DEVELOPMENT OF A SAFE WEIGHT OF LIFT MODEL FOR MANUAL WORKERS AT ARULOGUN, IBADAN, OYO STATE

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CERTIFICATION

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DEDICATION

This thesis is dedicated to every worker who engages in manual lifting activities that may be experiencing low back pain.

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ABSTRACT

The Low Back Pain (LBP) problem is prevalent among construction workers involved in the Manual Load Handling (MLH) of sandcrete blocks. Studies have shown that human and environmental based factors affect the weight of lift appropriateness and may lead to musculoskeletal disorders such as low back pain. Ergonomic models that utilise compounded human characteristic factors and environmental temperature to estimate Safe Weight of Lift (SWL) for construction workers are sparse. This study was, therefore, designed to develop a model for determining SWL among manual labourers at varying workplace temperatures.

A safe weight of lift model was developed with compounded human ergonomic factors of age, body weight, spinal shrinkage, spine length, lift frequency, and environmental temperature using the principle of strain energy. Subjective sampling technique was used in selecting fifty experienced male bricklayers involved in lifting sandcrete blocks of weight between 20.00 and 22.50 kg for 8-hours daily at Arulogun, Akinyele Local Government Area, Ibadan. For each subject, the compounded human ergonomic factors and environmental temperature were measured using the ZT-160 scale, stadiometer, measuring tape, clock timer and Extech RH/Temperature pen device. The obtained data were used as input into the developed model to estimate the SWL for each subject at varying temperature ranges of 26.00 – 27.90, 28.00 – 29.90, 30.00 – 31.90, 32.00 – 33.90, 34.00 – 35.90 and 36.00 – 37.00°C. These were compared with existing secondary SWL data at the temperature range of 27.00 – 32.00°C. Analysis was subsequently done to determine factors that were significant in estimating SWL. Data were analysed using ANOVA at $\propto_{0.05}$.

The model revealed that a non-linear relationship exists between the SWL and compounded ergonomic factors. The age, body weight, spinal shrinkage, spine length, lift frequency, and temperature were 33.26±7.22 years, 67.50±11.58 kg, 0.02±0.06 m, 0.47±0.03 m, 2.00±0.48 lifts/min, and 30.46±2.51°C, respectively. The safe weight of the lift at environmental temperature ranges of 26.00 – 27.90, 28.00 – 29.90, 30.00 – 31.90, 32.00 – 33.90, 34.00 – 35.90 and 36.00 – 37.00°C were 6.23±0.82, 5.79±1.45, 7.20±1.84, 8.04±2.74, 5.96±0.00, and 5.87±0.00, respectively. The SWL, which ranged between 3.78 and 12.77 kg implied that sandcrete blocks in this weight range when lifted, were incapable of causing low back pain. The SWL from the model and that of the compared secondary data were 6.10±1.29 and 16.34±6.40. These indicated that there was a significant difference between the model and secondary data, which could be attributed to differences in the environmental temperature at which the secondary data were obtained as compared with those of the model. The model SWL was significantly influenced by the interaction between compounded human ergonomic factors and environmental temperature.

An ergonomic model to estimate the safe weight of lifts for manual labourers was developed. The model is a useful tool for decision-making in the area of safety management of male labourers involved in the manual load handling.

Keywords: Ergonomic model, Low back pain, Manual load handling, Safe weight of lift, Sandcrete block lifting

Word count: 461

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LIST OF TERMINOLOGIES

Terms	Meaning
AG	Age
GN	Gender
TF	Temperature
L	Spine length
FM	Frequency of lifts
m_b	Body weight
x	Stature change
l_s	Chest width
l_f	Chest length
BMI	Body Mass Index
IVD	Inter-Vertebral Disc
HM	Horizontal Multiplier
VM	Vertical Multiplier
LC	Load Constant
WH	Worker’s Height
LV	Lifting Velocity
PO	Posture/Lifting angle
AM	Asymmetric Multiplier
CM	Coupling Multiplier
LH	Lifting Height
LL	Leg Length
LBP	Low Back Pain
g	Gravity
E	Modulus of Elasticity
SH	Shoulder Height
u	Velocity of lift
A	Elliptical Trunk Area

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Unassisted human activities of manual load handling include bending, climbing, letting down, rotating, pushing, pulling, carrying, releasing, holding and lifting (Girish *et al*., 2015). Most common occur manual load-handling jobs include heavy or bulky loads, loads with arms far from the trunk, load-lifting by twisting of back, neck, or upper body, load-lifting at low or above shoulder height level, one side load handling and postural during working in constricted or clogged location (Hamid and Tamrin, 2016; Celik *et al*., 2018; Ardiyanto *et al*., 2019). Manual load-handling musculoskeletal injuries are found in work places, like industries, construction sites, farms, factories, warehouses, hospitals, schools, building sites, offices, homes, banks, laboratories, and even when making deliveries (Mohapatra *et al*., 2022). The computerisation of manual load handling has not ceased continued need for Manual Load Handling (MLH) activities, especially in nations where labourers are readily available, where automation is moderately introduced, and where computerisation could be more cost-effective. Therefore, MLH is being practised in less technologically advanced, technologically developing and in some capacities of work in technologically advanced countries (Mital and Manivasagan, 1983; Madiha *et al*., 2020).

Manual lifting is an extensively performed load-handling engagement. Manual lifting due to inappropriate load weight is a major cause of lower back pain (Marras, 2012; Celik *et al*., 2018; Ardiyanto *et al*., 2019). Low backaches to manual lifting workers prompted by lifting are prevalent in less technologically advanced nations, developing and technologically advanced countries (Mital and Manivasagan, 1983; Marras, 2012). Manual lifting is perceived to add great energetic mass to the worker's low back. This could lead to low back pain over an extended time of lifting activities if the mass goes beyond the mechanical tolerance of the tissue (Antwi-Afari *et al*., 2017). According to Louw *et al*. (2007), low back pain is caused by muscle pull or rigidity immediately below the costal margin and beyond the unacceptable standard of gluteal folds with or deprive of leg hurt. A low back injury may result in substantial incapacity of manual lifting workers by creating constraints on joint activity involvement, such as the capacity to work (Kartz, 2006). Various lifting tasks identified to cause pain to the back of the manual lifting workers include unbalanced lifting, coalescing lifting, and meandering and snaking motions of the torso. These are detrimental to the spine of humans more than symmetric lifting (Lee, 2005; Hamid and Tamrin, 2016). Therefore, workplaces have been removing hefty lifting situations and substituting them with lighter loads that must be executed more often (Callaghan and Parkinson, 2010).

The weight of lift that minimises low back pain of manual lifting worker has been defined as weight whose axial component is the induced compressive force acting perpendicular to the plane of the spinal disc at the lumbar region and it is less than what has been found to cause plastic deformation of the disc (Ismaila, 2006). Recommended Weight Limit (RWL) has been defined by National Institute for Occupational Safety and Health (NIOSH, 1991) to be a specific load weight and set of task conditions that all health workers can lift over 8-hour work time, and devoid of increasing the threat of developing lifting related low back pain when manual lifting activities are performed at a temperature of between 19 and 26°C with a relative humidity of between 35 and 50% (Waters *et al*., 1993; Parida and Ray, 2015). The NIOSH (1991) recommended weight limit parameters were based on the factors related to the task performed by the manual lifting workers and not on the person who performed the task.

The recommended weight limit (NIOSH, 1991) equation was established based on the American populace and its environment at temperatures between 19 and 26°C with a relative humidity of 35 and 50%. The NIOSH (1991) recommended weight limit equation suitability in different racial populations apart from the American population has been controversial as work-related accidents are expected to depend on different body physique, anthropometry, and environmental conditions (Maiti and Ray, 2004; Ardiyanto *et al*., 2019). However, the NIOSH lifting equation vertical multiplier is inconsistent with the anthropometric conditions of different workers in various societies (Chegini *et al*., 2022). Also, the NIOSH (1991) lifting equation was developed to help evaluate lifting demand for manual lifting workers. However, consideration was not given to the full range of factors involved in manual lifting activities in developing the model (Alferdaws and Ramadan, 2020). Ahmad and Muzammil (2022) identified the absence of worker characteristics and environmental conditions in the revised NIOSH lifting equation as a limitation of its present adoptability. According to Hidalgo *et al*. (1997), the need for gender equality in employment opportunities involving both able and disabled American workers in American legislation made NIOSH (1991) develop equations without individual factors such as gender, age and fitness. The lifting limits have been suggested not to be generalized across different races and genders (Hung *et al*., 2020). Also, significant differences have been observed between males and females, such that the ability to lift reduces with increasing age in terms of lifting capacity (Stambough *et al*., 1995). Therefore, the weight lift limit recommendation model should include gender and age as factors.

Other observed factors affecting lifting performance include weight, spine length, age, stature change, gender and temperature above recommended weight limit value of between 19 and 26°C as it affects manual lifting workers (Drury and Pfeil, 1975; Ismaila, 2006; Kjellstrom *et al*., 2009; Choi *et al*., 2012). It is considered necessary to develop a model to compute the safe weight of lift in an environment where temperatures exceed recommended weight limit (NIOSH, 1991) lifting temperature of between 19 and 26°C, and also consider other factors such as workers' weight, spine length, age, gender and stature change.

There is a danger of injury in the construction industry's single or monotonous manual lifting of loads. The repetitive manual lifting of material weighing less than 20.00 kg has been identified to involve risks that are still significant (Health and Safety Commission, 2006). The danger of injury is primarily determined by the weight of the material lifted because the heavier the load, the higher the risk of injury.

The weight a worker can lift manually for 8–hours daily was put at 11.80 kg when the weight selection (psychophysical) was left to the participant at an average weight from 10.00 to 13.00 kg (Jomoah, 2014). This is a subjective perception lift that might have been affected by other factors that should be considered in determining the safe weight of the lift.

Harold and Ndubueze (2013) interviewed 28 concrete brickmakers on the perceived pain or discomfort in their bodies. The substantial part of the body assessed were the neck, shoulders, upper back, elbow, lower back, wrist, hips and thighs, knees, ankles and feet. The following percentages of the respondents indicated pain in the above body parts, such as 14.29, 39.29, 46.43, 10.71, 64.29, 17.86, 21.43, 7.20 and 0.00%, respectively. The upper back and low back had the highest percentage, 46.43 and 64.29%, respectively. The study considered workers such as bricklayers, plasterers and their assistants. The result indicated 52.77, 52.17 and 48.07% for low back pain, respectively.

To prevent low back pain, three different major approaches have been used in literature to determine weight limits, namely; a biomechanical approach whereby mechanics is applied to the physical structure of human beings, a physiological approach whereby subjects were made not to exceed some predetermined levels of air intake/exhale while lifting and psychophysical approach whereby subjects were allowed to adjust weight being lifted to their ability (Mital and Manivasagan, 1983; Chaffin and Page, 1994; Norman *et al*., 2000; Cheng and Lee, 2006). Also, a model that compared manual lifting workers' spines to spring and anthropometric dimensions was developed to measure manual lifting workers' chest width and length, spine length, stature change and angle to compute the safe weight of lift (Ismaila, 2006). Though the model considered some anthropometric dimensions of manual lifting workers, other personal factors have yet to be considered and were considered in this study.

Singh *et al*. (2022) studied 206 workers engaged in manual load-handling work at various industries in North India. The researchers used survey method of Cornell musculoskeletal discomfort questionnaires (CMDQ). The researchers found that 81.55% of the workers indicated that they had musculoskeletal symptom problems in one or more of the twelve defined parts of the body in the last 12 months. It was found that the non-availability of a standard optimum load for MLH tasks caused workers to be exposed to musculoskeletal disorders such as lower back, wrist, shoulder, neck and upper back. These were the most painful problem areas of the body indicated by the workers. Therefore, there is a need to develop a model to determine an optimum load weight safe to be lifted that will reduce musculoskeletal problems among manual lifting workers, as it has been done in this present research.

Low back pain injuries caused by manual lifting persist in being common incidents not merely in developing but also in developed countries. Low back pain is a common and costly problem throughout the United States (Ferguson *et al*., 2019). The prevalence rates for low back pain lasting at least a week, trying to find medical care and time lost were 25, 14 and 10%, respectively, of nearly 2000 workers considered in the study (Ferguson *et al*., 2019). According to Childs *et al*. (2004), Celik *et al*. (2018), and Ardiyanto *et al*. (2019), billions of dollars are incurred in medical expenditure every year across countries due to low back pain in Africa and globally. However, to save billions of naira (which may not be available) on medical treatment for low back pain problems among manual lifting workers in Nigeria. It is better to develop a model to compute the safe weight of lift for manual lifting workers, based on their workplace temperature as well as considering other personal characteristic factors.

The present study developed a model by considering observed personal characteristic factors such as worker age, length of the spine, body mass, gender, change in stature, frequency of lift and workplace temperature based on the strain energy principle to compute the safe weight of lifting for manual lifting workers in Ibadan, Oyo State.

1.2 Statement of the Problem

Several models have been presented in the literature to address the problem of low back pain among workers engaged in manual lifting activities. Among them are; Recommended Weight Limit (RWL) equation (NIOSH, 1991), the Mathematical and Comprehensive Lifting Model (Stambough *et al*., 1995; Hidalgo *et al*., 1997), the Safe Weight of Lift model using Young Modulus with anthropometric dimensions of the workers (Ismaila, 2006; Ismaila, 2017). Approaches that have been used include biomechanical, physiological, and psychophysical. These have been adopted to reduce the problem of low back pain among manual lifting employees. Therefore, there is need for further research to develop a model that would not require strict conditions and still gives the result of load weight that can reduce the problem of low backache to manual lifting workers.

The National Institute for Occupation Safety and Health (NIOSH, 1991) recommended weight limit equation has become the most widely used equation to evaluate Recommended Weight Limit (RWL) for manual lifting workers. However, consideration should be given to factors seem to be necessary in manual lifting activities in developing the model (Alferdaws and Ramadan, 2020; Ahmad and Muzammil, 2022;

Saman and Mohammad, 2022). The recommended weight limit was developed based on the American population and in an environment where the temperature ranged between 19 and 26°C (Waters *et al*., 1993). However, the suitability of the NIOSH (1991) equation in an environment where the temperature is above 26°C and in different racial populations apart from the American population is in doubt (Maiti and Ray, 2004; Choi *et al*., 2012; Barim *et al*., 2019; Firouzabadi *et al*., 2021). Also, ergonomic models incorporating individual characteristic factors and varying temperatures to determine safe weight are sparse (Pinder, 2002; Barim *et al*., 2019; Kudo *et al*., 2019; Firouzabadi *et al*., 2021). However, the persistence of the work-induced problem of low back pain among manual lifting labourers caused by inappropriate load weight is a concern in the field of ergonomics because this has resulted in disability and poor quality of life for labourers. Manual lifting workers working in an environment in which temperature ranges above 26°C, along with the observed and identified selected individual characteristic factors of males such as weight, spine length, age, gender, stature change and frequency of lifts, seem to influence safe weight to lift is an area of research considered in this study to develop a model to determine the safe weight of the lift.

1.3 Aim of the Study

The study aims to develop a Safe Weight of Lift with varying Temperatures (SWLwT) model by considering six personal factors (body weight, total disc length, age, gender, spinal shrinkage, and lift frequency) and workplace temperatures based on strain energy principle to determine the SWLs.

1.4 Objectives of the Study

1. To develop a model that will incorporate six-individual characteristic factors of male manual workers (gender, body weight, spine length, age, stature change and frequency of lifts) and workplace temperatures.
2. To use the developed model in computing the safe weight of lift for male manual lifting workers.
3. To validate the model by determining the relationship between selected factors and the developed model.

1.5 Justification of the Study

This research focused on developing an ergonomic model to determine the safe weight of lift for male manual workers at Arulogun, Ibadan, Oyo state by considering six-individual characteristic factors of male manual workers and the workplace temperature. The selected six-individual characteristic factors and workplace temperature were based on physiological, psychophysical and biomechanical approaches of the observed male manual workers during visitation to construction sites at Arulogun, Ibadan, Oyo state. One of the existing and standard ergonomic equations, which is the National Institute for Occupational Safety and Health (NIOSH) lifting equation, is a task-specific equation that considers factors such as load constant (*LC*), multipliers of; horizontal (*HM*), vertical (*VM*), asymmetric (*AM*), coupling (*CM*), distance (*DM*) and frequency (*FM*) and stated workplace temperature for its applicability to assess load demand for manual lifting workers known as recommended weight limit, but worker's distinguishing factors were not considered. In the literature, suggestions have been made that characteristic human factors should be considered to develop an ergonomic model to determine the safe weight of the lift. At the same time, this suggestion has been considered by a few authors. For example, the Safe Weight of Lift model using Young Modulus with anthropometric dimensions was developed by considering lifting velocity (u), gravitation acceleration (g), load-vertical position (V), and horizontal span from ankles (H), vertical shift (D) and angle of lift (θ) all these were task-specific factors. At the same time, spine length and shrinkage were the two human characteristic factors considered in the model to determine the safe weight of the lift. However, by modifying the developed Safe Weight of Lift model using Young Modulus with anthropometric dimensions, other individual characteristic factors to be considered in this present model to be developed include factors such as lifter’s weight, age, lifting frequency and gender and workplace temperature using the principle of strain energy. The gender factor allows the development of a model to apply to either male or female manual workers involved in manual lifting. The age factor allowed the model to take into consideration the age factor multiplier, body weight is the consideration for the mass of the manual worker adding to the load-weight to be lifted, and spinal shrinkage is the differences between the morning and evening height of the worker to determine the compression of the spine due to the weight lifted, spine length is the distance from the first thoracic to the last lumbar, and frequency of lift is the number of load lifts per minute by the manual worker. The workplace temperature is the environmental temperature at which the manual worker works. The use of compounded human ergonomic individual characteristic factors of manual lifting workers such as gender, age, body weight, spinal shrinkage, spine length, frequency of lifts, and workplace temperature to develop an ergonomic model to determine safe load weight to minimise the problem of low back pain among manual lifting workers as it is done in this research was yet to be seen in the literature.

1.6 Scope of the Study

The scope of the study involved human ergonomic factors of six-individual distinguishing factors and workplace temperatures in developing a model, which was used to determine the safe weight of lift of fifty male experienced bricklayers at Arulogun, Akinyele Local Government Area (L.G.A), in Ibadan, Oyo state. The model developed was a gender-based, which was applied to male manual workers to determine their respective safe weight lift.

1.7 Outline of Succeeding Thesis Chapters

Chapter Two is about the review of existing literature relevant to this study. The chapter stated what had been done and highlighted what needed to be done. The discussion varied from general critiques to the conceptual, theoretical and empirical review of the literature and the identification of knowledge gaps.

Chapter three presents the research methodology based on the scientific background on which the model was developed. It started with how the existing model was developed and linked to the present model development; it also requires research equipment, sampling technique and measurement procedure to be presented.

Chapter four is where results and discussion were done. The demonstration of how to use the developed model to compute the safe weight of lift was done, and a graphical presentation of the considered factors collected data and a table of results of the computed safe weight of lift were presented. The relationships between independent, two-ways interaction, mutual interaction of the selected factors and safe weight of the lift table and figures were presented and discussed.

Chapter five is divided into a summary, conclusion, recommendation, contributions to knowledge and area of further research.

CHAPTER TWO
LITERATURE REVIEW

2.1 Work Capacity and heat indices

Several heat exposure keys had been made to shield employees from extreme temperatures. The usual work-related health method is the Wet Bulb Globe Temperature (WBGT) (Kjellstrom *et al*., 2009). The argument had been that lifting tasks performed at temperatures significantly above 26°C may likely cause low-back pain to manual lifting workers (Choi *et al*., 2012). The WBGT proportion was used to estimate the work capacity of workers by computing carefully chosen heat exposure and work for the classification of work intensity. They discovered that work capacity quickly reduced as the WBGT exceeded 30°C. Another heat index method is the Universal Thermal Climate Index (UTCI), which extends to an extensive range of environmental conditions from extreme cold to hot (less than -40°C to above 46°C), which can be computed by solving Fiala's heat balance or regression model (Blazejczyk *et al*., 2014). These researchers' findings indicated the importance of temperature as a factor considered in determining the worker's work capacity. Temperature is one of the factors considered in the present research developed model.

