontal distance from the back most part of the buttocks to the back of the lower leg. This anthropometric measurement is used to determine the seat depth. (Igbokwe et al., 2019b). Table 3.3 shows the serial number and descriptions of the selected student’s body dimensions.

Table 3.3: Selection of body dimensions to be measured for classroom desktop-chair design.

S/NO. According to ISO 7250	*Basic students' body dimensions*	*Abbreviations and units*	*Description according to ISO 7250-1:2017*
6.1.2	Stature (body height)	S (cm)	The vertical distance from the floor to the highest point of the head (vertex).
6.2.1	Sitting height (erect)	SH (cm)	The vertical distance from a horizontal sitting surface to the highest point of the head (vertex).
6.2.4	Shoulder height, sitting	SHS (cm)	The vertical distance from a horizontal sitting surface to the acromion.
6.2.11	Popliteal height, sitting	PHS (cm)	The vertical distance from the foot-rest surface to the lower surface of the thigh immediately behind the knee bent at right angles.
6.2.10	Hip breadth, sitting	HBS (cm)	The breadth of the body measured across the widest portion of the hips.
6.2.5	Elbow height, sitting	EHS (cm)	The vertical distance from a horizontal sitting surface to the lowest bony point of the elbow bent at a right angle with the forearm horizontal.
6.4.7	Buttock popliteal length (seat depth)	BPL (cm)	The horizontal distance from the hollow of the knee to the rearmost point of the buttock.
6.4.8	Buttock knee length	BKL (cm)	The horizontal distance from the foremost point of the knee-cap to the rearmost point of the buttock.
6.2.12	Thigh clearance	TC (cm)	The vertical distance from the sitting surface to the highest point on the thigh.
6.2.2	Eye height, sitting	EHS (cm)	The vertical distance from a horizontal sitting surface to the outer corner of the eye (ectocanthus).
6.2.8	Shoulder (bideltoid) breadth	SB (cm)	The horizontal distance across the maximum lateral protrusions of the right and left deltoid muscles.
6.2.13	Knee height, sitting	KHS (cm)	The vertical distance from the floor to the highest point of the superior border of the patella (suprapatella, sitting).
6.1.1	Body mass (weight)	BM (kg)	The total mass (weight) of the body.
6.4.6	Forearm fingertip length	FFL (cm)	The horizontal distance from olecranon (back of the elbow) to the tip of the middle finger, with the elbow, bent at right angles.

Source: *(Esmaeel & Order, 2017).*

3.1.4 Measurements Procedure

The sample size was three hundred and eighty-two (382) Kenyan students (50% males and 50% females) were selected (at random) among the first year through the final year, from four selected tertiary institutions. The body size of each student was assessed using standard anthropometric measurement techniques (Esmaeel & Order, 2017), (Appendix XV). The consents of the students were obtained before the commencement of the measurements. In this present research, stature (body height) dimensions for each student were taken while they are standing as well as the body mass. All other dimensions were measured while they were sitting erect on adjustable-desk with the knees bent at 90^0. Each student was required to sit on an adjustable desk then the desk was adjusted till the desk gave the student maximum comfort. All anthropometric measurements were taken with the subjects wearing light clothing (shorts and t-shirts) in a relaxed and erect posture, without-shoes and with respect to the local culture (a female assistant was hired for measuring the females). Throughout the completion of all dimensions taken per subject, the time consumption was about 15 to 20 minutes. Furthermore, measurements were taken every working day for 20 days in February in year 2020. The students' measurements were done in the hostels for each of the four selected tertiary institutions. All anthropometric measurements were measured in centimeter (cm) expect the body weight (mass) by (kg).

3.1.5 Measuring Instruments and Materials

In order to measure various body dimensions of students, there are various techniques and tools, which are mostly used. Some of the methods include (1) Three-dimensional (3-D) scanners, which is too expensive and not accessible to all researchers and (2) The other methods include traditional anthropometric tools, which are considered to be simple, cheaper and accessible to many researchers comparing to 3D body scanner. It is a well-known fact that the use of standard mechanism may produce more accurate results. The equipment used in this present research comprises of:

1. Height and weighting scale were used to measure the body mass (weight) and stature (body height) as shown in figure 3.4.
2. Anthropometer was used to measure, sitting height, elbow height sitting, shoulder-height sitting, knee height, popliteal-height sitting and eye height sitting, buttock popliteal length (seat death) and buttock knee length as shown in figures 3.5.
3. Large sliding caliper (Range 0-600 mm with error 0.1 mm) was used to measure, shoulder (bideltoid) breadth, hip breadth sitting, thigh clearance and forearm-fingertip length as shown in figure 3.6.
4. Adjustable desk was used to make the subjects sit while measurements were being taken as shown in figures 3.7.
5. A metal tape was used to measure, classroom furniture dimensions as shown in figure 3.8. While a Goniometer was used to measure the backrest angles, seat angle and desk angle of the classroom furniture as shown in figure 3.9.
6. Minitab 17.0 was used to carry out statistical analysis of the record data.
7. ANOVA analysis was used to check for any variation of the results achieved.
8. Solid works 2019, software was used to design a desktop-chair.
9. CATIA V5R21, software was used to analyse the best selected desktop-chair.

Figure 3.4: Height and weighing scale.

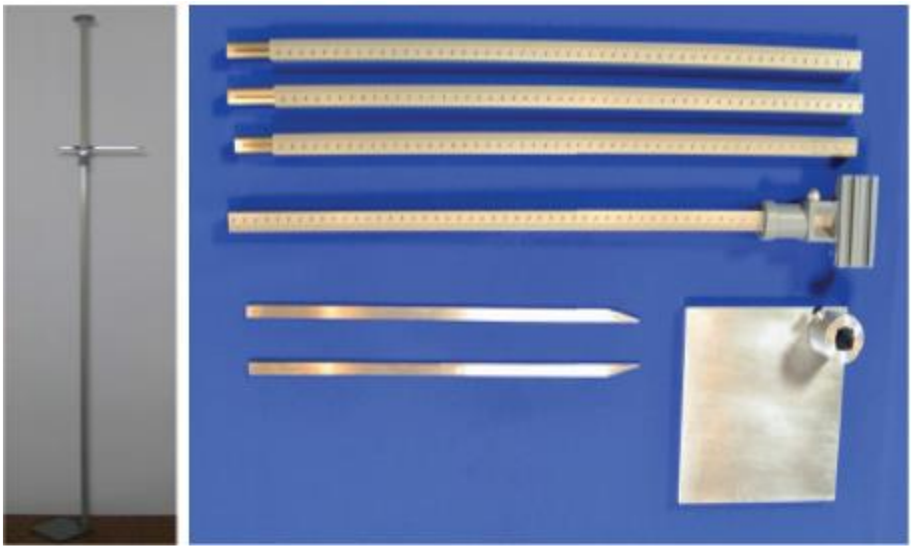


Figure 3.5: Anthropometer

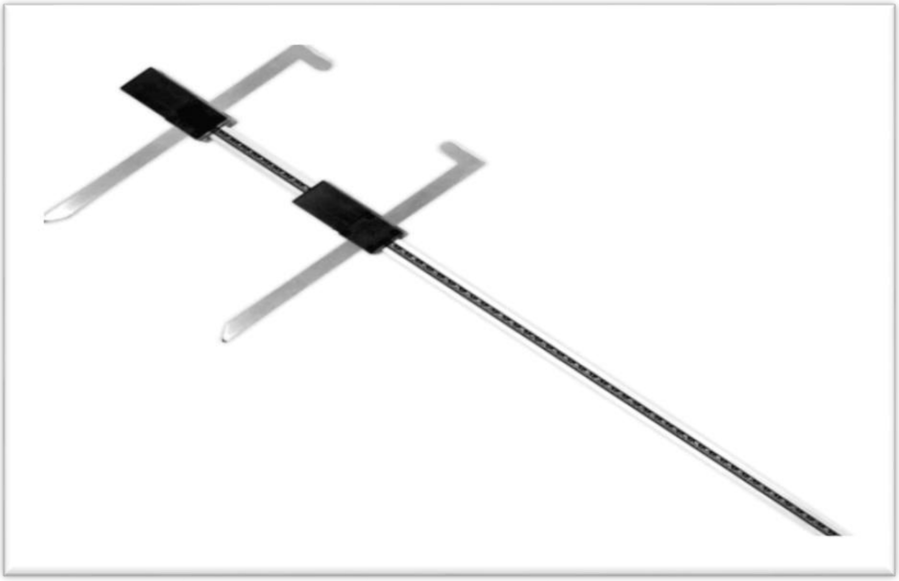


Figure 3.6: Large sliding caliper

Figure 3.7: Adjustable desk

Figure 3.8: Metal tape

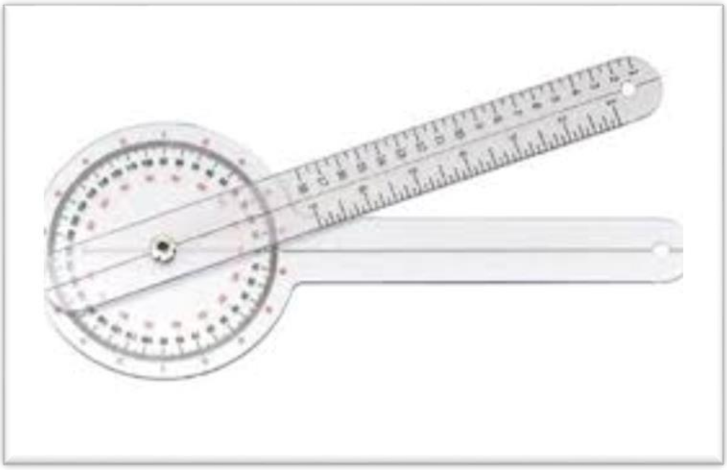
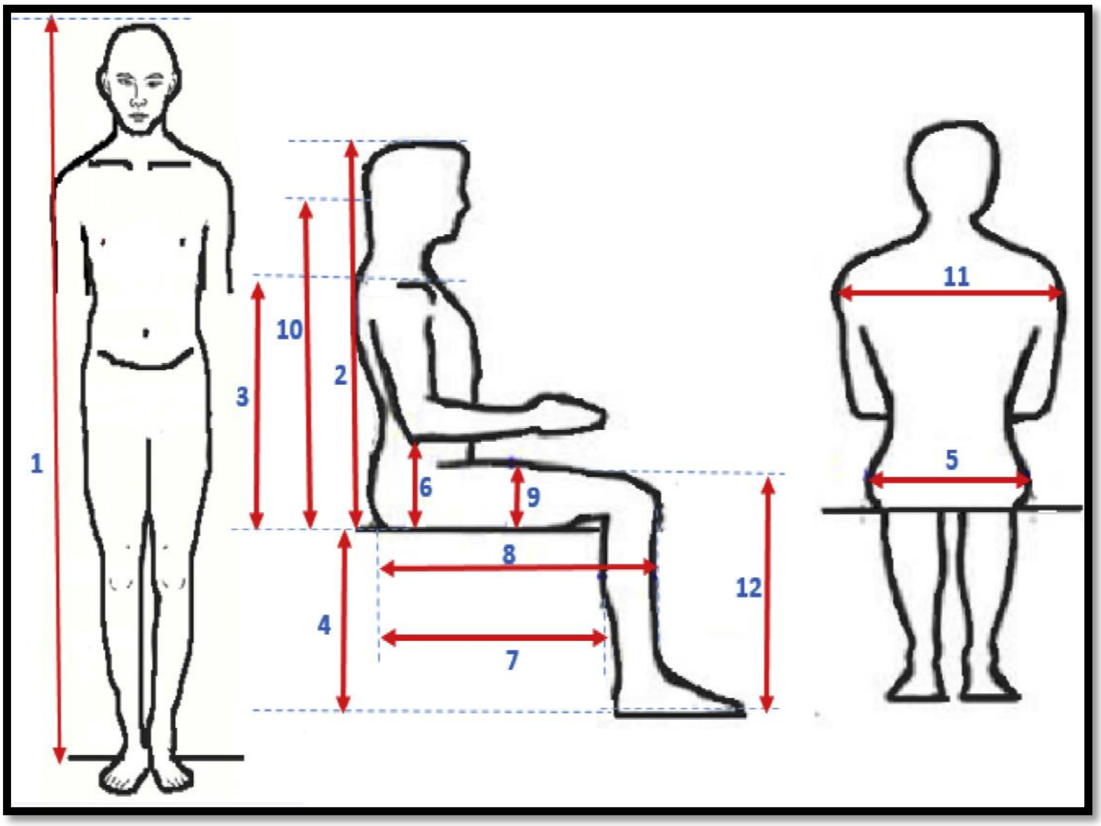


Figure 3.9: Goniometer

3.1.6 Data Acquisition

The dimensions measured were recorded in a form (Appendix VI). The form covers some personal information such as age, sex and name of the selected institutions. Participants were required to fill in their personal information before the measurement process started. This form also provides spaces for the entire fourteenth (14^{th}) anthropometric dimensions were measured (stature, sitting height, shoulder height, popliteal height, hip breadth, elbow height, buttock popliteal length, buttock knee length, thigh clearance, eye height, shoulder breadth, knee height, body mass and forearm fingertip length) from students with the help of anthropometric tools. Figures 3.10, 3.11 and 3.12 respectively, shows the exact location of all selected fourteen (14th) anthropometric dimensions.



Keys:

1	stature	7	buttock popliteal length
2	sitting height	8	buttock knee length
3	shoulder height	9	thigh clearance
4	popliteal height	10	Eye height
5	hip breadth	11	shoulder breadth
6	elbow height	12	knee height

Figure 3.10: Anthropometric data required in classroom furniture design.
Source: *(Igbokwe et al., 2019b).*

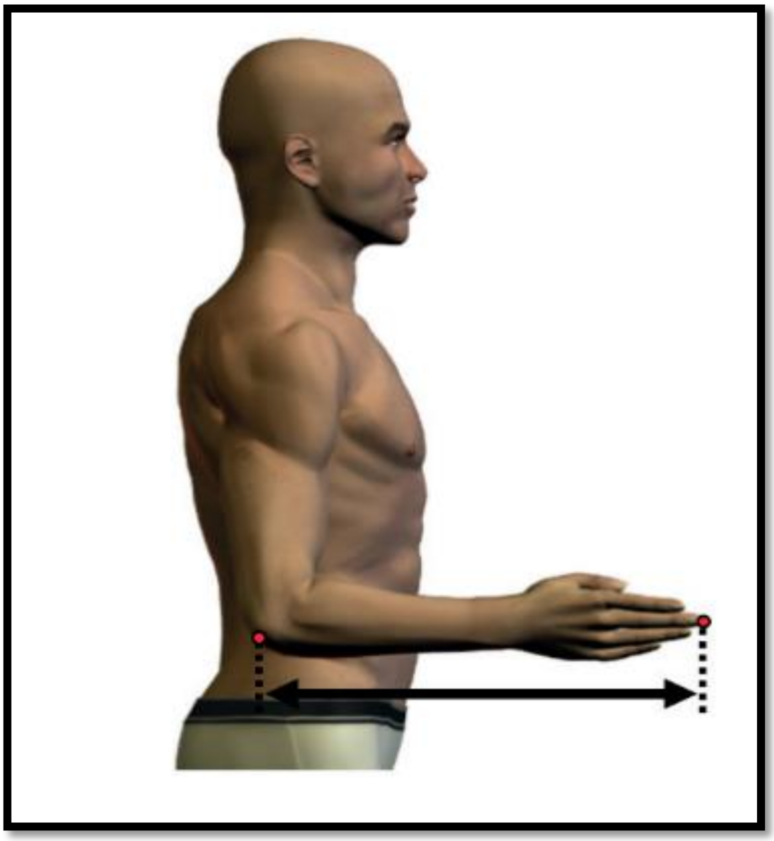


Figure 3.11: Forearm-fingertip length
Source: *(Esmaeel & Order, 2017)*

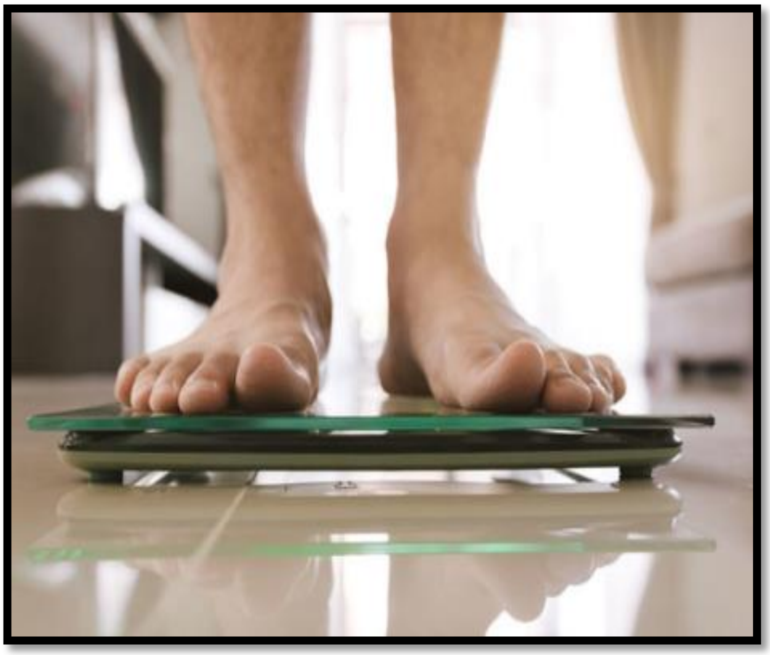


Figure 3.12: Body mass (weight)
Source: *(Esmaeel & Order, 2017 and https://health.clevelandclinic.org/do-bmi-scales-work).*

3.1.7 Furniture Measurement

Many types of classroom furniture are commonly used in the four selected tertiary institutions as shown in figure 3.13. These are made by local furniture businesses which lack standard dimensions. This is due to designers and manufactures having inadequate knowledge about ergonomics. Figure 3.14 and table 3.4 shown the dimensions of the student's desktop-chairs (Appendix V).

Figure 3.13: Use of existing desks and chairs in the classroom.
Source: *(Classroom at MU)*

Keys:	
SH	Seat height
BH	Backrest height
SW	Seat width
SD	Seat depth
DH	Desktop height from seat
DL	Desktop Length
DW	Desktop width

Figure 3.14: The dimensions of the desktop-chairs.

***Source**: (Classroom at MU)*

The dimensions of student's desktop-chairs are summarised in table 3.4.

Table 3.4: The dimensions of the student's desktop-chairs

Student's desktop-chairs	Dimensions
Seat height (SH)	The minimum distance measured vertically from the floor to the highest point on the front of the seat.
Seat depth (SD)	The minimum distance measured horizontally from the front edge of the sitting surface to its back edge.
Seat width (SW)	The horizontal distance between the lateral edges of the seat.
Backrest height (BH)	The minimum distance measured vertically from the top edge of the backrest to the sitting surface.
Desktop height (DH)	The minimum distance measured vertically from the upper
Desktop width (DW)	The maximum horizontal distance between the lateral edges of the desktop.
Desktop length (DL)	The maximum distance measured horizontally from the front edge of the desktop.

Source: *(Biswas et al., 2014).*

3.1.8 Classroom Furniture and Body Dimensions Mismatch

Comparison between required anthropometric measurements of each student and the relative dimension of current desktop-chair to define the range in which each furniture dimension is considered appropriate (Hoque et al., 2014). Different suggestions and relationships have been found in the literature to identify a match or mismatch between classroom furniture and students' anthropometric dimensions as shown in figure 3.15 as well as table 3.5.

3.1.8.1 Popliteal Height (PH) Against Sitting Height (SH)

A mismatch between PH and SH is defined when the SH is either > 95% or < 88% of the PH and it is possible to establish a criterion for SH (Hoque et al., 2014). Figure 3.15 shows the relationship between PH and SH.

Figure 3.15: Relationship between PH and SH.

Table 3.5: Relationship between the chair's dimensions and the body measurements

Body measurements	Relation
Popliteal height	Used to find the seat height of the chair
Buttock popliteal length	Used to find the seat depth of the chair
Hip breadth	Used to find the seat width of the chair
Shoulder height	Used to find the back rest height of the chair
Elbow height	Used to find the desktop height of the desktop
Forearm fingertip length	Used to find the desktop width of the desktop
Literature review	Used to find the desktop width of the desktop

Source: *(Al-Hinai et al., 2018b)***.**

3.2 Design of a Desktop-chair Using the Collected Anthropometric Measurements.

3.2.1 Introduction

the second objective of the research is to design a desktop-chair using the collected anthropometric measurements.

Using the collected anthropometric data, a students' desktop-chair was proposed. The engineering design software, SolidWorks 2019, was used to develop four different conceptual designs of the desktop-chair from which one option was selected through Concept Scoring Method (CSM). To select the best option, relevant data was collected from students through a survey. According to Taifa & Desai, (2017), It is highly recommended to consider requirements from students in designing classroom chairs. Anthropometric measurements whenever being considered for designing, it helps students in achieving comfortability level and reduce musculoskeletal disorders (MSDs). (Al-Hinai et al., 2018a), proposed an ergonomic chair to ensures better comfort and confidence for the students in the classroom environment. In this research, therefore, the ergonomic desktop-chairs used in the classroom environment should contribute towards the students' attention and motivation during the lecturing period.

To achieve the second objective, therefore, the entire methodology can be divided in the following steps as shown in figure 3.16.

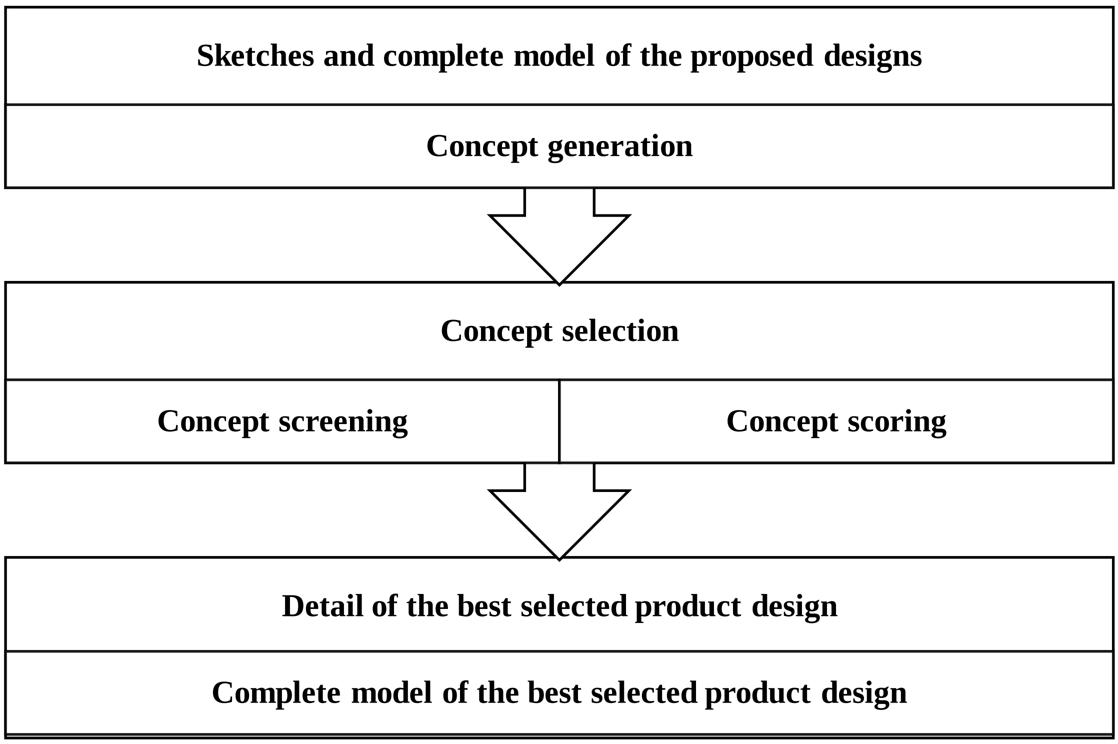


Figure 3.16: Main steps of the design methods.

3.2.2 Sketches and Complete Model of the Proposed Designs

The Sketches of the concept designs were designed after analysing all student's measurements, and these measurements were performed using a technical standard (Appendix XV). Sketching has proved to be the fastest way to define a problem, explore ideas and develop. Sketching generally means a rough or unfinished drawing, and the activity to sketch for general outline of something. Sketching has valuable activities such as brainstorming and concept evaluation (Shamsuddin et al., 2015). The idea of the sketch comes from automotive design for the desktop-chair, where the student has to be seated and this sketch of the desktop-chair was detailed design. The process of developing a fully defined design from a clear set of requirements, while creating deliverables and documentation appropriation. In this present research, therefore, engineering software (SolidWorks 2019), was used for proper drawing.

3.2.3 Concept Generation

The concept of the present desktop-chair was generated after analysing all the students' requirements. In this stage, four different concepts of the desktop-chair were generated based on students' requirements. These were: (a) Foldable desktop-chair with book holder at the back, (b) Desktop-chair and bag/book holder at a lower desk, (c) Foldable but fixed height desktop and (d) Fixed height desktop and book holder at the back. However, each concept desktop-chair design had one feature and functionalities.

3.2.4 Concept Selection

Concept selection is an activity in the product design process, where alternative concepts are compared and a decision is made to select the alternative(s) which proceed into the later phases of design. Several authors have raised concept selection as one of the most critical issues in design. There are at least three remarkable challenges in concept selection. First, the nature of available information is usually based on subjective perceptions and speculations and accurate calculations are seldom available. Second, the stake holders, users, designers and producers, can have conflicting requirements concerning (e.g. product design and manufacturing, or product performance and sales price). And third, the freezing of product concept can have far reaching effects on product costs and customer satisfaction, which can only be fixed with additional costs and time (Honkala et al., 2007).

3.2.4.1 Concept Screening

The concept screening is the method, which was used to narrow down the number of concepts quickly and to improve the qualities of the concepts. The concept screening method was considered as the way to reduce the number of the selected concept and to select the best one finally (Honkala et al., 2007; Al-Hinai et al., 2018a). Several selection criteria can be determined such as ergonomics safety, ease of use, ease of manufacture, usability, durability, etc.

3.2.4.2 Concept Scoring

After generating all four design concepts desktop-chair the next available step was to select the best design of a desktop-chair in order to analyse it. Moreover, both the concept screening and scoring process are followed by a six steps process, which leads the design team through the concept selection activity. These six steps are given as:

1. To prepare the collection matrix.
2. To rate the concepts based on selection criteria.
3. To rank the concepts based on the summed scores.
4. To combine and improve the concepts.
5. To select one or more concepts.

6. To reflect on the results and the process.

Also, the four existing concepts with their brief explanations are as follows:

Conceptual design a: Foldable desktop-chair with book holder at the back.

Conceptual design b: Desktop-chair and bag/book holder at the lower deck.

Conceptual design c: Foldable but fixed height desktop.

Conceptual design d: Fixed height desktop and book holder at the back.

The objective of concept scoring is to select the best conceptual design of the proposed ergonomic desktop-chair among the four concepts (a, b, c, and d) as preliminary selected through the concept screening process. In this process, all the selection criteria are given with specific weights in percentage, based on students' requirements. These weights are distributed among the selection criteria and sum of all weights should be 100 as displayed in table 4.18. After distributing the weights among thirteen (13) criteria, the next available step is to rate the concepts. The rates of the concepts are recommended to give a scale of 1 to 5 (1 is the lowest and 5 is the highest) based on students' requirements.

All of the weighted scores for the selection criteria is achieved by multiplying the rating with the specific weight, which is finally summed up to get the total weighted score as shown in the following formula (Mak, 2012; Al-Hinai et al., 2018a):

$$Total\ score = \sum_{1}^{n} w_n \text{ x } d_n \quad \text{(1)}$$

Where n is the count of selection criteria, w_n is the weight of n^{th} criteria and d_n is the rating of n^{th} criteria.

3.2.5 Detail of the Best Selected Product Design

Detailed design is the process of developing a fully defined design from a clear set of requirements while creating deliverables and documentation appropriation. In this research, therefore, SolidWorks 2019, as the engineering software was used for proper drawing.

3.2.6 Complete Model of the Best Selected Product Design

The modelling process was also done using SolidWorks 2019, as the engineering software with the rendering process of the desktop-chair design based on students' anthropometric data.

3.3 Analysis of the Desktop-chair Design Using RULA Ergonomic Analytical Tool

3.3.1 Introduction

The third objective was to analyse the desktop-chair design using RULA ergonomic analytical tool.

After the students' desktop-chair was proposed the best option was selected and analysed using ergonomic software, Computer-Aided Three-dimensional Interactive Application (CATIA) based on Rapid Upper Limb Analysis (RULA), ergonomic analytical tool.

The RULA ergonomic analytical tool considers biomechanical and postural load requirements of job tasks/demands on the neck, trunk and upper extremities (Manzoor et al., 2019). Ergonomics can be taken as the science of making things more efficient to the user's need and reducing any discomfort during application. Ergonomics aims to attain the best possible match between the product and its user in context of the intended applications (Romli & Aminian, 2018). Furthermore, Paul et al., (2019), discussed the process of ergonomically analysing design using CATIA V5 human digital models

(HDM) and details on possible design changes, which makes it ergonomic and user friendly. This research, Therefore, uses the CATIA V5R21 as the ergonomics/engineering software to analyse the best selected desktop-chair design. Figure 3.20 shows the methods adopted for the ergonomic design and analysis of desktop-chair using CATIA V5 human digital models (HDM).

To achieve the third objective, therefore, entire methodology can be divided in the following steps as shown in figure 3.17.

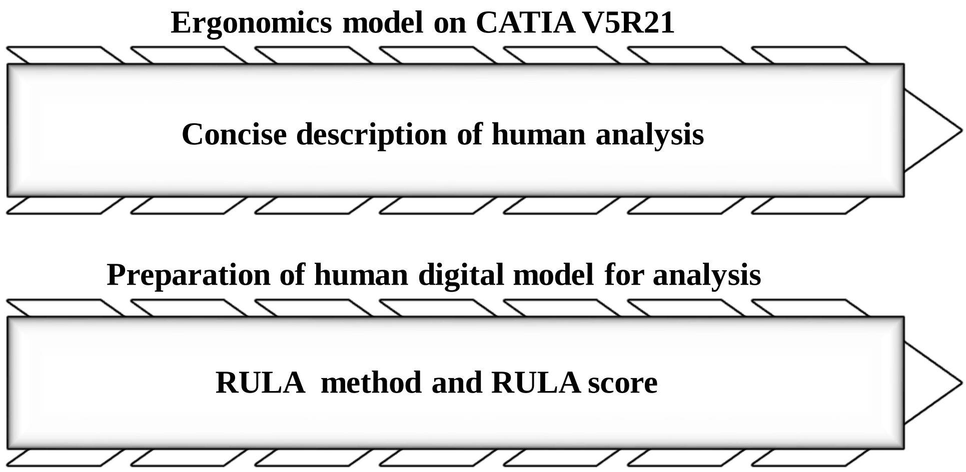


Figure 3.17: Main steps of the analysation process.

3.3.2 Ergonomics Model on CATIA V5R21

The desktop-chair comfort depends on aesthetic, maintainability, material quality, ergonomics and safety, structure, ease of manufacture, shape, utility and function, handling, durability, stability, etc. Structure and shape in the design of a desktop-chair depends on available anthropometric data of the users. CATIA V5R21 is the ergonomics work bench can be of aid for ergonomic analysis of desktop-chair.

Figure 3.20 shows the method adopted for the design of a desktop-chair by human digital model (HDM) using CATIA V5, as suggested by Paul et al., (2019), and Ye et al., (2013). The ergonomics design processes are defined by four sub-modules which are:

1. Human Measurement Editor Model (HME)
2. Human Activity Analysis Model (HAA)
3. Human Posture Analysis Model (HPA)
4. Human Builder Model (HBM).

On CATIA V5R21 the RULA analysis can be applied to a case study. Firstly, in the section "Human Builder (HB)" from the module "Ergonomics Design & Analysis" a manikin must be created as shown in figures 3.18 and 3.19 respectively.

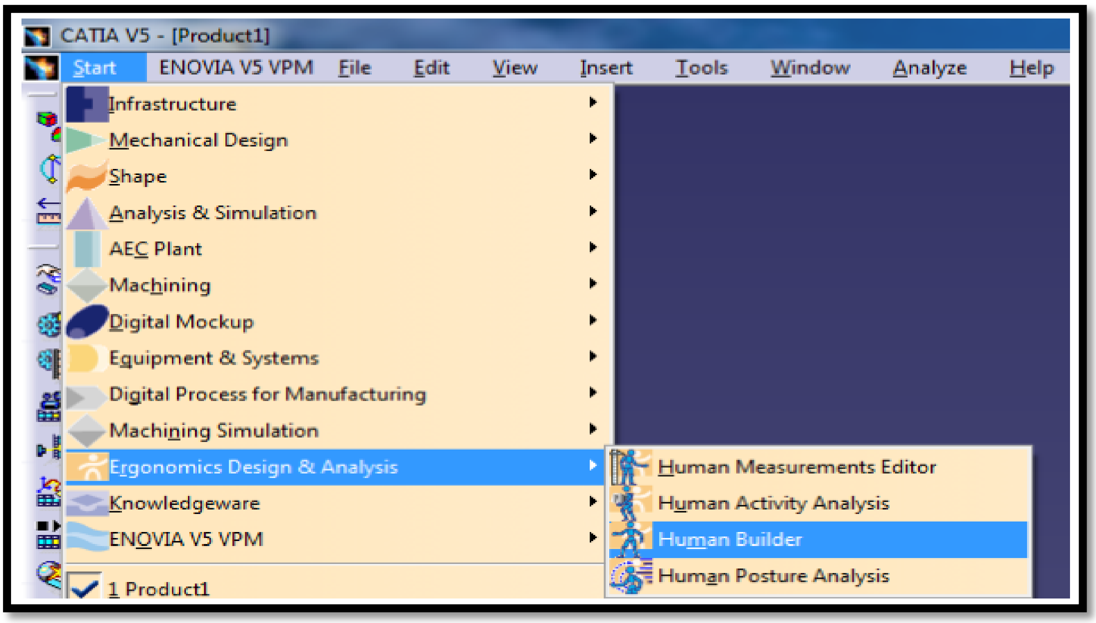


Figure 3.18: Ergonomics module on CATIA V5R21

Figure 3.19: Manikin insertion for the research

In order to realise the analysis, the manikin must be brought in section human activity analysis (HAA). Therefore, the present research was applied to human digital model (HDM) using human measurement editor model (HME). RULA virtually analyses user comfort on a desktop-chair design. And therefore, the flow chart shows the steps for analysing a model using RULA analytical tool as summarizing in figure 3.20.

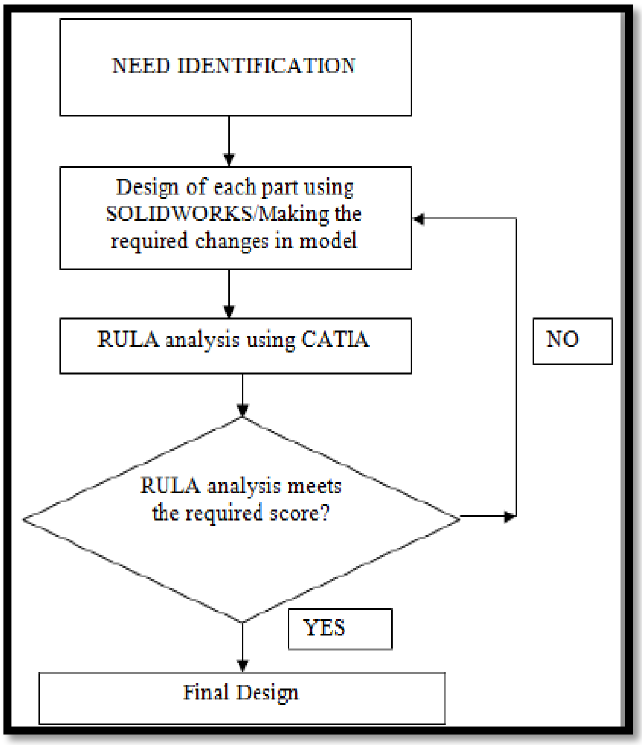


Figure 3.20: RULA analysis using CATIA methodology.
Source: *(John et al., 2020; Paul et al., 2019).*

3.3.3 Concise Description of Human Activity Analysis (HAA)

The virtual analysis in CATIA V5R21 can investigate and improve products and workplaces. Human activity analysis (HAA) uses manikin to evaluate postures by a range of tools and methods in the digital environment. The ergonomic fit of human manikin determines shape, size and dimensions.

3.3.4 Preparation of Human Digital Model (HDM) for Analysis

The focus of human measurements editor (HME) is on creating anthropometrically detailed digital human for advanced ergonomics analysis and global target audience accommodation. human measurements editor (HME), provides anthropometric data from the five default population such as (Japanese, American, French, Canadian and Korean). The human models can be shown in different posture such as (sitting and standing, etc.) and different point of views, along with the related anthropometric variables on them (John et al., 2020; Paul et al., 2019; Romli & Aminian, 2018).

3.3.5 RULA Method and RULA Score

CATIA V5R21 software, provides the feature of ergonomic analysis. The model of the desktop-char was designed using SolidWorks 2019, then was converted into a STEP file and then was opened in CATIA V5R21 for the analysis (Paul et al., 2019). Manikins of 50^{th} percentile of man/woman were created digitally with the student’s anthropometric data. For this ergonomics analysis, the human model has been generated for 50^{th} percentile of students' male/female anthropometric data. This set up is chosen to design for average, which is fit all.

Table 3.6 tabulates the essential anthropometric data inputs used in the developed of the manikin/human model in CATIA V5R21.

According to analysis, the posture of the manikin varies. Optimize criteria in I.K Behavior panel, aids to optimize posture for RULA analysis or postural score. RULA analysis tool is launched to select manikin. By clicking on the corresponding icon in the toolbar, the RULA dialog box appears. Figure 3.21 shows the RULA dialog box in CATIA V5R21. The side of the human digital model (HDM) to analyse and predetermined best suited posture was selected. There are three types of posture, static, intermittent and repeated. Intermittent repeat the tasks less than or equal to four times in one minute. The static and repeated option is posture repeats the task greater than four times in one minute. In the same posture option in the parameters ‘’load’’ is filled to specify the load of the object manipulated by the person. The RULA analysis method is based on score and colour. The score and colour are related to each other. The colours are green, yellow, orange and red. The green colour indicates that the posture is good and acceptable while the red colour indicates that the posture is bad and needs to be changed required immediately. The scores are divided into four (4) scales where each scale has its description. Table 3.7 shows the description of each scale in RULA analysis (Romli & Aminian, 2018).

Table 3.6: 50th percentile students' male/female anthropometric dimensions for HDM

Variables (Sitting)	50th percentile	Units	Input method
Sitting-height	81.80	cm	Manual
Eye height, sitting	68.00	cm	Manual
Hip-breadth, sitting	32.86	cm	Manual
Weight	59.50	kg	Manual

Source: *(student’s anthropometric-data, table 4.11).*

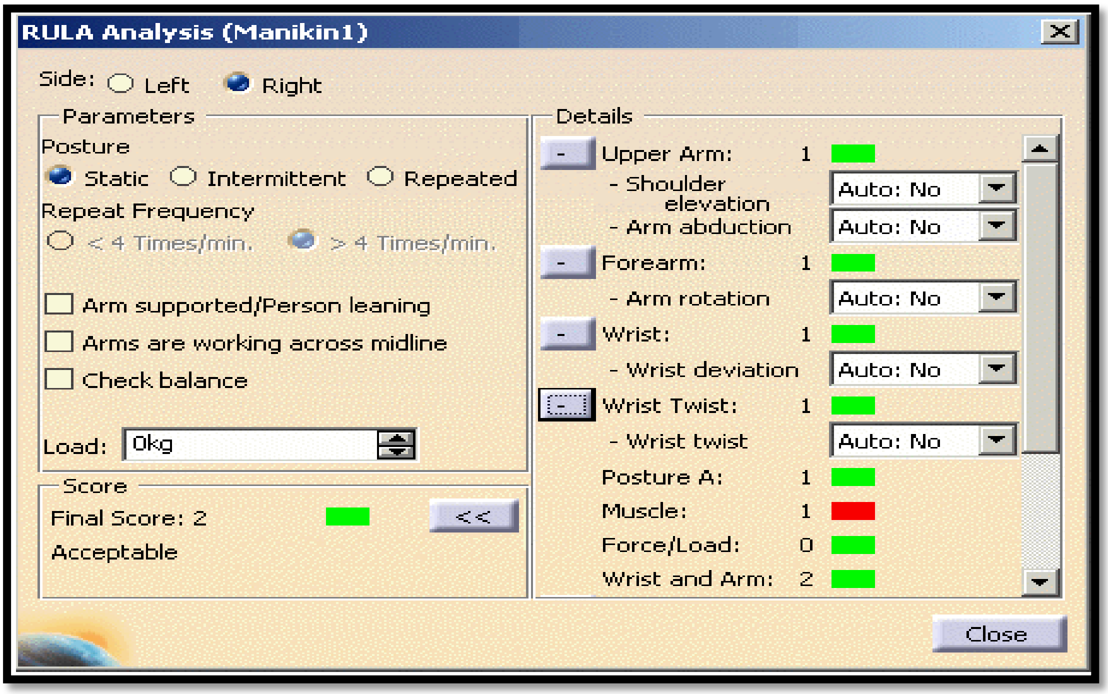


Figure 3.21: The RULA dialog box in CATIA V5R21

Source: *(Paul et al., 2019).*

Table 3.7: RULA analysis score description

RULA Score	Risk Level	Action
1 - 2	Negligible	Acceptable
3 - 4	Low	Further investigation and changes may be needed
5 - 6	Medium	Investigation and changes required soon
7	High	Investigation and changes required immediately

Source: *(Romli & Aminian, 2018).*

3.4 Calculation Pth Percentiles using Minitab 17.0.

The process of calculation pth percentile of a set of the database using Minitab 17.0 software as following (Borges, 1990):

1. Arrange the data such that the entries span from the smallest to the largest values (ascending order).
2. Calculation an index i (the position of the pth percentile) as in formula follows:

i = (p / 100) * n………………………………………………………………………... (1)

Where: p is the percentile and n is a number of values that appear in the data. If i is not an integer, round it up, the next integer greater than i represents the position of the p^{th} percentile.

3. If i is an integer, the p^{th} percentile is the average of values in positions i and i + 1.

In addition, the design of the desktop-chair for use by students in the higher educations was based on the following criteria:

1. Seat height: The popliteal height should be considered in the design of the seat height. Ismaila et al., (2013b), recommended 5^{th} percentile of popliteal height and allowance 0.45 cm for shoe heel. The 5^{th} percentile of the popliteal height is 40.50 cm and if this is added to shoe heel allowance of 0.45 cm, the seat height should be 40.95 cm as shown in table 4.12.
2. Seat width: The hip breadth should be considered in the design of the seat width. Musa & Ismaila, (2014), recommended that the 95^{th} percentile of hip breadth be used plus a clothing allowance of 15 percent. In this present research, the 95^{th} percentile of the hip breadth of 39.36 cm is used with an allowance of 15 percent of value (5.9 cm) which translates to a seat width of 45.26 cm as shown in table 4.12.
3. Seat depth: The anthropometric dimension to be considered in the design of the seat depth is the buttock popliteal length. Mohamed et al., (2010), recommended the 5^{th} percentile of the buttock popliteal length as the dimension to be used to determine the seat depth. In this research, the 5^{th} percentile of the buttock popliteal length and thus the seat depth is 38.10 cm as shown in table 4.12.

4. Desktop height from seat: According to Adekunle et al., (2014), the 5^{th} percentile of the elbow height should be considered in the design. This value is 19.11 cm as shown in table 4.12.
5. Backrest height (Upper): For the design of the upper part of the backrest, the shoulder height (sitting) is considered. The 5^{th} percentile of sitting shoulder height used by Mohamed et al., (2010), is adopted in the present research and this dimension is 50.96 cm from the seat surface as shown in table 4.12.
6. Desktop width: This dimension was determined as recommended by Ismaila et al., (2013b), to give a desktop width of 24.20 cm.
7. Desktop length: According to Mohamed et al., (2010); and Ismaila et al., (2013b), the 50^{th} percentile of the forearm fingertip length is considered for the dimension of the desktop length which was found to be 47.44 cm as shown in table 4.12.
8. Backrest angle: According to Ismaila et al., (2013b), the backrest should have a rearward slope of between 90^0 and 110^0 while Mohamed et al., (2010), recommended 96^0. A rearward slope of 109^0 is adopted in this present research to provide a good backward leaning.
9. Desk angle: According to Ansari et al., (2018); Adekunle et al., (2014); and Taifa & Desai, (2017), the desk angle should be between 0^0 to 20^0. Therefore, a rearward slope of 0^0 is adopted in this present research to provide a good desk ward leaning especially when the students are in the writing activity.
10. Seat angle: As proposed by (Igbokwe et al., 2019b), the seat angle should be 110^0.

3.5 Analysis of variance (ANOVA) using Minitab 17.0.

Frequently, scientists are concerned with detecting differences in means between various levels of a factor or between different groups. As an example of the one-way ANOVA (Analysis of variance) procedure using Minitab 17.0, statistical package as the popular software, Besides, one-way ANOVA was developed by the English mathematician statistician, R. A. Fisher (Bower, 2018; Altincicek, 2014).

In this research, therefore, one-way ANOVA was used as a statistical technique to compare three or more means. In addition, when applying one-way ANOVA analysis of variance, there are three key assumptions that should be satisfied (Wahid et al., 2017):

1. The observation are obtained independently and randomly from the populations defined by the factor levels.
2. The population at each factor level is (approximately) normally distributed.
3. These normal populations have a common variance.

3.6 Data Analysis

The data recorded were analysed statistically with the help of Minitab 17.0, statistical package. One-way ANOVA analysis was used to check for any variation of the results achieved. The anthropometric data was analysed using mean, standard deviation (***St. Dev***), minimum (min), maximum (max), 5^{th}, 50^{th} and 95^{th} percentiles. SolidWorks 2019, software, was used for modelling classroom desktop-chair.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents the results and discussions from the experiments carried out on the characteristics of current and new desktop-chair in the selected institutions covering students' measurements, student’s requirements, designed and analysed desktop-chair based on anthropometric-database. It is aimed to show the new design dimensions using anthropometric measurements in the four selected tertiary institutions and compares them with the work of other researches as well as the existing furniture. Also, the concepts of the proposed student’s desktop-chair as designed using an engineering design software (SolidWorks 2019). The RULA results are also presented.

4.1 Collect Anthropometric Data for Students from Four Selected Tertiary Institutions Namely: MU, UoE, RVTTI and TENP.

The results obtained from the four selected tertiary institutions were analysed using one-way ANOVA analysis and Minitab 17.0 statistical package.

4.1.1 Anthropometric Dimension of the Students at MU, UoE, RVTTI and TENP

Tables 4.1, 4.3, 4.5 and 4.7 shows the descriptive statistics of the recorded data for students at MU, UoE, RVTTI and TENP. These statistics include the mean, standard deviation (St. Dev), minimum (min) and maximum (max) of the entire data were collected. While the percentiles analysis of the recorded data for students from MU, UoE, RVTTI and TENP, is shown in tables 4.2, 4.4, 4.6 and 4.8. This analysis took into cognizance, the 5^{th}, 50^{th} and 95^{th} percentiles. The analysis considered as many students in the population group as possible.