Table 2.1 shows the proposed maximum wet bulb globe temperature levels for various work intensities and rest/work ratios of average acclimatised workers wearing light cloth. The work intensity had been classified into light, medium, heavy and very heavy, and categorised into different temperatures based on Wet Bulb Globe Temperatures (WBGT) and they require rest per hour for work done at these different temperatures. The classes of work intensity of light, medium, heavy and very heavy at different Wet Bulb Globe Temperatures (WBGT) of 31.00, 28.00, 27.00 and 25.50°C, respectively, require 0% rest/hour for anyone working at these temperatures; at temperatures of 31.50, 29, 27.50 and 26.50°C, respectively, require 25% rest/hour for a worker working at the different temperature; at a temperature of 32.00, 30.50, 29.50 and 28.00°C, respectively, require 50% rest/hour if working at any of this temperature; at temperatures of 32.50, 32, 31.50 and 31.00°C, respectively, require 75% rest/hour for work done at these temperatures; at temperatures of 39.00, 37.00, 36.00 and 34.00°C, respectively, require 100% rest/hour, which means no work should be done at this temperature. Adeodu *et al*. (2014) classified bricklaying activities as heavy tasks based on energy expended and not by considering their individual characteristic and temperature at which the bricklayers worked.

2.2 Clinical and Physiological Impact of Temperature

The human body is structured to keep the body's core temperature at 37°C, but the person involved in physical activities can create metabolic heat inside the body. This heat needed to be transferred to the person's external environment to avoid a dangerous increase in the body's core temperature (Kjellstrom *et al*., 2009; Lukman, 2016). Among the fundamental factors was body temperature balance, which was the metabolic heat produced by human physical activity. If a bodily event was high in a working environment with high environmental temperature, the employee could be in danger of increased body core temperature (beyond 38°C). This could lead to diminishing work capacities such as the ability to lift, mental tasks, increased accident hazards and inevitably, heat exhaustion or heat stroke if the body core temperature exceeds 39°C. It could also lead to acute heart disorders and at above 40°C, life-threatening severe hyperpyrexia resulted (Kjellstrom *et al*., 2009; Blazejczyk *et al*., 2014). Six significant factors were required to determine body heat balance: air and radiant temperature, humidity, air movement (wind speed), clothing and metabolic heat generated by human physical activity, including manual lifting (Kjellstrom *et al*., 2009). The researchers observed that an increase in human physical activities could cause an increase in body core temperature. Therefore, it is necessary to reduce human physical activities by reducing the load weight that manual lifting workers lift, thereby reducing workers' body core temperature.

An experiment was conducted in a laboratory room temperature of 28.00±1.30°C and was compared with actual field conditions observed in April, May and June 2001 in India, where the wet-bulb temperature was 26.80±0.65°C, and the dry-bulb temperature was 33.30±1.60°C, globe temperature was 46.70±5.00°C (under the sun) and 33.30±2.80°C (under shade) (Maiti, 2001). It was deduced that global temperatures under the sun and shade exceeded the required body core temperature of 37°C, while laboratory room and wet-bulb temperatures were conducive for manual lifting activities. However, construction activities involving bricklaying were majorly outdoor jobs. Therefore, it is necessary to develop a model that considered temperature as it is done in this research.

2.3 Assessing Workplace Temperature

The Wet Bulb Globe Temperature (WBGT) index developed by the United States Military considered air, radiant temperature, humidity, and air movement, which were the basis for time limitations of work in different workplaces. Other heat exposure indices were heat and thermal stress and predictive 4-hour sweat rate (Kjellstrom *et al*., 2009). The procedure based on WBGT stated the highest heat experiences for occupational heat exposure jobs at various intensities (watts). Compared to unorganized sectors, occupational heat exposure guidelines may be easier to follow. Renberg *et al*. (2020) studied the effect of cold weather (-15°C) and control (5°C) on the performance of 14 trained and acclimatised males manual workers of height between 1.70 and 1.90 m while working at a high height of 1.80 m or low height of 1.10 m involved in lifting 5.00 kg dumbbells, the participants' activities decreased at cold temperature (-15°C) more than at control temperature (5°C). Abokhashabah *et al*. (2021) observed that there would be a problem health safety of manual workers exposed to increased temperature. Therefore, the temperature is a factor considered to develop an ergonomic model to determine the safe load to lift in the outdoor workplace.

The working hour proportion during which workers needed to rest was presented by International Labour Organization (ILO) subjected to work intensity. Also, wet bulb globe temperature was used to avert body core temperature from exceeding 38°C for a middle-class worker. According to European Agency for Safety and Health (2006), the ideal temperature is 20 to 22°C. If the temperature rises above 26°C, there would be a drop in concentration, power loss, and the occurrence of mistakes, weakness, and overtiredness. This would increase the number of accidents in the manual lifting workplace. This can as well occur during manual handling activities. The worker used siesta, nightfall, or related tactics to work during less scorching weather every 24 hours to prevent mid-day work capacity loss. Renberg *et al*. (2020) conducted a cold environment effect on manual workers in a controlled laboratory environment that stabilised the participants' body temperature at 23°C. In Nigeria, for example, manual lifting workers engaged in manual lifting at a temperature above 22°C. However, to integrate findings of a possible drop in concentration, power loss, mistakes, fatigue, exhaustion and an increase in accidents during manual lifting. Hence, the temperature is considered in formulating a model to determine a safe weight to lift.

Table 2.2 shows the WBGT parameters for various work intensity ranks (watts = W). The classes of metabolic rate were given as 0 representing resting, M<117W; 1 represented light work, 117<M<234W; 2 represented sustained medium-level work, 234<M<360W; 3 represented intense work, 360<M<468W; 4 represented very intense work, M<468W. Any worker was permitted to work for 20 minutes each hour at 435 W of metabolic rate. This means such a worker would have just worked for 160 minutes for an 8-hour work per day. Therefore, to reduce the intensity, there is a need to reduce load weight. The outdoor work activities can be categorised into any of these categories; light, medium and heavy or very heavy work.

Kjellstrom *et al*. (2009) observed the highest level of WBGT in the hot periods during outdoor work, where sun exposure was the leading cause of high WBGTs. On average, the evaluated WBGTs for the afternoons in Delhi in May 2009 (the hottest month in Delhi, India) reached above 30°C. The workability of a person during a different hour at heavy work intensity in Delhi at 500.00 W was very low. It was assumed that if the temperature was considered in developing a model to determine the SWL, among other factors, work capacity should increase due to the expected reduction in load weight, hence leading to a reduction in manual lifting worker physical activity. Abokhashabah *et al*. (2021) stated that exposure to an unfavourable temperature environment reduced worker performance.

Renberg *et al*. (2020) studied the effect of performance of 14 healthy, trained and acclimatised males manual workers of age ranging 25±3 years, body mass 80.90±6.40 kg, and height 1.82±0.50 m performance under cold (-15℃) and control (5℃) ambient temperature situations in an environmental chamber stabilised for the participants' body temperature at 23℃. They observed higher muscle demand in the participants' forearms during cold situations and systematic cooling of the body forearm in an ambient temperature of 5℃ during lifting of 5.00 kg load weight, which led to lower skin and muscle temperatures; increased muscle activation and fatigue in the forearm muscle in comparison with thermo-neutral conditions.

Hafez (1984) conducted a study to assess the lifting capabilities of individuals at temperatures between 22 and 32°C environment and investigated physical and physiological stresses induced by the lifting process. The hypothesis test of acceptability of a combination of the biomechanical, physiological and thermal stresses that can lead to an overall measure of lifting task acceptability was carried out using a fuzzy set-based model. The six male subjects selected were inexperienced in lifting. Before involvement in the experiment, six subjects were heat acclimatized and trained for ten days. A psychophysical experiment was conducted under three temperature levels (22, 27, and 32°C) and three frequencies of lift (1.00, 3.00, and 6.00 lifts/min). The statistical analysis of the results showed that weights selected by subjects at 27°C were not significantly different from weights selected at 22°C, but the weights selected at 32°C were significantly different from those selected at 22°C. According to Hafez (1984), using a fuzzy sets model showed that stress caused by thermal cannot be expressed independently when combining stresses imposed on an individual while lifting due to apparent physiological stress. The model demonstrated that a combination of acceptability measures of the biomechanical and physiological stresses could be used to predict the overall acceptability of lifting tasks with a reasonable degree of precision.

Despite the heat acclimation of the subjects, the work capacity of the subjects still dropped when the temperature rose to 32°C as the load weight lifted reduced. This is a pointer to the importance of temperature and frequency of lift in determining the SWL in this study. The psychophysically selected weight by the subject during lifting at different frequencies of lifts and temperatures is shown in Table 2.3.

2.4 Physiological Responses of Masons to Environmental Conditions

The outdoor manual workers worked under intense sunlight and engaged in work that required much energy in a hot environment, thereby increasing the chances of generating more body heat above their body core temperature (37°C) (Lukman, 2016).

Blazejczyk *et al*. (2014) assessed environmental temperature through world globe bulb temperature (less than 18 to above 30°C) and universal thermal climate index (less than

Table 2. 1. Recommended maximum WBGT exposures levels (°C)

Metabolic rate class (work intensity) Continuous work	**1 (light work) WBGT (°C)**	**2 (medium work) WBGT (°C)**	**3 (heavy work) WBGT (°C)**	**4 (weighty work) WBGT (°C)**
0% rest/hour	31.00	28.00	27.00	25.50
25% rest/hour	31.50	29.00	27.50	26.50
50% rest/hour	32.00	30.50	29.50	28.00
75% rest/hour	32.50	32.00	31.50	31.00
No work at all (100% rest/hour)	39.00	37.00	36.00	34.00

Source: Kjellstrom *et al*. (2009)

Table 2. 2. References values for WBGT (°C)

Metabolic rate (class intensity)	**0 (rest)**	**1 (light work)**	**2 (medium work)**	**3 (intense work)**	**4 (very intense work)**
Approximate metabolic rate, M (W)	100.00	200.00	300.00	400.00	500.00
WBGT reference values (°C)	33.00	30.00	28.00	25.00	23.00

Source: Kjellstrom *et al*. (2009)

Table 2. 3. Maximum acceptable weight of the lift

Frequency of lifts lifts/min	22°C	27°C	32°C
1.00	25.34	25.34	23.41
3.00	15.49	14.56	12.54
6.00	13.06	12.02	10.19

Source: Hafez (1984)

-40 to above 46℃). Ismaila *et al*. (2015) measured environmental and physiological parameters using thermal indices to assess environment temperature. The environmental factors were illustrated by air and radiant temperature values, wind speed, relative humidity, solar radiation, metabolic heat production (activity), and clothing isolation. These were used to analyse heat transfer from subjects' bodies to the environment. The measuring instrument used to record air temperature was GM013–Digital Thermometer–Hygrometer (Thermo Hydro) with an external sensor. The infrared thermometer pointed to the body was used to measure radiant temperature. A solar power Meter (SM 206) was used to measure solar emissions. The vane probe anemometer was used to measure wind speed. The subject responses were assessed through a developed questionnaire.

The temperature components of thermal perception, comfort, preference, pleasantness, acceptance and satisfaction were included in the questionnaire (Ismaila *et al*., 2015). The results were divided into points such that thermal perception has eleven points scale between extremely hot and cold. The thermal comfort had four points scale between uncomfortable and very comfortable. Preference had seven points scale between much cooler and much warmer. Pleasantness had seven points scale between very unpleasant to very pleasant. The acceptable was separated into two points acceptable and unacceptable. The satisfaction had two points satisfied and dissatisfied. According to Ismaila *et al*. (2015), the tolerable weather condition was observed between May 2013 and April 2014, with the average lowest air temperature of 27.90°C recorded.

The highest mean air temperature of 36.10°C occurs between November 2013 and March 2014 at Abeokuta, Ogun State, Nigeria. Out of 204 masons that participated in the study, 76.50% were very uncomfortable with the thermal condition, and the thermal unacceptability of the masons affected their output performance during lifting activities. Although, the weather condition was tolerable for over a year. The researcher suggested a mason could have cold or heat stress during the year. It was likely for a mason to develop cold stress in July 2013, subjected to the type of dressing. Therefore, the possibility of heat or cold stress depends on the period of the year. The 76.50% obtained by the researchers, which was 156 out of 204 masons, indicated un-comfortability and unacceptable temperature as a significant loss to an employer as it affected Mason's performance output during lifting activities. Therefore, a model was developed to minimise such loss and increase productivity by determining the safe weight to be lifted by considering, among other factors temperatures of the lift.

2.5 Effect of excessive exposure of manual lifting workers to Workplace Temperature

The exposure of manual lifting workers to extreme temperature working environments can make manual lifting workers experience different heat-induced disorders. In case the thermal stress was not identified and treated in the initial stage. It can seriously impact manual lifting workers, leading to impacts like heat stroke, exhaustion and cramps (Health and Safety Commission, 2006; Lukman, 2016; Abokhashabah *et al.*, 2021).

2.5.1 Heat stroke: When sweating becomes inadequate with rising body temperature to a critical level above 38°C, the body system temperature regulation fails, called heat stroke.

2.5.2 Heat exhaustion: Excessive salt loss is caused by losing a large amount of fluid through sweating.

2.5.3 Heat cramps: It is due to an electrolyte imbalance initiated by sweating. Heat cramps occur when people accomplishing hard bodily labour (heavy lifting) in a temperate environment gulp plenty of water without adequate salt replacement. The warning sign includes hurting arms and legs or stomach cramps that occur unexpectedly at work or after working hours (Health and Safety Commission, 2006; Lukman, 2016).

2.6 Task performance evaluation

Qutubuddin *et al*. (2013) evaluated tasks accomplished physically in brick kilns in Karnataka, India. The researchers investigated work associated with musculoskeletal disorders going through manual lifting workers for the duration in which raw brick-making activities were going on, using a revised Nordic questionnaire for sixty selected workers from six basic brick-making units in Karnataka, India. The brick kiln activities involved personal factors such as interaction, exhaustion, aptness, age, and experience. The inferred influences of brick kiln include work arrangement, agenda, load, workshop layout, furniture and equipment. The psychological backing within the workgroup combined personal factors and inferred influences as affected the worker's efficiency of work and working life.

In an equal distribution ratio method, thirteen workers were selected from each of the 20 coal mines in four Punjab, Pakistan districts. Each group comprised six coal cutters, two dumpers, two timbering and supporting persons, one drilling and blasting person, one transporter and loader workers. Only employees with two years minimum experience with discomfort on the backbone were allowed to participate in the study. The factors considered were six work tasks, age, body mass index, work experience, shift period, reiterations period, travel interval, vacation work, working days per week, working months per year, back harm caused by factors not related to the work, body discomfort as the day ends and workers who had pain in both upper and lower back or either. Nordic Musculoskeletal Disorder Questionnaire (NMDQ) was used to assess work-related musculoskeletal disorders of workers. The survey was amended to reflect the requirements of underground coal mining. The multi-variable logistic regression model was used in analysing the data. Omnibus, Hosmer and Lemeshow test indicated model significance. Coal cutting was identified as the most harmful work, followed by years of working experience and repetitions. The underground coal mines' occupational factors (hours of working per day and numbers of repetitions performed) and personal factors (age, height, weight and BMI) were strongly associated with aching in the upper and lower back of workers (Madiha *et al*., 2020). Their occupation requires considering personal factors (age, weight, height and BMI) to decide on work to be done by workers. Therefore, consideration for personal characteristics (age, gender, weight, spine length and stature change) is necessary to formulate a model and determine the safe weight of the lift.

The posture adopted by manual material handling workers depended on how heavy or light the work was, the design of the workplace, personal characteristics (fatigue, fitness, age, and experience), and tools needed to accomplish a specific task, duration and frequency of lift. In an unstructured workplace, workers were engaged momentarily on a seasonal basis for an entire period of brick-making. The workers were not exposed to nor provided with any training. The workers did not know about unsafe acts and dangers associated with work postures or workers flouting safe working process rules (Qutubuddin *et al*., 2013; Khan *et al*., 2019).

The methodology used was Nordic Musculoskeletal Disorder Questionnaire (NMDQ), postural analysis, Rapid Upper Limb Assessment (RULA) and Rapid Entire Body

Assessment (REBA). These were methods for information gathering and analysis (Hita-Gutierrez *et al*., 2020). Among factors identified by the researchers to be affecting workers include the weight of the load, frequency of lifts and personal characteristics. Therefore, consideration was given to workers' weight, age, gender, frequency of lifts, and spine length in the proposed model formulated.

In a study of work-related musculoskeletal disorders involving interviews of workers, Nordic questionnaire distribution, anthropometry measurement, the Right Upper Limb Assessment (RULA) sheet, CATIA V5 RULA analysis, the Lifting Index (LI) and Recommended Weight Limit (RWL) (NIOSH, 1991). Ten aerospace warehouse workers were selected to study the contribution of repetitive and heavy lifting activities to ergonomic injuries. The CATIA V5 RULA analysis scored seven as proof of the risk of getting ergonomic injuries due to heavy and repetitive lifting. Introducing a helping device to the workplace environment reduced the RULA score from seven to two (Kamat *et al*., 2017). In the area of work where helping devices was not possible, there is a need to observe factors that influence safe weight to develop a model to determine the SWL as it was done in this research.

In the investigation of the correlation between load and low back pain among manual lifting workers at vegetable and fruit supply centres in the state of Sergipe, Brazil, Monteiro *et al*. (2019) conducted a transversal study of 49 male workers with a mean: age (34.00 years), height (1.76 m), weight (77.30 kg) and body mass index (25.10 kg/m^2). Their tasks were to load and unload farm produce from trucks to the immobile stage installed in the shipping area. The non-availability of the platform caused the worker's position on the ground. Three related data stages of workers' characteristics were collected. In the first stage, the Strarret scale was used to measure workers' height for anthropometric evaluation. Avanturi digital scale was used to measure workers' weight. Measurements were taken when an individual was in the Orthostatic position and the head was held in the horizontal Frankfurt plane. In the second stage, low back pain intensity was measured by Numerical Visual Scale (NVS) with a horizontal line from 0.00 to 10.00, marked at extremes as no or maximum pain. The workers spatially identified how much pain they felt before and after the work. The value from 0.00 to 3.00, 4.00 to 7.00 and above 8.00 were classified as mild, moderate and severe pain, respectively. The functional disability due to low back pain was measured using Roland

Morris Disability Questionnaire (RMDQ). For the third stage, task variables at the source and destination of lifting were collected. Starrett metric was used to measure Horizontal (*H*), Vertical (*V*) distances and Displacement (*D*) of the load. A trident goniometer was used to measure Load Asymmetry (*A*). The frequency of lifting (*F*) was determined using Vollo Digital. Coupling (*C*) of handle quality was evaluated based on the NIOSH (1991) committee report. Photo and filming were used for symmetric observation of workers' postures during lifting. The NIOSH (1991) lifting equation, three – Dimensional Static Strength Prediction Program (3DSSPP version 7.0.4), and descriptive and non – parametric analyses were used to analyse the data. The workers were lifting an average weight of between 38.60 and 40.90 kg. Hence, 73.60% of the workers were noted to be experiencing low back pains. The lower back pain was attributed to the weight between 38.60 and 40.90 kg lifted by the workers. Therefore, the weight must be adjusted to minimise the problem of low backaches among vegetable and fruit workers. It is necessary to use selected factors that seem to influence the SWL to develop a model to find the weight that can reduce lower backache among manual lifting workers. The frequency of lift (rarely, occasionally, and frequently) load mass (low: 1.00 – 7.00 kg, moderate: 8.00 – 30.00 kg, and heavy: >30.00 kg), and trunk posture (upright or forward bent forward) of female healthcare workers involved in occupational lifts were investigated using multi-adjusted logistic regressions. Frequently lifting and carrying low load mass with forward bent back doubled the risk of developing chronic LBP, while occasionally and frequently lifting or carrying of any load mass with upright back did not increase the risk of chronic LBP (Holtermann *et al*., 2013).

Table 2.4 shows discomfort areas experienced by manual material handling workers in manual lifting activities. The manual lifting workers were involved in arranging, loading and unloading bricks. It was observed that workers experienced a medium to high risk of musculoskeletal discomfort at low and upper back, also neck and shoulder.

The researchers observed two major steps in brick-making in Karnataka, India. The principal first step was forming the brick from the mud moulder. After that, bricks were manually lifted to a place where bricks would dry in sunlight between two and three days. The second major step was when dried bricks were manually lifted to the kiln and loaded on top of the kiln for additional dry hardening. After the bricks were burnt for about one week, it was moved from the kiln to a construction site. The constant activities in the brick kilns include pushing, pulling, bending, reaching, stretching, lifting, lowering, sitting, standing, walking, carrying, moulding and drying bricks. The prolonged stress and strain during various activities of different load conditions were seen as the cause of the work-related musculoskeletal disorder (Singh *et al*., 2009). To determine the safe weight, the stature change of the worker due to load weight in terms of strain force was considered in this study to develop a model. Another possibility is the temperature at which workers were working, but the researchers did not state whether it affected the manual lifting worker in their research. The researchers observed two major steps in brick-making in Karnataka, India. The principal first step was forming the brick from the mud moulder. After that, bricks were manually lifted to where the brick would dry in sunlight between two and three days.