Table 4.1: Descriptive statistics of the record data for students at MU (n = 171)

Variable and Units	Mean	St. Dev	Min	Max
Age (Yrs.)	20.52	1.66	17.00	26.00
Stature (cm)	168.43	8.45	147.50	187.50
Sitting height (cm)	80.99	4.33	71.60	91.50
Shoulder height (cm)	54.40	2.99	47.10	63.20
Popliteal height (cm)	44.48	2.95	37.00	51.20
Hip breadth (cm)	33.80	3.85	23.38	63.30
Elbow height (cm)	20.39	1.16	17.09	23.28
Buttock popliteal length (cm)	42.68	2.92	32.10	49.20
Buttock knee length (cm)	52.01	3.14	41.90	59.00
Thigh clearance (cm)	14.32	1.73	10.84	20.10
Eye height (cm)	67.41	3.75	54.50	78.23
Shoulder breadth (cm)	41.76	3.89	20.96	68.50
Knee height (cm)	51.87	3.75	40.60	66.80
Body mass (kg)	60.44	9.77	39.50	102.0
Forearm fingertip length (cm)	47.72	2.82	38.45	54.99

Table 4.2: Percentile analysis of the recorded data for students from MU

Variable and Units	**5th Percentile**	**50th percentile**	**95th percentile**
Age (Yrs.)	18.00	20.00	24.00
Stature (cm)	155.00	168.00	183.50
Sitting height (cm)	74.50	81.90	88.70
Shoulder height (cm)	50.50	54.50	58.40
Popliteal height (cm)	39.70	44.30	49.50
Hip breadth (cm)	29.50	33.06	39.76
Elbow height (cm)	19.12	20.36	22.02
Buttock popliteal length (cm)	38.00	43.10	46.90
Buttock knee length (cm)	47.00	52.30	57.30
Thigh clearance (cm)	11.88	14.14	17.40
Eye height (cm)	62.00	68.00	73.10
Shoulder breadth (cm)	36.96	41.48	46.59
Knee height (cm)	46.50	52.10	57.50
Body mass (kg)	47.50	59.50	77.50
Forearm fingertip length (cm)	43.46	47.44	51.72

Table 4.3: Descriptive statistics of the record data for students at UoE (n = 139)

Variable and Units	**Mean**	**St. Dev**	**Min**	**Max**
Age (Yrs.)	1994	1.44	17.00	24.00
Stature (cm)	168.15	6.98	152.50	188.00
Sitting height (cm)	80.99	3.57	73.00	91.50
Shoulder height (cm)	54.39	2.43	48.50	63.50
Popliteal height (cm)	44.89	2.61	38.60	51.20
Hip breadth (cm)	32.92	2.51	28.82	41.08
Elbow height (cm)	20.42	1.09	17.89	23.28
Buttock popliteal length (cm)	42.52	2.56	36.40	49.00
Buttock knee length (cm)	51.81	2.95	43.70	59.80
Thigh clearance (cm)	14.74	1.35	11.67	18.94
Eye height (cm)	67.44	3.12	61.40	78.50
Shoulder breadth (cm)	41.52	2.74	32.33	48.57
Knee height (cm)	51.97	2.74	45.60	59.10
Body mass (kg)	60.57	7.04	44.00	77.00
Forearm fingertip length (cm)	47.63	2.61	41.40	54.34

Table 4.4: Percentile analysis of the recorded data for students from UoE

Variable and Units	**5th Percentile**	**50th percentile**	**95th Percentile**
Age (Yrs.)	18.00	20.00	23.00
Stature (cm)	157.50	168.00	180.00
Sitting height (cm)	75.99	81.70	87.00
Shoulder height (cm)	50.97	54.40	57.80
Popliteal height (cm)	40.50	44.60	49.60
Hip breadth (cm)	29.76	32.00	38.31
Elbow height (cm)	19.11	20.29	22.52
Buttock popliteal length (cm)	38.10	42.70	47.30
Buttock knee length (cm)	47.20	51.80	56.90
Thigh clearance (cm)	12.61	14.75	17.01
Eye height (cm)	62.96	68.00	71.98
Shoulder breadth (cm)	36.79	41.40	45.96
Knee height (cm)	47.40	52.00	56.80
Body mass (kg)	49.00	60.00	74.50
Forearm fingertip length (cm)	43.13	47.44	52.29

Table 4.5: Descriptive statistics of the record data for students at RVTTI (n = 37)

Variable and Units	Mean	St. Dev	Min	Max
Age (Yrs.)	21.35	1.49	18.00	25.00
Stature (cm)	168.80	8.75	150.00	185.00
Sitting height (cm)	81.04	4.43	72.00	90.10
Shoulder height (cm)	54.58	3.19	47.50	62.30
Popliteal height (cm)	45.23	2.84	40.00	50.00
Hip breadth (cm)	33.92	4.34	29.19	48.37
Elbow height (cm)	20.26	1.27	17.17	22.61
Buttock popliteal length (cm)	42.29	2.55	38.00	47.90
Buttock knee length (cm)	51.82	3.12	46.80	57.90
Thigh clearance (cm)	14.66	2.26	11.37	20.55
Eye height (cm)	67.47	3.74	60.40	75.00
Shoulder breadth (cm)	42.26	3.35	35.56	51.62
Knee height (cm)	52.39	3.23	47.10	58.50
Body mass (kg)	61.13	12.64	45.00	102.00
Forearm fingertip length (cm)	47.37	2.65	43.11	52.80

Table 4.6: Percentile analysis of the recorded data for students from RVTTI

Variable and Units	5th Percentile	50th Percentile	95th Percentile
Age (Yrs.)	19.00	21.00	25.00
Stature (cm)	157.00	168.00	185.00
Sitting height (cm)	75.90	81.70	90.10
Shoulder height (cm)	50.95	55.00	62.30
Popliteal height (cm)	40.80	45.30	50.00
Hip breadth (cm)	29.51	33.04	45.65
Elbow height (cm)	17.78	20.14	22.44
Buttock popliteal length (cm)	38.40	42.50	46.40
Buttock knee length (cm)	46.90	52.40	56.20
Thigh clearance (cm)	11.40	14.43	19.56
Eye height (cm)	62.88	68.00	75.00
Shoulder breadth (cm)	36.79	42.00	47.59
Knee height (cm)	47.60	52.40	57.80
Body mass (kg)	47.00	58.00	80.60
Forearm fingertip length (cm)	43.49	47.44	51.49

Table 4.7: Descriptive statistics of the record data for students at TENP (n = 35)

Variable and Units	Mean	St. Dev	Min	Max
Age (Yrs.)	21.83	1.69	19.00	26.00
Stature (cm)	168.54	7.51	152.00	182.50
Sitting height (cm)	81.07	3.78	72.50	88.50
Shoulder height (cm)	55.38	2.39	48.00	57.80
Popliteal height (cm)	44.72	2.54	40.20	50.00
Hip breadth (cm)	33.45	3.78	29.28	44.46
Elbow height (cm)	20.37	1.52	17.22	22.80
Buttock popliteal length (cm)	42.24	2.67	36.50	47.70
Buttock knee length (cm)	51.23	3.02	45.50	58.70
Thigh clearance (cm)	14.69	2.04	11.56	19.93
Eye height (cm)	67.44	3.08	61.00	72.98
Shoulder breadth (cm)	42.45	3.56	37.03	55.72
Knee height (cm)	51.95	3.07	46.30	58.60
Body mass (kg)	60.29	8.84	45.00	83.50
Forearm fingertip length (cm)	47.38	2.62	41.49	52.44

Table 4.8: Percentile analysis of the recorded data for students from TENP

Variable and Units	5th Percentile	50th Percentile	95th Percentile
Age (Yrs.)	19.00	22.00	26.00
Stature (cm)	156.00	168.00	182.00
Sitting height (cm)	74.99	81.70	88.00
Shoulder height (cm)	50.95	54.40	57.80
Popliteal height (cm)	40.30	45.00	48.50
Hip breadth (cm)	29.57	31.80	43.89
Elbow height (cm)	17.65	20.84	22.76
Buttock popliteal length (cm)	38.50	42.10	47.50
Buttock knee length (cm)	47.30	51.10	56.70
Thigh clearance (cm)	11.69	14.20	19.03
Eye height (cm)	62.50	68.00	72.50
Shoulder breadth (cm)	37.48	41.55	47.84
Knee height (cm)	46.50	52.00	56.80
Body mass (kg)	45.50	60.00	78.50
Forearm fingertip length (cm)	43.46	47.44	52.31

According to Ismaila et al., (2013); and Al-Hinai et al., (2018), the seat height, seat width, seat depth and backrest height are the important dimensions for the design of the chair while desktop width and desktop length are the dimensions that are essential for the design of the desktop. Besides, popliteal height is used to find the seat height, hip breadth is used to find the seat width, elbow height is used to find desktop height from the seat of the desktop-chair, buttock popliteal length is used to find the seat depth, shoulder height is used to find the backrest height and forearm fingertip is used to find the desktop length. The above parameters obtained from the four selected institutions were compared to check for any variability using one-way ANOVA analytical tool, the following hypotheses were analysed:

H_0: All means of samples are significantly equal.

H_1: At least one mean is significantly different.

Significance level: $\alpha = 0.05$.

The criterion for rejection:

Reject H_0 if p-value is less than 0.05.

All the tests' results were failed to reject the null hypothesis (e.g., popliteal height p = 0.39). This implies, therefore, that the mean of the different samples is equal showing that there is no significant difference among the anthropometric data from the four selected tertiary institutions. The measurements conducted from students at these institutions were done under the same condition with the standard procedure. One-way ANOVA results are shown in tables 4.9 (a), (b), (c), (d), (e) and (f) for popliteal height, hip breadth, elbow height, buttock, popliteal length, shoulder height and forearm fingertip length respectively:

Table 4.9 (a): One-way ANOVA of popliteal height for students at four selected institutions

Source of Variation	SS	df	MS	F	P-value	F-crit
Between institutions	23.37108	3	7.790362	1.005923	0.390123	2.62852
Within institutions	2927.417	378	7.744488			
Total	2950.788	381				

Table 4.9 (b): One-way ANOVA of hip breadth for students at four selected institutions

Source of variation	SS	df	MS	F	P-value	F-crit
Between institutions	68.34739	3	22.78246	1.889392	0.130867	2.62852
Within institutions	4557.959	378	12.05809			
Total	4626.307	381				

Table 4.9 (c): One-way ANOVA of elbow height for students at four selected institutions

Source of variation	SS	df	MS	F	P-value	F-crit
Between institutions	0.814131	3	0.271377	0.199548	0.89667	2.62852
Within institutions	514.0642	378	1.359958			
Total	514.8784	381				

Table 4.9 (d): One-way ANOVA of buttock popliteal length for students at four selected institutions

Source of variation	SS	df	MS	F	P-value	F-crit
Between institutions	8.711935	3	2.903978	0.387054	0.762393	2.62852
Within institutions	2836.048	378	7.502772			
Total	2844.76	381				

Table 4.9 (e): One-way ANOVA of shoulder height for students at four selected institutions

Source of variation	SS	df	MS	F	P-value	F-crit
Between institutions	1.221368	3	0.407123	0.053128	0.983837	2.62852
Within institutions	2896.632	378	7.663049			
Total	2897.854	381				

Table 4.9 (f): One-way ANOVA of forearm fingertip length for students at four selected institutions

Source of variation	SS	df	MS	F	P-value	F-crit
Between institutions	8.017107	3	2.672369	0.34281	0.794383	2.62852
Within institutions	2946.694	378	7.795487			
Total	2954.711	381				

The anthropometric measurements of male and female are analysed in table 4.10, to understand the variance between them. From the results, there was a small variation. According to Romli & Aminian, (2018); and Taifa & Desai, (2017), anthropometry has three major principles. The first principle is to design for an extreme individual, that is either the extreme population (95^{th} percentile) or minimum population (5^{th} percentile). The second principle is to design for an adjustable range that considers both the 5^{th}

percentile of female and the 95th percentile of male in order to accommodate 90% of the population. The third principle is to design for the average, which is primarily corresponding to the 50th percentile of male and female. Therefore, this research focused on the design and analysis of a desktop-chair for the 50th percentile, so as to fit all students at four selected institutions.

Table 4.10: Statistical approach for the anthropometric measurement of male/female students

Gender / Dimension and Units	Male (n = 191)			Female (n = 191)		
	5th	***50th***	***95th***	***5th***	***50th***	***95th***
Age (Yrs.)	18.00	21.00	24.00	18.00	20.00	23.00
Stature (cm)	161.50	173.00	183.50	154.00	164.00	174.50
Sitting height (cm)	76.82	83.20	88.70	74.02	77.69	83.60
Shoulder height (cm)	51.85	55.90	58.40	48.50	52.50	56.07
Popliteal height (cm)	42.50	46.50	50.00	39.70	43.30	46.90
Hip breadth (cm)	29.26	31.75	36.49	30.20	34.03	40.79
Elbow height (cm)	18.96	20.21	21.99	19.11	20.34	22.58
Buttock popliteal (cm)	38.40	43.40	47.70	38.00	42.00	45.70
Buttock knee length (cm)	47.50	52.90	57.80	46.80	50.90	55.70
Thigh clearance (cm)	11.69	13.75	16.07	12.56	15.25	18.75
Eye height (cm)	63.85	69.90	73.10	61.98	64.90	70.06
Shoulder breadth (cm)	39.20	42.79	46.83	36.35	40.30	46.50
Knee height (cm)	48.50	53.40	58.40	46.50	50.20	54.20
Body mass (kg)	50.50	61.50	75.50	46.50	58.00	77.50
Forearm finger length (cm)	43.73	48.35	52.60	43.11	47.00	50.86

The anthropometric data of the students are presented in table 4.11 as means, standard deviations, and 5th, 50th and 95th percentiles. Besides, the minimum and maximum of the dimensions and the body mass are included. In anthropometry, percentiles of various body dimensions are used to determine design values for an application. For seat height, the 5th percentile (lower percentile) of the popliteal height of the population is typically suggested so that a larger number of the population is usually recommended so that a larger number of the population is accommodated and thus allow a short person to use the desktop-chair. Similarly, 5^{th} percentile of buttock popliteal length is considered for seat depth, sitting shoulder height for upper backrest height, armrest height for lower back-rest height. But, the 95^{th} percentile (larger percentile) of the hip breadth is usually recommended in the design of the seat widths to accommodate as many people of the population as possible and thus allows a fat person to use the desktop-chair. Therefore, table 4.11 gives a summary of the anthropometric measures based on the average of the collected anthropometric data, which can be used in designing a desktop-chair for students at four selected tertiary institutions in Uasin-Gishu County, Kenya.

Table 4.11: Summary of anthropometric dimension for students of the selected institutions (n = 382)

Variable and Units	Mean	St. Dev	Min	Max	5th Percentile	50th percentile	95th Percentile
Age (Yrs.)	20.51	1.67	17.00	26.00	18.00	20.00	23.00
Stature (cm)	168.38	7.86	147.50	188.00	155.50	168.00	182.00
Sitting height (cm)	81.01	4.01	71.60	91.50	75.00	81.80	88.00
Shoulder height (cm)	54.41	2.76	47.10	63.50	50.96	54.50	57.80
Popliteal height (cm)	44.73	2.78	37.00	51.20	40.50	44.50	49.60
Hip breadth (cm)	33.46	3.49	23.38	63.30	29.57	32.86	39.36
Elbow height (cm)	20.39	1.16	17.09	23.28	19.11	20.30	22.37
Buttock popliteal (cm)	42.54	2.73	32.10	49.20	38.10	42.65	46.90
Buttock knee length (cm)	51.85	3.05	41.90	59.80	47.20	51.90	56.70
Thigh clearance (cm)	14.54	1.70	10.84	20.55	11.96	14.43	17.39
Eye height (cm)	67.43	3.46	54.50	78.50	62.88	68.00	72.50
Shoulder breadth (cm)	41.78	3.43	20.96	68.50	37.02	41.47	46.59
Knee height (cm)	51.96	3.29	40.60	66.80	46.80	52.10	57.30
Body mass (kg)	60.54	9.09	39.50	102.0	48.00	59.50	75.50
Forearm finger length (cm)	47.62	2.70	38.45	54.99	43.46	47.44	51.88

After, analysing all the anthropometric data of the students, therefore, the ergonomic desktop-chair is proposed which can cover the maximum number of students. Table 4.12 shows the recommended dimensions for a new desktop-chair with their criteria for use in the four selected tertiary institutions in Uasin-Gishu County, Kenya.

Table 4.12: Recommended dimensions for a new desktop-chair for use in tertiary institutions in Uasin-Gishu County, Kenya.

Seat feature	Anthropometric measure	Design dimensions and Units	Criteria/Determinant	References
Seat height	Popliteal height	40.95 (cm)	5th percentile of popliteal height + 0.45 cm shoe heel allowance	(Ismail a et al., 2013)
Seat width	Hip breadth	45.26 (cm)	95th percentile of hip breadth + 15% allowance for clothing	(Musa & Ismaila, 2014)
Seat depth	Buttock popliteal length	38.10 (cm)	5th percentile of buttock popliteal length	(Mohamed et al,2010)
Desktop height from seat	Elbow height	19.11 (cm)	5th percentile of elbow-height	(Musa et al., (2014),
Backrest height	Shoulder height	50.96 (cm)	5th percentile of shoulder height	(Mohamed et al,2010)
Desktop width	-	24.20 (cm)	Literature review suggestions	(Ismaila et al., 2013)
Desktop length	Forearm fingertip length	47.44 (cm)	50th percentile of forearm fingertip length	(Ismaila et al., 2013)
Backrest angle	-	109^0	Literature review suggestions	(Mohamed et al, 2010)
Desk angle	-	0^0	From literature review	(Ansari et al, 2018)
Seat angle	-	110^0	From literature review	(Igbokwe et al, 2019)

Table 4.12 shows that seat height of proposed concept desktop-chair should be 40.59 cm for the students in the four selected tertiary institutions as opposed to the existing seat heights of 48.10 cm (desktop-chair), 46.00 cm (steel foldable chair), 48.26 cm (wood foldable-chair) and 42.50 (fixed chair) as shown in table 4.14. A high seat makes the underside of the thigh to become compressed causing discomfort and restriction in blood circulation (Ismaila et al., 2013a). The dimension of the seat height in this present research is lower than 52 cm recommended by Al-Hinai et al., (2018a) for students in Sultan Qaboos University in Finland and 44.50 cm proposed by Mohamed et al., (2010) for students in Sri Lanka. Also, higher than 38.60 cm proposed by Tunay & Melemez, (2008) for Turkish students, 37.70 cm proposed by Mououdi, (1997) for students in higher institutions in Iran and 36.45 cm proposed by Ismaila et al., (2013a) for students in tertiary institutions in Nigeria as shown in table 4.13. Thus, this predisposes that chairs designed for the students in these countries, especially Finland and Nigeria may not be comfortable for Kenyan students. From the present research, the seat depth should be 38.10 cm for the students in the four selected tertiary institutions in Uasin-Gishu County, Kenya. As seen in table 4.14, the seat depths of the existing chairs are 35.51 cm (desktop-chair), 41.91 cm (steel foldable chair), 20.32 cm (wood foldable chair) and 48.26 (fixed chair), which makes the seats deep for the students, shallow and large. However, large a depth does not allow appropriate use of back support, which causes curvature of the spine (kyphosis) and may lead to uncomfortable posture. Also, shallow of the seat may cause the user to have the sensation of falling off and may result in the back of support of the lower thighs (Ismaila et al., 2013b). In these selected institutions, therefore, there is a mismatch between the students' body dimensions and the classroom chairs dimensions that may have discomfort for students in the long run.

Table 4.13: Comparison of dimensions of the seat height of new desktop-chair with selected countries

Dimensions and country / Institutions	Country	Seat height and Units	References
For students in Sultan Qaboos University in Finland	Finland	52.00 (cm)	(Al-Hinai et al., 2018)
For students in height institutions in Sri Lank	Sri Lanka	44.50 (cm)	(Mohamed et al., 2010)
For students in the selected tertiary institutions in Uasin-Gishu, Kenya	Kenya	40.95 (cm)	
for Turkish students	Turkish	38.60 (cm)	(Tunay & Melemez, 2008)
for students in higher institutions in Iran	Iran	37.70 (cm)	(Mououdi, 1997)
For students in tertiary institutions in Nigeria	Nigeria	36.45 (cm)	(Ismaila et al., 2013)

4.1.5 Characteristics of the Chairs in the Four Selected Tertiary Institutions

Many types of classroom chairs were identified in the four selected tertiary institutions in Uasin-Gishu County, Kenya. The dimensions were different in the respective institutions, due to different companies may have constructed them.

Table 4.14: Dimensions of the existing classroom chairs in the four selected tertiary institutions.

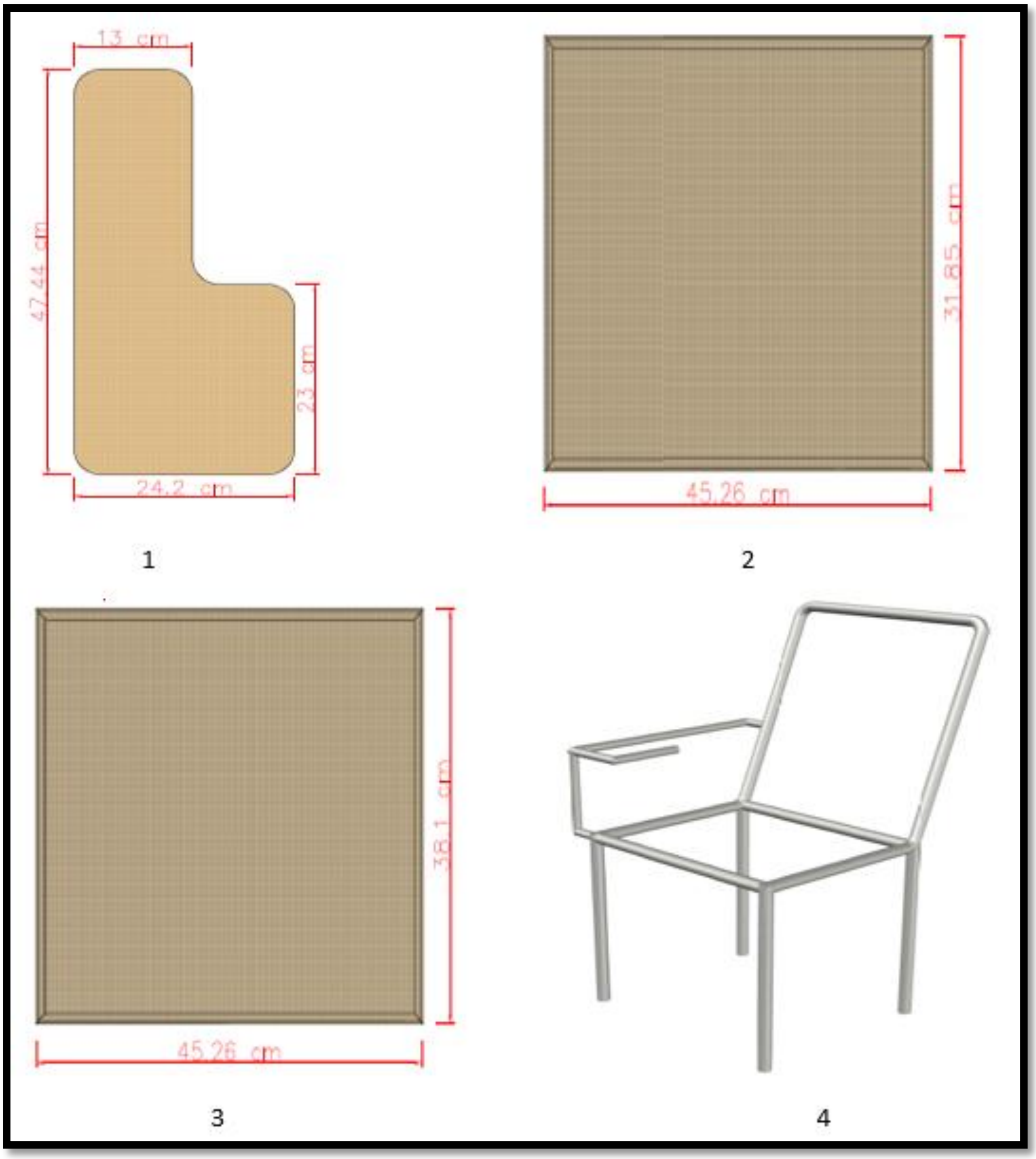
Types of the existing classroom furniture	Seat height and Units	Seat depth and Units
Desktop-chair	48.10 (cm)	35.51 (cm)
Steel foldable chair	46.00 (cm)	41.91 (cm)
Wood foldable chair	48.26 (cm)	20.32 (cm)
Fixed chair	42.50 (cm)	48.26 (cm)

The anthropometric characteristics of the users are essential for the accomplishment of various tasks safely and economically. If the mismatches exist among the human anthropometric data and classroom furniture, it may result in decreased productivity, discomfort, accidents, biomechanical stresses fatigue, injuries, pain and cumulative traumas etc. (Ismaila et al., 2013b).