Table 2.5 shows workers' physical characteristics such as age, height, weight, and years of experience, duration of work per day and body mass index. The workers' average height and age were 1.58 m and 26.00 years, respectively. The Body Mass Index (BMI) indicates whether a worker is obese.

The weight in kilograms divided by height in meters to the power of two is the method to evaluate BMI. The average BMI was given as 21.90 kg/m^2. This means that, on average, the studied subjects were not obese. The BMI value for a non-obese person was from 18.50 to 24.90 kg/m^2. Overweight was from 25.00 to 29.90 kg/m^2, moderate obese was from 30.00 to 39.90 kg/m^2, and above 40 kg/m^2 as highly obese (Singh *et al*., 2009).

Table 2.6 shows the discomfort in various parts of workers' bodies. The affected workers were both male and female. The subjects were involved in manual lifting, loading, unloading and carrying. 81.70% complained of lower back pain and 76.70% complained of upper back pain; subjects involved in manual material handling indicated more pain in the back. This was attributed to continuous awkward lifting tasks and brick weight—the males of, 73% and females, 67%, experienced shoulder pain. As regards harm and discomfort in the neck, 60% reported pain. Concerning pain in their elbows, 80% of males and 76% of females experienced pain. 76% of males and 70% of females indicated pain in their hands/wrists. At the same time, 63% of the respondents indicated pain in their hips/thighs. In addition, the study showed that 85% of respondents had ankle/feet pain, while harm and discomfort in the knees were reported by 68% of respondents. The complaint noted by the researchers was attributed to the weight of the load lifted by manual lifting workers. Dianat *et al*. (2020) identified low back, knees, upper back, and neck pain as 75.10, 62.10, 61.55, and 59.90%, respectively, among 377 farmers assessed using rapid upper limb assessment, and more than 72.60% of farmers experienced three locations of discomfort in their body. Therefore, there is a need to determine the safe weight to mitigate the musculoskeletal disorder problem identified among manual lifting workers.

Vandermolen *et al*. (2008) studied the influence of the weight of blocks on work requests and physical workload for masons. They set sandstone blocks over 8 hours of a workday. Five masons of three categories participated. There were no differences in the five masons regarding age, body height, or weight of the three categories. Each category worked with different block weights of 11.00, 14.00, and 16.00 kg (these were the three types of blocks primarily used in the Netherlands). The actual time consideration on the site was adopted to determine the activities and productivity of the workers. The rate of heartbeat monitoring and oxygen depletion on the site was adopted to assess the energetic workload of the workers. Spinal loading of the lower back was valued by computing cumulated elastic energy reserved in the lumbar by considering the period of events and existing data on the compressive force. The three block-weight had no throughput influence nor the frequency of lift, energetic workload, or cumulative spine loading by involving in any of the block weights that were beyond expected limitation for work request and physical capacity. The researchers' observation showed that lifting block weights in the range of 11.00, 14.00, and 16.00 kg may not lead to low back pain for manual lifting workers that engaged in weight of such range. Therefore, block weights of 11.00, 14.00, and 16.00 kg were deemed fit not to cause low backache among manual lifting workers. In this study, other factors that may influence the physical workload of manual lifting workers were considered in the developed model and determine the SWL for male manual lifting workers.

Bootsman *et al*. (2019) introduced wearable sensing technology to minimise the problem of low back pain among nurses. However, it has yet to be seen how this method can be adopted among manual lifting workers and wearing protective clothes may not immune manual workers from other factors considered in this study to develop a model to minimise the problem of low back pain. Iran adopted 32.00 kg as the load limit for physical lifting workers based on the American Conference of Governmental Hygienist Threshold Limit Values (ACGIHLTVs) to protect manual lifting workers from back injuries without understanding its accuracy with Iranian workers in 201l (Afshari *et al*., 2018). The suitability of adopted ACGIHLTVs based on the North American working population for Iranian workers has been doubted because this may need to reflect the risk of the LBP in Iran accurately.

However, Afshari *et al*. (2018) adopted the biomechanical criterion of 3.40 kN as compressive force and 700.00 N as a shear force to examine the accuracy of adopted Iran allowable load limits to suggest the risk of low back pain disorder for a group of Iranian workers. The researchers followed adopted Iranian guidelines for manual lifting in a laboratory-based experiment (temperature was not stated) and participants completed a series of two-handed lifting tasks. The accuracy test was done on the effect of compressive and shear forces on fifteen male Iranian workers that completed 25.00 lifts (duration of lifts not stated) combinations at different heights and reached the maximal allowable weight of 32.00 kg. An Inclinometer and photographic camera collected the data to estimate spinal loading. Afshari *et al*. (2018) discovered that the ACGIHLTVs overestimated the safety of Iranian manual lifting workers and that differences in anthropometrics between North Americans and Iranians should be considered. Body weight was suggested to have played an essential role in predicting spinal loading (Afshari *et al*., 2018). In order not to adopt load limits or safe weight in Nigeria that will not reflect the peculiarity of Nigerian manual lifting workers, a model was developed that considered factors such as lifter's weight, age, gender, length of the spine, change in stature, frequency of lift, and temperature to determine the SWL to reflect the peculiarity of Nigerian manual lifting workers.

2.7 Postural analysis methods

Aghazadeh *et al*. (2019) developed Artificial Neural Networks (ANN) to predict posture, lumbosacral moments and spinal loading. Fifteen healthy young University male individuals without a history of musculoskeletal disorder were selected to participate in the experiment and performed various tasks once. Their physique postures were measured with Simi Reality Motion System, bodyweight with a bathroom scale and hand location with a tape rule. The body heights varied from 1.70 to 1.80 m, hand

Table 2. 4. The RULA and REBA scores

Posture and Activities	RULA Scores	RULA Action Level	REBA Score	Risk Level REBA	Maximum discomfort
Digging	7.00	4.00	10.00	High	Low back, Upper back
Wetting and mixing clay	7.00	4.00	9.00	High	Low back, shoulder
Carrying mud by pushing	7.00	4.00	9.00	High	Low back
Moulding bricks	7.00	4.00	10.00 – 13.00	High to very high	Legs and low back
Arranging bricks for drying	6.00 – 7.00	3.00 – 4.00	9.00 – 10.00	High	Low back, neck and shoulders
Loading and unloading	6.00 – 7.00	3.00 – 4.00	7.00 – 10.00	Medium-high	Low back, shoulder and upper back

Source: Qutubuddin *et al*. (2013)

Table 2. 5. Workers' physical characteristics

Variables	Mean (SD)
Age (year)	26.40 (±9.50)
Height (m)	1.58 (±0.11)
Weight (kg)	41.90 (±9.70)
Experience in year	3.70 (±8.50)
Work duration per day (hour)	9.50 (±1.80)
Body Mass Index (BMI) kg/m^2	21.90(±3.40)

Source: Qutubuddin *et al*. (2013)

Table 2. 6. Manual lifting Workers' discomfort feeling at different Body Parts

Different body parts	Affected workers (%)		
	Male	Female	Total
Neck	19 (64.00)	17 (57.00)	36 (60.00)
Shoulder	22 (73.00)	20 (67.00)	42 (70.00)
Elbows	24 (80.00)	23 (76.00)	47 (78.30)
Wrist/Hand	23 (76.00)	21 (70.00)	44 (73.30)
Upper back	24 (80.00)	22 (74.00)	46 (76.70)
Lower back	26 (87.00)	23 (76.00)	49 (81.70)
Hips/Thighs	18 (60.00)	20 (67.00)	38 (63.30)
Knees	21 (70.00)	20 (67.00)	41 (68.30)
Ankle/Feet	25 (83.33)	26 (86.70)	51 (85.00)

Source: Qutubuddin *et al*. (2013)

load from 0.00 to 5.00 kg and 0.00 to 10.00 kg. The ANN posture and angle output were affected by 0.65, 0.33, and 0.56 m and 19.90, 7.20, and 13.60 degrees. The ANN moment output was affected by 25.60, 21.50, 16.00 and 31.60 Nm by varying body height from 1.70 to 1.80 m, bodyweight from 80.00 to 90.00 kg, hand load from 0.00 to 5.00 kg, 0.00 to 10.00 kg. The load weights considered were between 0.00 and 10.00 kg at reached heights 0.00, 0.30, 0.60, 0.90 and 1.20 m from the floor. Most current load weights being lifted by manual lifting workers exceeded the maximum weight of 10.00 kg (Aghazadeh *et al*., 2019). In order to determine safe weight, other influencing factors were considered for the weight yet to be seen as safe.

Working posture analysis was adopted to solve the problem of low back pain caused by manual load handling (Hignett and McAtamney, 2000). Analysis was done by directly evaluating working posture, visual observation and video of different activities accomplished by manual load-lifting workers. After identifying various postures, risk levels were analysed using Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) techniques. The RULA and REBA were not techniques to recommend or determine safe load weight to be lifted but to assess problems caused by load weight lifted by manual lifting workers (Hignett and McAtamney, 2000).

Qzay *et al*. (2020) analysed workers working posture in the construction industry by considering nine distinct types of construction lifting activities, such as plaster mortar preparation, metal and die cutting, roofing, welding, concrete crushing, drilling and plumbing processes using RULA, and the NIOSH method for brick stacking process. The processes were found very risky as the RULA score was seven for the eight processes considered, and the frequency multiplier (FM) in the NIOSH was seen as high during the brick stacking process. All these required immediate ergonomic improvements to avoid lower back injuries. Among the recommendations was the need to limit the manual lifting of materials such as bricks and cement bags and reduce the frequency of lifts. In this study, among other factors considered to develop a SWL model to determine the SWL is the frequency of lifts.

2.7.1 Rapid Upper Limb Assessment (RULA)

It is a method in ergonomics to investigate workstations where musculoskeletal disorders (MSDs) were reported. It is a screening measure that evaluates biomechanical and postural loading on the body. It focused on the neck, trunk, and upper limbs. It is ideal for sedentary workers. To reduce risks of injury due to physical loading in operation, a coding system is required to produce an action list to indicate the level of required intervention. To reduce physical load, it is necessary to follow the scientific method and not only the administrative method. Dianat *et al*. (2020) recorded a RULA score of 6.70, which indicated that the workers required necessary changes soon in the working posture. Hence, a model was formulated to determine the safe weight among manual lifting workers.

2.7.2 Rapid Entire Body Assessment (REBA)

It provides immediate and easy posture analysis of whole-body activities (static and dynamic) when the musculoskeletal hazard action level is known (Hignett and McAtamney, 2000). The REBA aim at dividing the body into individual coded segments about body plane movement. It suggested that handles are essential in handling loads but may only sometimes be through hands.

Table 2.7 shows the RULA and REBA scores to assess the risk level of manual material handling activities and take corrective measures to prevent musculoskeletal disorders, including low back pain. As such, load heaviness depends on the individual's perception (psychophysical) (Ismaila and Aderele, 2015). An emotionally safe lift weight should be safe enough for manual lifting workers if the safe weight of the lift is determined by considering the subject rather than the object.

Sheppard *et al*. (2016) conducted a gender-based study to determine alteration in lifting techniques across load-increase conditions. Eleven male and fourteen female participants without a history of low back pain disorder completed freestyle lifting. The participants symmetrically lift the box with handles from floor to table positioned at 50% of the participants' height for five trials under three load weight conditions: 10, 20 and 30% of individual maximum isometric back strength. The mean maximum back strength for males and females was 72.00 and 53.00 kg, respectively and the mean load lifted was 7.18, 14.36 and 21.64 kg for males and 5.21, 10.71 and 15.86 kg for females. Two–camera Optotrak 3020 motion capture system was used to measure joint kinematic data for the ankle, knee, hip, lumbar, and thoracic spine. The joint angles were calculated by three dimensional Euler rotation sequence. Lifting technique variation across entire waveforms was assessed using Principal Component Analysis (PCA) and Single

Component Reconstruction (SCR). There was a significant difference between males and females across all load conditions as determined by the independent samples t-test. There was no significant load effect on the thoracic and lumbar spine because the load was standardized to individual back strength characteristics, and males and females adopted a similar lifting technique. Therefore, gender was considered in determining the safe weight to be lifted among manual lifting workers in this study to develop a model.

Adeyemi *et al*. (2014) studied postures adopted by two classes of construction workers, Bricklayers (BL) and Bricklayers' Assistants (BA), in Southwestern Nigeria. The researchers adopted the Ovako Working Analysing System (OWAS) in measuring and comparing stages of safe postures in lifting tasks amidst manual lifting employees. The research was conducted with 250 healthy workers sampled from different construction sites in Southwestern Nigeria. Window Ovako Working Analysis System (WINOWAS) software was used as a tool of analysis based on the Ovako Working Analysis System (OWAS) method. The 844 postures were recorded and analysed based on four categories: back, arms and legs posture; lastly, load on two categories of workers, such as bricklayer and bricklayers' assistant. Adeyemi *et al*. (2014) observed that 31% of back positions could be safe while the remaining 69% involved bent or twisted contributed to back injuries. Only 22% of the manual material lifted by the workers was less than 10.00 kg, while 78% of material lifted by the workers was above 10.00 kg, which was capable of contributing to bodily harms and other musculoskeletal lifting associated harms that includes low back hurt (Adeyemi *et al*., 2014; Alumbugu *et al*., 2014). The researchers' focus was the posture of manual lifting workers, while other factors such as stature change, temperature, spine length, gender, age, frequency of lift and lifter's weight were not considered as it has been considered in this study to develop a model to determine the SWL irrespective of posture adopted by manual lifting workers.

A good body position should keep the body free from any form of musculoskeletal disorder (e.g., low back pain) by allowing the body to stay flexible by providing the strength and motion necessary to accomplish the job without unwarranted stress on any part of the body (Ismaila, 2006; Dianat *et al*., 2020). In order to identify the effects of the limits set for categories of workers grouped into three: group A, no handling; group B, handling loads up to 40% or 24% or less of body weight, and group C, handling loads over 40% or 24% of body weight.

Table 2. 7. The RULA and REBA postural classification scores

RULA Score	RULA action required	REBA score	Risk level	Correction action
1.00 – 2.00	Acceptable	1.00	0.00 (negligible)	None necessary
3.00 – 4.00	Change may be necessary	2.00 – 3.00	1.00 (low)	May be necessary
5.00 – 6.00	Change necessary soon	4.00 – 7.00	2.00 (medium)	Necessary
7.00	Change immediately	8.00 – 10.00	3.00 (high)	Necessary soon
		11.00 – 15.00	4.00 (very high)	Necessary now

Source: Hignett and McAtamney (2000)

The load weights were group into eight: no handling, 1.00 – 5.00 kg, 5.00 – 10.00 kg, 10.00 – 15.00 kg 15.00 – 20.00 kg, 20.00 – 25.00 kg, 25.00 – 30.00 kg and ≥30.00 kg, a multiple logistic regression analysis was used to identify the effects of the limits, in groups A, B, and C, 25.50, 39.20, and 47.30% of males or 16.90, 26.40, and 38.00% of females had LBP, respectively, however, LBP among workers handling loads under 10.00 kg was not significantly different compares to no-handling workers (Iwakiri *et al*., 2023)Generally, two significant types of lifting methods are recognized, namely squat and stoop lifting, but there is also freestyle. Stoop lifting (mainly leg lifting) had been regarded as the correct lifting technique, but the squat technique (mainly back lifting) was reported to be more commonly used in practice. For manual lifting workers to choose a convenient style of lifting, it is necessary to develop a model that considered the lifter's distinguishing factors and workplace temperature to determine the safe weight of the lift.

In a study conducted by Adeyemi *et al*. (2014), four hundred and twenty-two task positions were documented during bricklayer job activities, while the remaining were documented during bricklayers' assistant tasks. Action Group 1 (AG-1) used the following terms, categorized as positions not requiring actions (safe position). Action Group 2 (AG-2) was categorized as positions requiring actions soonest (not safe). Action Group 3 (AG-3) was categorised as positions requiring speedy corrective actions (unsafe). Action Group 4 (AG-4) was categorised as positions requiring immediate corrective actions (unsafe).

For the most occurring frequencies, 303 positions were documented as category 1 (AG-1), while the most minor, 124, were documented as category 2 (AG-2). The OWAS recorded 36, 15, 34 and 15% for AG-1, AG-2, AG-3 and AG-4 in that order, respectively. The postural analysis must involve how heavy the load is to solve the problem of musculoskeletal disorder. In the first place, what determines postures is how heavy the load is, but if it is not, it can be easily lifted without significant consideration for the worker's postures.

2.9 Biomechanical analysis of lifting task

Jomoah (2014) conducted an empirical study to measure biomechanical forces in the human body during material handling tasks such as manual lifting to identify where serious injuries occur. Sixty participants were involved. Worker's age, height, body mass index, and body angles were significant parameters considered in a work-related muscular disorder. The acceptable weight of lift was determined through a psychophysical approach. The participant was allowed to select the object (weight) to be lifted according to their ability. The researcher observed load that a manual lifting worker can manually lift in an 8-hour job was 11.80 kg when the load selection was determined by the participant at an average weight of between 10.00 and 13.00 kg. The biomechanical loading of the tissues of the low back is directly impacted by trunk kinematics, thus quantifying the variability in the trunk kinematics may provide deeper insights into biomechanical loading and low back injury (Tetteh *et al*., 2021).

The participants aged between 20.00 and 24.00 years handled more load weight; the maximum load weight was 20.00 kg. The researcher had shown the importance of age as a factor in determining the SWL for manual lifting workers, as it was determined in this study through a model to be developed.

To calculate mechanical stresses on the major joints of the musculoskeletal system of manual lifting workers, a two-dimensional static biomechanical model was developed by Jomoah (2014). The impact of load and lifting technique on the spine loading during lifting actions were examined. Three different weights (5.00, 15.00 and 25.00 kg) and lifting techniques (squat, stoop and freestyle) were chosen, and compressive and shear forces were determined. The objective functions considered were one active muscle, abdominal pressure and ten muscle to minimize muscle intensity. The researcher observed that the result of the objective function for one active muscle produced consistently higher values of compressive forces, while the objective function for ten muscles produced the lowest. The heavier the load, the more muscle was required to lift the load. This may cause musculoskeletal injuries to manual lifting workers that may not have such muscle ability. Song and Qu (2014) recommended physical exercise practice as an effective ergonomic intervention for older workers (above 55 years) lifting 21.80±11.60 kg and instructions on safe lifting methods among younger workers (between 20 and 30 years) involved in the manual lifting of 26.00±9.30 kg as ways of reducing the problem of low back pain, so age was identified as a factor influencing safe weight lift. Hence, the need to determine the safe load weight based on subjective factors such as the worker's age, weight, spine length, gender, and other observed factors to develop a model is deemed necessary.

Table 2.8 shows the average, standard deviation and range of some anthropometric measures of the subjects taken. The subject parameters considered include age, stature, weight, sitting shoulder and knee height, buttock–popliteal, shoulder–elbow, elbow–finger and font length, chest width and depth, and abdominal depth.

Table 2.9 shows the workers' mean, the lowest and highest acceptable lift weight, according to age categories. The lowest and highest acceptable lift weight ranged from 5.00 to 20.00 kg.

It was reported in a study of Nigerian bricklayers from a medical record review of 6500 workers that 97% were discovered to suffer from musculoskeletal disorders with seriousness ascending with age (Chukwuemeka and Ugo, 2013). The rural bricklayers had an appreciably higher prevalence than urban dwellers. It was noted that younger bricklayers had difficulties restricted to upper limbs and legs, while older bricklayers were more likely to have low back pain (Chukwuemeka and Ugo, 2013).

Pinder *et al*. (2001) reported a cross-sectional study of 195 German bricklayers undergoing clinical examination. The researchers observed that musculoskeletal reports and functional impairments rose with age, but the analysis did not show a positive relationship between musculoskeletal problems and duration of employment. The findings of these researchers emphasized the importance of age as a factor in the developing model. In the Netherlands, the block used in constructing interior walls consists of gypsum and specialised categories of workers arranged it. The gypsum block weighs between 23.00 and 25.00 kg. These weights were more significant than the sandcrete block of 20.00 kg.

However, Pinder *et al*. (2001) recommended that the weight of the gypsum block be reduced to less than 18.00 kg. To reduce the weight of the lift, there is a need to follow the scientific method by considering other factors that can necessitate the need to reduce the weight of the lift. Pinder *et al*. (2001) suggested that a block moulded in average density, half size, or hollowed size will reduce block weight by 30%.