4.2 Design of a Desktop-chair Using the Collected Anthropometric Measurements

4.2.1 Sketches and Complete Model of the Proposed Designs

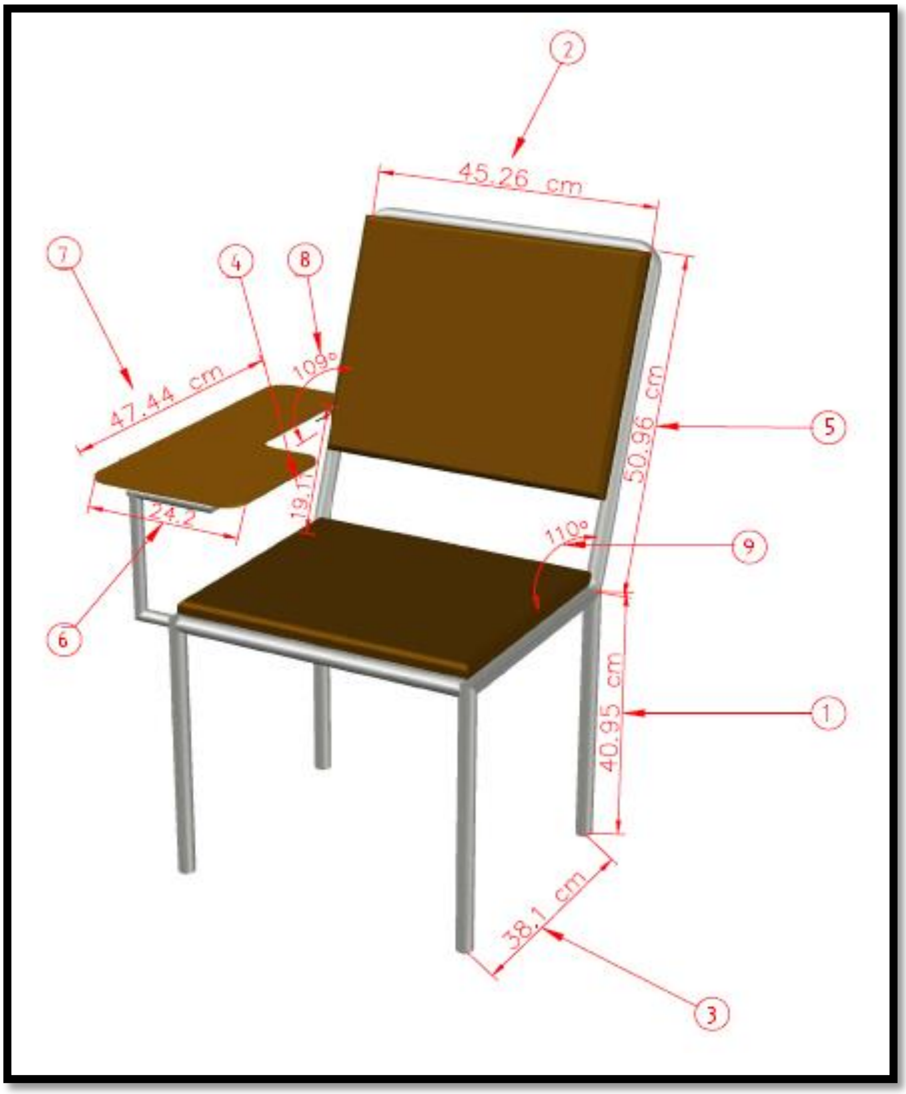
The design process began with concept creation based on a user-centred design that factored in safety and health to reduce the ergonomics risks. This is because the user-centred design is a principle technique for the product design that will be integrated with the anthropometric data and the recommendation by the users. The design approach must fit 95% of the students. For an instant, the good conceptual design allows users to predict the effects of their actions. This means that the good conceptual design of classroom desktop-chairs will motivate or inspire students to sit on it comfortably and confidently. After, running the analysis of the recorded data, as shown in table 4.12, there is one type of innovative ergonomically suitable desktop-chair design was identified in the four selected tertiary institutions. The proposed innovative ergonomic desktop-chair design was drawn in two (2) different ways using SolidWorks 2019, software, as shown in figures 4.1a, 4.1b, 4.2a and 4.2b.



Keys:

1	*Desktop*
2	*Backrest*
3	*Seat*
4	*Frame*

Figure 4.1a: Sketches of the proposed students' desktop-chair.



Keys:

1	*Seat height*
2	*Seat width*
3	*Seat depth*
4	*Desktop height from seat*
5	*Backrest height*
6	*Desktop width*
7	*Desktop length*
8	*Backrest angle*
9	*Seat angle*

Figure 4.1b: Complete model of the proposed students' desktop-chair.

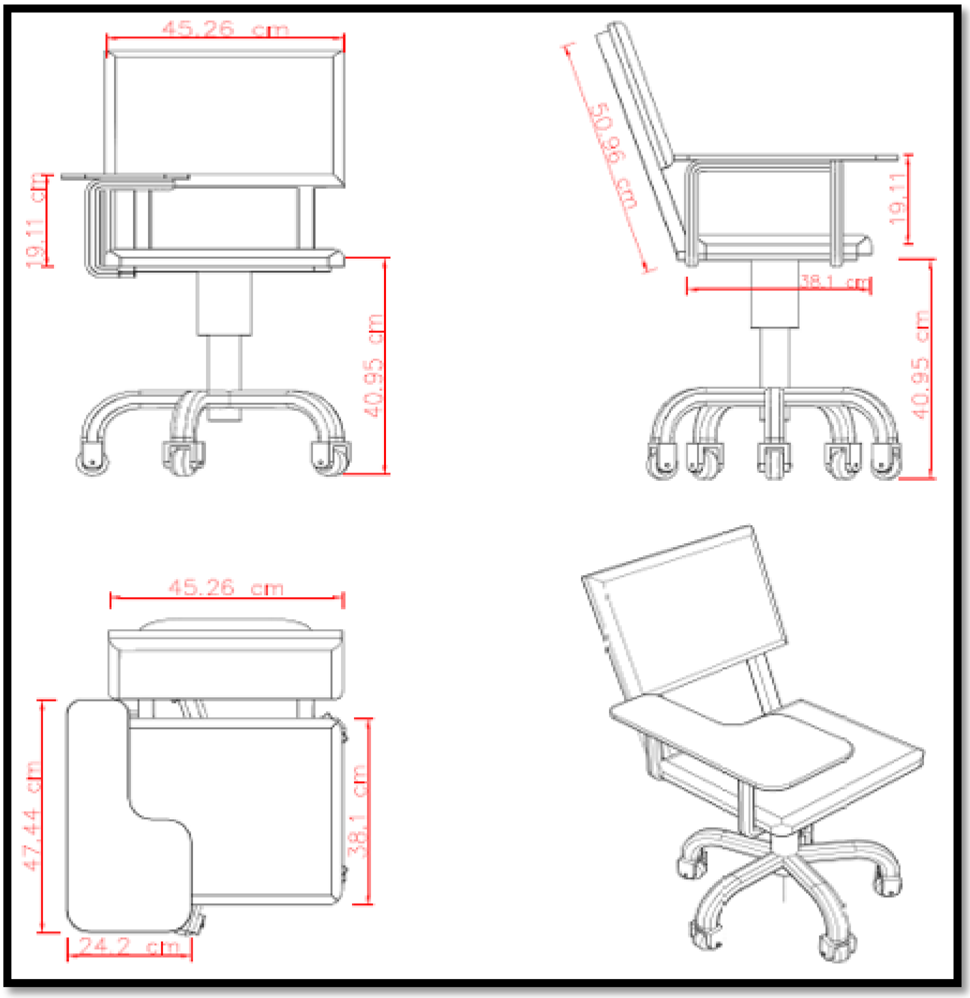


Figure 4.2a: Sketches of the proposed adjustable students' desktop-chair.

Figure 4.2b: Complete model of the proposed adjustable students' desktop-chair.

4.2.2 The best Selected Conceptual Design of the Desktop-chair

The goal here is to select the best conceptual design of the proposed ergonomic desktop-chair among the four concepts designs based on students' requirements. These requirements were performed using questionnaires as the most suitable, which was pre-tested to ensure its reliability and validity (Madara, 2016). To design these concept desktop-chairs, relevant anthropometric data were collected from the students through questionnaires.

4.2.2.1 Students' Requirements Survey Results

A pretest study targeting the key stakeholders, at (i) MU, (ii) UoE, (iii) RVTTI and (iv) TENP, was conducted. 382 respondents were randomly selected, from students. A questionnaire was selected as the most suitable method, which pre-tested to ensure its validity and reliability. Questionnaire data were analysed list wise in Minitab 17.0 statistical package.

4.2.2.1.1 Arranging the Importance of the Needs

Ranking was done after all the questionnaire data were analysed using Minitab 17.0 statistical package. Table 4.15 presents the importance of the needs of the desktop-chair as received from the students' requirements survey results. This ranking was done for the scale from 1 to 5 (1 is the lowest and 5 is the highest).

Table 4.15: Importance of the needs of the desktop-chair

No.	*Functional requirements*	*Importance*
1.	(a) Foldable desktop with book holder at the back	2
2.	(b) Desktop-chair and bag/book holder at lower desk	1
3.	(c) Foldable but fixed height desktop	3
4.	(d) Fixed height desktop and book holder at the back	4

4.2.2.1.2 Arranging the Importance of the Factors

After all the questionnaire data were analysed using Minitab 17.0 statistical package, the factors were arranged as per importance. Table 4.16 presents the importance of the factors of the desktop-chair as received from the students' requirements survey results. This ranking was done in a scale of 1 to 5 (1 is the lowest and 5 is the highest) which were calculated to weights. Their results are only presented as a summary.

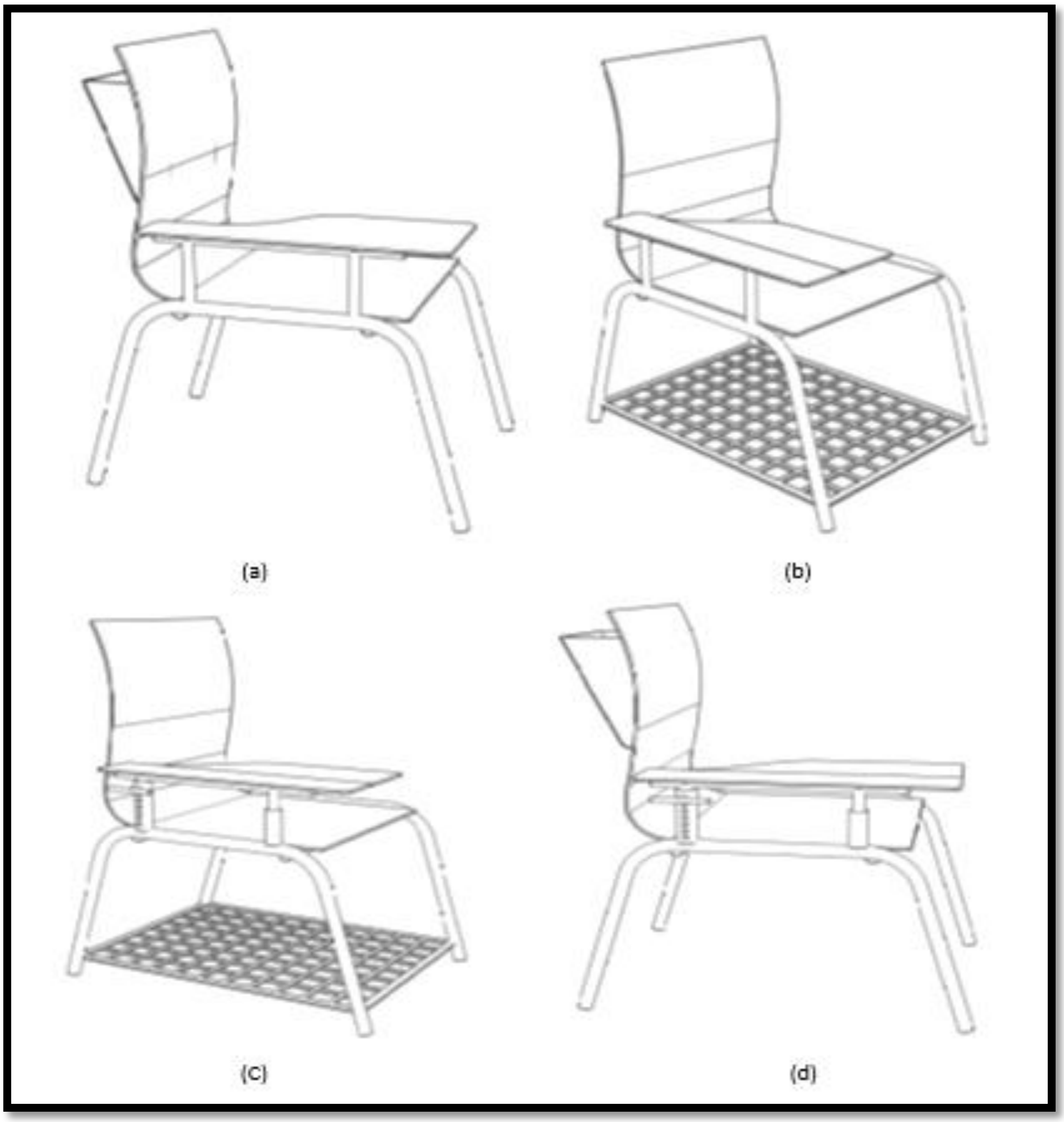
Table 4.16: Importance of the Factors of the desktop-chair

No.	Selection factors	%
1.	Ergonomics and safety (EAS)	6.7%
2.	Ease of use (EOU)	6.6%
3.	Ease of manufacture (EOM)	8.9%
4.	Durability (D)	6.9%
5.	Aesthetic (Ae)	8.4%
6.	Reliability	7.3%
7.	Maintainability (M)	7.4%
8.	Social appeal (SA)	8.5%
9.	Environmental soundness (ES)	7.9%
10.	Economic value (EV)	7.8%
11.	Utility and function (UAF)	7.2%
12.	Life cycle cost (LCC)	8.6%
13.	Availability (Av)	7.8%

4.2.3 Concepts Generation

The concept of the present desktop-chair was generated after analysing all the students' requirements. In this stage, four different concepts of the desktop-chair were generated based on students' requirements. Each concept desktop-chair deign had one feature and functionalities. These four conceptual desktop-chairs were: (a) Foldable desktop-chair with book holder at the back, (b) Desktop-chair and bag/book holder at a lower desk,

(c) Foldable but fixed height desktop and (d) Fixed height desktop and book holder at the back. These four conceptual desktop-chairs, therefore, were drawn by using SolidWorks 2019 software, are presented in figures 4.3 (a), (b), (c) and (d).



Keys:

a) Foldable desktop with book holder at the back

b) Desktop-chair and book holder at a lower desk

c) Foldable but fixed height desktop

d) Fixed height desktop and book holder at the back

Figure 4.3: Four concept design of desktop-chairs done by SolidWorks software.

4.2.4 Concept Scoring

The aim of concept scoring method is to select the best conceptual design of the proposed ergonomic desktop-chair among the four concepts designs (a, b, c and d) as shown in figure 4.3. In this process, therefore, all the selection criteria are given with specific weights in percentage, based on students' requirements. These weights are distributed among the selection criteria and sum of all weights should be 100 as displayed in table 4.18. After distributing the weights among the thirteen (13) criteria, the next step is to rate the concepts. The rates of the concepts were given a scale of 1 to 5 (1 is the lowest and 5 is the highest) based on students' requirements, which are defined and categorized in table 4.17:

Table 4.17: Relative performance and their rating

Relative performance	**Rating**
Much worse than the reference	1
Worse than the reference	2
Same as the reference	3
Better than the reference	4
Much better than the reference	5

Each of the weighted scores for the selection criteria was achieved by multiplying the rating with the specific weight, which is finally summed up to get the total weighted score. The results from the concept scoring are displayed in table 4.18. From table 4.18, it is noticed that the concept (d) was selected as the best one and used for the analysis.

Table 4.18: Display of concept scoring matrix.

Selection criteria	**weight**	**Conceptual designs**							
		A		***B***		***C***		***D***	
		Rating	Weighting score	Rating	Weighting score	Rating	Weighting score	Rating	Weighting Score
Ergonomics and safety	6.7%	2	0.134	1	0.067	3	0.201	4	0.268
Ease of use	6.6%	2	0.132	1	0.066	3	0.198	4	0.264
Ease of manufacture	8.9%	2	0.178	1	0.089	3	0.267	4	0.356
Durability	6.9%	2	0.138	1	0.069	3	0.207	4	0.276
Aesthetic	8.4%	2	0.168	1	0.084	3	0.252	4	0.336
Reliability	7.3%	2	0.146	1	0.073	3	0.219	4	0.292
Maintainability	7.4%	2	0.148	1	0.074	3	0.222	4	0.296
Social appeal	8.5%	2	0.170	1	0.085	3	0.255	4	0.340
Environmental soundness	7.9%	2	0.158	1	0.079	3	0.237	4	0.316
Economic value	7.8%	2	0.156	1	0.078	3	0.234	4	0.312
Utility and function	7.2%	2	0.144	1	0.072	3	0.216	4	0.288
Life cycle cost	8.6%	2	0.172	1	0.086	3	0.258	4	0.344
Availability	7.8%	2	0.156	1	0.078	3	0.234	4	0.312
Total of weighting score		**2**		**1**		**3**		**4**	
Rank		Third		Fourth		Second		First	
Continue?		No		No		No		**Develop**	

4.2.5 Details of the Best Selected Product Design of the Desktop-chair

After the best concept of the desktop-chair was selected, the next step was to design each part of it using SolidWorks 2019. The complete details of the desktop-chair concept assembly with necessary dimensions is displayed in figure 4.4. The desktop-chair design is 'S' shaped. All required dimensions of the desktop-chair are given based on the anthropometric details collected during the students' survey.

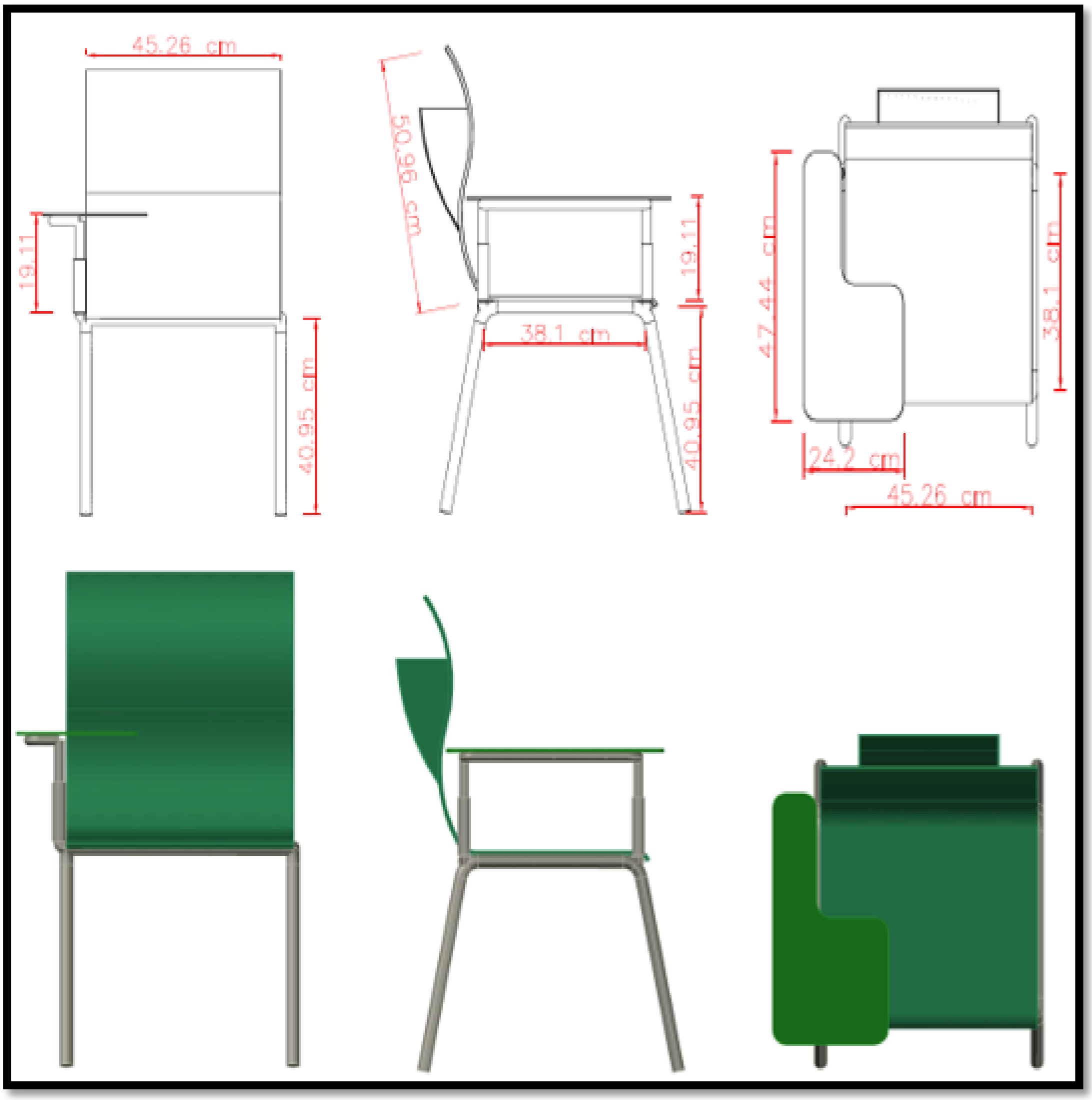


Figure 4.4: Details of the best selected concept desktop-chair design

4.2.6 Complete Model of the Best Selected Product Design of the Desktop-chair

The design process began with concept creation which was user-centred and incorporated with safety and health measures aimed at reducing ergonomic risks. The user-centred design is a principle method that integrates anthropometric measurements and the recommendation of the users. The design approach must fit 95% of the users. For an instant, a good conceptual design allows users to predict the effects of their actions. This means that a good design of the classroom desktop-chair will motivate or inspire students to sit on it confidently and comfortably. From the literature, it is identified that the best ergonomics and healthy position while sitting on a chair is 130^0 (Al-Hinai et al., 2018b). The desktop-chair was designed using SolidWorks 2019 software, based on the average anthropometric data as mentioned earlier in table 4.12. The complete model of the best selected concept desktop-chair is shown in figure 4.5.

Figure 4.5: Display of the best selected desktop-chair done by 3D SolidWorks.

4.3 Analysis of the Desktop-chair Design Using RULA Ergonomic Analytical Tool

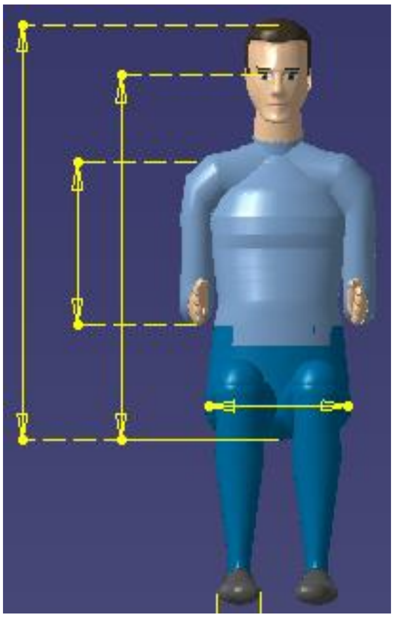
After the best desktop-chair design was selected, the next step was to analyse it by using RULA ergonomic analytical tool.

4.3.1 Preparation of Human Digital Model for RULA Analysis

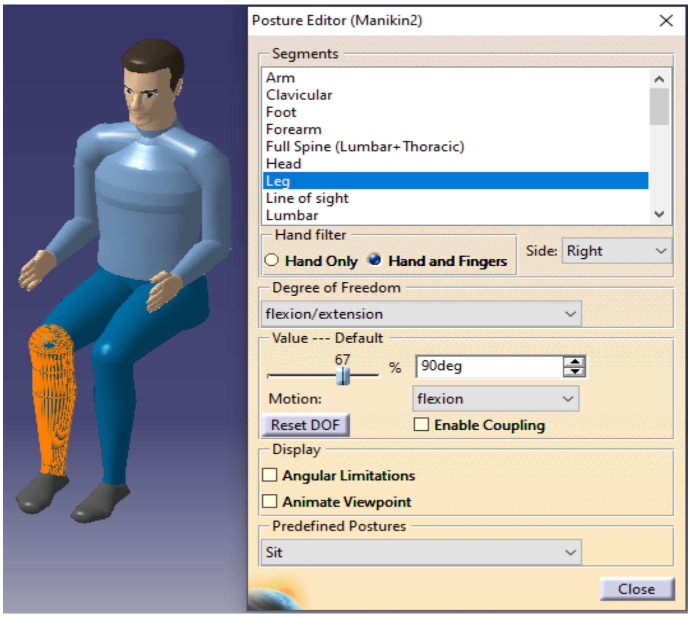
The specific postural analysis in CATIA V5R21 was based on the ergonomics posture analysis of Rapid Upper Limb Analysis (RULA). There were two steps that needed to be addressed before the final evaluation could be made. This were: (1) development of a manikin and (2), assessment of the recommended desktop-chairs through posture analysis.

4.3.1.1 Development of a Manikin

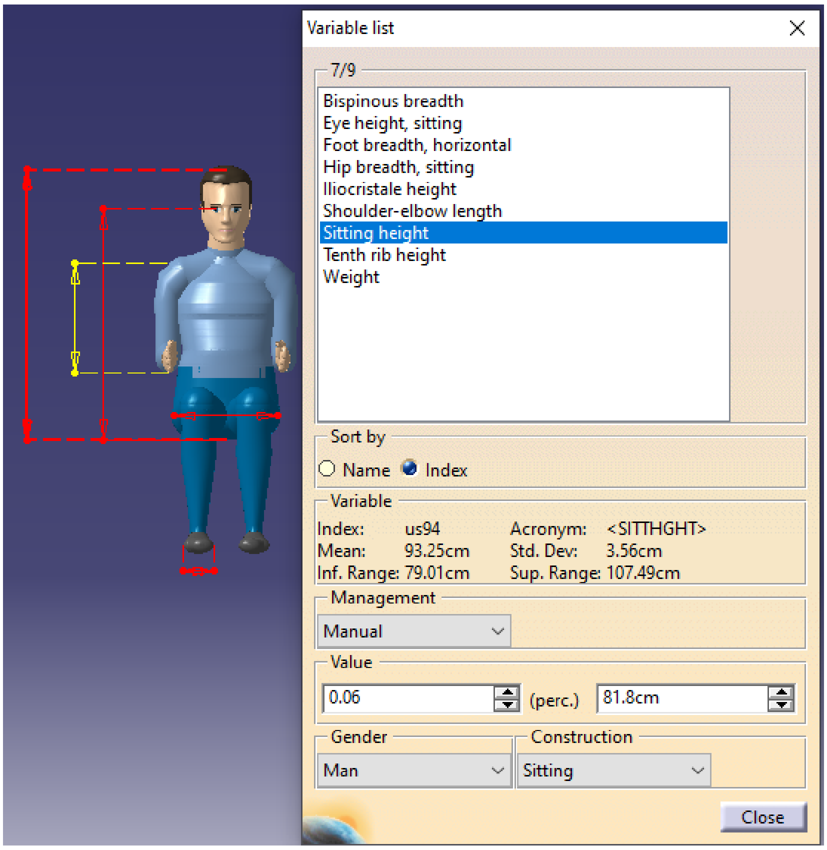
A manikin was created using human builder (HB) in CATIA V5R21 software. The tools in the human builder (HB) included manikin generation, gender specification and percentile specification. Figure 4.6(a) shows the human digital model that was generated while a posture-editor is shown in figure 4.6(b). Figure 4.6(c) shows how dimensions were assigned to the manikin's variables.



(a) New sitting manikin



(b) Posture editor.



(c) Assigning dimensions to a sitting manikin

Figure 4.6: Getting manikin ready for RULA analysis.

4.3.1.2 Assessment of the Recommended Desktop-chair Through Posture Analysis.

The measurements of the classroom desktop-chairs and manikin were integrated to develop classroom desktop-chairs. The mismatch between the anthropometric dimensions and classroom desktop-chairs was considered. The dimensions of the new concept design and existing design are shown in table 4.19.

Table 4.19: Dimensions of the new concept design and existing design

Parameter	**Existing design and Units**	**Concept design and Units**
Seat height	48.10 (cm)	40.95 (cm)
Seat width	34.00 (cm)	45.26 (cm)
Seat depth	35.40 (cm)	38.10 (cm)
Desktop height from seat	18.21 (cm)	19.11 (cm)
Backrest height	43.00 (cm)	50.96 (cm)
Desktop length	42.32 (cm)	47.44 (cm)

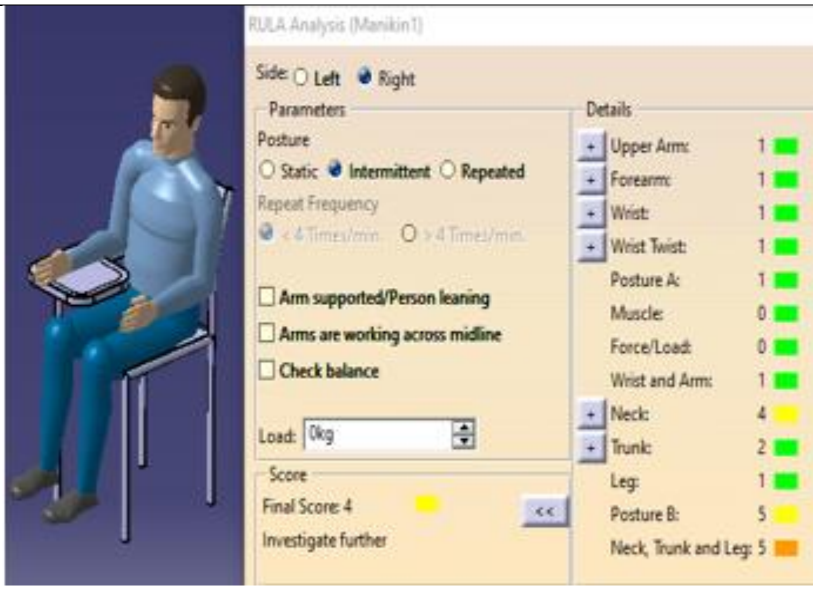
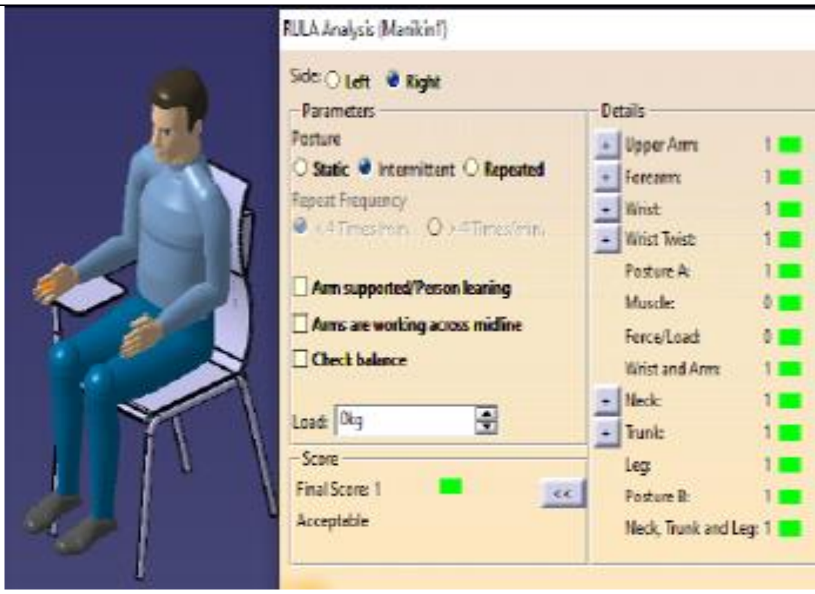
4.3.2 Desktop-chair Comparison (RULA Analysis Results)

The complete desktop-chair design was evaluated using a manikin of 50th percentile of students' male/female for both existing desktop-chair design and new concept desktop-chair design. The RULA analysis was done in the sitting position while a student is performing a task (writing and reading) in the classroom environment. RULA analysis method evaluates based on a score and colour which are interrelated. The colours are green, yellow, orange and red. The green colour indicates that the posture is good and acceptable while the red colour indicates that the posture is bad and changes are required immediately. The RULA results are shown in tables 4.20 and 4.21. RULA analysis is a combination of postural analysis of the different groups of muscles characterized as: muscle group A (consists of the upper arm, lower arm and wrist), muscle group B (consists of the neck, trunk and leg). The combinations of both groups of muscles were calculated as the total score. As shown in table 4.21, the analysis score reduced considerably, from 4 to 1 for upper arm, forearm wrist, neck and trunk for the new concept desktop-chair design. This meant the chances of musculoskeletal disorders could be reduced.

Table 4.20: The evaluation analysis of upper limb for the existing design and new concept selected design

Place	***Scores and colours for;***				***Improvement***
	Existing design		***Concept design***		
Upper arm	1		1		The RULA scores of all the parameters of the new design were within the appropriate range while for the existing design, some of the parameters had poor scores indicating that changes were required.
Forearm	1		1		
Wrist	1		1		
Wrist twist	1		1		
Posture A	1		1		
Muscle	0		0		
Force/load	0		0		
Wrist and arm	1		1		
neck	4		1		
Trunk	2		1		
Legs	1		1		
Posture B	5		1		
Neck, trunk and leg	5		1		
Final score	4		1		

Table 4.21: RULA analysis for the 50th percentile of student's male/female

<table>
<tr><th>Design pattern</th><th>RULA analysis results</th></tr>
<tr><td>Existing design</td><td>
</td></tr>
<tr><td>Concept design</td><td>
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CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter gives the conclusions and recommendations based on the results and analysis of the present research. Areas of further research and limitations/challenges are also indicated.

5.1 Conclusions

This research, therefore, aimed to use the concept of innovative ergonomics to design and analyse a classroom desktop-chair for students in Kenya based on anthropometric measurements collected from students at four selected tertiary institutions in Uasin-Gishu County. These institutions were (i) Moi university (MU), (ii) University of Eldoret (UoE), (iii) Rift Valley Technical Training Institute (RVTTI) and (iv) The Eldoret National Polytechnic (TENP).

From the results of this research, therefore, the following conclusions can be drawn:

1. The ANOVA tests results were failed to reject the null hypothesis (e.g., popliteal height $p = 0.39$), which meant that there was no significant difference among the anthropometric data sets from the four selected institutions. The measurements conducted from students at these institutions were done under the same condition with the standard procedure.
2. From the present research, it is well expected that a criteria determinant for an adjustable desktop-chair needs to be used whenever designers wish to have adjustable classroom desktop-chairs in which ergonomic principles are considered. In this research, therefore, one type of innovative ergonomically suitable classroom desktop-chair design was proposed to improve the match between classroom desktop-chairs dimensions and student's anthropometric characteristics.

3. From the analysis done in CATIA V5R21, it is observed that the proposed ergonomically desktop-chair design gives a better result where the final score was reduced from 4 to 1, which meant that the chances of musculoskeletal disorders could be reduced.

5.2 Recommendations

It is fully suggested that further study can be done on the cost and affordability of the classroom furniture that should be taking into account the budget constraints of targeted institutions as potential consumers. In order to further improve the final design, it is highly recommended that further research can be done in two areas: (1) To build a prototype and (2) To conduct on it usability and durability testing.

5.3 Areas of Further Research

After the above findings on classroom desktop-chair design based on anthropometric data were collected according to ISO international standards that were obtained from Kenya Bureau of Standards (KEBS) website, it is fully suggested that similar scientific research should be carried out in other countries in order to have an adequate database of anthropometric measurements, which can help designers to come up with the solutions for students who are currently continuing to suffer from using un-ergonomically designed classroom furniture in their countries. It is also, recommended that further research should be done on the fabrication of classroom desktop-chairs by using soft materials (e.g., seat cushion) for comfortable seating during lecture time. The anthropometric data can be used to carry out modelling and simulation therefore, that the study can be applied widely.

5.4 Limitations/challenges

Although the present research has achieved its objectives and were wisely prepared, there were some limitations which require to be carefully considered in future research. For instance, this present research, only considered students from tertiary institutions, hence the results cannot be extended to primary or secondary school level students. In addition to designing a desktop-chair based on student's anthropometry, there is also a requirement to carry out proper sensitization on postures, safe study and ergonomic practices that promote comfort, health and safety among the students. Also, during collection of the anthropometric measurements, a lot of challenges were faced in finding the appropriate time and place for students.

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APPENDICES

Appendix I: Introductory Letter

RIFT VALLEY TECHNICAL INSTITUTE
DEPUTY PRINCIPAL ACADEMICS
12 JUL 2019
P.O. Box 244, Eldoret-30100

MOI UNIVERSITY

SCHOOL OF ENGINEERING

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School of Engineering
P.O. BOX 3900
ELDORET, **KENYA**

Our Ref: MU/DMIT/SP/002

DATE: 08 July, 2019

TO WHOM IT MAY CONCERN

RE: ABDALLA ESMAEEL - TEC/PGMT/10/18

The above named is a Postgraduate student in the School of Engineering, department of Manufacturing, Industrial and Textile Engineering. He is enrolled in a two years program. He would like to carry out his research study in your University.

Mr. Abdalla is doing a research on: *"Design and optimization of classroom furniture for students at Tertiary Institutions based on Anthropometric measurements."* In this regard, I humbly request for your permission to allow him carry out his research at your University.

We thank you most sincerely in advance for the assistance.

HEAD
DEPARTMENT OF MANUFACTURING,
INDUSTRIAL AND TEXTILE ENGINEERING,
MOI UNIVERSITY

DR. ERIC OYONDI NGANYI
HOD, MANUFACTURING, INDUSTRIAL AND TEXTILE ENGINEERING

EON/rk

(ISO 9001:2015 Certified Institution)

Appendix II: Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **664151**

Date of Issue: **15/October/2019**

RESEARCH LICENSE

This is to Certify that Mr.. Abdalla ESMAEEL of Moi University, has been licensed to conduct research in Uasin-Gishu on the topic: DESIGN AND OPTIMIZATION OF CLASSROOM FURNITURE FOR STUDENTS AT TERTIARY INSTITUTIONS BASED ON ANTHROPOMETRIC MEASUREMENTS" for the period ending : 15/October/2020.

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Appendix III: Research Authorization

MOI UNIVERSITY

OFFICE OF THE DEPUTY VICE CHANCELLOR
(ACADEMICS, RESEARCH AND EXTENSION)

Tel: (053) 43355
(053) 43620
Fax: (053) 43412
Email: dvc_are@mu.ac.ke or dvcaremoi@gmail.com

P.O. Box 3900
Eldoret - 30100
Kenya.

REF: MU/DVC/REP/27B

Date: 22nd October, 2019

TO WHOM IT MAY CONCERN

RE: PERMISSION TO CARRY OUT RESEARCH – ABDALLA ESMAEEL

The above subject matter refers.

Mr. Abdalla Esmaeel who is a post graduate student at Moi University, School of Engineering has applied for authority to carry out research at Moi University. We would be grateful if he is permitted to conduct his research on *"Ergonomic Design and Optimization of Classroom Furniture for Students at Tertiary Institutions Base on Anthropometric Measurements"*.

By a copy of this letter authority is hereby granted to him to conduct the research.

After the completion of the research, a complete report both on hard and soft copy will be handed over to the office of Deputy Vice-Chancellor, Academics, Research & Extension.

Any assistance accorded to him will be highly appreciated.

Thank you.

Yours faithfully,

DEPUTY VICE CHANCELLOR
ACADEMICS, RESEARCH &
EXTENSION
MOI UNIVERSITY

PROF. I. N. KIMENGI, Ph.D.
DEPUTY VICE-CHANCELLOR
(ACADEMICS, RESEARCH & EXTENSION)

SKM/bk

(ISO 9001: 2015 Certified Institution)

University of Eldoret
flame of knowledge and innovation

P. O. Box 1125 - 30100, Eldoret, Kenya
Tel: +254 788 232 004/+254 740354966
E-mail: dvcpre@uoeld.ac.ke

OFFICE OF THE DEPUTY VICE-CHANCELLOR
(PLANNING, RESEARCH & EXTENSION)

REF: UoE/D/DVPRE/DRIV/028 **14th November 2019**

Abdalla Elnour Ahmed Esmaeel
School of Engineering
Moi University
P.O. Box 3900-30100
ELDORET

Dear Mr. Esmaeel,

RE: REQUEST TO CARRY OUT RESEARCH IN UNIVERSITY OF ELDORET

We refer to your application to carry out research on your proposal entitled: ***'Design and optimization of classroom furniture for students at tertiary institutions based on anthropometric measurements'*** at University of Eldoret and are pleased to inform you that your request has been approved.

You are advised to report to the Deputy Vice- Chancellor (PRE) on arrival at University to commence your research. The permission is also granted on condition that you will share the findings with the University once you complete your studies.

Yours faithfully,

Deputy Vice Chancellor
Planning, Research & Extension
University Of Eldoret

for **PROF. P. O. RABURU**
DEPUTY VICE-CHANCELLOR (PLANNING, RESEARCH & EXTENSION)

UNIVERSITY OF ELDORET

OFFICE OF THE VICE CHANCELLOR

SECURITY AND SAFETY DEPARTMENT

VISITOR'S GATE PASS

DATE: 31/1/2020 BOOK NUMBER:

PLACE OF ISSUE: Hostel Officer

1. Name of visitor: Abdalla Esmail ID No: 10096449
2. Phone No: 0723605043
3. Name of organization/Institute/Place From:
4. Name of staff/officer /student to be visited: Hostel officer
5. Purpose of visit: Contact research for students
6. Location/office/department: Hostel
7. Car Make:
8. Vehicle Registration No:

TIME In: 10:42 Sign: TIME Out:

Signature of officer visited: E. Moses. Stamp:

Security Officer Name: H. Abdi Sign:

UNIVERSITY OF ELDORET HOSTELS OFFICER 30 JAN P.O. BOX 1125, ELDORET

University of Eldoret 31 JAN 2020 PRINCIPAL SECURITY OFFICER P.O. Box 1125, ELDORET

Allowed to work with House keepers for the exercise

THIS FORM MUST BE RETURNED BACK AT THE PLACE OF ISSUE DULY FILLED, SIGNED AND STAMPED UPON LEAVING THE UNIVERSITY.

RVTTI/QMS/MR/F

Request for Permission to Conduct Research at the RVTTI

1. Name of Principal Investigator: Abdulla Ermaeel
2. Institutional Affiliation: Moi – University
3. Degree/Diploma Sought (if applicable) MSc
4. Mailing /Email Address: abohmam33065@gmail.com
5. Phone: +254723060543
6. Category of Research: Indicate the type and form of research to be conducted (e.g., interviews, survey) Survey + measurements for students.
7. Research Subjects: Indicate from whom data will be collected (e.g., lecturers, students, non-teaching staff, documents) Students
8. Has your research proposal been approved by your university's unit responsible for ensuring compliance with regulations governing research involving human subjects? _____ Yes ____ No (attach a copy of the approval to this form). Yes
9. State the title of research/project: "Design and Optimization of Classroom furniture for students at tertiary Institutions Based on Anthropometric Measurements".
10. Purpose (briefly identify the purpose[s] of your study): To design and

optimize classroom furniture for students.

11. Why is it important or necessary to conduct your research at RVTTI?

Because the RVTTI is one of the tertiary institutions in Uasin-Gishu, County, Kenya.

12. What are the timelines for administering your research? 4 months.

13. When and where do you anticipate reporting the results of your research?

on April 2020 at NACOSTI, Moi-University.

CONDITIONS FOR MAINTAINING ETHICS AND SHARING PROJECT RESULTS

I agree to maintain the anonymity of individual students, staff members and RVTTI in any report(s) and in any publication(s), e.g., journal article(s), book(s), etc., which incorporate any information derived from the research conducted within RVTTI.

I agree that if information about subjects is disclosed, including personal characteristics and confidential data concerning RVTTI during research, I ensure that they will not be at risk for damage to their financial standing, employability, or reputation

I agree that this study does not involve deception (i.e., withholding from or giving false or misleading information to subjects/institution)

I agree that the procedures do not cause any degree of discomfort, harassment, invasion of privacy, risk of physical injury, threaten the dignity or otherwise potentially harm subjects/institute.

I agree to provide the Office of Research and Development with the research results, complete documentation and information on the location of the complete research and, in the future, subsequent publications.

Signature of the Researcher .... **Date** 17/10/19

Instructions: Attach a copy of cover letter, the research instruments, consent form, debriefing statement (if research involves deception) and NACOSTI approval to this form.

Send all materials to: Research and Development Coordinator
RVTTI, P O BOX 244-30100, ELDORET
Or email to: info@rvti.ac.ke &

EAC Centre of Excellence

An ISO 9001:2008 Certified Institution

THE ELDORET NATIONAL POLYTECHNIC

Tel: 0714 871 685 / 0738 092 126
Website:www.eldoretpolytechnic.ac.ke
Email:eldopoly@africaonline.co.ke
:info@eldoretpolytechnic.ac.ke

UFUNDI KWA MAENDELEO

P.O.BOX: 4461-30100
ELDORET

TENP/DP ADM/29/VOL. 1

25th October 2019

TO WHOM IT MAY CONCERN

RE: PERMISSION TO CARRY OUT RESEARCH - ABDALLA ESMAEEL FC NO. 10096449

We have allowed Mr Abdalla Esmaeel a post graduate student at Moi University to carry out his research at the institution. The permission is only limited to his research on *"Ergonomic Design and optimization of classroom furniture for students in tertiary institutions based on Anthropometric measurements".*

On completion , we would also wish to have a copy of his findings.

Abdalla is asked to always liaise with the undersigned for smooth execution of his tasks.

We wish him well in his studies.

Yours Faithfully

Meres

Meres E.K
DEPUTY PRINCIPAL-ADMINISTRATION
For: PRINCIPAL

THE ELDORET NATIONAL POLYTECHNIC

INTERNAL MEMO

FROM: Deputy Principal –Administration

TO: Academic HOD's

REF: TENP/DP ADM/09/vol. 2

DATE: 5TH February 2020

SUBJECT: RESEARCH BY ABDALLA ESMAEEL

The above named is a postgraduate student of Moi University carrying out a research DESIGN AND OPTIMIZATION OF CLASSROOM FURNITURE FOR STUDENTS AT TERTIARY INSTITUTIONS BASED ON ANTHROPOMETRIC MEASUREMENTS. He has a NACOSTI permit and wishes to commence taking measurement on 6TH February 2020.

Kindly assist him as the undertaking will also benefit us.

Thank you.

Meres E.K
DEPUTY PRINCIPAL-ADMINISTRATION

THE ELDORET NATIONAL POLYTECHNIC
D/PRINCIPAL ADMINISTRATION
05 FEB 2020
P.O. Box 4461-30100 ELDORET

cc: Principal
HOD Research

Appendix IV: Questionnaire on students' Requirements of the Desktop-chair

A. Arranging the Importance of the needs

1. What is the important-need of the desktop-chair for a classroom setting? Ranking is in a scale from 1 to 5 (1 is the lowest and 5 is the highest).

No.	Functional-requirements	Importance
1.	Foldable desktop with book holder at the back	
2.	Desktop-chair and bag/book holder at lower desk	
3.	Foldable but fixed height desktop	
4.	Fixed height desktop and book holder at the back	

B. Arranging the Importance of the Factors

2. What is the important-factor of the desktop-chair? Ranking is in a scale from 1 to 5 (1 is the lowest and 5 is the highest).

No.	Selection-factors	Importance
1.	Ergonomics and safety	
2.	Ease of use	
3.	Ease of manufacture	
4.	Durability	
5.	Aesthetic	
6.	Reliability	
7.	Maintainability	
8.	Social appeal	
9.	Environmental soundness	
10.	Economic value	
11.	Utility and function	
12.	Life cycle cost	
13.	Availability	

Source:(Al-Hinai et al., 2018).

Thank you!!!