Table 2. 8. Averages, Standard Deviations and Range of some Anthropometric Measures of the Workers

Parameters	Average	Std. Dev	Range
Age (year)	28.00	5.00	19.00 – 40.00
Stature (m)	1.70	0.05	1.60 – 1.82
Weight (kg)	71.00	9.00	50.00 – 90.00
Sitting Shoulder Height (m)	0.91	0.10	0.75 – 1.04
Buttock – Popliteal length (m)	0.51	0.06	0.42 – 0.59
Knee Height (m)	0.52	0.03	0.47 – 0.58
Shoulder – Elbow Length (m)	0.33	0.03	0.29 – 0.39
Elbow – Finger length (m)	0.44	0.03	0.04 – 0.05
Foot Length (m)	0.26	0.02	0.23 – 0.29
Chest Width (m)	0.35	0.05	0.29 – 0.45
Chest Depth (m)	0.28	0.06	0.22 – 0.46
Abdominal depth (m)	0.26	0.05	0.19 – 0.38

Source: Jomoah (2014)

Table 2. 9. Means, lowest and highest Acceptable Weight of Lift

Age (yrs)	No of participant	Mean	Lowest (kg)	Highest (kg)
15.00 – 19.00	1.00	13.00	13.00	13.00
20.00 – 24.00	14.00	12.10	5.00	20.00
25.00 – 29.00	27.00	13.00	5.00	19.00
30.00 – 34.00	12.00	12.10	5.00	17.00
35.00 – 39.00	5.00	10.60	7.00	16.00
40.00 – 44.00	1.00	10.00	10.00	10.00

Source: Jomoah (2014)

This reduced the physical workload on the spine and physiological costs by lowering the heartbeat rate. Reduction in load weight is expected to result in a reduction in biomechanical load and heartbeat rate and significantly extend workers' working time during manual lifting jobs. To reduce the weight of the lift, there is a need to follow the scientific method by considering other factors that can necessitate the need to reduce the weight of the lift.

In a strictly controlled laboratory experimental (temperature value not given) environment, a study evaluated the effects of lifting weights and postures on the spine biomechanically by simulating repetitive lifting tasks. Antwi-Afari *et al*. (2017) studied twenty healthy males who participated in simulated repetitive lifting tasks with three different weights. The participants continue lifting until when participants cannot continue further. The spinal loadings were measured using surface electromyography (sEMG). Hence, an increase in load weight led to an increase in spinal loading. Antwi-Afari *et al*. (2017) recommended a 50% reduction in load weight, work to be planned based on individual physical capability, and reduced temperature factor risk to reduce lower back harm on manual lifting workers. However, suggestions should have been given on how to implement their recommendations. In this study, consideration is given to identifying factors (lifter's weight, age, gender, length of spine, and change in stature, temperature and frequency of lift) that may influence safe weight to formulate a model and determine the safe weight of the lift.

Corbeil *et al*. (2019) observed a significant effect of body weight on the spinal loading of a manual material handler lifting 23.00 kg weight. The study conducted involved 17 healthy males, having individual characteristic mean age, height, weight and body mass index of 25.30 years, 1.75 m, 67.50 kg, and 21.90 kg/m^2, respectively and 20 obese males having individual characteristic mean age, height, weight and body mass index of 34.00 years, 1.74 m, 95.40 kg and 31.40 kg/m^2, respectively.

Ground reaction forces imposed during handling tasks were recorded through an extended force platform mounted on an AMTI six-axis load cell. Signals were collected at a frequency of 1024.00 Hz. An optotrak system was used at a test group rate of 30.00 Hz to record 3-D coordinates of markers attached to primary body segments. Workers' age, weight and differences in height (spinal shrinkage) are part of the factors considered in this present research to formulate a model to determine the safe weight for manual lifting labourers. Adeodu *et al*. (2014) studied physical strain encountered by experienced bricklayers by application of heartbeat rate indices to assess bodily strain in bricklaying operations by aiming at total energy consumption and physiological workload during the task. Adeodu *et al*. (2014) discovered that bricklayers used high energy on average. Thereby classifying bricklaying activities as a heavy task. Kjellstrom *et al*. (2009) classified work intensity into light, medium, heavy and very heavy based on the temperature at which manual works were done.

Nevertheless, measuring oxygen depletion is expensive and performing such activities on the site may interfere with manual lifting workers' task performance (Ismaila, 2006). Therefore, other means should be developed to determine how to reduce the physical workload of manual lifting workers. This can be done by considering other observed factors contributing to the increase in the physical workload of physical lifting workers, thereby developing a model to determine safe weight among manual lifting workers.

Table 2.10 shows the physical characteristic of workers, where the average age was 38.50 years (from 29.00 to 46.00 years), the height of 1.80 m (from 1.70 to 1.90 m) and the weight of 76.80 kg (from 68.00 to 83.00 kg). The Body Mass Index (BMI) means 24.30 kg/m^2 (from 21.60 to 26.20 kg/m^2) shows that workers had the right body mass for their height. The workers had a predictable total aerobic capacity ($VO_{2\,max}$) mean of 47.80 ml/kg/min (from 42.70 to 59.40 ml/kg/min).

Table 2.11 shows the mean working heart rate from 110.00 to 132.00 bt/min with an overall mean heart rate (HRw) of 122.80 bt/min. The pre-work resting heart rate (HRr) was between 65.00 and 76.00 bt/min and an overall mean of 70.50 bt/min. The physical workload rate (%HRR) mean was 47.30. The working heart rate ratio to resting heart rate (HRw/HRr) was 1.70. The mean working heart rate ratio at 50% (HRw/50% level) was 0.90. The 50% level and HRw/50% level indices backed %HRR findings. The researchers suggested that the 50% level can be effectively applied as a simple and selective way of documenting strain. Adeodu *et al*. (2014) noted that if the heart rate ratio at work at 50% level was equal to one, then work done can be categorised as continuous hard work because the mean value of %HRR is 47.30%. The physiological workload of manual lifting workers was appraised to be 47% of the weight of the brick.

It was categorised as heavy work between 40 and 50%, as shown in Table 2.12. Heavy work fell into the group of between 7.50 and 10.00 kcal/minute energy spending and heartbeat rate from 110.00 to 132.00 beats/min. Hence, there is a need to reduce the workload by considering other factors observed that can help in minimising the physical workload of the manual lifting workers by reducing the heartbeat rate.

In the 278 construction workers survey, it was observed that masons and carpenters have age between 25.00 and 34.00 years, while 30% were less than 25.00 years, 40% of the mason were below 25.00 years of age and most were between 25.00 and 34.00 years of age, 60% of the welders have age between 25.00 and 34.00 years. 30% of ground-level and grass-cutter workers are between 35.00 and 44.00 years old. Ray *et al*. (2015) observed that workers worked more than 8-hour with more than 3 hours of extra time in either environment (opened or closed and indoor or outdoor). The 34% of mason helpers had between 6.00 and 10.00 years of work experience. 50% of carpenters and ground-level workers had between one and five years of work exposure. Most welders and grass cutters had between 6.00 and 10.00 years of work exposure.

These workers were exposed to numerous kinds of hazard factors leading to various categories of musculoskeletal disorders, which led to a decrease in productivity and decrepitude of physical health, despite their skills and experience in work. Whether a worker is experienced or inexperienced in manual material handling, once necessary factors are not considered to determine the safe weight, the worker can be in danger of low back pain (Ray *et al.*, 2015). Manual material lifting-related issues such as low back pain, shoulders, wrist, sprain injury, musculoskeletal disorders, severe fatigue, improper design and unsafe practice were factors identified that were making lifting highly hazardous in the work system, and work-related hurts frequently happened among workers (Ray *et al*., 2015). Other identified and considered factors were used to develop a model to determine safe weight. This is to minimise the problem of musculoskeletal disorders among manual lifting workers.

Table 2.13 shows occupations that several workers selected and interviewed. Six occupations were considered, totalling 800 workers, 278 workers were selected, and 268 workers were interviewed.

Table 2. 10. Workers' physical characteristic

Subject	Mean	Range
Age (year)	38.50	29.00 – 46.00
Weight (kg)	76.80	68.00 – 83.00
Height (m)	1.80	1.70 – 1.90
Body Mass Index (kgm^{-2})	24.30	21.60 – 26.20
Resting Heart Rate (beat/min)	70.50	65.00 – 76.00
Working Heart Rate (beat/min)	122.80	110.00 – 132.00
Estimated VO_2 (ml/kg/min)	25.70	22.10 – 28.20
Estimated VO_{2max} (ml/kg/min)	47.80	42.73 – 59.40
Percentage Heart Rate Range (%)	42.80	33.60 – 55.90

Source: Adeodu *et al*. (2014)

Table 2. 11. The Mean Heart Rate

Subject	Age (year)	Height (m)	BMI (kg/m^2)	VO_{2max}	HR_w	HR_r	%HRR	HR_w/HR_r	50.00% level	HR_w/50% level
1	42.00	1.90	21.60	59.40	124.00	70.00	50.00	1.80	124.00	1.00
2	29.00	1.80	22.00	54.90	110.00	69.00	33.60	1.60	130.00	0.90
3	30.00	1.90	23.40	41.50	130.00	72.00	49.20	1.80	131.00	0.90
4	34.00	1.80	23.20	47.20	125.00	76.00	44.60	1.60	131.00	0.90
5	40.00	1.72	26.00	43.20	132.00	71.00	55.90	1.90	126.00	1.10
6	35.00	1.80	23.60	47.70	122.00	67.00	46.60	1.80	126.00	0.90
7	38.00	1.60	25.10	45.10	127.00	72.00	50.00	1.80	127.00	1.00
8	46.00	1.70	25.40	42.70	124.00	70.00	51.90	1.80	122.00	1.00
9	46.00	1.80	26.80	44.50	118.00	65.00	48.60	1.80	120.00	0.90
10	45.00	1.80	26.20	45.50	116.00	73.00	42.20	1.60	124.00	0.90
Mean	39.00	1.80	24.30	47.80	122.80	70.50	47.30	174.00	126.10	0.90
Range	29.00 – 46.00	1.70 – 1.90	21.60– 26.20	42.70– 59.40	110.00 – 132.00	65.00 – 76.00	33.60– 55.90	1.60 – 1.90	120.00 – 131.00	0.90 – 1.10

Source: Adeodu *et al*. (2014)

Table 2. 12. Physical Works Grade

Work grade	Energy expenditure (kcal/min)	Energy expenditure (kcal/day)	Heart Rate (beat/min)	Physiological Workload (%)
Resting	1.50	<720.00	50.00 – 60.00	0.00 – 10.00
Very light work	1.60 – 2.50	768.00 – 1200.00	60.00 – 70.00	10.00 – 20.00
Light work	2.50 – 5.00	1200.00 – 2400.00	70.00 – 90.00	20.00 – 30.00
Moderate work	5.00 – 7.50	2400.00 – 3600.00	90.00 – 110.00	30.00 – 40.00
Heavy work	7.50– 10.00	3600 – 4800	110.00 – 130.00	40.00 – 50.00
Very heavy work	10.00 – 12.50	4800.00 – 6000.00	130.00 – 150	50.00 – 60.00
Unduly heavy work	>12.50	>6000.00	>150.00	>60.00

Source: Adeodu *et al*. (2014)

Table 2. 13. Sample data collected

s/no	Occupation	Workers number	Number of Workers Selected as per Sampling	Number of Workers Interviewed
1	Mason	144	49	45
2	Mason Helpers	248	84	82
3	Carpenters	256	87	86
4	Welders	48	20	20
5	Gas Cutters	40	16	15
6	Ground–level Helpers	64	22	20
	Total	800	278	268

Source: Ray *et al*. (2015)

2.10 Conceptual review

This section presents the reviewed outcome of relevant factors considered to develop a model from the cited literature in this study.

2.10.1 Predictive lifting capacity model

Drury and Pfeil (1975), cited by Stambough *et al*. (1995), developed one of the earliest empirical equations for predicting lifting capacity for manual lifting workers that should reduce the problem of low back pain. The developed equation included parameters such as base weight (maximum weight that can be lifted manually) and factor multipliers involving the effects of various tasks. These factors include age, gender, the lift's height, the object's awkwardness and percentile values. The numbers were scaled into one for optimal condition and other values were between zero and one. However, factors such as the lifter's weight, length of the spine, and change in stature, temperature and frequency of lift were not included as was done in this study.

Ghezelbash *et al*. (2016) used a novel technique to estimate the representation of obesity accurately. The main effects plot and analysis of variance were used to locate influential factors at five symmetric sagittal loading conditions. In the five simulated tasks, body weight showed 98.90 and 96.10% in compressive and shear forces, respectively and had maximum effect on spinal loads from L4 to L5 and L5 to S1 levels. This was followed by gender at 0.70 and 2.10% and body height at 0.40 and 1.50% in compressive and shear forces, respectively. The spinal loading in females was slightly larger than males by approximately 4.70 and 8.70% in compressive and shear forces, respectively. Body weight indicated a greater risk of back disorders. Therefore, spinal loads were seen to be much affected by body weight, followed by gender, body height and age in that order.

In a repetitive box of 13.00 kg lifting at 10.00 lifts per minute for a maximum of 20-minute, it was found that older workers at the mean age of 46.50 years quickly experienced an increased risk of back injury more than younger workers at the mean age of 24.60 years (Boocock *et al*., 2020). In this study, the effect of other factors (spine length and stature change) and workplace temperature were not considered. In this study, selected factors such as lifter's weight, age, gender, spine length, and stature-change, frequency of lift and workplace temperature were considered to formulate a model and determine safe weight lift.

Ramani and Shubha (2021) studied factors hindering manual material handlers' capacity among Indian male construction workers. Factors considered were age, body mass index, lifting height and frequency in the Maximum Allowable Weight Limit (MAWL). For body mass index division, the MAWL increased with an increase in workers' age to the limit of 33.00 years and decreased as the age rose above 33.00 years. Therefore, age factor was considered in developing a model to determine the safe weight, among other identified factors.

The 635 incident-qualified industrial workers' demographic, health status, psychosocial and job physical exposure hazard factors were quantified. The researchers found that differences in age, gender, and medical and low back pain (LBP) history contributed to workers' productivity loss (Tang *et al*., 2022). The present study considers factors such as age and gender, among other factors, to develop a model that may reduce the problem of LBP, thereby increasing workers' productivity.

A quota sampling was used to stratify 217 male construction workers into four age groups. The age for the two groups of 60 workers was between 19.00 and 28.00 years, 29.00 and 38.00 years, 51 workers between 39.00 and 48.00 years, and 46 workers between 49.00 and 58.00 years. This was to determine the influence of age on the maximum acceptable weight of lift amidst manual material handlers. Lifting capacity was determined with progressive inertial lifting evaluation and semi-squat techniques posture was adopted for lifting at two levels (waist and shoulder heights). One-way Analysis of Variance (ANOVA) showed a significant increase in the Maximum Acceptable Weight of Lift (MAWL) from the first to second age group, then a gradual decline in the MAWL. There was an 11.89 and 14.74% decrease from the second to third age group, 5.60, and 19.90% decrease from the third to the fourth age group for waist and shoulder lift levels. It was concluded that recommending a uniform weight limit for all workers across ages could have been better (Girish *et al*., 2018). Hence, there is a need to formulate a model that can determine safe weight based on personal characteristic factors and workplace temperature, as was done in this present study.

The dimensions of the segment in kinematics, ground reaction forces, and moments depend on traditional musculoskeletal models restricted to laboratory settings. Nevertheless, the latest improvement in Inertial Motion Capture (IMC) and styles of predicting ground reaction forces and moments have allowed input data collection in the field.

Larsen *et al*. (2019) evaluated the validity of this novel methodology to assume dynamic lumbar spine loading during manual load handling based on a musculoskeletal model involving the IMC data majorly and to predict ground reaction forces and moments. This was done by relating thirteen subjects performing different lifting and carrying tasks. This involved trunk kinematics, ground reaction forces, moments from L4 to L5 common reaction, and erector spine muscle forces. Thereby modelled simultaneously recorded skin–marker trajectories and plate force data. Moderate to excellent correlations and comparatively low magnitude differences were found from L4 to L5 axial compression, erector spine muscle, and vertical ground reaction forces during symmetrical and asymmetrical lifting. The researchers changed from *in vitro* to *vivo* to find a solution to the problem of musculoskeletal disorders among manual lifting workers. The *in vitro* laboratory simulation results were no longer enough to solve musculoskeletal disorder problems. Hence, observed factors influencing load weight lift to develop a model to determine the safe weight for manual lifting workers as *an in vivo* method to lessen the musculoskeletal problem among manual lifting workers is a needed area of research.

Stambough *et al*. (1995) developed a model they called Comprehensive Lifting Model (CLM), and this was an extension of the mathematical formulation developed by Drury and Pfeil (1975). The CLM was based on findings generated in scientific literature. Therefore, no different assumptions were made about the distribution of each factor they considered. This was done to maintain the original distribution of findings reported by researchers based on experiments and to easily incorporate future data without disrupting the model structure (Stambough *et al*., 1995). Equation (2.1) was developed by Stambough *et al*. (1995).
where

L.C. = lifting capacity

W_B = weight

H = horizontal distance

V = vertical distance multiplier

D = travel distance vertical multiplier

F = lifting frequency

T.D. = task duration

T = trunk twisting angle multipliers

C = coupling factor

H.S. = heat stress

A.G. = age group

B.W. = body weight multipliers.

$$LC = W_B \times H \times V \times D \times F \times TD \times T \times C \times HS \times AG \times BW \quad (2.1)$$

Workers' weight, height, gender, and age were identified as factors contributing to spine disc compression (Hajihosseinal *et al*., 2015; Arjmand *et al*., 2015). The factors considered in a model developed by Stambough *et al*. (1995) did not include spine length, stature change, frequency of lift, and gender, while age was considered a group. However, in this study, age was considered an individual factor.

To demonstrate a situation where Load Capacity (L.C.) is known with other multipliers given while Weight Base (W .B.) is unknown, Hidalgo *et al*. (1997) modified Stambough *et al*. (1995) to develop:

$$W_B = \frac{LC}{H \times V \times D \times F \times TD \times T \times C \times HS \times AG \times BW} \quad (2.2)$$

Stambough *et al*. (1995) obtained multipliers based on gender, and the multipliers were used by Hidalgo *et al*. (1997). The factor multipliers of age, temperature, frequency of lift, and gender found in the cited literature were adopted in this study. This was done to maintain the original distribution of findings reported by the researchers, based on their experimental findings, and for easy incorporation of future data without disrupting the structure of the model to be developed.

Table 2.14 shows age (year) with the corresponding multiplier values for the male and female manual lifting workers. Table 2.15 shows the frequency of lifts (lifts/min) with the corresponding multiplier values for male and female manual lifting workers. Table 2.16 shows temperature (°C) with the corresponding multiplier values for manual lifting workers.

Table 2.17 shows the result of age (years) on the lifting capacity of manual lifting workers. The lifting capacity was reduced as age increased in Stambough *et al*. (1995), except in Drury and Pfeil (1975), where lifting capacity increased from 38.00 to 48.00 kg between 20.00 and 25.00 years. Drury and Pfeil's (1975) lifting capacity were not separated into genders. Stambough *et al*. (1995) separated lifting capacity into male and female capabilities. In the present research, a model to be developed considers the gender of the manual lifting worker.

Hidalgo *et al*. (1997) adopted the Stambough *et al*. (1995) lifting equation based on a multiplicative approach with weight constant and discounting multipliers. The revised NIOSH (1991) equation was based in opposition to some decisions made to develop the former NIOSH equation. This was based on scientific theory and philosophical differences.

The revised NIOSH (1991) equation was structured with the absence of gender and age factors to obtain Recommended Weight Limit (RWL) because of the existing rule of the same employment opportunity legislature and the Americans with disabilities act (Hidalgo *et al*., 1997). The safe weight lift recommendation should include age to accommodate various working-age populations in manual lifting jobs and gender of manual lifting workers as an input factor to accommodate the significant difference between male and female workers (Hidalgo *et al*., 1997). The significant difference between genders should make gender critical factor included in developing a model to determine the safe weight of the lift. The inclusion of gender as a factor would help to determine the safe weight to be lifted according to gender capability. Among factors that have been identified to be affecting manual material lifting workers includes gender (Jomoah, 2014). Gender was identified as one of the factors that can determine the ability of the worker to conduct manual material lifting tasks in any given environment (Hafez, 1984; Powell *et al*., 2005).

Hafez (1984) reported the maximum range of acceptable weight of lifts of female manual lifting workers to be between 49 and 62% of the male lifting capacity. Clusiault *et al*. (2022) identified gender and strength as factors influencing manual lifting. The 28 participants' motion and force plate data were captured during backboard lifting as the load weight scrabbled to strength capacity.