Appendix V: Classroom Desktop-chair dimensions' form

No	**Dimensions of classroom desktop-chairs**	**Unit/cm**
1.	Seat height (SH)	
2.	Seat depth (SD)	
3.	Seat width (SW)	
4.	Backseat height (BH)	
5.	Desktop/Desk height from seat (DH)	
6.	Backrest angle (BA)	
7.	Desktop width (DW)	
8.	Desktop length (DL)	
9.	Desk angle (DA)	.
10.	Seat angle (SA)	

Source: *(Hoque, et al., 2014; Ismaila, et al., 2013).*

Appendix VI: Anthropometric Data Collection Form

Department of Manufacturing Industrial and Textile Engineering,

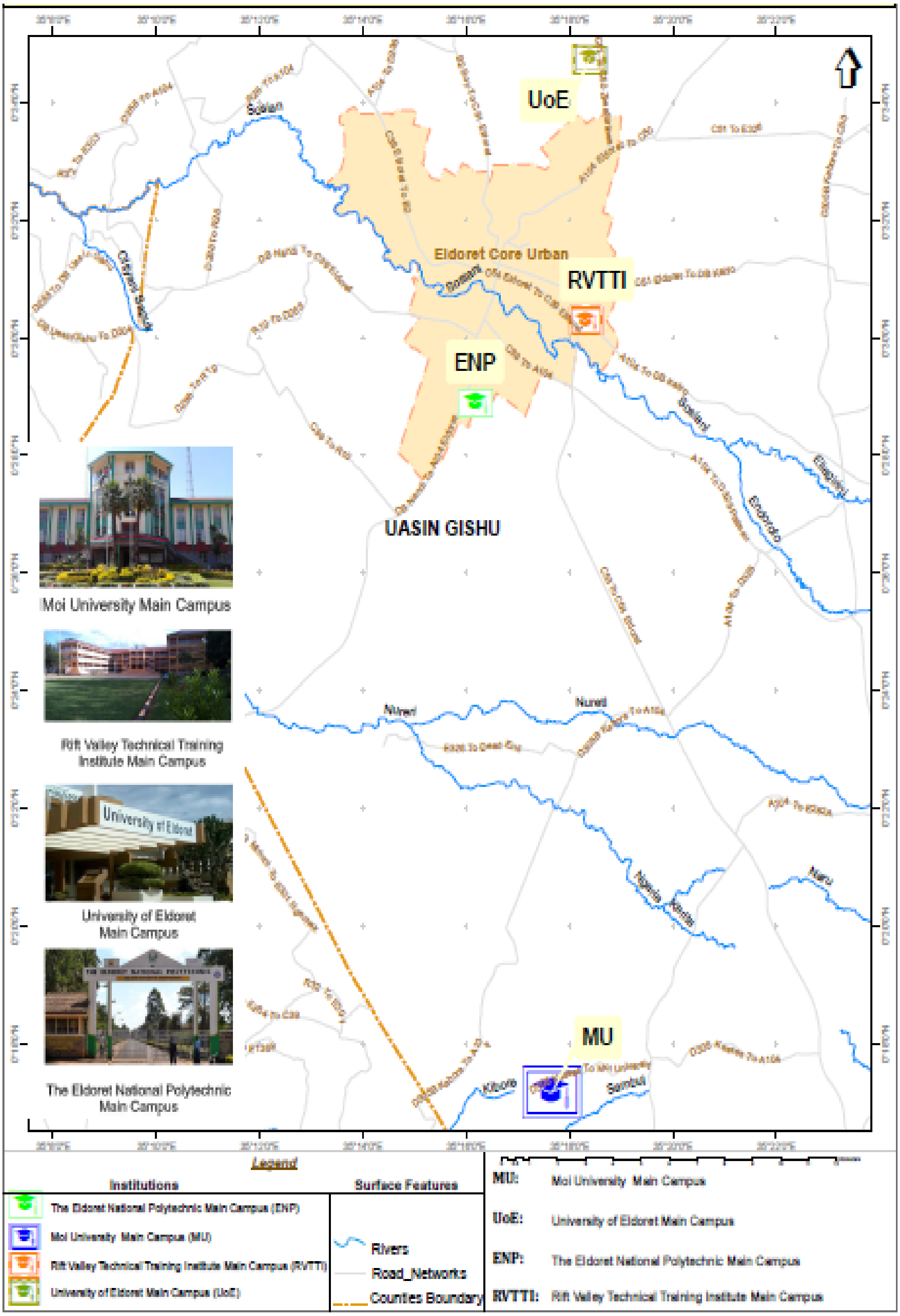
School of Engineering,

Moi University, Eldoret, Kenya

Students anthropometric data			
Data No.		Age	
Sex		institutions	

No.	Anthropometric-data	Units
1.	Stature (body height)	cm
2.	Sitting height (erect)	cm
3.	Shoulder height sitting	cm
4.	Popliteal height, sitting	cm
5.	Hip breadth, sitting	cm
6.	Elbow height, sitting	cm
7.	Buttock popliteal length (seat death)	cm
8.	Buttock knee length	cm
9.	Thigh clearance	cm
10.	Eye height, sitting	cm
11.	Shoulder (bideltoid) breadth	cm
12.	Knee height sitting	cm
13.	Forearm fingertip length	cm
14.	Body Mass (weight)	Kg

Appendix VII: Research Area Map



Source: *(mapsworld.com).*

Appendix VIII: Some ISO Standards for Ergonomists

Standard	Year published	Title
General:		
-ISO 7317	1987	Ergonomics: Standards guidelines for designers.
-ISO 6385	1981	Ergonomics principles in the design of work-systems.
-ISO 18529	2000	Ergonomics-Ergonomics of human system interaction-human-centered lifecycle process descriptions.
-ISO 13407	1999	Human-centered design processes for interactive systems.
Physical-workload:		
-ISO 1128-1-3	2000	Ergonomics-manual handling parts 1 to 3
-ISO 53120	1996	Equipment for manual handling.
-ISO 11226	2000	Ergonomics-evaluation of static work postures.
Workspace design:		
-ISO 9241	1990S	Ergonomics requirements for office work with visual display terminals-parts 1-9.
-ISO 11064-1	-	Ergonomic design of control centers. Control room layout.
Physical environment:		
-ISO 13340-1	1995	Protective equipment in general.
-ISO 1996	1996	Protective gloves.
Physical work/stress:		
-ISO 8996	1990	Ergonomics-determination of metabolic heat production.
Mental work/HCI:		
-ISO 9241	1990s	Ergonomic requirements for office work with visual display terminals-parts 1017.

Display and controls:		
-ISO 9355	1999	Ergonomic principles for the design of signals.
-ISO 11429	1996	Ergonomics-system of auditory and visual danger and information signals.
-ISO 7731	1986	Ergonomics. Danger signals for public and work areas auditory danger signals.
Work environment:		
-ISO 13731	1995	Ergonomics of the thermal environment. Vocabulary and symbols.
-ISO 11399	2001	Ergonomics of the thermal environment-principles and application of relevant international standards.
-ISO 9116-1	1989	Lighting in general.
-ISO 91160-10	1989	Interior lighting.
-ISO 8995	1989	Principles of visual ergonomics-the lighting of indoor work systems.
-ISO 1996-1	1982	Acoustics-description and measurement of environment noise.
-ISO 9921-1	1996	Ergonomic assessment of speech communication.
Safety:		
-ISO 15534-1-3	2000	Ergonomic design for the safety of machinery, parts 1-3.
-ISO 14121	1999	Safety of machinery-principles of risk assessment.
-ISO 13854	1996	Safety of machinery-minimum gaps to avoid crushing parts of the human body.

Source: *(Woo et al., 2016; Parsons, 1995).*

Appendix IX: Basic Students Body Dimensions and Their Importance

Basic-students body-dimensions	Importance	Critical
Sitting height	Sitting height is important for designing backrest of chair.	If backrest of your chair is not according to the sitting-height than to use that chair is not comfortable for user.
Eye height	Eye-height is important for TV-height in house, blackboard for study-room or in school, soft board, etc.	If TV-height is not-according to the eye-height of human than person will not-feel comfortable while watching TV in-sitting-posture
Shoulder height	Shoulder-height is important for designing backrest of chair	If backrest of your chair is not according to the shoulder-height than to use that chair is not-comfortable for user.
Elbow height	Elbow height is important for designing a height of arm-rest in-chair & table (study table, Dining table, etc.).	If height of arm-rest is not according to the elbow height, it will give pain to the user's hand.
Knee height	Knee height is important for designing a sitting height of the chair.	If sitting-height of chair is not according to the knee height, then your legs will hang without any support & will pain in your legs.
Buttock popliteal length	Buttock to popliteal-length is important for designing depth of the chair.	If depth of the chair is not according to this, user will not feel comfortable.
Popliteal height	Popliteal-height is important for designing chair & WC sitting-height, bed-height, stool-height, etc.	If the height of WC pan is not according to the popliteal height, then person will not feel comfortable while using it.
Buttock leg length	Buttock-length is important for designing a chair, table, etc.	Width-of Kenyan-sitting should-be-according to the buttock-leg-length to make it user-friendly.
Hip breadth	Hip-breadth is important to design a breadth of chair.	Person will not feel comfortable if the breadth of chair-sitting is not according to the hip-breadth.

Shoulder to Shoulder-Breadth	Shoulder to shoulder breadth is important to design a width of back-rest of chair.	If breadth of backrest of rocking chair is not-according to the shoulder-to-shoulder breadth than user will not feel free while using it.
Elbow to Elbow-Breadth	Elbow to elbow-breadth is important for designing a distance between arm-rests in-chair.	Distance between arm rests in any chair should be according to the elbow-to-elbow breadth for make it user friendly.
Forearm-hand length	Forearm-hand length is important for designing width of study-table, working-table, dining table, etc.	If the distance between chair & table is not-according to the forearm-hand length then person-will-not-feel comfortable while working, writing, or eating.

Source: *(Scott et al., 2006; Baharampour et al., 2013)*

Appendix X: Anthropometric-Data Record for Students from Moi University (n = 171)

S. No	Age	S	SH	SHS	PHS	HPS	EH	BPL	BKL	TC	EHS	SB	KH	BM	FFL
1	20	176.50	84.30	57.30	47.30	31.24	19.39	44.00	53.10	13.23	70.30	42.63	54.00	55.50	49.53
2	22	184.50	88.90	59.10	48.70	36.29	19.16	46.00	55.60	14.37	74.30	50.45	56.50	85.00	51.23
3	21	183.50	88.70	58.40	49.90	31.57	20.56	45.60	54.10	12.32	73.10	44.83	57.40	56.50	50.32
4	20	172.00	83.00	55.50	47.20	30.03	21.96	40.90	49.70	11.11	69.40	41.56	53.30	55.00	45.73
5	20	166.00	80.80	54.30	44.00	29.78	19.62	40.50	57.30	10.84	66.50	42.11	50.90	52.00	45.55
6	25	176.50	84.30	57.30	45.70	35.04	19.33	43.60	54.00	16.10	70.30	42.60	54.70	80.25	48.23
7	21	166.50	81.10	55.80	44.50	31.14	17.32	40.30	48.00	11.50	67.40	40.96	50.00	52.50	45.29
8	21	170.50	82.30	54.90	43.80	32.88	19.16	39.90	50.70	14.72	68.50	45.56	51.50	70.50	44.47
9	20	182.00	88.00	57.50	48.10	34.05	20.80	34.50	55.00	12.09	72.50	44.24	56.50	67.00	49.63
10	20	177.50	85.00	57.80	47.20	33.10	19.29	44.60	54.30	12.14	71.00	44.74	53.60	63.00	49.23
11	21	177.00	84.80	57.80	50.00	34.59	19.70	42.00	50.80	13.06	70.10	44.80	53.50	72.00	47.44
12	19	167.50	81.90	55.96	44.00	30.68	19.83	41:10	49.30	12.10	67.90	42.60	59.90	58.00	46.76
13	24	169.50	82.20	54.70	47.00	33.21	19.63	42.60	51.40	13.34	69.50	44.76	54.30	67.00	47.92
14	21	178.00	85.50	57.99	46.80	33.01	18.06	45.00	54.10	13.39	71.50	44.75	54.50	64.50	50.72
15	17	173.00	83.20	55.96	46.80	30.73	20.38	44.00	51.50	13.36	69.90	41.48	52.20	59.50	49.54
16	24	173.00	83.20	55.90	46.50	31.34	19.16	43.40	53.00	11.88	69.90	40.93	53.20	55.50	48.23
17	21	169.50	82.20	54.70	44.00	31.18	21.95	39.60	51.30	12.93	69.50	41.53	51.30	60.00	44.78
18	22	185.00	90.10	62.30	49.30	31.84	21.27	45.20	58.00	14.19	75.00	46.09	57.50	71.50	50.43
19	20	176.00	84.00	57.80	48.50	34.45	19.89	43.20	54.90	14.02	70.80	43.73	56.20	74.50	48.66
20	20	179.50	84.30	57.30	50.70	35.27	19.46	46.10	55.70	12.14	70.30	40.54	66.80	63.50	51.01
21	20	168.00	81.70	54.40	44.00	30.37	20.02	41.50	51.30	13.18	68.00	39.35	52.50	53.50	46.05
22	21	167.00	81.00	55.00	42.50	30.24	21.60	39.20	50.20	12.89	67.00	37.53	50.90	49.00	44.61
23	21	187.50	91.50	63.20	48.50	34.13	20.00	46.50	57.50	13.34	78.23	46.12	57.10	70.50	51.72
24	23	187.00	91.00	63.00	51.00	34.39	19.39	49.00	59.00	14.30	78.00	43.26	56.99	76.50	44.84
25	19	173.00	83.20	55.90	46.70	30.54	19.14	42.10	52.40	12.31	69.90	41.22	53.20	56.00	47.44
26	21	177.50	85.00	57.80	48.40	33.21	21.93	43.90	53.40	14.83	71.00	44.32	55.90	67.00	48.24
27	25	181.00	87.50	57.00	47.00	32.30	21.56	45.00	52.80	13.22	72.00	44.44	53.30	63.50	50.84
28	20	170.50	82.30	54.90	46.50	31.55	20.36	44.50	52.60	13.93	68.50	68.50	43.67	55.00	49.31
29	19	172.00	83.0	55.00	46.30	30.87	19.27	42.50	53.10	13.53	69.00	45.50	53.40	59.50	47.44
30	21	170.00	82.00	54.00	48.40	29.58	20.40	42.50	51.70	13.60	68.00	41.47	54.20	58.00	47.44
31	19	176.00	84.00	57.80	48.20	30.02	19.55	47.50	55.50	13.87	70.80	44.67	56.90	63.50	52.25
32	23	174.00	83.60	56.00	46.30	32.64	19.14	45.00	55.10	14.43	70.00	41.12	54.80	66.50	50.47
33	21	175.50	83.99	56.87	45.20	31.05	19.21	45.50	53.30	13.60	70.56	43.09	51.80	60.00	50.27
34	20	173.00	83.20	55.90	46.00	32.59	21.10	44.50	55.10	15.00	69.90	44.10	54.80	68.50	49.40
35	20	179.00	84.10	57.05	51.00	35.23	21.60	44.50	55.80	13.67	70.09	44.94	58.80	76.00	49.38
36	23	182.00	88.00	57.50	51.10	36.89	21.27	49.20	57.30	13.26	72.50	44.63	58.60	64.50	54.63
37	21	166.00	80.80	54.30	44.30	29.00	21.04	43.70	51.20	13.70	66.50	42.79	51.20	57.50	47.44
38	21	186.00	90.90	62.99	49.70	31.87	21.62	49.00	58.90	15.70	75.52	46.59	57.40	72.00	54.99
39	20	168.00	81.70	54.40	44.10	29.53	20.27	42.80	50.60	13.49	68.00	39.48	50.30	53.40	47.44
40	20	180.00	87.00	56.87	47.30	32.64	20.42	46.00	55.90	15.45	71.88	39.92	55.90	65.00	51.00
41	18	174.00	83.60	56.00	46.50	30.21	19.13	44.30	52.90	14.11	70.00	42.95	53.50	61.00	49.50
42	21	170.00	82.00	54.00	44.60	32.70	20.53	42.00	51.50	15.16	68.00	44.98	53.20	70.50	47.44
43	25	183.00	88.20	58.10	49.50	32.25	21.05	44.80	56.10	15.50	73.00	44.40	57.60	69.50	49.53
44	20	164.00	77.69	52.50	42.10	29.03	20.66	39.70	47.60	14.04	64.90	41.60	48.10	51.00	44.04
45	20	176.00	84.00	57.80	48.00	31.80	19.14	47.20	56.10	12.79	70.80	42.29	55.20	58.50	52.49
46	22	178.00	85.96	58.01	48.40	42.80	21.99	47.80	58.50	20.04	71.98	46.36	58.40	102.0	52.60
47	21	171.00	82.67	54.93	44.60	30.79	18.38	44.00	53.50	14.53	68.92	45.95	52.50	61.00	49.53
48	23	177.00	84.80	57.80	48.20	32.43	19.65	45.70	53.30	16.22	70.10	43.09	56.80	71.50	50.63
49	18	163.00	77.00	52.00	43.00	29.20	19.65	41.00	47.20	12.76	64.00	39.53	50.40	46.50	47.44
50	21	172.50	83.50	55.50	45.80	29.85	21.85	46.80	55.20	12.60	69.50	41.77	53.00	59.00	51.55
51	20	161.50	76.20	51.63	43.00	32.28	19.13	42.60	51.10	12.20	63.46	39.87	47.60	53.50	47.44
52	22	175.50	83.99	56.87	47.40	32.35	20.30	44.50	53.60	12.40	70.56	42.54	55.50	58.50	49.60
53	20	182.00	88.00	57.50	46.70	31.98	21.46	45.50	53.00	14.01	72.50	44.32	56.40	61.50	50.92
54	18	167.50	81.90	55.96	44.30	33.06	19.24	44.40	52.00	13.63	67.90	42.45	51.30	61.50	49.44
55	21	172.50	83.50	55.50	47.90	33.20	19.19	46.70	56.40	13.82	69.50	42.63	55.90	58.00	51.10
56	21	183.50	88.70	58.40	49.00	35.16	19.50	48.50	58.70	16.24	73.10	44.15	58.60	79.50	53.08
57	23	178.00	85.96	58.01	49.00	31.77	21.86	43.40	53.00	13.15	71.98	42.63	56.90	56.00	47.44
58	22	176.00	84.00	57.80	46.00	34.19	20.53	45.60	55.70	14.84	70.80	44.75	50.90	70.00	50.26
59	20	165.00	80.00	54.00	46.40	29.26	20.14	43.50	51.30	11.88	66.00	40.12	51.70	50.50	47.44
60	21	180.50	87.50	56.97	48.50	33.23	19.83	46.90	54.80	14.15	71.88	44.56	57.00	69.50	51.24
61	21	174.50	83.69	56.50	45.90	32.33	20.12	43.60	52.40	14.18	70.50	41.73	52.90	63.00	47.44
62	21	183.50	88.70	58.40	51.20	33.92	19.68	48.20	56.70	14.50	73.10	44.08	58.90	67.50	53.97
63	21	177.00	84.80	57.80	47.00	36.90	22.43	44.50	53.70	15.50	70.10	46.35	56.00	78.50	49.68
64	20	174.00	83.60	56.00	46.80	32.80	21.59	42.50	50.60	14.44	70.00	43.66	52.80	63.50	47.00
65	24	177.50	85.00	57.80	48.40	33.82	20.65	42.40	57.80	13.12	71.00	44.38	56.00	65.00	47.10
66	18	163.50	77.50	52.50	42.50	30.82	19.36	39.50	48.00	13.47	64.00	41.98	46.50	56.00	44.36
67	18	171.00	82.67	54.93	43.10	31.20	21.40	41.20	50.20	13.99	68.92	42.17	52.30	52.50	46.95
68	18	170.50	82.00	54.00	46.40	29.00	20.07	41.10	49.80	12.72	68.00	40.88	52.50	50.50	46.33
69	20	174.50	83.69	56.50	44.40	30.33	19.24	46.00	54.40	13.85	70.50	42.67	53.10	61.50	59.70
70	22	172.50	83.50	55.50	44.50	34.94	21.46	45.60	55.70	15.82	69.50	44.36	51.80	69.00	50.58
71	22	170.50	82.30	54.90	45.20	34.00	20.66	43.10	52.50	14.05	68.50	44.93	52.00	66.50	48.31
72	20	182.50	88.50	57.59	47.00	33.88	19.84	45.10	56.10	13.89	72.98	47.28	57.00	68.50	50.55
73	21	166.30	80.85	54.35	43.20	35.41	17.67	42.30	51.00	12.79	66.57	40.93	51.30	55.00	47.44
74	22	157.50	76.00	51.00	41.00	44.63	21.96	39.50	48.10	14.64	63.20	37.57	46.00	52.00	44.24
75	20	160.50	76.99	51.87	40.90	36.90	20.73	40.50	50.20	13.42	63.85	41.94	48.50	64.50	45.20
76	20	163.50	80.89	54.45	43.30	30.55	21.93	38.00	49.20	11.72	66.95	38.43	50.00	49.00	43.73
77	20	170.50	82.00	54.00	46.50	42.70	21.46	43.20	52.90	12.58	68.00	42.40	53.40	55.50	48.70