Table 2. 14. Age factor multiplier

Age (year)	Male	Female
20.00	1.00	1.00
25.00	0.91	0.95
30.00	0.88	0.90
35.00	0.88	0.87
40.00	0.86	0.82
45.00	0.78	0.79
50.00	0.69	0.72
55.00	0.62	0.64
60.00	0.59	0.49

Source: Stambough *et al*. (1995); Hidalgo *et al*. (1997)

Table 2. 15. Frequency factor multiplier

Frequency (lifts/min)	Male	Female
1.00	0.95	0.91
2.00	0.89	0.87
3.00	0.83	0.84
4.00	0.78	0.80
5.00	0.73	0.77
6.00	0.69	0.74
7.00	0.65	0.70
8.00	0.62	0.68
9.00	0.59	0.66
10.00	0.56	0.65
11.00	0.54	0.64
12.00	0.52	0.63
13.00	0.50	0.63
14.00	0.49	0.62
15.00	0.47	0.61
16.00	0.46	0.60

Source: Stambough *et al*. (1995); Hidalgo *et al*. (1997)

Table 2. 16. Temperature factor multiplier

Temperature °C	Multiplier
19.00 – 27.00	1.00
28.00	0.98
29.00	0.95
30.00	0.93
31.00	0.90
32.00	0.88
33.00	0.86
34.00	0.83
35.00	0.81
36.00	0.78
37.00	0.76
38.00	0.74
39.00	0.71
40.00	0.69

Source: Stambough *et al*. (1995); Hidalgo *et al*. (1997)

Table 2. 17. Lifting Capacity Based on Age and Gender

Age (year)	Drury and Pfeil (1975) Lifting capacity (L.C.) (kg)	Stambough *et al*. (1995). Lifting capacity (L.C.) (kg)	
		Male	Female
20.00	38.00	25	17
25.00	48.00	24	16
30.00	45.00	23	15
35.00	45.00	23	15
40.00	41.00	22	15
45.00	37.00	20	14
50.00	34.00	18	12
55.00	32.00	15	11
60.00	31.00	15	9

Source: Stambough *et al*. (1995)

The participating subjects were tested for differences in normalised peak low back moment, peak knee-hip power magnitude ratio and timing as a function of gender strength and load weight. The researchers found that energetic participants had a lower normalised peak low back moment, an average of 32% difference from low capacity across all load weights and no gender-significant relationship at $p=0.58$. However, as load weight increased, normalised peak low back moment, peak knee-hip magnitude and synchronicity reduced. The 28 subjects' participant gender was not indicated. The present research is to develop a safe weight lift with varying temperatures models by considering, among other factors gender of the manual lifting workers to determine the SWL to minimise the problem of low back pain.

A lifting capacity prediction model was developed based on the muscle and endurance of manual lifting workers by adapting stepwise multiple linear regression. The researchers engaged 65 construction workers based on socio-demographics (age and BMI) and physical performance characteristics (endurance, core and grip strength, and lower limb flexibility). Progressive inertial lifting evaluation was done to assess the 65 construction workers lifting capacity. The study showed that age, BMI, grip strength, flexibility prone-plank, and trunk lateral flexor endurance significantly affected lifting capacity at $p<0.05$ (Mohapatra *et al*., 2022). The researchers considered construction workers' physical performance characteristics and socio-demographic factors. However, the present study is also considering socio-demographic factors (age and gender), personal characteristic factors (body weight and spine length), and physical performance characteristic factors of change in stature (differences between worker's height before and after the day's work), frequency of lifts and workplace temperature to develop a SWL with varying temperature model to determine the SWL to minimise the problem of low back pain for manual lifting workers. In a psychophysical study, the strength capabilities of female manual lifting workers were put at 0.60 compared to male workers at 0.76, while another study stated 0.56 capability for females and 0.72 capability for males (Chapla, 2004; Hamid and Tamrin, 2016). Plamondon *et al*. (2019) stated that the overall back strength of female manual lifting workers was two-thirds of that of male manual lifters in a psychophysical and physiological study.

Maiti and Ray (2004) developed a multiplicative equation centred on the result of three lifting variables acting on the working heartbeat rate. These involved knees, waist, and shoulder. The maximum reach height, lifting frequency (1.00, 4.00, 7.00 and 14.00 lifts/min) and load weights (5.00, 10.00 and 15.00 kg) within the age group from 28.00 to 32.00 years to compute the maximum load limit for adult Indian women involving in manual lifting. The equation of Working Heart Rate (*WHR*) was given as follows:

$$WHR = C \times FM \times WM \times DM \tag{2.3}$$

where

C = constant

FM = frequency of lift multiplier

W.M. = weight multiplier

D.M. = vertical distance multiplier.

The experiment involved ten experienced adult female workers engaging in building construction activities. While lifting, the subject stayed on a cell stage of weighing equipment during the experiment, and a digitally generated sound was used to record the lifting frequency observed. It was found that the maximum load an adult Indian woman could lift was 15.40 kg. The researcher recommended 15.40 kg as the maximum load weight based on the age group assumption of between 28.00 and 32.00 years without using it to determine the maximum load weight for an adult Indian woman. In this study, the individual worker's age is a factor considered to develop a model to determine the safe weight of the lift.

Widia *et al*. (2019) assumed a psychophysical approach to determine the Maximum Acceptable Frequency of Lift (MAFL). Two load weight types were considered (one and five kilograms). The Actiheart monitoring device determined the energy expenditure to obtain heart rate and activity data. Ten healthy Malaysian males were selected based on age (22.00 to 36.00 years), gender, and health status. The ten participating males had no background history of musculoskeletal disorders. The MAFL decreased as load lifting increased, and the energy expenditure increased as load lifting increased. Hence, the frequency of lifts is essential in determining the safe weight. The two–way Analysis of Variance (ANOVA) showed that load weight has a significant effect on both the MAFL and energy expenditure during metronome–paced and unpaced tasks (p<.01). To develop a model to determine the safe weight of the lift, frequency of lift is one of the factors considered.

Oktavia (2022) used a total sampling technique to sample 52 subjects and analysed the data using the chi-square test. The researcher found factors such as age, BMI, smoking habits, manual material handling, and years of work experience have a significant relationship with LBP complaints ($p<0.05$). The BMI was the ratio of the worker's weight to the square of the worker's height. However, in this study, other factors considered to develop a safe weight lift with varying temperatures models include the worker's age, weight, spine length, and change in height.

Figure 2.1 is the conceptual framework of the relationship of independent factors of worker's age, weight, stature change, spine length, gender, frequency of lift and temperatures, and dependent factor of SWL with varying Temperature (SWLwT) of the model developed.

2.11 Theoretical review

This section presents the outcome of reviewed relevant theories related to the present study.

2.11.1 Human spinal shrinkage

Jorgen (1986) noticed increased body height when the load on the spine was partially removed and experiment participants laid down. Jorgen (1986) considered that much of the body height loss originated within the spine. This was shown by determining body height in sitting and standing positions (Jorgen, 1986; Rabat-Pelay *et al*., 2019). The decreased body height was almost the same in sitting and standing positions. The body height reduction was attributed to a decrease in the disc length. The terms spinal shrinkage, stature change, or change in body height have been used interchangeably to mean the same thing in the literature. Arjmand *et al*. (2015) observed that body weight is critical in predicting spine loadings.

A spinal shrinkage response to shoulder loading was investigated by Sun *et al*. (2018) by recruiting twenty–two inexperienced subjects from a University population. The subjects included five females and seventeen males. The criteria for inclusion or exclusion of participants included factors such as age, weight, height, body mass index, and absence of prevailing back pain. Therefore, subjects with the following criteria were selected from 23.00 to 26.00 years, from 56.00 to 80.00 kg, from 1.65 to 1.82 m, and from 19.00 to 24.00 kg/m^2. These were based on age, weight, height, and body mass index. The subjects loaded with 20% of their body mass in front and back loading conditions. A stature shrinkage was recorded using a precision stadiometer, and a shrinkage of 0.03 m was recorded. The front-loading was found to cause low back pain more quickly than backloading. One-way Analysis of Variance (ANOVA) was used to test loading posture. Stadiometer equipment is an equipment to determine the spinal shrinkage of the selected workers. The model developed by Ismaila (2006) comprises stature change (x), spine length from where the thoracic begins to lumbar ends of the backbone (L), chest length and width (l_f and l_s), articular cartilage young modulus of elasticity (E), lifting velocity (u), acceleration due to gravity (g), loads at vertical location (V), horizontal length from ankles (H), vertical displacement (D) and lifting angle (θ) were used in determining the safe weight to be lifted (Ismaila *et al*., 2010; Ismaila and Charles – Owaba, 2012).

For lifting, the lifter must exert a force more significant than the weight lifted. The force exerted produces strain, especially at joints (the weakest points of the human skeletal structure) (Ismaila, 2006). Among such joints was the interface between vertebrae where cartilaginous tissue exists. In developing the model, three main forces were assumed to act while the lifting task was carried out. These were a vertical force, horizontal force, and spine, axial component at a right angle to the disc.

According to Ismaila (2006), the axial component of load and compressive force being at right angles to the disc plane that cannot result in malleable disc distortion was defined as the safe weight to be lifted. The safe weight to be lifted should be a function of anthropometric characteristics, work characteristics and task characteristics (Ismaila, 2006). It was also stated that work-related accidents depended on differences in body physique, anthropometry, and environmental conditions (Maiti and Ray, 2004). Based on Ismaila's (2006) model, the following assumptions were adopted.

1. The most significant feature of the lifting structure is the human spine.
2. Each of the spine endplates contains hyaline and fibrocartilage. This can be formed as an isotonic elastic material.
3. An Elliptical truncal cross-sectional area of the human subject was predicted.

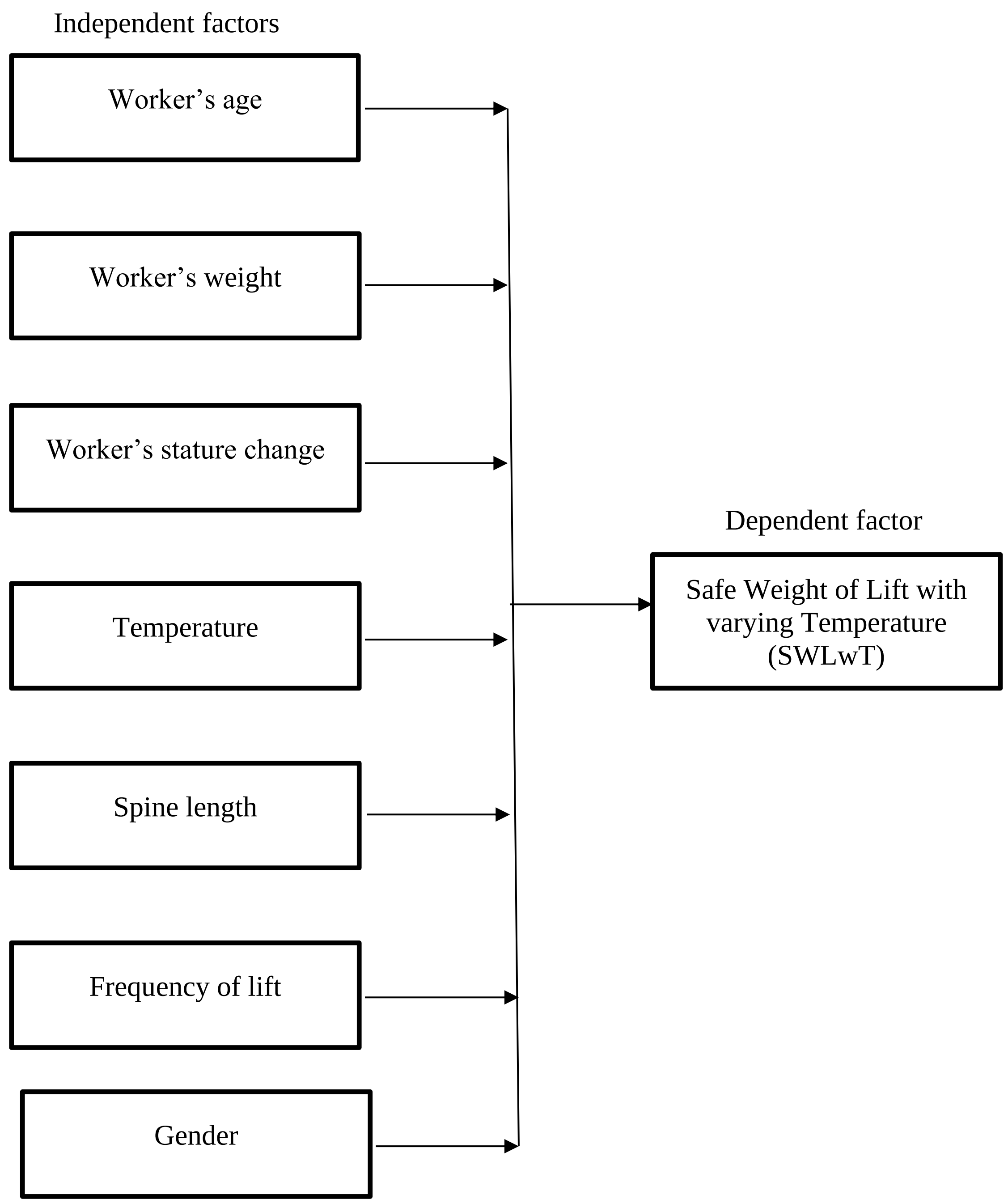

Figure 2. 1. Conceptual framework

where

l_f = chest length measured across the chest at the nipple

l_s = chest width measured at chest from front (sternum) to back (spinal groove)

$\pi = 3.14$

Elliptical Truncal Area (Marshek, 1987) is expressed as:

$$A = \frac{\pi \times l_f \times l_s}{4} \qquad (2.4)$$

The Modulus of Elasticity of articular cartilage:

E = assumed 7.00 MN/m^2.

The factor of safety = 1.25.

E ÷ 1.25 = 5.60 MN/m^2 (Fick and Espino, 2011) (2.5)

4. The sum of the potential and kinetic energy of the load been lifted is the total strain energy on the spine.

The human spine disc was adopted as non – a linear spring. The strain energy is expressed as:

$$\varphi_i = \int_0^{\tau_i} F_i \, d\tau_i \qquad (2.6)$$

where

φ_i= strain energy

F_i= force on the spine

k_i= force constant

τ_i= series of single spine disc connection

i= 1……………. N

N = total disc number from first thoracic to end of the lumbar spine

Deflection force law is expressed as:

$$F_i = k_i \tau_i \qquad (2.7)$$

Substituting (2.6) into (2.5) gives:

$$\varphi_i = \int_0^{\tau_i} k_i \tau_i \, d\tau_i \qquad (2.8)$$

Integrating (2.7) gives:

$$\varphi_i \frac{k_i \tau_i^2}{2} \qquad (2.9)$$

Eq. (2.6) gives:

$$k_i = \frac{F_i}{\tau_i} \quad (2.10)$$

Substituting (2.9) into (2.8) gives:

$$\varphi_i = \frac{F_i \tau_i}{2} \quad (2.11)$$

Seventeen discs and endplates existed from the last cervical vertebrae to the last lumbar vertebrae. Each of these behaved like a spring (Ismaila, 2006; Daniels and Hoffman, 2011; Khotimah *et al*., 2011; Ismaila and Charles – Owaba, 2012)

At the human back sum of strain energies expected is expressed as:

$$\varphi_T = \sum_{i=1}^{17} \varphi_i = \sum_{i=1}^{17} \frac{F_i \tau_i}{2} \quad (2.12)$$

where

φ_T = total strain

F_i = compressing force acting the same on the spine's disc at the back.

$$F_i = F_1 = F_2 = F_3 \ldots \ldots . = F_{17} = F \quad (2.13)$$

(Marshek, 1987; Ismaila, 2006; Ismaila and Charles – Owaba, 2012; Jiemjai *et al*., 2014).

$$L = \tau_1 + \tau_2 + \tau_3 + \cdots . . + \tau_{17} \quad (2.14)$$

where

L = sum of the disc length

x = stature change

ΔL = change in spine length

$\Delta L = x$

The strain energy at the spine is expressed as:

$$\varphi_i = \frac{Fx}{2} \quad (2.15)$$

where

F = force on the spine

$S.E.$ = Strain Energy

$$S.E. = \frac{1}{2} Fx \quad (2.16)$$

A rigidity measurement known as spring constant (k) allowed for an axial force (F) that did not stress the spine (L) beyond the elastic limit (Ismaila, 2006; Khotimah *et al*., 2011).

Assuming the spine behaved like spring, spring constant (k) is given and related to the spine.

$$k = \frac{F}{x} = \frac{AE}{L} \quad (2.17)$$

where

A = cross-sectional area

E = Young Modulus of elasticity

L = length of the spine

k = spring constant

$S.E.$ = Strain Energy

$K.E.$ = Kinetic Energy

$P.E.$ = Potential Energy

F = force on the spine

D = vertical displacement of the load

V = vertical location of the load

m_T = total mass

u = velocity of lift

g = gravitation acceleration.

H = horizontal length of the load from the ankle.

θ = angle between hip and thigh during lifting.

$$S.E. = \frac{1}{2} Fx \quad (2.18)$$

$$K.E = \frac{1}{2} m_T u^2 \quad (2.19)$$

$$P.E = m_T g(D + V) \quad (2.20)$$

Eq. (2.16) gives:

$$k = F = \frac{AEx}{L} \quad (2.21)$$

Substituting (2.20) into (2.17) gives:

$$S.E. = \frac{AEx^2}{2L} \quad (2.22)$$

Resolving force along the spinal column, potential energy (P.E.) is expressed as:

$$P.E = \frac{m_T g(D+V)}{sin\theta} \quad (2.23)$$

and

$$Tan\ \theta = \left(\frac{D+V}{H}\right) \quad (2.24)$$

Adapting conservation of energy principle of the sum of potential and kinetic energy expressed as:

$$S.E. = P.E. + K.E. \quad (2.25)$$

Therefore, total strain energy involving lifting and upper body weight must equal the sum of upper body weight and weight of lift strain energy.

where

$S.E_T$ = total strain energy of upper body and weight of the lift

$S.E_b$= upper body strain energy only

$S.E_l$ = weight of lift strain energy only.

$$S.E_T = S.E_b + S.E_l \quad (2.26)$$

Also, total strain energy is the sum of total potential and kinetic energy.

$$S.E_T = P.E_T + K.E_T \quad (2.27)$$

where

$P.E_T$ = total potential energy

$K.E_T$ = total kinetic energy

m_b = upper body weight

m_l = lifted weight

m_T = sum of the upper body and lifted the weight

$$m_T = m_l + m_b \quad (2.28)$$

$$K.E_T = \frac{1}{2} m_T u^2 \quad (2.29)$$

$$P.E_T = \frac{m_T g(D+V)}{sin\theta} \quad (2.30)$$

Substituting (2.28) and (2.29) into (2.26) gives:

$$S.E_T = \frac{m_T g(D+V)}{sin\theta} + \frac{1}{2} m_T u^2 \quad (2.31)$$

Substituting (2.27) into (2.30) gives:

$$S.E_T = \left[\frac{(m_l + m_b)g(D+V)}{sin\theta} + \frac{(m_l + m_b)u^2}{2}\right] \quad (2.32)$$

The strain energy of the body $S.E_b$ can be expressed as:

$$S.E_b = \frac{m_b g(D+V)}{sin\theta} + \frac{m_b u^2}{2} \quad (2.33)$$

Making $S.E_l$ subject (2.25) gives:

$$S.E_l = S.E_T - S.E_b \quad (2.34)$$

Substituting (2.31) and (2.32) into (2.33) gives:

$$S.E_l = \left[\frac{(m_l + m_b)g(D+V)}{sin\theta} + \frac{(m_l + m_b)u^2}{2}\right] - \left[\frac{m_b g(D+V)}{sin\theta} + \frac{m_b u^2}{2}\right] \quad (2.35)$$

Expanding and subtracting (2.34) gives:

$$S.E_l = \frac{m_l g(D+V)}{sin\theta} + \frac{m_l u^2}{2} \quad (2.36)$$

Therefore (2.21) and (2.35) yield:

$$\frac{AEx^2}{2L} = \frac{m_l g(D+V)}{sin\theta} + \frac{m_l u^2}{2} \quad (2.37)$$

Factorising m_l (2.36) gives:

$$m_l \left[\frac{2g(D+V) + u^2 sin\theta}{2sin\theta}\right] = \frac{AEx^2}{2L} \quad (2.38)$$

Multiplying (2.37) with 2L gives:

$$m_l L \left[\frac{4g(D+V) + 2u^2 sin\theta}{2sin\theta}\right] = AEx^2 \quad (2.39)$$

Cross multiplying (2.38) gives:

$$m_l L[4g(D+V) + 2u^2 sin\theta] = 2AEx^2 sin\theta \quad (2.40)$$

Trigonometric rule is expressed as:

$$tan\theta = \frac{sin\theta}{cos\theta} \quad (2.41)$$

Making $sin\theta$ subject (2.40) gives:

$$sin\theta = tan\theta cos\theta \quad (2.42)$$

Substituting (2.23) into (2.41) gives:

$$sin\theta = \left(\frac{D+V}{H}\right) cos\theta \quad (2.43)$$

Substituting (2.42) into (2.39) and making m_l subject gives:

$$m_l = \frac{\pi l_f l_s x^2}{4L} \left[\frac{E\left\{\frac{D+V}{H}\right\} cos\theta}{2gD + u^2 \left\{\frac{D+V}{H}\right\} cos\theta}\right] \quad (2.44)$$

Equation (2.44) was the model Ismaila (2006) developed to obtain a safe weight to be lifted. According to Ismaila (2006), the model consisted of some worker characteristic factors compared to task-oriented models. However, in the Ismaila (2006) model, personal characteristics such as the lifter's weight, age, gender, and workplace temperature were not considered. The identified factors were considered in this present study to develop a model to determine the SWL to reduce the problem of low back injuries during unaided human lifting jobs.