78	22	174.50	83.69	56.50	45.20	35.63	19.42	42.80	53.10	15.40	70.50	44.61	53.00	75.50	47.20
79	21	157.50	76.00	51.00	42.00	33.42	19.79	38.10	46.50	13.27	63.20	37.94	46.30	53.50	43.69
80	21	160.00	76.39	51.47	43.20	32.95	21.82	37.20	47.00	11.65	63.50	35.95	49.00	43.50	42.43
81	24	174.50	83.69	56.50	46.00	32.50	21.65	34.10	52.10	12.83	70.50	42.25	53.90	61.00	39.42
82	22	166.50	81.10	55.80	42.00	30.40	19.49	40.80	50.40	10.98	67.40	39.85	48.50	46.50	45.10
83	20	180.50	87.50	56.97	48.70	32.00	20.98	44.30	55.20	13.36	71.88	45.94	55.30	64.50	49.34
84	21	171.00	82.67	54.93	42.50	63.30	22.00	41.30	52.90	14.56	68.90	48.27	52.10	73.50	46.61
85	18	168.50	81.95	54.96	44.40	31.56	21.06	41.20	51.10	11.93	68.50	20.96	51.10	51.50	46.46
86	20	179.00	84.10	57.05	46.20	36.69	22.10	44.00	55.80	14.07	70.09	45.14	54.80	75.00	49.64
87	**22**	**163.50**	**77.50**	**52.50**	**44.30**	**34.82**	**20.74**	**40.90**	**49.80**	**13.15**	**64.00**	**41.53**	**51.20**	**50.50**	**45.51**
88	23	172.50	83.50	55.50	43.40	40.01	20.34	44.70	55.70	20.10	69.50	45.49	54.30	74.50	49.30
89	23	170.00	82.00	54.00	45.00	37.57	21.44	44.00	54.60	14.14	68.00	39.95	53.80	60.50	49.38
90	20	162.00	76.82	51.85	43.00	33.85	20.57	40.50	47.80	13.02	63.96	37.33	49.60	53.50	45.18
91	19	159.00	76.09	51.07	43.20	35.06	21.89	41.10	49.80	11.72	63.10	39.91	49.70	59.50	46.06
92	21	153.50	73.40	49.00	40.50	32.76	21.84	41.10	48.00	12.51	61.70	36.00	46.00	48.50	46.51
93	20	166.50	81.10	55.80	43.50	33.01	19.48	40.90	51.00	12.91	67.40	39.04	46.50	54.00	45.95
94	19	155.00	74.50	50.50	40.00	37.25	20.00	39.40	49.90	15.80	62.00	38.86	47.80	61.50	44.12
95	23	156.00	74.99	50.95	42.30	35.01	21.12	39.60	47.90	14.65	62.50	41.40	48.40	57.50	44.18
96	18	159.00	76.09	51.07	39.80	30.73	20.16	37.50	49.10	12.44	63.10	37.89	46.50	48.50	42.49
97	19	166.00	80.80	54.30	42.90	32.71	19.78	43.50	53.50	15.58	66.50	41.43	52.30	64.00	47.30
98	21	163.50	77.50	52.50	42.10	30.87	19.27	38.10	50.30	12.73	64.00	39.89	49.10	51.50	43.46
99	20	160.00	76.39	51.47	42.50	31.37	19.70	37.90	45.00	12.84	63.50	38.05	49.00	55.50	42.06
100	21	157.00	75.90	50.96	40.90	28.04	20.73	38.80	49.80	11.28	63.00	36.35	48.70	39.50	43.97
101	18	170.00	82.00	54.00	44.00	38.85	21.08	43.20	52.30	14.24	68.00	40.30	53.00	67.50	48.62
102	18	170.00	82.00	54.00	43.90	23.38	19.12	43.50	52.40	13.57	68.00	41.20	53.50	52.00	48.71
103	19	174.50	83.69	56.50	45.10	37.76	22.58	44.00	55.80	16.27	70.50	42.89	55.70	77.50	49.23
104	21	160.50	76.99	51.87	39.40	36.26	19.28	43.50	52.40	16.00	63.85	41.02	47.50	66.50	48.31
105	20	160.00	76.39	51.47	41.50	36.23	19.18	32.10	41.90	15.65	63.50	39.84	48.83	60.00	38.45
106	20	164.00	77.69	52.50	43.50	39.06	21.84	44.10	53.50	16.58	64.90	40.94	51.10	68.50	49.70
107	22	157.50	76.00	51.00	39.00	32.52	19.52	40.70	48.20	13.84	63.20	39.47	47.10	52.50	45.69
108	21	165.00	80.50	54.50	43.70	39.36	20.52	45.10	54.20	17.34	66.50	41.67	51.20	69.25	50.46
109	19	147.50	71.60	47.10	37.00	31.66	20.79	38.50	47.00	15.02	54.50	34.99	43.20	59.00	43.53
110	19	166.00	80.80	54.30	44.50	37.85	19.26	43.60	54.10	14.85	66.50	40.85	50.20	68.50	47.44
111	19	154.00	74.02	48.40	41.30	33.35	20.73	41.80	49.80	14.20	61.98	40.19	48.00	51.50	46.27
112	21	162.50	76.96	51.95	40.50	31.49	20.60	42.50	51.50	12.86	63.99	38.63	48.30	50.50	47.44
113	18	152.50	73.00	48.50	39.50	32.34	20.14	38.60	47.00	14.30	61.40	39.85	48.40	46.50	43.28
114	19	170.00	82.00	54.00	44.80	33.28	21.88	44.30	52.70	14.47	68.00	40.43	53.20	54.00	49.61
115	20	156.00	74.99	50.95	39.70	35.09	19.26	40.00	48.60	16.86	62.50	43.70	46.90	59.50	45.80
116	21	166.00	80.80	54.30	43.70	33.92	20.04	41.60	51.00	15.25	66.50	39.57	52.20	54.00	46.43
117	22	154.00	74.02	48.40	41.70	31.40	19.25	40.50	48.20	14.57	61.98	39.90	46.50	49.00	45.50
118	18	162.50	76.96	51.95	42.40	32.30	19.28	41.00	49.40	14.23	63.99	38.80	49.50	52.00	46.45
119	19	169.00	82.00	54.20	45.00	41.24	20.40	43.50	54.40	17.40	69.00	42.47	56.00	73.50	48.64
120	20	161.50	76.20	51.63	44.40	33.70	19.27	42.50	49.00	14.15	63.46	38.13	50.00	49.50	47.00
121	21	161.50	76.20	51.63	40.50	35.32	21.60	39.50	48.00	17.53	63.46	44.20	48.70	64.50	44.14
122	20	171.00	82.67	54.93	43.80	32.86	21.23	44.70	53.60	15.28	68.90	38.15	52.00	56.50	49.80
123	21	164.00	77.69	52.50	43.70	32.05	20.14	42.60	50.20	14.56	64.90	35.80	50.50	52.50	47.20
124	20	161.50	76.20	51.63	41.50	33.50	22.12	42.00	50.00	15.66	63.46	40.56	49.10	58.50	47.34
125	20	154.00	74.02	48.40	37.90	29.50	20.34	38.00	46.80	13.83	61.98	38.10	40.65	50.00	43.79
126	21	155.00	74.50	50.50	40.50	37.09	20.80	38.00	47.80	16.73	62.00	46.20	48.50	60.50	43.56
127	19	163.00	77.00	52.00	42.00	35.87	20.20	41.50	52.70	16.43	64.00	41.70	51.30	64.00	46.65
128	23	170.50	82.50	54.50	47.00	38.10	21.24	43.50	53.50	16.04	68.50	40.70	53.00	68.50	48.24
129	20	163.00	77.00	52.00	43.30	36.25	22.43	42.00	52.10	15.90	64.00	41.13	52.10	59.25	47.44
130	20	164.00	77.69	52.50	44.30	34.62	20.25	38.10	48.70	14.49	64.90	40.70	50.50	53.00	43.97
131	23	161.00	76.00	51.03	43.50	32.82	20.54	42.50	51.00	13.95	63.06	47.55	49.20	48.00	47.44
132	18	162.00	76.82	51.85	42.20	37.51	20.63	42.90	50.90	16.54	63.96	39.27	50.80	58.90	47.03
133	18	156.50	75.00	51.00	43.40	30.68	20.82	39.50	47.50	13.67	62.96	38.32	48.90	45.50	44.50
134	18	165.50	80.50	54.50	44.50	32.59	18.42	41.30	49.60	13.59	66.50	38.40	51.10	50.50	46.63
135	21	160.00	76.39	51.47	43.50	32.09	19.17	43.10	51.50	15.09	63.50	36.79	48.00	52.00	48.49
136	21	161.50	76.20	51.63	40.50	33.06	19.50	42.10	51.30	14.46	63.46	38.93	47.10	54.00	47.44
137	20	167.50	81.90	55.96	43.80	32.18	20.97	40.70	48.30	14.66	67.90	39.87	50.80	48.50	45.39
138	20	152.0	72.50	48.00	37.50	32.46	22.70	37.40	45.20	14.00	61.00	36.87	40.60	48.00	42.51
139	26	160.00	76.39	51.47	41.00	32.95	22.02	43.60	51.20	14.80	63.50	47.04	47.05	51.50	48.90
140	20	157.00	75.90	50.96	41.60	39.67	19.64	45.20	54.20	18.05	63.00	41.40	49.40	63.50	50.73
141	20	159.00	76.09	51.07	41.90	37.47	20.65	41.10	49.00	15.86	63.10	37.22	48.00	55.00	46.31
142	19	174.00	83.60	56.00	44.70	38.14	21.80	44.50	54.50	17.93	70.00	38.78	52.70	73.50	49.24
143	20	169.50	82.20	54.70	43.30	39.76	22.65	44.80	55.70	19.56	69.50	47.66	53.00	88.50	49.63
144	19	166.00	80.80	54.30	44.90	34.50	19.77	46.60	54.30	13.16	66.50	36.96	54.40	52.50	51.88
145	19	156.50	75.00	51.00	38.50	36.52	19.30	39.80	48.00	15.87	62.96	40.29	46.70	59.50	44.29
146	19	160.00	76.39	51.47	40.80	32.45	19.15	39.10	47.60	13.24	63.50	38.04	46.80	47.50	44.33
147	19	159.00	76.09	51.07	41.20	34.85	20.47	39.70	48.40	15.05	63.10	39.17	48.50	54.50	44.03
148	20	170.00	82.00	54.00	46.90	35.79	20.70	43.80	53.90	15.72	68.00	41.60	52.30	64.00	48.94
149	20	167.50	81.90	55.96	44.70	41.67	20.32	43.80	53.00	16.46	67.90	42.95	52.40	75.00	48.60
150	18	174.00	83.60	56.00	45.20	34.53	19.25	43.20	53.20	15.86	70.00	43.00	53.30	66.00	48.61
151	19	156.00	74.99	50.95	39.50	34.28	17.09	38.00	47.00	16.10	62.50	40.37	46.80	57.00	43.55
152	21	164.00	77.69	52.50	42.20	37.68	21.84	42.00	51.00	17.20	64.90	37.02	49.90	60.00	47.00
153	23	162.50	76.96	51.95	42.20	33.88	21.06	40.20	48.00	14.37	63.99	40.13	47.40	59.50	45.05
154	21	170.00	82.00	54.00	43.80	33.32	19.88	45.50	53.30	12.14	68.00	39.36	52.20	53.00	50.55
155	19	154.00	74.02	48.40	41.80	33.45	20.40	39.00	47.60	14.22	61.98	39.90	46.80	51.50	44.52
156	20	166.00	80.80	54.30	42.20	35.17	20.30	45.60	53.80	14.65	66.50	41.28	50.00	60.00	50.66
157	25	160.00	76.39	51.47	40.80	41.90	21.43	45.00	54.70	19.36	63.50	47.38	49.50	85.50	50.35
158	20	160.00	76.39	51.47	42.90	34.03	20.20	42.10	50.70	15.10	63.50	40.09	49.70	55.50	47.44
159	19	161.00	76.00	51.03	43.10	29.16	20.94	38.40	47.30	11.93	63.06	39.62	49.60	41.50	43.27
160	22	164.50	77.99	52.90	44.50	33.63	21.80	44.70	52.80	15.47	64.99	40.38	51.30	59.50	49.29
161	20	162.50	76.96	51.95	42.40	34.60	19.12	44.60	51.80	16.16	63.99	41.60	51.00	60.25	49.28
162	22	165.50	80.50	54.50	43.80	32.05	21.90	43.50	51.50	14.13	66.50	41.60	51.30	58.00	48.93
163	19	170.00	82.00	54.00	46.70	31.90	21.73	46.80	55.30	13.45	68.00	38.69	55.40	53.00	51.16
164	23	159.00	76.09	51.07	40.80	37.30	20.30	41.70	49.60	16.53	63.10	40.17	49.50	53.00	46.08
165	19	168.00	81.70	54.40	44.00	36.83	21.68	45.20	54.50	17.84	68.00	40.96	53.30	68.50	50.27
166	19	170.50	82.50	54.50	46.00	32.33	22.80	42.50	49.20	12.98	68.50	38.85	52.60	43.25	47.24
167	18	176.00	84.00	57.80	45.30	35.15	21.27	44.30	53.70	15.02	70.80	41.44	54.20	60.00	49.33
168	19	167.00	81.00	55.00	43.80	32.86	21.73	43.00	51.50	14.30	67.00	41.50	52.90	55.50	48.26
169	21	185.00	90.10	62.30	47.80	33.23	20.09	46.90	55.70	14.90	75.00	46.50	55.50	77.50	51.17
170	22	172.00	83.00	55.50	43.50	31.67	19.51	45.00	54.00	13.77	69.40	41.12	52.80	59.50	50.84
171	20	167.00	81.00	55.00	44.60	34.83	19.11	45.20	54.20	17.28	67.00	46.05	52.20	70.00	50.81

Appendix XI: Anthropometric-Data Record for Students from University of Eldoret (n = 139)

S. No	Age	S	SH	SHS	PH	HPS	EH	BPL	BKL	TC	EHS	SB	KH	BM	FFE
1	21	174.00	83.60	56.00	48.30	34.52	19.87	45.40	54.00	14.42	70.00	45.96	55.60	75.00	50.93
2	22	159.00	76.09	51.07	43.00	30.47	20.50	38.00	47.50	13.06	63.10	41.63	48.90	52.50	43.26
3	22	173.00	83.20	55.90	45.40	30.52	19.11	42.50	51.20	12.92	69.90	42.09	52.20	60.50	47.44
4	24	172.00	83.00	55.50	46.80	32.95	19.18	43.40	53.60	14.67	69.40	46.32	52.40	69.50	48.83
5	22	158.00	75.99	50.97	43.50	31.00	20.80	38.20	47.50	12.57	62.88	39.26	49.60	60.00	43.23
6	18	170.00	82.00	54.00	44.30	29.76	19.11	39.10	49.50	14.51	68.00	44.86	50.60	60.50	44.05
7	19	173.00	83.20	55.90	49.00	31.57	20.14	40.10	49.80	16.04	69.90	43.12	53.40	65.50	45.64
8	20	175.00	83.09	56.07	49.00	34.56	19.24	43.50	54.20	14.75	70.06	47.26	54.80	70.00	48.63
9	22	180.00	87.00	56.87	49.20	34.13	19.24	45.50	57.70	16.07	71.88	43.19	57.30	73.00	50.26
10	19	165.00	80.50	53.99	42.00	39.07	19.11	44.20	52.90	17.39	66.50	46.39	50.80	73.50	49.25
11	21	170.00	82.00	54.00	44.80	29.33	20.03	42.70	51.20	12.78	68.00	40.31	50.40	49.00	47.28
12	23	176.00	84.00	57.80	48.00	30.13	19.44	43.80	54.70	14.96	70.80	44.19	54.80	62.20	48.39
13	20	167.00	81.00	55.00	47.10	31.28	21.87	41.50	51.50	14.07	67.00	43.62	53.10	63.50	46.48
14	20	170.00	82.00	54.00	45.80	28.85	17.89	43.10	52.50	13.15	68.00	43.66	53.10	62.00	48.23
15	21	170.00	82.00	54.00	47.40	31.95	21.46	42.80	52.80	13.93	68.00	41.14	52.90	60.00	47.44
16	20	182.00	88.00	57.50	50.00	31.47	21.70	44.50	55.20	13.62	72.50	41.45	56.80	64.00	49.31
17	20	167.00	81.00	55.00	43.80	33.00	19.94	37.70	46.70	16.97	67.00	44.14	50.20	74.00	42.32
18	20	162.00	76.82	51.85	41.50	31.25	22.52	37.60	47.60	15.37	63.96	40.28	48.30	58.00	42.09
19	21	173.00	83.20	55.90	45.30	31.65	21.63	42.70	53.90	14.81	69.90	44.04	52.60	61.50	47.43
20	22	173.00	83.20	55.90	48.20	31.22	19.38	43.60	53.90	13.75	69.90	45.67	55.90	68.00	48.65
21	21	179.00	84.10	57.05	50.00	32.34	23.28	43.50	53.40	14.50	70.09	40.97	59.10	63.50	48.32
22	19	178.00	85.96	58.01	48.10	30.39	19.99	42.30	51.30	13.63	71.98	42.26	56.60	62.50	47.26
23	21	161.00	76.00	51.03	43.50	31.24	21.40	39.50	49.30	14.63	63.06	41.19	49.20	62.00	44.98
24	23	166.50	81.10	55.80	45.60	31.69	19.22	44.70	52.80	14.83	67.40	43.37	53.30	60.00	49.41
25	20	169.50	82.20	54.70	48.00	30.67	21.03	42.00	50.50	13.63	69.50	41.06	55.00	61.00	47.31
26	19	168.00	81.70	54.40	45.00	34.09	20.29	41.50	51.20	14.86	68.00	41.54	50.10	70.00	46.43
27	20	168.50	81.95	54.96	45.70	30.26	19.23	44.40	52.60	13.72	68.50	43.19	53.70	57.00	49.24
28	18	168.00	81.70	54.40	45.60	31.31	19.39	41.30	52.00	15.07	68.00	45.40	52.10	65.00	46.88
29	22	159.50	76.79	51.47	41.80	31.46	20.67	39.20	47.20	14.38	63.60	44.37	49.10	59.50	44.96
30	20	167.00	81.00	55.00	46.50	31.45	21.57	43.90	53.60	13.10	67.00	40.86	53.20	60.00	48.35
31	23	172.50	83.50	55.50	47.00	30.70	20.20	43.60	52.60	15.46	69.50	43.66	55.20	68.00	48.23
32	20	172.00	83.00	55.50	47.20	33.45	19.67	41.80	51.70	14.73	69.40	44.60	54.40	68.00	46.93
33	19	181.00	87.50	57.00	50.80	32.33	21.35	46.00	55.20	13.75	72.00	43.32	56.30	65.50	51.23
34	21	179.00	84.10	57.05	48.00	29.14	21.91	45.00	54.00	12.72	70.09	40.36	55.00	58.00	50.47
35	22	176.00	84.00	57.80	47.20	32.64	20.36	42.70	52.30	13.60	70.80	44.22	55.00	65.00	47.11
36	18	168.00	81.70	54.40	44.50	30.63	20.90	41.70	51.50	13.10	68.00	40.87	50.90	53.50	46.55
37	19	188.00	91.50	63.50	51.20	32.20	18.82	46.00	55.10	14.61	78.50	41.52	56.00	66.00	51.77
38	22	178.00	85.96	58.01	49.60	31.06	19.70	45.00	54.30	13.26	71.98	41.49	55.70	58.00	50.97
39	20	167.00	81.00	55.00	44.60	31.96	19.11	43.00	53.00	13.65	67.00	40.36	51.00	58.50	48.41
40	20	180.00	87.00	56.87	48.50	31.10	19.51	47.60	56.20	13.49	71.88	42.80	56.10	66.00	52.29
41	20	169.00	82.00	54.20	44.30	31.45	19.15	43.00	51.80	13.72	69.00	41.79	52.00	57.50	48.74
42	24	182.50	88.50	57.59	50.30	32.17	21.53	47.90	58.40	13.87	72.98	46.83	58.00	73.00	52.58
43	21	165.00	80.50	53.99	44.60	31.81	20.45	41.70	51.60	13.94	66.50	42.96	51.30	61.50	46.47
44	19	160.00	76.39	51.47	43.30	29.19	19.13	40.50	49.80	12.61	63.50	39.59	53.10	51.00	45.27
45	19	173.00	83.20	55.90	45.50	33.80	19.11	41.00	51.50	14.99	69.90	41.44	54.00	64.50	46.72
46	21	182.00	88.00	57.50	48.40	30.90	21.09	47.30	56.30	13.61	72.50	42.18	56.30	58.00	52.64
47	19	169.00	82.00	54.20	46.70	28.82	19.50	44.50	52.30	11.67	69.00	42.71	53.00	55.50	49.25
48	18	162.00	76.82	51.85	44.00	32.20	20.86	39.80	50.10	14.61	63.96	41.92	51.10	61.00	44.70
49	19	166.00	80.80	54.30	45.00	29.55	20.37	41.90	49.70	12.20	66.50	39.20	54.10	50.50	46.49
50	20	170.00	82.00	54.00	47.10	31.81	21.48	43.00	53.40	13.76	68.00	44.52	54.00	64.00	48.43
51	18	167.00	81.00	55.00	45.70	31.29	19.82	44.00	52.20	14.05	67.00	45.59	52.00	60.00	49.26
52	19	180.00	87.00	56.87	46.50	30.76	21.62	48.20	56.90	15.06	71.88	44.71	57.80	62.00	53.11
53	23	187.00	91.00	63.00	50.70	33.30	20.93	47.60	57.90	16.32	78.00	48.57	58.30	77.00	52.76
54	21	171.00	82.67	54.93	46.60	30.03	19.49	41.40	50.00	11.96	68.90	41.26	53.60	56.00	46.33
55	22	171.50	82.97	54.99	46.80	30.22	20.78	45.10	55.10	14.87	68.96	41.40	52.60	62.50	50.65
56	20	168.00	81.70	54.40	47.00	35.60	19.51	45.40	53.70	15.53	68.00	44.24	52.20	71.00	50.54
57	19	165.00	80.50	53.99	44.50	30.53	21.71	44.80	52.90	13.13	66.50	40.78	51.90	56.50	49.43
58	20	177.00	84.80	57.80	48.30	35.41	19.01	46.50	56.40	17.55	70.10	47.52	55.70	77.00	51.91
59	19	176.50	84.30	57.30	48.20	30.61	21.21	44.00	52.90	12.95	70.30	41.26	55.00	55.00	49.54
60	20	176.00	84.00	57.80	47.30	31.58	19.37	47.30	56.60	13.11	70.80	44.24	58.00	63.50	52.36
61	20	170.00	82.00	54.00	45.70	30.51	20.53	42.80	49.60	12.36	68.00	38.27	52.30	52.50	47.44
62	21	177.00	84.80	57.80	47.10	33.96	22.23	41.90	52.00	15.62	70.10	45.06	54.80	74.50	46.16
63	20	169.00	82.00	54.20	45.90	30.04	20.69	42.00	50.50	12.70	69.00	38.56	53.70	55.50	47.44
64	20	171.00	82.67	54.93	45.80	30.26	19.92	40.60	50.00	12.43	68.90	39.35	53.30	52.00	45.29
65	20	168.00	81.70	54.40	46.00	32.05	19.83	45.00	53.50	13.76	68.00	44.31	51.70	58.00	50.37
66	21	171.50	82.97	54.99	47.00	30.45	19.37	43.00	52.80	13.39	68.96	41.05	53.00	64.00	48.54
67	22	164.00	77.69	52.50	43.40	31.16	19.37	39.40	50.20	15.09	64.90	42.75	50.00	62.50	44.25
68	20	172.00	83.00	55.50	47.40	31.23	21.65	43.20	52.80	13.99	69.40	42.43	53.70	58.00	48.89
69	20	165.50	80.50	54.50	45.80	32.96	20.21	42.30	51.70	14.61	66.50	45.53	52.10	72.00	47.44
70	17	165.00	80.50	53.99	43.80	32.83	22.62	40.10	49.70	14.48	66.50	37.60	50.20	52.50	45.47
71	22	156.50	75.00	51.00	43.00	31.20	20.30	37.10	46.60	15.22	62.96	40.76	48.30	55.00	42.68
72	22	167.50	81.90	55.96	44.60	33.13	20.02	41.80	52.50	15.27	67.90	40.40	51.80	56.50	46.22
73	19	165.00	80.50	53.99	44.00	33.04	20.00	40.40	50.10	15.27	66.50	38.04	49.80	57.00	45.50
74	17	158.50	76.00	50.99	41.80	33.98	19.53	39.00	48.40	14.53	62.99	40.10	46.50	53.50	44.79
75	20	160.00	76.39	51.47	44.50	32.69	20.06	41.00	48.30	14.80	63.50	41.19	49.50	52.50	46.60
76	19	168.00	81.70	54.40	46.20	36.83	19.11	44.90	53.60	15.14	68.00	39.88	52.30	59.50	49.31
77	19	160.00	76.39	51.47	42.30	29.97	22.00	39.30	46.30	14.94	63.50	35.62	49.80	49.50	44.29
78	19	164.00	77.69	52.50	46.00	38.41	20.15	41.50	51.40	16.98	64.90	33.68	51.20	75.00	46.46

79	18	166.50	81.10	55.80	47.10	34.67	21.34	45.00	53.60	15.00	67.40	42.64	52.80	56.50	50.75
80	18	164.00	77.69	52.50	43.50	33.00	20.15	41.90	50.30	16.09	64.90	42.29	51.00	59.00	46.19
81	21	158.50	76.00	50.99	40.50	30.80	19.22	40.80	49.30	14.84	62.99	39.51	47.00	50.00	45.89
82	19	170.00	82.00	54.00	43.80	34.98	20.74	45.10	53.20	15.47	68.00	41.06	51.40	59.50	50.34
83	19	152.50	73.00	48.50	38.60	34.53	21.06	38.80	47.30	15.72	61.40	39.46	45.60	59.00	42.90
84	19	168.00	81.70	54.40	46.60	36.94	19.11	44.20	52.90	15.50	68.00	41.09	53.00	62.00	49.68
85	20	171.50	82.97	54.99	45.30	35.67	22.56	49.00	58.90	17.29	68.96	39.71	52.30	67.50	54.34
86	18	176.50	84.30	57.30	47.20	34.26	20.47	45.30	53.70	15.59	70.30	41.33	54.00	63.00	50.72
87	21	160.00	76.39	51.47	42.50	32.18	20.08	44.00	51.80	14.22	63.50	37.44	49.30	57.00	49.51
88	19	166.00	80.80	54.30	44.50	33.86	19.94	41.40	51.00	16.14	66.50	40.00	51.30	63.00	46.69
89	21	162.00	76.82	51.85	41.50	35.64	19.30	42.50	51.50	16.67	63.96	41.43	49.40	62.00	47.44
90	20	171.00	82.67	54.93	43.50	33.77	19.56	45.30	53.50	15.53	68.90	40.77	52.10	63.50	50.77
91	19	163.00	77.00	52.00	45.00	35.60	22.67	42.40	50.30	15.40	64.00	42.37	52.60	59.00	47.44
92	20	166.00	80.80	54.30	44.50	32.95	19.94	44.40	52.50	14.47	66.50	41.78	52.00	60.00	49.69
93	18	165.50	80.50	54.50	44.00	32.36	17.92	43.30	51.60	15.33	66.50	41.18	50.00	54.00	48.74
94	19	162.00	76.82	51.85	42.70	33.70	20.29	40.00	48.50	14.43	63.96	41.45	49.80	60.00	45.04
95	19	152.50	73.00	48.50	42.50	32.65	20.71	38.10	47.00	16.00	61.40	39.00	50.20	56.50	43.78
96	19	158.50	76.00	50.99	40.70	32.32	21.89	43.30	59.80	14.02	62.99	35.65	45.60	49.00	48.88
97	20	165.50	80.50	54.50	44.70	32.02	21.92	44.50	50.50	14.32	66.50	39.65	50.20	50.00	49.23
98	19	168.00	81.70	54.40	43.70	36.69	20.63	42.70	51.80	16.16	68.00	44.13	51.50	66.00	47.44
99	20	159.00	76.09	51.07	42.40	34.93	21.72	43.00	50.80	15.57	63.10	44.77	48.00	62.50	48.55
100	19	158.00	75.99	50.97	40.50	30.06	20.38	40.20	48.30	13.82	62.88	36.79	47.20	48.00	45.77
101	18	163.00	77.00	52.00	41.70	37.00	21.12	42.00	50.50	16.32	64.00	41.38	48.90	60.00	47.34
102	18	169.00	82.00	54.20	45.00	38.31	20.50	46.00	55.80	15.87	69.00	41.69	52.40	67.50	51.27
103	19	173.00	83.20	55.90	46.20	34.60	19.60	41.00	54.80	15.28	69.90	43.20	52.50	64.50	54.17
104	18	171.00	82.67	54.93	44.00	32.99	21.15	43.30	52.30	14.41	68.90	39.07	51.20	53.00	48.55
105	19	172.00	83.00	55.50	46.60	35.41	21.35	44.60	54.20	15.14	69.40	40.15	53.50	56.50	49.53
106	19	160.00	76.39	51.47	41.20	30.01	20.94	40.40	47.60	12.80	63.50	33.94	48.80	44.00	45.55
107	20	157.00	75.90	50.96	40.30	29.84	19.35	39.00	45.30	13.16	63.00	37.76	47.40	48.00	44.39
108	18	164.50	77.99	52.90	43.30	30.33	19.58	40.60	49.40	13.73	64.99	36.89	51.70	53.50	45.67
109	21	160.00	76.39	51.47	40.50	36.72	19.80	40.90	48.10	15.96	63.50	36.37	49.70	58.50	45.99
110	19	167.00	81.00	55.00	43.80	38.54	20.66	45.00	56.10	15.49	67.00	45.19	52.20	70.00	50.66
111	19	168.50	81.95	54.96	47.60	35.54	19.90	36.40	43.70	15.90	68.50	43.04	54.20	63.00	41.40
112	23	172.00	83.00	55.50	44.50	31.65	19.73	42.60	52.60	16.00	69.40	39.77	53.30	58.50	47.44
113	23	177.00	84.80	57.80	43.40	30.52	20.18	43.10	50.30	12.67	70.10	37.40	51.00	48.00	48.80
114	20	165.00	80.50	53.99	42.10	36.99	19.12	41.30	51.40	14.97	66.50	40.13	50.20	59.00	46.90
115	19	166.50	81.10	55.80	43.10	34.39	19.22	43.10	51.80	15.35	67.40	41.37	50.80	59.50	48.37
116	19	157.50	76.00	51.00	40.20	33.88	20.30	40.20	49.10	15.12	63.20	39.65	47.40	54.00	45.31
117	20	167.50	81.90	55.96	42.00	34.77	22.52	38.00	47.70	14.68	67.90	39.65	50.10	59.00	43.13
118	19	160.00	76.39	51.47	41.10	34.43	21.30	40.50	49.10	14.20	63.50	32.33	49.20	59.50	45.13
119	19	156.50	75.00	51.00	40.30	33.59	20.92	38.70	48.60	16.13	62.96	41.90	47.20	59.50	43.48
120	18	162.50	76.96	51.95	43.90	41.08	22.94	40.00	50.10	18.94	63.99	41.50	49.70	67.50	45.10
121	20	163.00	77.00	52.00	41.80	33.29	21.56	39.20	48.50	15.13	64.00	38.77	48.40	54.00	44.85
122	18	164.00	77.69	52.50	41.50	37.06	20.86	41.00	52.10	18.12	64.90	43.11	50.00	68.00	46.21
123	19	167.00	81.00	55.00	42.80	33.53	20.75	39.80	58.30	15.92	67.00	41.32	50.50	56.50	44.90
124	19	165.50	80.50	54.50	42.70	31.60	19.80	41.30	51.20	14.87	66.50	40.57	50.10	56.50	46.50
125	20	176.00	84.00	57.80	44.50	37.07	21.73	42.30	52.60	16.06	70.80	42.27	53.30	69.00	47.44
126	19	176.00	84.00	57.80	46.60	37.61	21.94	45.40	55.60	16.29	70.80	43.18	54.20	66.00	50.26
127	20	174.00	83.60	56.00	45.10	39.05	21.89	45.90	55.30	16.92	70.00	44.73	54.20	75.00	50.51
128	20	173.00	83.20	55.90	44.70	32.05	21.06	43.80	52.80	16.14	69.90	41.44	52.00	57.50	48.93
129	21	168.50	81.95	54.96	43.30	34.07	21.89	43.70	53.60	15.78	68.50	41.46	51.10	66.50	48.33
130	21	170.00	82.00	54.00	43.50	34.75	22.21	45.20	53.40	18.75	68.00	40.67	52.60	67.50	50.83
131	20	168.00	81.70	54.40	43.60	33.74	19.27	39.00	47.60	14.26	68.00	39.75	50.90	57.50	44.05
132	21	175.00	83.09	56.07	44.90	35.91	22.28	45.50	55.10	17.01	70.06	43.89	53.90	74.50	50.28
133	17	159.00	76.09	51.07	42.30	31.77	20.77	38.70	47.40	14.20	63.10	40.25	48.90	48.00	43.10
134	19	161.50	76.20	51.63	43.70	33.13	18.92	41.70	49.70	13.63	63.46	40.08	50.30	51.00	46.18
135	20	158.00	75.99	50.97	40.50	39.88	19.96	43.20	52.10	15.71	62.88	40.00	48.50	60.50	48.35
136	21	158.50	76.00	50.99	40.60	31.94	20.22	39.70	47.70	14.17	62.99	38.53	47.80	46.50	44.99
137	20	157.00	75.90	50.96	41.50	35.38	19.11	39.70	48.40	15.31	63.00	41.51	48.60	55.00	44.92
138	19	167.50	81.90	55.96	44.30	31.68	19.24	45.00	53.60	14.50	67.90	39.76	50.60	52.50	50.86
139	22	171.50	82.97	54.99	44.40	33.79	19.37	43.80	52.60	15.28	68.96	41.01	52.00	61.50	48.55