2.12 Empirical review

This section presents the results of computations of the researchers that developed models and determined that weight seems safe for manual lifting workers without causing low back pain.

Ismaila and Charles – Owaba (2012) studied 84 factory and market workers with a wide age ranging from 18.00 to 57.00 years, at a mean stature change of 0.014 m and maximum allowed stature change of 0.025 m were obtained to calculate the safe weight to be lifted and SWL maximum (SWL_{max}). A paired sample T-Test at 95% confidence was used to statistically compare values of Weight Limit Recommended (RWL) and Acceptable Weight Maximum of Lift (MAWL). It was found that the value of SWL evaluated with L = 0.60 m, x = 0.014 m, and A = 0.05 m^2 were significantly varied between resultant RWL ($p<0.05$) and MAWL ($p<0.05$). SWL maximum (SWL_{max}) values obtained with x = 0.025 m, L = 0.60 m and A = 0.05 m^2 were found to significantly vary from resultant parameters RWL (p = .00) and MAWL ($p<0.05$). Anthropometric parameters of the workers such as mean, maximum, minimum, and percentiles of age (years), height (metre) (morning and evening), chest depth (metre), chest breadth (metre), stature change (metre), and chest area (metre squared) were shown in Table 2.18.

2.12.1 Determination of safe mass backpack

The SWL model proposed by Ismaila (2006) includes consideration for the subject's anthropometric characteristics. This was used to determine safe mass backpacks for students in a tertiary institution. It was established that tertiary students' should not carry more than 12% of their body mass as a backpack. The result was different from the previously suggested limited weight between 30 and 40% of the body mass. Also, it was recommended that it should not be more than 15% of the body mass (Ismaila and Oriolowo, 2015). Previous works did not consider the subject's anthropometric characteristics, which may have caused variation in the results. Table 2.19 shows anthropometric data (chest depth and width), age (years), height (metre), weight (kilogram), the body weight percentage of the subjects, and backpack mass (kilogram).

Ismaila (2017) developed a model based on the strain energy principle to determine safe weight backpacks for female and male secondary students. Three hundred and twenty–four secondary school students comprised 141 males and 183 females. These were randomly selected from private and government-owned secondary schools in the Ibadan metropolis, Oyo state, Nigeria. The instruments used to obtain standing heights, body weights, and trunk and leg lengths were Vernier calliper and stadiometer scale ZT-160 and tape rule, respectively. The backpack of 2.87 and 2.53 kg obtained for males and females were 5.18 and 4.91% of their body weight, respectively. This showed the importance of body weight in developing a model to determine the safe load weight to be lifted.

The human physical characteristic and task requirements were considered in developing a Digital Human Model (DHM) (Al-Meanazel *et al*., 2021). This was a computer-generated representation of humans and the work environment. The simulated experimental effects of evaluated boxes of weights of 10.00, 15.00 and 20.00 kg, gender (male or female), percentile (5th, 50th and 95th), and postures (standing or sitting) involving compression force on lower back L4/L5 and tension stress on Latissimus Dorsi were developed. Multivariate and Univariate Analysis of Variance (MANOVA and ANOVA) were the tool of analysis adopted. The researchers found that all the factors were significant and impacted at L4/L5 compression force. The box weight had a more significant ($p<0.05$) impact on the L4/L5 than other factors considered. Gender showed no significant impact on the compressive force. A distinct difference was found in muscle tension between males and females. The increase in box weight was found to have led to an increase in muscle tension and compressive force (Al-Meanazel *et al*., 2021). Applying more muscle to lift can cause musculoskeletal disorders like low back pain at L5/S1 among manual lifting workers. Therefore, necessary factors influencing the SWL were considered to formulate a model to determine the safe weight in this study.

2.12.2 Load strain Susceptibility index

In a study of twenty block moulders that had mean height (1.74 m), mean age (21.55 years), mean weight (62.25 kg), mean chest width (0.32 m), mean chest depth (0.20 m) and mean spine length (0.53 m), the maximum and computed SWL average were 11.21 and 3.55 kg, respectively.

Table 2. 18. Workers' anthropometric parameters

	Age (year)	Height Morning (m)	Height Evening (m)	Chest Depth (m)	Chest Breadth (m)	Length of Vertebral Column (m)	Spinal Shrinkage (m)	Chest Area (m^2)
Mean	37.00	1.69	1.68	0.19	0.25	0.52	0.014	0.04
Maximum	57.00	1.80	1.78	0.26	0.28	0.70	0.025	0.05
Minimum	18.00	1.56	1.56	0.16	0.22	0.44	0.000	0.03
5^{th}%tile	23.00	1.61	1.59	0.17	0.23	0.46	0.000	0.03
50^{th}%tile	38.00	1.69	1.68	0.19	0.26	0.52	0.013	0.04
95^{th}%tile	50.00	1.77	1.76	0.23	0.28	0.60	0.025	0.05

Source: Ismaila and Charles – Owaba (2012)

Table 2. 19. Workers' anthropometric data and Backpack Mass Limit

Percentiles	Age (year)	Weight (kg)	Height (m)	Chest depth (m)	Chest width (m)	Mass of backpack (kg)	% of body weight
5th	18.90	54.50	1.63	0.16	0.23	5.23	8.29
50th	23.50	59.00	1.73	0.18	0.25	5.86	9.72
95th	25.60	69.50	1.77	0.20	0.28	0.66	11.87

Source: Ismaila and Oriolowo (2015)

Also obtained was Load Strain Susceptibility Index (LSSI), which was classified as LSSI safe, LSSI tolerable, and LSSI hazardous. Values obtained were 1.00, 2.48, and 3.94, respectively. It was concluded that 3.53 kg was a safe weight to be lifted. The 8.75 kg was a weight tolerable to be lifted, and 13.93 kg was a hazardous weight to be lifted (Ismaila and Aderele, 2015). The researchers developed the following equations for Load Strain Susceptibility Index (LSSI):

$$LSSI\ (SAFE) = \frac{WL}{SWL} \qquad (2.45)$$

$$LSSI\ (TOLERABLE) = \frac{WL + 5}{SWL} \qquad (2.46)$$

$$LSSI\ (HAZARDOUS) = \frac{WL + 10}{SWL} \qquad (2.47)$$

where

W.L. = block Weight Lifted by block moulders.

Table 2.20 shows the result of descriptive statistics for parameters used to implement the SWL model. The H is the horizontal location of the load (metre), V represents the vertical location of the load weight (metre), and D is the vertical displacement of the load weight (metre). The subjective parameters were height, spine length, chest width and length (metre), weight (kilogram), and age (years).

$$M_o = SWL = \frac{\pi l_f l_s x^2}{4L}\left[\frac{E\left\{\frac{D + V}{H}\right\} cos\theta}{2gD + u^2\left\{\frac{D + V}{H}\right\} cos\theta}\right] \qquad (2.48)$$

Table 2.21 shows the weight of two categories of blocks from three different selected industries with the corresponding mean by comparing the evaluated maximum SWL (15.50 kg) with the actual block weight mean of 17.90 and 22.76 kg of six and nine inches blocks, respectively. It was observed that workers were lifting blocks heavier than the expected safe weight of the lift. A block weight of about 10.00 kg would be endurable since the weight was less than the risky weight of 13.91 kg reported (Ismaila and Aderele, 2015).

However, the researchers suggested that block weight should be reduced to minimise the problem of low back pain to bring ergonomic improvement and a rise in productivity in the sector. To reduce the load weight, consideration should be given to other identified factors that may influence safe weight among manual lifting workers in this research.

2.12.3 Determination of maximum acceptable weight of the lift

Maximum Acceptable Weight of Lift (MAWL) was determined by adopting a psychophysical approach on ten female Indian adults working as Construction Workers (CW) and eight Household Workers (HW) lifting various load weights to their knees and waists. Maximum reach height measurements were obtained. The maximum acceptable lift weight was estimated at 15.00 kg (Maiti, 2001).

Participants were requested to select a maximum load weight according to their choice, which they could continue for 8 hours. The load weight was adjusted at four different points at the beginning, after 5, 10 and 20 minutes of the work. When selecting the load weight, workers were verbally encouraged to take the maximum load weight they could lift without strain (Maiti, 2001). The psychophysical approach could be applied when there was a possibility of selecting the weight of lift by the worker. The demographic description of the two participating categories of workers is presented in Table 2.22. The problem, however, was that workers might decide to pretend about a possible weight they could lift. Therefore, it is necessary to develop a model to consider factors affecting safe weight lift among manual lifting workers.

Maximum Acceptable Weight of Lift (MAWL) was investigated among Indonesian inexpert female manual material handlers. Ardiyanto *et al*. (2019) selected twenty–inexperienced female manual material handlers' that were college students and were freed from any form of musculoskeletal disorder. They were trained for an hour to familiarise themselves with the procedure before the experiment. Psychophysical and physiological approaches were used to determine the MAWL. The participants' physical activities were grouped into low, moderate, high, and two levels of frequencies (1.00 lift/min and 4.00 lifts/5 min). The initial weight was 6.00 kg, and participants were requested to continuously increase the weight to what they could lift for an 8-hour work without being strained, tired, weakened and overheated, or out of breath by 1.00 kg.

Table 2. 20. Descriptive statistics for parameters of the model

	N	Smallest	Largest	Average	Standard Deviation
Height (m)	20	1.68	1.80	1.74	0.04
Age (year)	20	18.00	33.00	21.55	0.75
Weights (kg)	20	50.00	80.00	62.25	0.77
Chest width (m)	20	0.28	0.37	0.32	0.03
Chest depth (m)	20	0.14	0.23	0.20	0.02
Length of the spine (m)	20	0.48	0.60	0.53	0.03
H	20	0.26	0.38	0.31	0.03
D	20	0.62	0.62	0.62	0.00
V	20	0.44	0.56	0.50	0.04
SWL(kg)	20	2.50	4.90	3.53	0.06
SWL_{max}(kg)	20	7.90	15.50	11.21	1.98
LSSI					
SAFE	20	1.00	1.00	1.00	0.00
TOLERABLE	20	2.00	3.00	2.48	0.26
HARZADOUS	20	3.10	5.00	3.94	0.52
Valid N (listwise)	20				

Source: Ismaila and Aderele (2015)

Table 2. 21. Weight of two selected types of Blocks

Block types	1st industry (kg)	2nd industry (kg)	3rd industry (kg)	Average weight (kg)
6.00 inches	18.20	17.80	17.90	17.90
9.00 inches	23.10	22.70	22.50	22.76

Source: Ismaila and Aderele (2015)

Table 2. 22. Workers demographic description

Group	Age(yrs)	Height(m)	Body weight (kg)	Knee height (m)	Waist height (m)	The eye height (m)
C.W.	30.00±2.80	1.48	37.50±5.40	0.47	0.86	1.31
HW	30.00±1.60	1.45	45.60±4.90	0.43	0.85	1.28

Source: Maiti (2001)

There was no significant difference between what an Indonesian and Chinese inexperienced female manual material lifters could lift ($p<0.05$). There was a significant difference between what an Indonesian's inexperienced and American's experienced female manual material lifters can lift ($p>.05$). The American's experienced female manual material lifts at 1.00 lift/min and 4.00 lifts/5min and lifted 16.40 and 11.60 kg, respectively. This indicated the unsuitability of applying a weight model developed outside a particular racial group to determine a safe weight lift that will not cause low back pain in another race.

2.12.4 Psychophysical and Biomechanical Approach of Revised NIOSH Lifting Equation

In research carried out by Elfeituri and Taboun (2002), a significant difference was observed between the National Institute for Occupational Safety and Health (NIOSH) and the reported Maximum Acceptable Weight of Lift (MAWL). The techniques used were psychophysical and biomechanical approaches, respectively. The biomechanical effect on the worker's low back during lift was determined by load weight and lift posture. The NIOSH lifting equation was structured to appraise the danger of lifting tasks related to low back harm (Waters *et al.*, 1993). It is a widely used industry equation to set acceptable worker lift limits (Elfeituri and Taboun, 2002). A load constant (L.C.) of 23.00 kg was given as the maximum recommended weight limit to lift under temperature conditions between 19 and 26°C (NIOSH, 1991).

In the NIOSH equation, three factors closely connected to biomechanical loading were load constant and horizontal and vertical locations of the load. The biomechanical principle of the NIOSH is based only on compressive forces on lumbar vertebrae and should not go beyond 3.40 kN but neglect ant-posterior and lateral shear forces. The NIOSH equation was based on static analysis of lifting tasks instead of the realistic dynamic nature of lifting (Elfeituri and Taboun, 2002). However, the present study's developed model have dynamic factors based on measured and recorded values inputted to determine the weight to be lifted that may not result in low backache.

Lee (2005) used a psychophysical approach to determine asymmetrical lifting capabilities, for ten young, healthy experienced males, for three lifting frequencies of three asymmetrical containers at 90°. To perform 90° asymmetric lifting, participants flexed their knees, twisted the trunk, and lifted containers located 90° right to the sagittal plane from the floor to 0.74 m table height, which was 0.90 m horizontal distance to the front of the participant. The participants lifting capability of the container of two different sizes decreased as the frequency of lifts increased. At lifting frequencies of 1.00, 2.00, and 4.00 lifts/min for container size of 0.50×0.35×0.15, the participants lifted 18.00, 16.60, and 15.00 kg, respectively, while for container size 0.50×0.50×0.15 the participants lifted 16.20, 15, and 13.70 kg, respectively.

The lifted load weight ranged from 13.70 to 18 kg. It was discovered that the maximum acceptable lift weight decreased with increasing frequency. In contrast, the interaction effect of frequency and container size on the load weight of lifting was insignificant. The researcher's finding pointed to the need to include the frequency of lifts as a factor in the model to determine safe weight lifts.

Table 2.23 shows the result of the mean and standard deviation of the maximum acceptable weight of lift in kilogram for the nine experimental conditions.

2.12.5 Low back pain and Fuzzy logic model

A fuzzy logistic model was used to investigate the danger of Lower Back Pain (LBP) among construction workers by Marras *et al*. (2009); Adeyemi *et al*. (2013). The fuzzy set theory was an expert system to decide the level of risk related to selected workers. The three elements of input used were position at work, frequency of lift, and load weight, while output was danger of lower back pain. The validated result showed a strong positive relationship between the human calculated result and the experts' lower back pain hazard result. The expert model gave a coefficient of determination of 0.93. The researcher deduced that the fuzzy model system minimized low back hazards in construction tasks by efficiently assigning a workforce (Marras *et al*., 2009; Adeyemi *et al*., 2013). Apart from the three constituent elements these researchers consider, other identified factors influencing SWL amid manual lifting workers should be considered. Other factors considered in this study include the lifter's weight, spine length, age, gender, change in stature, and temperature.

Table 2.24 shows the expert value for Load Index (LI). The parameters were from LI<one to LI>three, and model results were compared with the human calculated results. The human expert opinion classified LI into five categories: LI= zero (No risk), LI=

from zero to one (low risk), LI= from one to two (medium risk), LI= from two to three (high risk), and LI= greater than three (Very high risk) (Adeyemi *et al*., 2013). It can also be deduced from Table 2.24 that the lower the load (kilogram), the less likely the occurrence of low back pain is based on the Load Index value. The load values of 2.00, 2.50, 6.00, 7.00, 8.00, 10.00, 11.00, and 12.00 had Load Index (LI) models of 0.76, 0.57, 2.33, 1.00, 1.28, 1.52, 1.88 and 1.87, respectively.

2.12.6 The National Institute for Occupational Safety and Health Lifting Equation

The widely used Recommended Weight Limit (RWL) technique to assess the risk of injury to the spine was developed by NIOSH (1991). The criteria of NIOSH (1991) were maximum disc compression of 3.40 kN, maximum energy expenditure between 2.20 and 4.70 kcal/min and weight acceptable to healthy 75 and about 99% of females and males manual lifting populations, respectively (Water *et al*., 1993). These criteria require a level of equipment to determine, apart from a restricted temperature of between 19 and 26°C. Hence, the possibility of these criteria being met in developing nations' uncontrolled lifting activities to use the Recommended Weight Limit equation is in doubt, especially in underdeveloped nations like Nigeria. Therefore, there is a need for further research to develop a model that would not require strict conditions and still gives the result of load weight that can reduce the problem of low backache to manual lifting workers.

In this study, factors such as workers' age, weight, spine length, stature change, lift frequency, gender, and workplace temperature seem to influence safe weight lift to formulate a model to determine load weight that can reduce low back pain. Table 2.25 shows various criteria used in developing the revised equation of the National Institute for Occupational Safety and Health (1991); Recommended Weight Limit (RWL).

According to Waters *et al*. (1993), the revised NIOSH (1991) equation was applicable in lifting jobs involving two hands to move the load, primarily where biomechanical conditions restricted the effects of stress on the lumbosacral. Physiological conditions restricted metabolic stress and fatigue related to repetitive lifting tasks. Psychophysical conditions restricted the Workload built by considering workers' perception of lifting capability. This method can be applied to nearly all lifting tasks except high frequency, beyond six lifts per minute.

Table 2. 23. Mean and Standard Deviation of Maximum Acceptable Weight of Lifting

Container size	1 lift/min		2 lifts/min		4 lifts/min	
	Mean	SD	Mean	SD	Mean	SD
0.026 m^3	18.00	0.80	16.60	0.70	15.00	0.90
0.034 m^3	17.60	1.00	16.30	1.00	14.80	0.90
0.038 m^3	16.20	1.50	15.00	0.80	13.70	1.30

Source: Lee (2005)

Table 2. 24. Expert and Model calculated risk values

Sample	Load (kg)	Frequency (lift/min)	Posture (degree)	RWL (kg)	LI (Expert Value)	Model Value
1	24.00	1.30	35.00	6.80	3.53	3.57
2	24.00	2.10	55.00	5.74	4.18	3.74
3	24.00	1.10	45.00	5.30	4.53	3.57
4	2.00	1.90	40.00	4.06	0.49	0.76
5	8.00	3.20	0.00	7.89	1.01	1.28
6	10.00	3.80	0.00	7.31	1.37	1.52
7	24.00	1.50	10.00	11.10	2.16	2.55
8	24.00	2.00	45.00	6.09	3.94	3.57
9	28.00	1.90	10.00	11.47	2.44	2.48
10	28.00	8.80	30.00	5.49	5.10	3.64
11	26.00	2.10	35.00	7.84	3.32	3.65
12	6.00	5.00	30.00	2.23	2.69	2.33
13	11.00	0.50	39.00	6.82	1.61	1.88
14	12.00	0.80	50.00	6.37	1.89	1.87
15	28.00	2.60	50.00	6.04	4.64	3.67
16	2.50	0.30	40.00	7.54	0.33	0.57
17	7.00	0.10	65.00	7.09	0.99	1.00
18	15.00	1.30	60.00	5.15	2.92	2.34
19	24.00	2.00	25.00	7.56	3.17	3.31
20	22.00	1.80	30.00	5.44	4.03	3.27

Source: Adeyemi *et al*. (2013)

Table 2. 25. Criteria in developing NIOSH (1991) lifting equation

Discipline	Design criteria	Cut–off value
Biomechanical	Maximum disc compression force	3.40 KN
Physiological	Maximum energy expenditure	from 2.20 to 4.70 Kcal/min
Psychophysical	Maximum acceptable weight	Weight acceptable to healthy 75% and 99% female and male manual lifting populations, respectively.

Source: Water *et al*. (1993)

The predicted NIOSH (1991) maximum disc compressive force of 3.40 kN across genders and races had been seen as unreliable due to different disc compressive force predictions in the literature (Arjmand *et al*., 2015; Hung *et al*., 2020). Hung *et al*. (2020) predicted different disc compressive forces for Asian males and females, manual lifting workers at L5/L1 as 3.00 kN and 2.80 kN, respectively.

Therefore, disc compressive force was gender and racial-dependent. Kudo *et al*. (2019) estimated subjects' risk curves of the lumbar spine for samples size of 85, 129, and 106 for age groups between: 20.00 and 39.00, 40.00 and 59.00, 60.00 and 79.00 years, the predicted compressive force for the age groups were 3.72, 2.98 and 2.03 kN. Therefore, there should have been a consideration for age and gender in the NIOSH (1991) to predict maximum disc compressive force. In this study, factors considered in formulating a model to determine safe weight include age and gender.

The variation in the load recommendation for manual lifting depends on the criteria applied. Metabolic data (physiological) suggested that it was more efficient to lift a heavier weight less frequently than to lift a lighter weight frequently. Biomechanical studies suggested that load weight should be minimised by lifting lighter weights frequently to reduce muscle and vertebral stress. The psychophysical method suggested lifting manually from the floor to make workers lift heavier loads than the estimated load of biomechanical or physiological estimated studies (Waters *et al*., 1993; Shahu, 2016).

2.13 Recommended Weight Limit Multipliers

The factors that were considered in developing the NIOSH (1991) lifting equation of Recommended Weight Limit (RWL):

2.13.1 Horizontal multiplier (H.M.): Biomechanical and psychophysical studies indicated that with increased load distance from the spine, the predicted disc compressive force increases and there was a decrease in maximum acceptable weight limit (Waters *et al*., 1993). Psychophysical data had consistently shown that the horizontal distance of the load from the spine caused the size of weight an individual was prepared to lift to reduce proportionally. To satisfy lifting conditions, the horizontal multiplier were determined as

$$HM = {}^{25}/_{H} \quad (2.49)$$

where

H = horizontal distance.

2.13.2 Vertical multiplier (V.M.): Biomechanical studies suggested that lifting loads near the floor can cause a rise in lumbar stress (Waters *et al*., 1993). Other studies based on epidemiology and physiology indicated that lifting from the near floor was related to a high percentage of low back harm. Nevertheless, lifting close to the floor requires considerably more energy than lifting from a higher height. Hence, the rationale behind decreased load weight to lift above 0.75 m from the floor was based on empirical psychophysical studies. It indicated that the worker's maximum acceptable lift weight decreased as the lifting (V) vertical height rose beyond 0.75 m.

where

V = vertical height

$$VM = [1 - 0.003|v - 0.75|] \quad (2.50)$$

2.13.3 Distance multiplier (D.M.): Given Waters *et al*. (1993), for a lift in which the total distance moved was <0.25 m, the physiological expectation did not significantly reduce, and they concluded that the multiplier should be held constant.

where

D = total distance moved

$$DM = \left[0.82 + \left(\frac{4.5}{D}\right)\right] \quad (2.51)$$

2.13.4 Asymmetric multiplier (AM): An asymmetry plane is a vertical plane that meets at the midpoint between ankles and the midpoint between knuckles of asymmetric location. Waters *et al*. (1993); Lee (2005) noted that few studies provided data on the association between asymmetric and maximum acceptable lifting capabilities. The maximum weight reduction and isometric reduction in strength for asymmetric lifting tasks of 90° had been reported to relate to symmetric lifting tasks. An asymmetric multiplier was to reduce the allowable weight of lift by 30% for lifting, including asymmetric twists of 90°.

where

A = angle between sagittal and asymmetry plane.

$$AM = [1 - (0.0032A)] \quad (2.52)$$

2.13.5 Frequency multiplier (F.M.): This was obtained in a given table as the revised NIOSH (1991) equation concluded. The ad-hoc committee on the revised NIOSH lifting equation deduced that frequency multipliers provided closely observed approximation and suggested effects of lifting frequency on acceptable workloads.

2.13.6 Coupling multiplier (CM): Loading with appropriate handles aided lifting and decreased the possibility of the load falling (Waters *et al*., 1993). Also, lifting capacity decreased in tasks involving containers or objects without a suitable holder (Garg and Saxena, 1980; Smith and Jiang, 1984; Drury *et al*., 1989).

where

CM = 1.00, 0.95, and 0.90.

This depends on lift vertical height and couplings standard.

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM \quad (2.53)$$

The present study considers factors such as the lifter's age, weight, spine length, and change in stature, frequency of lift, gender, and workplace temperature to formulate a model and determine the weight that can reduce low back injury for workers lifting manually. The identified selected factors considered in this study were not included in the RWL (NIOSH, 1991) equation. The present study considered six individual characteristic factors and workplace temperature to determine the safe weight of the lift. The present study is a subjective model, while RWL is a task-based model.

Waters *et al*. (1993) noted that the revised NIOSH lifting equation calculated the lifting Index (LI) to evaluate the danger of injury to manual lifting workers caused by load weight or job demands beyond the worker's capacity. In theory, the Lifting Index (LI) value may be adopted as a guide to estimate the percentage of the workforce that may likely risk lifting as related to low back pain.

where

L = actual load weight

RWL = recommended weight limit

LI = lifting Index.

$$LI = \frac{L}{RWL} \tag{2.54}$$

The illustration of non–lifting tasks includes holding, pushing, pulling, carrying, walking, and climbing (Waters *et al*., 1993). For such tasks, worker energy spending and heartbeat rate may be required to assess the metabolic demands of different tasks (Waters *et al*., 1993). The present study's proposed model can be used to determine safe weight lift for manual lifting workers.

Arjmand *et al*. (2015) developed a predictive equation based on the detail of the finite trunk element biomechanical model to estimate spinal load and verify whether the RWL generated L5/S1 load was within 3.40 kN recommended by the NIOSH and 1.00 kN shear force recommended in some studies. Fifty lifting activities were simulated by collecting kinematics data from healthy male subjects (52.00 years, 1.75 m, and 68.40 kg). These lifting tasks were used to determine the horizontal (*H*) and vertical (*V*) distance of handled load concerning inter – feet midpoint needed to estimate the RWL in *vivo* symmetric lifting activities in upright and flexed postures of the male subjects. The estimated RWL generated L5/S1 spine load exceeded the 3.40 kN recommended limits. The researchers observed that the vertical multiplier factor was the possible cause of variations in the RWL equation. Therefore, they recommended a re-evaluation of biomechanical compressive force value and consideration for individual body weight, height, gender, and age in the NIOSH (1991). Due to recent discoveries, the continuous use of the NIOSH (1991) equation to evaluate the risk of lower back pain in manual lifting requires critical consideration. However, in this study, consideration were given to factors observed and identified based on biomechanical, physiological and psychophysical approaches (lifter's weight, age, gender, spine length, stature change, frequency of lift and workplace temperatures) seen to influence safe weight to formulate a model to determine safe weight lift among workers lifting manually without fixing compressive force value.

Barim *et al*. (2019) ascertained the sparse of ergonomic models or equations that incorporated personal characteristics and suggested the addition of factors such as Intervertebral Disc (IVD) cross-sectional area, age, gender, and body mass Index to the revised NIOSH Lifting Equation (RNLE). This advances the NIOSH (1991) lower back injury risk assessment. However, Barim *et al*. (2019) adjusted the RNLE by allowing additional factors and modifying existing multipliers. Novel multipliers considered were age, gender, Body Mass Index (BMI), IVD cross-sectional area (CSA) and coupling multiplier with lower coefficients for non-optimal. Multipliers considered for elimination were vertical, distance, coupling and asymmetry. A surveying case-control procedure was engaged to determine the predictive ability and modified measures of the RNLE. An epidemiological study database that involved large automobile manufacturers was used to validate modifications done to the RNLE. The data were from six automobile plants and comprised 667 manufacturing jobs with 1022 subjects with properly defined lifting activities that met RNLE criteria. The proposed multipliers for RNLE modification were gender (*G*.M.), body mass index (*BMIM*), age (*AGEM*), and an approximation of low back intervertebral disc (IVD) size (*IVDM*) as a scaling factor to adjust risk based on the subject's specific anthropometry. A gender multiplier (*G*.M.) was two-thirds and one for females and males, respectively. The Body Mass Index Multiplier (BMIM) for BMI greater than 30.00 is expressed as

$$BMIM = {}^{30}/_{BMI} \tag{2.55}$$

For BMI less than or equal to 30.00, the BMIM is one.

An age multiplier (*AGEM*) for subjects under age 40.00 years is one, and *AGEM* for an additional yearly age increase from 40.00 years is one decreasing by 0.01 per year.

The modified RWL of the RNLE is given as follows:

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM \times GM \times BMIM \times AGEM \times IVDM \tag{2.56}$$

where

RWL = recommended weight limit

L.C. = load constant

H.M. = horizontal multiplier

V.M. = vertical multiplier

D.M. = distance multiplier

AM = asymmetrical multiplier

CM = coupling multiplier

G.M. = gender multiplier

BMIM = body mass index multiplier

AGEM = age multiplier

IVDM = intervertebral disc multiplier

The analysis showed that among introduced modified factors, the IVDM had the highest impact on the RNLE, while G.M. modestly improved model performance. Hence, by modifying and extending Ismaila's (2006) model in this research, another model was developed to incorporate selected factors that can influence weight to determine the SWL among manual lifting workers.
There were concerns about the suitability of the revised NIOSH (1991) lifting Recommended Weight Limit (RWL) equation applicability to the different racial populations at a temperature above 26°C (Hafez, 1984; Maiti and Ray, 2004; Choi *et al*., 2012) which NIOSH used. The reason is that NIOSH's (1991) lifting equation was developed in an environment where temperatures were between 19 and 26°C. The argument had been that lifting tasks performed at temperatures significantly above 26 °C may likely cause low-back pain to manual lifting workers (Choi *et al*., 2012).

In the research by Choi *et al*. (2012), the revised NIOSH (1991) recommended weight limit equation was adopted to evaluate the data sample and assess the performance of manual lifting in the construction field. To evaluate the situation observed data of the weight of the lifted object, horizontal and vertical hand locations at keys points during the lifting task, frequency of lift, duration of lifting, type of handhold on the lifting object, and angle of twisting were collected at the temperature of 31°C and analysed.

The data were used to calculate Recommended Weight Limit (RWL), the primary product of the revised NIOSH lifting equation (Choi *et al*., 2012). The 146 jobs in 14 different occupational groups were carpenter, ceiling installer, drywall installer, electrician, fitter, floor, finisher, floor tile layer, flooring, insulator, labourer, mason, painter, plumber, and sod layer were studied at 31°C. They reported lifting indices of 1.80, 6.50, 7.30, 0.60, 1.10, 3.20, 1.60, 1.10, 2.70, 3.10, 1.20, 2.50, 2.90, and 4.80, respectively, across the group. Out of all the occupational groups lifting indices, only the electrician group had a lifting Index of less than one. The electrician lifting activities were considered safe compared to other occupational groups with a lifted Index higher than one. Therefore, lifting activities above one lifting index was considered unsafe weight that can cause low back pain. The higher lifting index recorded might have been due to the lifting done outside the temperature between 19 and 26°C used by NIOSH (1991). Therefore, the use of the RWL at a temperature above its stated value to assess the risk of low back injury and recommended weight for manual lifting workers may not be safe. There is a need to develop a model that will consider workplaces' varying temperatures and other observed factors to determine the SWL as it was done in this study.

2.14 Sampling technique

The words subjective, judgemental, purposive, or selective sampling techniques mean the same thing in the literature. Subjective sampling can better match samples to the research aim (Campbell *et al*., 2020). Thereby improving the rigour of the study, data trustworthiness and results. Boocock *et al*. (2020) adopted a subjective sampling approach to divide 28 adult males into two age groups older and younger. Ratu (2020) used the subjective sampling technique to select 19 male brick workers in the study conducted. Maalim (2020) adopted subjective sampling to select the Garissa learning centre as a study locality in Kenya for their research. In this study, the subjective sampling technique was used to select the required number of workers for the validation of the developed model.

2.15 Multiple Linear Regression

Multiple regression allows the estimation of a single dependent continuous variable from a group of independent variables. It predicts the power of a set of variables and assesses the reliable contribution of each variable (Chen, 2016). The multiple linear regression techniques are not one but a family of techniques available to explore the relationship between one continuous dependent variable and the number of independent variables or predictors. It is best to investigate more complex real-life than laboratory-based research questions (Pallant, 2005).

In the standard multiple regression software, all observed selected factors such as worker's age, weight, spine length, frequency of lift, stature change, and varying workplace temperature (independent factors) were entered into the *x*-axis. The SWL (dependent factor) was entered into the *y*-axis of multiple linear regression software applications. Each selected factor, such as worker's spine length, weight, age, frequency of lift, stature change, and temperature (independent factors), was assessed in terms of their analytical power over and above what was offered to SWL (dependent factor). This approach showed how much unique variance selected factors (independent factors) contributed to the SWL (dependent factor) explained.

Chen (2016) conducted research using multiple linear regression involving twelve inexperienced male university students to determine the Maximum Acceptable Weight of Lifts (MAWLs) for polypropylene laminated bags. The twelve male subjects were requested to determine their MAWLs under the following task conditions of three lifting ranges (floor to the knuckle, floor to shoulder, and knuckle to shoulder), three lifting frequencies (one-time maximum, 1lift/min, and 4lifts/min) and two hands conditions (chest circumference and wrist circumference). The result was analysed using multiple regression at a level of significance. It was observed that the MAWL was significantly affected by the frequency of lift and range variables ($p<0.05$), while the hand condition did not influence the MAWL. The percentage of variance was from 43.50 to 83.40%, which accounted for anthropometric data (chest circumference, waist circumference and acromial height) involved in determining the MAWL. The value of MAWL obtained for the infrequent floor-to-knuckle lift was 5.60 kg, knuckle-to-shoulder was 2.40 kg, and floor-to-shoulder was 4.10 kg. The MAWL for frequent lifting from floor to knuckle was 1.10 kg, floor to shoulder was 3.20 kg, and knuckle to shoulder was 2.10 kg. The MAWL for one lift/minute from floor to knuckle was 1.80 kg and floor to shoulder was 2.10 kg. Knuckle to shoulder was 2.50 kg, for one-time maximum from floor to knuckle was 3.70 kg, floor to shoulder was 4.10 kg, knuckle to shoulder was 2.40 kg, at four lifts/minute from floor to knuckle was 1.10 kg, floor to shoulder was 3.20 kg and knuckle to shoulder was 2.10 kg. The factors such as the lifter's age, spine length, stature change, and temperature were not part of the factors considered by the researcher.

In sedentary research conducted to determine the presence of pain in the musculoskeletal system among office workers, a cross-sectional descriptive study was conducted for 528 workers who filled out a questionnaire (Celik et al., 2018). A multiple regression analysis was conducted at the statistical alpha level of 0.05. The average age of workers was 38.55±9.79 years. The female and male had experienced between one and five years as University office workers. 58.50% of female workers had a standard body mass index of 18.50 and 24.90 kg/m^2, while 51.20% of males were overweight with a body mass index of 25.00 and 29.90 kg/m^2. The multiple regression analysis showed that female office workers had no significant relationship with other characteristics and lower back pain complaints ($p>.05$). The factors such as challenging recurrent activity in the workplace and position of the mouse when working on the desk were found to be independently associated with the prevalence of low back pain among male workers. A significant relationship was not found between other characteristics and lower back pain complaints (p>.05) (Celik et al., 2018). This study will use the multiple regression tool to study the significance and investigate the relationship between dependent and independent factors.

2.15.1 Hypothesis Testing in multiple regression

Hypothesis testing allows the determination of the statistical significance of the result in terms of the model and individual independent factors. The significance test of a model is a test to determine whether a linear relationship exist between response and predictor factors.

The Hypothesis (H) can be written as:

$$H_O = \beta_1 = \beta_2 = \beta_3 = \cdots \beta_k = 0 \quad (2.57)$$

$$H_1 = \beta_j \neq 0 \; for \; at \; least \; j = 1 \quad (2.58)$$

The rejection of the null hypothesis (H_1.O.) implies that at least one independent variable contributes significantly to the model. The low level of significance (*p<0.05*) indicates that the null hypothesis (H_2.O.) can be rejected (Pallant, 2005).

2.15.2 Correlation analysis

The correlation is used to interpret specific coefficients to measure the strength and direction of the relationship between two variables (Schober *et al*., 2018).

Table 2.26 shows value ranges and interpretations of the correlation values.

2.16 Analysis of Variance (ANOVA)

Analysis of Variance (ANOVA) was used to validate whether the six-individual selected characteristic factors and environmental temperatures in the developed model are significant or not at an alpha level of 0.05.

2.17 Compare means test

The compare means, also known as t–test is a statistical tool used for comparing the means of two groups, often for hypothesis testing to determine if a process impacted the population of interest or if two groups were different. The compare means statistical test tool was used in this study to compare the existing secondary SWL with the model SWL at an alpha level of 0.05.

Table 2. 26. Interpretation of correlation value

Value Ranges	Interpretation
0.00 – 0.10	Negligible
0.10 – 0.39	Weak
0.40 – 0.69	Moderate
0.70 – 0.89	Strong
0.90 – 1.00	Very strong

Source: Schober *et al*. (2018)

2.18 Research Gap

Low back pain has been acknowledged as a common form of injury among manual lifting workers. Ergonomists have designated it as a workplace concern because of its work-induced health impact on manual lifting workers caused by the inappropriate weight of the lift, which may result in disability and poor quality of life (Hoy *et al*., 2014; Ghezelbash *et al*., 2016). Methods, models and equations have been adopted to reduce low back pain problems by determining the weight that can be lifted without the risk of low backache during manual lifting. Most existing equations and models were task-specific that did not consider personal characteristic factors and workplace-varying temperatures. However, few existing models have introduced personal characteristic factors and temperatures to determine the weight to reduce low back pain challenges. The existing subject-specific model considered parameters that comprised stature change (x), spine length from where thoracic begins to the ends of trunk lumbar vertebrae (L), chest length and width (l_f and l_s). In addition to the subject-specific model were other variables listed as; Young Modulus of elasticity of articular cartilage (E), lifting velocity (u), gravitation acceleration (g), load-vertical position (V), horizontal span from ankles (H), vertical shift (D) and angle of lift (θ) to determine the safe weight to be lifted. The model parameters did not include the lifter's weight, age, gender and workplace temperature.

The NIOSH (1991) considered parameters such as load constant (*LC*), multipliers of horizontal (*HM*), vertical (*VM*), asymmetric (*AM*), coupling (*CM*), distance (*DM*) and frequency (*FM*) to assess load demand for manual lifting workers known as the recommended weight limit. However, the parameters considered in developing NIOSH lifting equations were task-based, also on the American population in the environment where the temperature range was speculated to be between 19 and 26°C. There were concerns about the suitability of using the revised NIOSH (1991) lifting equation of Recommended Weight Limit (RWL) in different racial populations apart from the American population and at a temperature above 26°C (Hafez, 1984; Maiti and Ray, 2004; Choi *et al*., 2012; Afshari *et al*., 2018). The developed revised NIOSH (1991) lifting equation to help evaluate lifting demand for manual lifting workers did not consider a full range of factors involved in manual lifting activities (Alferdaws and Ramadan, 2020). Ahmad and Muzammil (2022) identified the absence of worker characteristics and environmental conditions in the revised NIOSH lifting equation as a limitation for its present adoptability. Lifting limits were not generalised for different races and genders (Sheppard *et al.*, 2016; Plamondon *et al.*, 2019; Hung *et al.*, 2020). Factors that affect weight lift recommendation include the lifter's weight, age and gender (Arjmand *et al*., 2015; Barim *et al*., 2019). Hidalgo *et al*. (1997) suggested that the NIOSH (1991) did not include gender in their Recommended Weight Limit (RWL) because of the existing American legislation that recommended gender equality and equal occupation chance for both capacitated and incapacitated American workers. However, significant differences have been found between male and female manual lifting workers (Sheppard *et al*., 2016; Barim *et al*., 2019; Plamondon *et al*., 2019). In the present study, consideration is given to workers' age, gender (male), and other observed factors to develop a model to determine the safe weight of the lift.

An equation to determine Lifting Capacity (*LC*) developed by Stambough *et al*. (1995) for manual lifting workers considered parameters such as weight base (W_B) as the total load acceptable to the various percentage of the working populace. The distance from the body to the middle of the ankles was taken as a horizontal distance multiplier (*H*). The multiplier for vertical distance (*V*) was the distance from the floor to the hands at the origin of the lift. The vertical travel distance (*D*) multiplier was the distance between the source and destination of the hands of the lift. The frequency of lifts *F* and *TD* as task duration were multipliers. *T* represents the trunk twisting angle multiplier, and C represents the coupling factor multiplier. The heat stress (*HS*) multiplier, *AG*, was the age group multiplier. *BW* represented the bodyweight multiplier. Despite the number of parameters considered, some factors were not included, such as individual workers' gender, weight and age, were considered in this present study to compute the SWL that may reduce low back injuries for manual lifting workers.