Appendix XII: Anthropometric-Data Record for Students from Refit Valley Technical Training Institute (n = 37)

S. No	Age	S	SH	SHS	PH	HPS	EH	BPL	BKL	TC	EHS	SB	KH	BM	FFL
1	21	172.00	83.00	55.50	45.70	33.04	19.66	43.60	52.90	13.51	69.40	40.23	52.30	56.50	48.45
2	24	167.00	81.00	55.00	45.30	29.51	20.12	40.30	48.70	12.46	67.00	41.58	50.20	49.00	45.53
3	22	173.00	83.20	55.90	46.00	31.32	21.77	43.30	52.30	13.84	69.90	42.08	54.00	61.50	48.44
4	21	174.50	83.69	56.50	47.00	36.49	17.78	44.10	55.70	17.16	70.50	44.76	55.10	75.30	49.67
5	19	174.50	83.69	56.50	45.30	32.35	20.54	44.00	54.00	15.28	70.50	45.13	52.70	70.00	49.73
6	21	185.00	90.10	62.30	50.00	33.21	21.65	47.90	57.90	11.80	75.00	42.33	56.80	54.50	52.80
7	21	180.00	87.00	56.87	48.00	29.82	19.11	45.00	55.50	14.66	71.88	44.22	55.00	62.00	50.61
8	20	185.00	90.10	62.30	50.00	34.69	22.17	44.00	53.00	14.14	75.00	44.71	58.50	75.00	49.32
9	19	168.00	81.70	54.40	45.10	29.95	20.67	42.50	50.60	11.40	68.00	41.90	51.10	55.00	47.44
10	25	162.00	76.82	51.85	43.10	29.60	18.96	38.40	47.30	11.37	63.96	40.99	48.00	47.50	43.64
11	22	177.00	84.80	57.80	47.50	31.33	19.24	45.10	55.00	12.94	70.10	40.28	52.70	57.00	50.71
12	21	181.00	87.50	57.00	50.00	34.12	20.30	45.20	56.20	15.32	72.00	47.59	57.00	74.25	50.87
13	23	173.50	83.90	55.99	47.00	31.96	21.27	43.30	53.00	14.96	69.99	42.23	53.30	61.00	48.44
14	25	176.50	84.30	57.30	46.00	32.94	21.23	43.40	54.70	15.63	70.30	46.33	53.70	72.00	48.62
15	22	173.50	83.90	55.99	46.20	32.74	22.41	42.60	53.40	14.13	69.99	43.71	53.70	63.50	47.44
16	21	174.50	83.69	56.50	47.00	31.11	19.20	42.70	52.40	12.83	70.50	39.97	53.60	55.00	47.44
17	21	179.00	84.10	57.05	50.00	33.87	21.03	46.40	56.20	13.12	70.09	43.11	57.80	65.00	51.49
18	22	162.00	76.82	51.85	44.80	29.19	19.97	40.80	50.40	13.24	63.96	39.55	49.70	50.00	45.44
19	22	179.00	84.10	57.05	49.40	30.90	19.11	45.50	55.50	14.47	70.09	42.95	56.00	65.00	50.32
20	**21**	**161.50**	**76.20**	**51.63**	**40.80**	**36.46**	**20.52**	**40.10**	**48.80**	**16.77**	**63.46**	**40.48**	**47.60**	**61.00**	**45.17**
21	21	163.00	77.00	52.00	41.30	31.37	20.76	38.70	46.90	12.76	64.00	36.79	49.00	47.00	43.11
22	22	159.50	76.79	51.47	42.30	45.65	19.11	39.70	50.60	19.28	63.60	44.49	51.10	80.60	44.67
23	21	158.00	75.99	50.97	43.40	31.61	19.98	38.70	47.30	12.97	62.88	39.50	50.00	48.50	43.87
24	21	164.00	77.69	52.50	43.80	41.90	21.11	42.30	52.80	19.56	64.90	45.53	51.20	78.70	47.44
25	22	158.00	75.99	50.97	42.20	30.00	17.17	42.50	49.20	13.49	62.88	41.07	48.40	49.00	47.44
26	22	157.00	75.90	50.96	42.30	34.63	20.14	39.70	47.70	15.31	63.00	39.43	48.00	48.00	44.00
27	22	161.50	76.20	51.63	43.00	30.23	20.30	39.10	48.50	12.06	63.46	35.56	48.10	45.00	44.23
28	20	173.00	83.20	55.90	48.30	38.41	19.40	44.50	54.20	17.21	69.90	43.99	56.30	68.00	49.24
29	21	167.00	81.00	55.00	44.00	48.37	19.44	43.30	52.70	20.55	67.00	51.62	52.40	102.0	48.29
30	19	157.00	75.90	50.96	42.00	33.61	19.94	40.60	49.50	13.80	63.00	38.45	48.00	50.50	45.21
31	21	177.00	84.80	57.80	47.60	34.41	22.61	42.00	51.70	14.71	70.10	39.21	56.30	58.00	47.44
32	20	169.00	82.00	54.20	47.30	30.43	20.83	41.60	50.90	11.83	69.00	39.15	53.80	48.00	46.05
33	20	162.00	76.82	51.85	42.10	33.07	22.44	38.90	48.10	15.39	63.96	38.28	56.40	50.00	43.64
34	18	159.00	76.09	51.07	42.70	33.04	18.95	39.00	48.50	14.43	63.10	39.83	49.90	50.50	44.52
35	22	150.00	72.00	47.50	40.00	36.55	19.11	38.00	46.80	15.64	60.40	42.00	47.10	56.50	43.49
36	22	165.50	80.50	54.50	43.00	40.46	21.76	45.70	55.60	17.23	66.50	47.35	52.10	78.50	50.57
37	23	167.00	81.00	55.00	44.00	36.63	19.88	42.30	53.00	17.00	67.00	47.35	51.40	73.00	47.82

Appendix XIII: Anthropometric-Data Record for Students from The Eldoret National Polytechnics (n = 35)

S. No	Age	S	SH	SHS	PH	HPS	EH	BPL	BKL	TC	EHS	SB	KH	BM	FFL
1	24	170.00	82.00	54.00	45.10	30.97	20.93	38.50	47.40	13.67	68.00	55.72	51.00	61.00	43.46
2	23	176.00	84.00	57.80	47.70	30.57	19.11	44.00	53.10	13.90	70.80	41.53	55.00	56.00	49.46
3	19	168.00	81.70	54.40	45.50	29.28	21.48	43.20	50.30	11.69	68.00	40.27	52.00	53.00	48.26
4	26	162.50	76.96	51.95	43.80	31.80	21.97	39.10	47.30	12.42	63.99	42.42	50.10	58.50	44.80
5	22	180.00	87.00	56.87	48.00	30.38	21.27	45.30	53.80	13.18	71.88	41.55	53.70	61.00	50.35
6	21	173.00	83.20	55.90	47.80	33.29	22.58	44.40	54.40	14.20	69.90	45.17	55.80	65.50	49.70
7	23	177.00	84.80	57.80	46.00	31.87	17.65	43.90	53.20	13.85	70.10	45.26	55.30	62.00	48.66
8	24	182.00	88.00	57.50	46.00	31.75	21.66	45.00	55.00	14.74	72.50	44.84	56.60	62.00	50.56
9	21	171.50	82.97	54.99	48.00	33.30	19.27	41.60	51.10	13.16	68.96	44.05	54.60	64.00	46.82
10	22	170.00	82.00	54.00	45.10	31.98	20.92	42.10	51.70	14.67	68.00	44.79	51.70	64.00	47.44
11	20	165.00	80.50	53.99	44.00	29.57	20.98	40.00	49.50	11.56	66.50	38.17	50.70	51.00	45.77
12	23	175.00	83.09	56.07	46.70	33.38	21.59	42.00	51.60	15.46	70.06	44.31	54.60	70.50	47.44
13	21	179.00	84.10	57.05	48.50	30.29	18.06	43.80	52.70	13.81	70.09	41.25	56.80	60.00	48.01
14	22	172.00	83.00	55.50	46.10	30.37	19.25	42.30	51.60	12.80	69.40	40.29	54.00	54.50	47.66
15	23	168.00	81.70	54.40	45.30	30.94	19.28	41.00	51.00	14.20	68.00	43.15	50.50	60.00	46.97
16	22	169.00	82.00	54.20	44.40	31.11	20.94	42.00	51.10	13.17	69.00	43.69	53.30	55.00	47.08
17	22	182.50	88.50	57.59	50.00	31.62	19.45	47.70	58.70	12.56	72.98	40.08	58.60	59.50	52.01
18	**22**	**166.50**	**81.10**	**55.80**	**44.00**	**30.20**	**17.22**	**41.50**	**50.00**	**12.56**	**67.40**	**39.77**	**48.16**	**50.50**	**46.57**
19	23	157.00	75.90	50.96	44.30	34.51	19.13	40.00	50.60	15.90	63.00	42.13	52.00	61.00	45.77
20	20	163.00	77.00	52.00	42.30	31.20	19.38	42.30	48.00	12.15	64.00	37.48	48.80	45.50	47.44
21	21	163.00	77.00	52.00	43.60	38.45	19.11	40.60	50.00	16.58	64.00	45.57	51.00	73.00	45.19
22	23	164.50	77.99	52.90	43.20	31.50	22.10	39.70	48.70	13.85	64.99	38.89	50.10	53.00	44.12
23	20	152.0	72.50	48.00	40.20	35.81	20.84	40.00	48.30	15.76	61.00	39.63	46.50	53.50	45.84
24	20	157.50	76.00	51.00	40.30	34.10	22.37	39.60	47.60	16.94	63.20	41.02	48.00	58.00	44.47
25	26	161.50	76.20	51.63	40.80	44.46	22.80	42.40	51.20	19.93	63.46	47.84	51.00	83.50	47.66
26	20	166.50	81.10	55.80	43.80	31.13	19.11	40.00	47.40	13.11	67.40	37.03	46.30	45.00	45.70
27	21	167.00	81.00	55.00	45.60	35.55	22.18	43.60	52.20	17.34	67.00	40.08	52.90	68.00	48.37
28	23	165.50	80.50	54.50	44.00	43.89	20.86	42.60	53.30	19.03	66.50	46.74	52.50	78.50	47.44
29	22	170.00	82.00	54.00	45.00	35.55	19.22	44.00	52.40	16.66	68.00	41.18	53.20	58.00	49.23
30	20	165.00	80.50	53.99	40.40	31.75	19.62	36.50	45.50	15.51	66.50	41.08	48.00	53.50	41.49
31	22	160.00	76.39	51.47	41.00	33.74	20.11	39.70	48.30	15.07	63.50	40.70	48.00	53.50	44.23
32	22	174.00	83.60	56.00	45.00	36.41	19.72	46.20	55.00	16.62	70.00	44.10	53.00	69.50	51.19
33	20	172.50	83.50	55.50	45.20	40.79	22.76	47.00	56.00	17.81	69.50	45.76	52.80	72.50	52.31
34	19	156.00	74.99	50.95	40.70	31.56	18.53	39.30	48.40	14.39	62.50	38.42	47.70	48.50	44.21
35	22	177.00	84.80	57.80	47.70	37.61	21.61	47.50	56.70	15.92	70.10	41.60	54.00	67.50	52.44

Appendix XIV: students' Survey Data Record from the Selected Institutions

Respo. No	(a)	(b)	(c)	(d)	EAS	SOU	EOM	D	Ae	R	M	SA	ES	EV	UAF	LCC	Av
1	1	2	3	4	2	1	3	4	5	5	5	5	5	2	3	4	5
2	2	3	1	5	4	3	5	1	2	3	4	5	1	2	5	1	2
3	3	4	5	3	2	5	4	4	5	5	2	3	4	4	5	4	2
4	4	5	3	4	5	5	4	5	4	4	4	3	4	4	4	4	4
5	3	2	4	3	5	5	4	3	3	5	5	4	3	3	2	5	4
6	5	4	3	2	1	2	3	4	5	5	4	3	2	1	5	2	3
7	3	4	3	2	5	5	2	5	2	4	5	3	5	3	5	5	2
8	3	2	1	5	1	2	3	4	5	2	3	4	5	2	1	3	5
9	1	3	4	5	2	1	3	2	4	1	2	3	5	2	3	4	2
10	1	5	2	4	5	4	5	4	1	5	4	2	3	4	4	3	5
11	4	2	3	2	3	5	1	4	2	4	3	2	3	2	4	1	2
12	4	4	2	3	4	5	3	4	4	5	5	3	2	4	5	3	2
13	4	5	3	2	4	5	4	3	4	5	4	4	4	5	5	4	3
14	3	5	2	1	5	4	2	3	4	5	4	2	3	1	5	1	3
15	5	4	2	1	4	5	4	5	3	5	4	2	5	3	2	1	3
16	4	5	2	3	5	4	3	4	3	3	4	3	5	5	3	4	3
17	3	5	1	2	5	4	2	4	5	3	1	2	3	3	4	1	2
18	5	3	2	1	3	5	1	1	5	3	2	5	4	3	2	4	3
19	3	5	1	2	3	5	2	1	4	5	2	5	4	4	5	3	1
20	1	4	3	2	2	4	2	3	5	3	2	5	5	1	3	2	1
21	3	3	1	2	4	5	1	1	1	4	2	1	5	1	5	4	3
22	5	3	1	2	5	5	3	1	5	1	3	5	5	5	5	5	1
23	1	3	2	1	3	2	1	1	1	1	1	1	1	1	1	1	1
24	4	3	2	5	4	3	2	1	4	5	3	5	2	4	3	2	3
25	4	2	2	3	2	4	1	5	4	3	5	3	2	3	4	2	4
26	2	5	3	4	1	2	3	1	4	2	5	3	2	4	3	5	4
27	4	3	2	5	3	1	2	2	4	1	2	3	3	5	1	5	3
28	3	2	1	4	2	3	4	2	5	2	3	1	1	2	3	4	5
29	5	4	2	2	2	5	2	3	5	4	3	4	4	3	2	3	2
30	4	5	3	1	2	4	5	5	2	2	5	3	4	5	2	1	3
31	4	2	2	3	4	5	4	4	3	3	3	5	4	3	5	5	2
32	5	3	2	4	5	4	3	3	3	4	4	3	3	3	4	4	4
33	1	2	3	4	1	2	3	4	5	2	1	2	3	4	5	3	2
34	1	3	2	1	1	3	2	3	3	5	4	4	1	2	2	2	4
35	4	4	5	5	5	4	2	4	5	4	4	4	5	2	4	4	3
36	4	4	5	4	5	4	4	2	5	4	4	5	3	3	5	2	5
37	4	3	2	1	4	5	3	2	5	4	1	3	5	2	5	2	2
38	5	4	2	2	3	5	4	5	2	5	4	3	4	5	5	2	5
39	5	5	4	3	5	5	4	4	3	4	4	4	4	5	5	4	5
40	3	2	4	5	5	4	2	3	1	3	4	3	1	2	3	4	3
41	2	1	4	2	1	4	1	1	1	1	1	1	1	1	1	1	1
42	1	3	2	3	3	2	2	5	3	4	2	3	2	4	2	2	3
43	3	1	5	4	4	2	1	5	4	5	5	2	3	3	4	1	1
44	2	4	3	2	1	5	3	2	1	4	3	5	3	2	1	1	3
45	5	5	5	5	4	3	2	4	4	5	5	3	5	5	5	5	5
46	5	5	5	5	4	3	5	5	5	5	5	2	3	4	5	5	5
47	5	4	2	1	2	4	1	3	1	4	3	4	4	3	3	2	1
48	3	5	3	2	4	3	2	4	3	4	4	1	3	4	5	5	2
49	5	4	3	3	5	5	4	5	3	4	5	1	1	2	3	2	4
50	5	3	2	2	3	5	4	5	2	5	4	3	4	5	5	4	5
51	3	4	5	5	3	2	1	3	4	5	5	5	5	5	2	1	1
52	3	3	3	3	5	3	2	1	5	3	2	1	1	4	3	1	2
53	4	1	1	2	5	4	5	3	5	5	4	5	3	1	2	3	5
54	5	4	4	3	1	4	3	4	5	3	4	3	4	3	5	2	5
55	4	5	4	3	5	4	3	3	5	4	3	3	5	4	2	2	3
56	2	5	1	3	5	4	1	5	3	2	5	1	1	4	3	1	2
57	5	4	3	2	2	3	4	5	1	2	3	4	5	5	4	3	2
58	3	1	4	5	4	3	1	3	5	4	2	2	5	3	2	4	1
59	5	4	3	1	3	2	2	3	4	4	3	2	4	1	2	2	2
60	4	1	2	3	4	5	1	3	1	2	3	5	5	1	4	1	2
61	4	2	2	2	3	4	2	4	2	3	3	1	2	3	4	2	3
62	2	2	2	3	3	4	2	5	2	5	3	1	2	3	1	4	2
63	2	2	2	3	3	4	2	5	2	5	4	2	2	3	1	4	3
64	3	2	4	3	4	4	3	3	5	4	2	3	4	3	2	2	3
65	5	1	1	4	5	5	3	4	4	2	1	4	5	5	3-	1	5
66	5	4	1	4	1	5	3	4	3	5	4	5	5	1	5	2	5
67	3	4	1	2	5	4	3	3	2	3	3	3	1	1	1	1	5

68	1	3	4	2	2	3	4	2	1	3	5	2	3	4	5	4	5
69	2	4	3	5	5	1	1	5	1	2	4	5	1	3	5	2	2
70	5	2	1	2	5	4	1	5	4	3	3	4	2	2	3	4	3
71	4	3	1	5	3	5	2	1	4	1	2	1	5	4	2	1	3
72	2	4	5	1	4	2	1	5	3	4	2	3	1	4	5	2	5
73	4	5	3	3	5	4	5	5	4	4	5	3	4	5	3	5	5
74	5	4	2	3	5	5	2	3	4	3	4	4	5	4	3	3	2
75	2	3	2	1	2	3	2	4	1	3	1	4	3	2	1	2	3
76	2	4	1	3	2	4	3	5	2	4	4	3	2	4	3	4	1
77	3	4	1	2	5	2	3	4	1	2	5	4	1	2	3	2	4
78	3	2	1	5	2	3	5	4	1	4	2	3	5	1	2	4	1
79	5	2	3	1	3	4	2	1	5	4	3	1	1	2	3	5	4
80	5	4	2	3	3	4	5	2	2	3	5	2	1	5	4	4	3
81	4	3	2	2	5	3	4	5	4	4	3	2	4	5	4	5	5
82	2	4	3	2	4	3	1	4	3	2	1	2	3	5	3	5	4
83	4	2	3	4	4	3	3	4	4	4	4	5	5	4	5	5	4
84	4	3	5	1	1	2	1	3	4	5	2	3	4	5	4	2	1
85	2	4	2	3	1	3	2	4	1	2	3	4	5	4	3	2	3
86	4	5	1	2	5	4	5	1	3	5	4	5	4	2	3	1	2
87	4	5	3	2	4	2	3	5	3	3	1	1	2	5	2	1	5
88	4	4	2	1	4	2	3	5	1	2	2	3	2	5	4	2	5
89	4	1	1	3	5	5	4	4	5	3	5	4	5	4	3	5	2
90	3	5	4	1	4	3	5	4	2	4	3	1	5	3	4	1	5
91	3	4	4	3	3	3	2	3	4	5	3	4	4	3	4	2	2
92	3	4	2	4	3	4	2	1	2	4	4	5	1	5	4	3	4
93	4	1	2	3	3	1	5	5	5	5	2	1	4	3	2	4	5
94	4	5	3	4	4	5	2	3	4	4	4	4	3	3	5	3	3
95	3	4	1	2	3	2	2	2	1	3	4	4	3	2	2	1	1
96	4	5	2	3	5	5	1	5	2	5	3	1	1	1	5	4	5
97	1	4	5	4	5	5	4	4	1	2	3	5	5	3	4	4	5
98	3	5	1	2	5	5	4	5	5	5	5	5	5	4	5	5	5
99	2	3	4	5	3	2	1	5	1	5	4	2	3	2	1	4	3
100	3	4	2	2	4	5	5	5	4	5	5	4	5	5	4	5	5
101	5	4	1	1	5	2	1	1	1	4	5	4	1	3	2	1	2
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Appendix XV: ISO 7250-1 International Standard

INTERNATIONAL STANDARD

ISO 7250-1

Second edition
2017-08

Basic human body measurements for technological design —

Part 1:
Body measurement definitions and landmarks

Définitions des mesures de base du corps humain pour la conception technologique —

Partie 1: Définitions des mesures du corps et repères

Reference number
ISO 7250-1:2017(E)

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AN INNOVATIVE ERGONOMIC DESIGN OF CLASSROOM FURNITURE AND ITS ANALYSIS BASED ON ANTHROPOMETRIC MEASUREMENTS AT TERTIARY INSTITUTIONS

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