Stambough *et al*. (1995) equation was modified and extended by Hidalgo *et al*. (1997) to develop another equation to determine the base weight that can be lifted by manual lifting workers when Load Capacity (LC) was known. The developed model in this study determined the safe weight to lift without including any known load weight or lifting capacity value but considered data of individual characteristic observed and selected factors (body weight, total disc length, age, gender, spinal shrinkage, frequency of lift and varying temperatures).

Barim *et al*. (2019) modified the revised NIOSH equation (RNLE) to include new factors of gender, body mass index, age, and intervertebral disc (IVD) size as multiplier factors to regulate low back risk based on the subject's specific anthropometry. The effects of temperatures between 19 and 26°C on the modified RNLE were neither discussed nor investigated. Other factors that were considered in this present research different from Barim *et al*. (2019) include stature change, spine length, body weight and temperature.

The summary of various factors considered in the literature was compared with this present study factors and was presented in Appendix 1. This showed different factors that had been considered by indicating yes or no. Yes, indicated factors considered, and No, for those not considered. Out of the twenty-two different authors identified, 12 authors did not consider age, 17 authors did not consider lift frequency, 18 authors did not consider gender, 19 authors did not consider spine length, 19 authors did not consider spinal shrinkage, 20 authors did not consider temperature, and 20 authors did not consider body weight. None of the cited authors considered the factors in this present study together as were done in this research.

The present study aims at developing a SWL with varying Temperatures (SWLwT) model by considering six personal factors (body weight, total disc length, age, gender, spinal shrinkage, and lift frequency) and workplace temperature based on strain energy principle to determine the SWLs.
Table 2.27 shows the authors' names, contributions and existing research gaps in the cited literature.

Table 2. 27. Contributions and research gaps

Author's name and year	Contributions	Research gaps
Hafez (1984)	A study was conducted to assess the lifting capacity of an individual in a hot environment at 22, 27 and 32°C, with lifting frequencies of 1.00, 3.00 and 6.00 lifts/minute. It was observed that the weights selected were 25.34, 15.49 and 13.06 kg at 22 and 27°C. These significantly differed from the weight selected (23.41, 12.54 and 10.19 kg) at 32°C.	Two factors (temperature and frequency) of lifts were considered to assess the lifting capacity of manual lifting workers. This present study considered six factors (worker's weight, height, gender, spine length, stature change, frequency of lift) and workplace temperature to determine the safe weight of the lift.
Ismaila (2006)	The study developed model considered factors such as stature change (*x*), spine length from where thoracic begins to the ends of trunk lumbar vertebrae (*L*), chest length and width (l_f and l_s). Other variables in the model included were Young Modulus of elasticity of articular cartilage (*E*), lifting velocity (*u*), gravitation acceleration (*g*), load-vertical position (*V*), horizontal span from ankles (*H*), vertical shift (*D*) and angle of lift (θ) to determine the safe weight to be lifted.	The model parameters did not consider lifter's weight (m_b), age (AG), gender (GN) and workplace temperature (TF).
Kjellstrom *et. al*. (2009)	The proportion of working days in which workers can withstand work and period of the same working day in hours workers needed to rest, cool, and keep their body down at core temperature below 38°C using Wet Bulb Globe Temperature (WGBT) were assessed. They found that work capacity reduced as the WGBT exceeded 26 and 30°C.	The model was not developed to determine the weight load to be lifted, as were done in this research. Workplace temperature is one of the factors considered to develop a safe weight of lift with varying temperature (SWLwT) model to determine the safe weight of the lift.
Ghezelbash *et al*. (2016)	They studied the influence of subject-specific parameters (age, gender, body height and weight) on spinal loads and the risk of back disorders. They simulated five tasks. They found that body weight had the highest effect, followed by gender, height, and age.	The observed and identified factors influencing the SWL are age, gender (gender), body height and weight. These were considered to develop a model to compute the SWL. Other factors include spine length, stature change, frequency of lifts and workplace temperature.
Antwi-Afari *et al*. (2017)	They used mixed model repeated measures analysis of variance. They found that there was a significant increase ($p<0.05$) in lower back pain (L3) in lifting weights between 7.10 and 17.80 kg but lifting postures had no significant effect on the spinal load.	A safe weight to be lifted that will not cause low back pain was not determined. The present research objectives include determining the safe weight to reduce low back pain problems by considering six personal characteristics and workplace temperature.
Afshari *et al*. (2018)	They investigated the accuracy of the maximal allowable weight of 32.00 kg for Iranian workers recommended by the American Conference of Governmental Hygienist Threshold Limit Values (ACGIHLTVs) to predict the risk of low	The present study considered factors observed to influence the SWL to develop a model to determine the safe weight to be lifted among manual lifting workers in Ibadan, Oyo state. It will avoid over-

	back pain (LBP). Data to estimate spinal loading were collected with an inclinometer and photographic camera. The CGIHLTVs were found to overestimate the safety of Iranian manual lifting workers. It was attributed to differences in anthropometry between North Americans and Iranians.	dependence on the foreign model not developed based on Nigeria's manual lifting workers' environment, anthropometrics and body weight.
Barim *et al.* (2019)	They explored the possibility of adding personal characteristic factors such as estimated L5/S1 Intervertebral Disc (IVD) cross-sectional area, age, gender and body mass index to improve the Revised NIOSH lifting equation (RNLE) risk assessment.	Personal characteristic factors of spine length, stature change, and workplace temperature were just added to the RNLE. The present study is not just adding the identified factors influencing the SWL but developing a model using the strain energy principle and determining the safe weight of the lift.
Kudo *et al.* (2019)	They predicted different compressive forces based on the age of the workers. Sample size 85, 129 and 106 for age groups, such as between 20.00 and 30.00, 40.00 and 59.00, 60.00 and 79.00 years, had the compressive force of 3.72, 2.98 and 2.03 kN, respectively.	The only factor considered was the worker's age to observe different rates of compressive force values for the different age groups. Workers' age and other factors were considered to develop a model to calculate the safe weight of lift in the present study.
Hung *et al.* (2020)	They predicted different disc compression forces for males (3.00 kN) and females (2.80 kN) instead of the Revised NIOSH lifting equation (RNLE) of 3.40 kN for both genders. They observed that recommended weight limit should not be generalised across different races and gender.	Estimation was only given about disc compression force but recommended safe weight was not determined. Therefore, gender is one of the factors considered to develop a model, to determine the SWL in the present study.
Firouzabadi *et al.* (2021)	They developed a gender-specific model to estimate lumbar spinal and muscle forces during static, manual material handling the task of 10.00 kg. They ascertained that lack of consideration for gender in developing a safe weight lift model could lead to overestimating load weight for male and female manual lifting workers.	Gender is one of the factors considered in the present study to compute the SWL for manual lifting workers.
Al-Meanazel *et al.* (2021)	The human physical characteristic and task requirements were considered in developing a Digital Human Model (DHM). The simulated experimental effects of evaluated boxes of weights of 10.00, 15.00 and 20.00 kg, gender (male or female), percentile (5th, 50th and 95th), and postures (standing or sitting) involving compression force on lower back L4/L5 and tension stress on Latissimus Dorsi. A distinct difference was found in muscle tension between males and females.	A multiplier factor for the lifting capability of genders (male) were considered to formulate a SWL model to determine the SWL in the present study.

Ahmad and Muzammil (2022)	They identified an absence of worker characteristics such as age, gender, weight, BMI, ethnicity, anthropometry and environmental condition in the revised NIOSH lifting equation as limitations for its present adoptability.	In the present study, a safe weight lift with varying temperatures was developed to include workers' characteristics such as age, gender, stature change, spine length, weight, frequency of lifts and workplace varying temperature.
Mohapatra *et al.* (2022)	A lifting capacity prediction model was developed using stepwise multiple regression based on workers' muscles and endurance. Age, BMI, endurance, core and grip strength, and lower limb flexibility were considered. The factors considered were grouped into physical performance characteristics (endurance, core and grip strength, and lower limb flexibility) and socio-demographics (age and BMI).	The factors such as spine length, the weight of the body, change in stature and temperature were not part of the factors considered. The researchers did not consider body weight as they observed that body weight is directly related to BMI. These and other factors were considered in this present study. They can be grouped into physical performance characteristics (change in stature, frequency of lifts and temperature), socio-demographic (gender and gender) and personal characteristic (spine length and body weight).
Tang *et al.* (2022)	The researchers found that differences in age, gender, medical and LBP history contributed to worker productivity loss. A particular model was not developed.	A SWL with varying temperature model that considered age and gender, among other factors, to determine SWL that may reduce low back pain (LBP) problem were developed in this present study.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Existing model for the safe weight of the lift

There are 33 discs in the human spine, which is divided into seven in the cervical region, twelve in the thoracic region and five each in the lumbar and sacral and four in the caudal region. However, modelling the human spine in a spring-like behaviour to develop the model to determine the safe weight of the lift, the seventeen discs between the last cervical and lumbar vertebrae of the human spine were considered (Ismaila, 2006; Khotimah *et al*., 2011). Therefore, the lifter must exert a force more than the weight load lifted for any lifting to be done. The force applied will produce strain felt at the joints (weakest points of the human skeletal structure) (Ismaila, 2006; Daniels and Hoffman, 2011). Among such joints is the interface between vertebrae where cartilaginous tissue exists. A force equation can be developed to model the human spine like a spring.

where

φ_i= strain energy (SE)

F_i= force on the spine

k_i= force constant of the load

τ_i= represents a single disc of the spine connected in series

i = 1…………….N

N = total disc number from first thoracic to end of the lumbar spine

A non–linear spring was assumed for each disc of the human spine.

Ismaila (2006); Khotimah *et al*. (2011) expressed strain energy as:

$$\varphi_i = \int_0^{\tau_i} F_i \, d\tau_i \tag{3.1}$$

Force deflection law is expressed as:

$$F_i = k_i \tau_i \tag{3.2}$$

Figure 3.1 shows the anatomy of back, vertebral column.

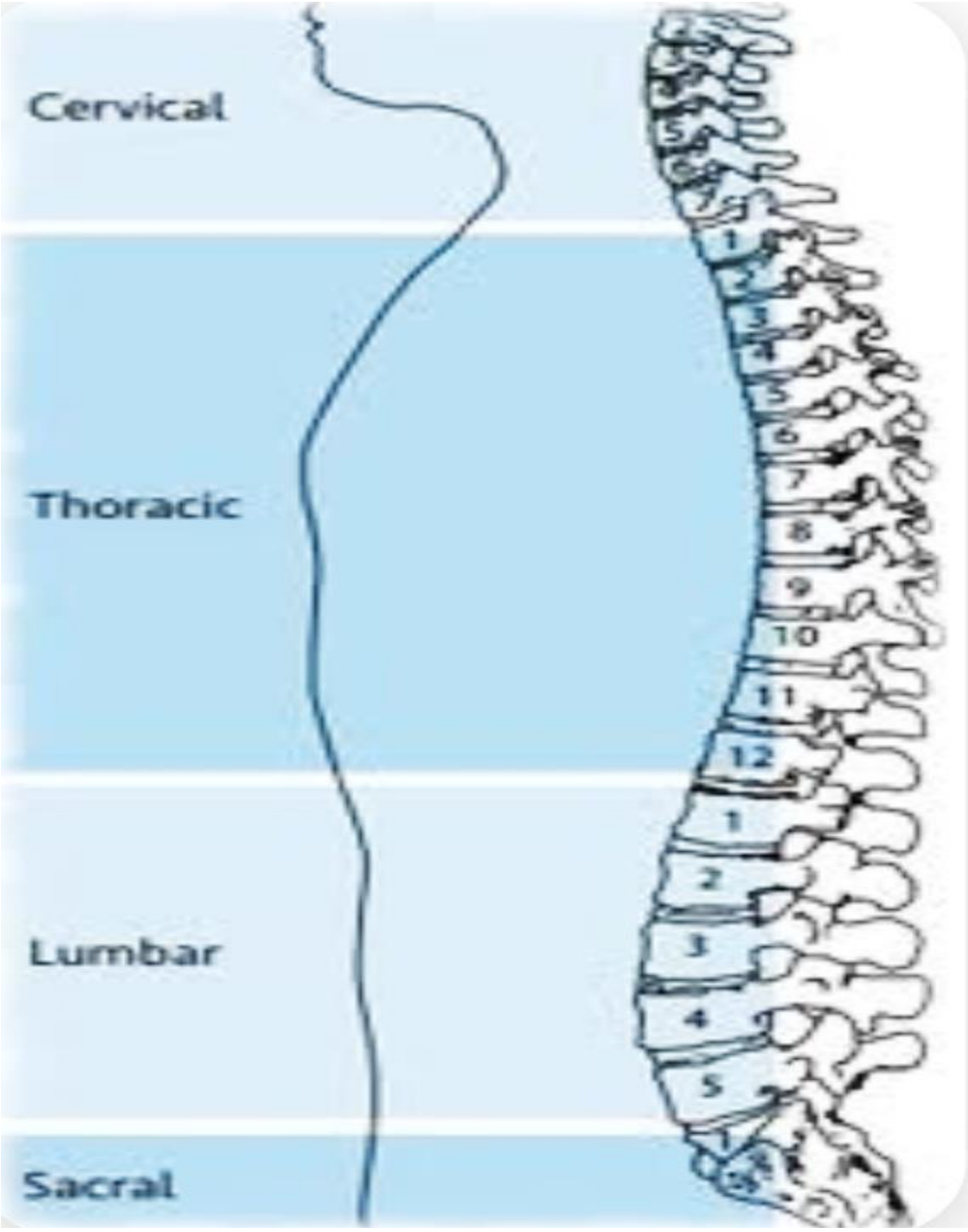

Figure 3. 1. Human spine structure
Source: Desai *et al*. (2023)

Substituting (3.2) into (3.1) gives:

$$\varphi_i = \int_0^{\tau_i} k_i \tau_i \, d\tau_i \qquad (3.3)$$

Integrating (3.3) gives:

$$\varphi_i = \frac{k_i \tau_i^2}{2} \qquad (3.4)$$

Eq. (3.2) gives:

$$k_i = \frac{F_i}{\tau_i} \qquad (3.5)$$

Substituting (3.5) into (3.4) gives:

$$\varphi_i = \frac{F_i \tau_i}{2} \qquad (3.6)$$

There were seventeen discs and end plates from the beginning of the cervical to the end of the lumbar vertebrae. Each behaves like a spring (Ismaila, 2006; Daniels and Hoffman, 2011; Ismaila and Charles – Owaba, 2012).

The sum of strain energies expected on the human back is expressed as:

$$\varphi_T = \sum_{i=1}^{17} \varphi_i = \sum_{i=1}^{17} \frac{F_i \tau_i}{2} \qquad (3.7)$$

Where

F_i = compressing force acting on the spinal disc.

L = disc length

x = stature change

ΔL = change in length

$$\Delta L = x \qquad (3.8)$$

$$F_i = F_1 = F_2 = F_3 \ldots \ldots . = F_{17} = F \qquad (3.9)$$

(Marshek, 1987; Ismaila, 2006; Ismaila and Charles – Owaba, 2012; Jiemjai *et al.*, 2014).

$$L = \tau_1 + \tau_2 + \tau_3 + \cdots .. + \tau_{17} \qquad (3.10)$$

The spine strain energy is expressed as:

$$\varphi_i = \frac{Fx}{2} \qquad (3.11)$$

$$S.E = \frac{1}{2} Fx \qquad (3.12)$$

A rigidity measurement (a material property) called spring constant (k) allows for an axial force (F) which did not tension the material (spine) (L) beyond the elastic range (Marshek, 1987; Ismaila, 2006; Khotimah *et al*., 2011).

Assuming the spine behaves like spring, therefore, relating spring constant (k) to the spine.

$$k = \frac{F}{x} = \frac{AE}{L} \qquad (3.13)$$

where

A = cross-sectional area

E = Young ModulusModulus of elasticity

L = length of the spine involved

l_f = chest length

l_s = chest width

π = 3.14

Elliptical Truncal Area (Marshek, 1987; Ismaila, 2006) is expressed as.

$$A = \frac{\pi l_f l_s}{4} \qquad (3.14)$$

where

SE = Strain Energy

$P.E_T$ = sum of potential energy

$K.E_T$ = sum of kinetic energy

F = force on the spine

D = vertical displacement of the load

V = vertical location of the load

m_T = total mass

u = velocity of lift

g = gravitation acceleration

H = horizontal length of the load from the ankle.

θ = angle between hip and thigh during lifting.

$$S.E = \frac{1}{2}Fx \qquad (3.15)$$

$$K.E_T = \frac{1}{2}m_T u^2 \qquad (3.16)$$

$$P.E_T = m_T g(D + V) \qquad (3.17)$$

Eq. (3.13) gives:

$$k = F = \frac{AEx}{L} \qquad (3.18)$$

Substituting (3.18) into (3.15) gives:

$$SE = \frac{AEx^2}{2L} \tag{3.19}$$

Resolving the force along the spinal column, the potential energy is expressed as:

$$P.E_T = \frac{m_T g(D+V)}{sin\theta} \tag{3.20}$$

and

$$Tan\,\theta = \left(\frac{D+V}{H}\right) \tag{3.21}$$

Adopting the principle of conservation of energy, total strain energy is the sum of potential and kinetic energy.

$$SE = PE + KE \tag{3.22}$$

The total strain energy due to lifting and upper body weight is the sum of the upper body and weight of the lift.

where

$S.E_T$ = total strain energy

$S.E_l$ = weight of lift strain energy

$S.E_b$= strain energy of the upper body

m_b = upper body weight

m_l = lifted weight

m_T = sum of the upper body and lifted weight.

$$S.E_T = S.E_b + S.E_l \tag{3.23}$$

$$S.E_T = P.E_T + K.E_T \tag{3.24}$$

$$m_T = m_b + m_l \tag{3.25}$$

Substituting (3.16) and (3.20) into (3.24) gives:

$$S.E_T = \frac{m_T g(D+V)}{sin\theta} + \frac{1}{2} m_T u^2 \tag{3.26}$$

Substituting (3.25) into (3.26) gives:

$$S.E_T = \left[\frac{(m_l + m_b)g(D+V)}{sin\theta} + \frac{(m_l + m_b)u^2}{2}\right] \tag{3.27}$$

The strain energy due to the body $S.E_b$ can be expressed as:

$$S.E_b = \frac{m_b g(D+V)}{sin\theta} + \frac{m_b u^2}{2} \tag{3.28}$$

Making $S.E_l$ subject (3.23) gives:

$$S.E_l = S.E_T - S.E_b \tag{3.29}$$

Substituting (3.27) and (3.28) into (3.29) gives:

$$S.E_l = \left[\frac{(m_l + m_b)g(D+V)}{sin\theta} + \frac{(m_l + m_b)u^2}{2}\right] - \left[\frac{m_b g(D+V)}{sin\theta} + \frac{m_b u^2}{2}\right] \quad (3.30)$$

Expanding and subtracting (3.30) gives:

$$S.E_l = \frac{m_l g(D+V)}{sin\theta} + \frac{m_l u^2}{2} \quad (3.31)$$

Therefore (3.19) and (3.31) yield:

$$\frac{AEx^2}{2L} = \frac{m_l g(D+V)}{sin\theta} + \frac{m_l u^2}{2} \quad (3.32)$$

Factorising (3.32) gives:

$$m_l\left[\frac{2g(D+V) + u^2 sin\theta}{2sin\theta}\right] = \frac{AEx^2}{2L} \quad (3.33)$$

Cross multiplying (3.33) gives:

$$m_l L\left[\frac{4g(D+V) + 2u^2 sin\theta}{2sin\theta}\right] = AEx^2 \quad (3.34)$$

Multiplying (3.34) LHS and RHS with $2sin\theta$ gives:

$$m_l L[4g(D+V) + 2u^2 sin\theta] = 2AEx^2 sin\theta \quad (3.35)$$

Trigonometric rule is expressed as:

$$tan\theta = \frac{sin\theta}{cos\theta} \quad (3.36)$$

Cross multiplying (3.36) gives:

$$sin\theta = tan\theta cos\theta \quad (3.37)$$

Substituting (3.21) into (3.37) gives:

$$sin\theta = \left(\frac{D+V}{H}\right) cos\theta \quad (3.38)$$

Substituting (3.38) into (3.35) and making m_l subject gives:

$$m_l = \frac{\pi l_f l_s x^2}{4L}\left[\frac{E\left\{\frac{D+V}{H}\right\} cos\theta}{2gD + u^2\left\{\frac{D+V}{H}\right\} cos\theta}\right] \quad (3.39)$$

Equation 3.39 is the model developed by Ismaila (2006) with parameters that include stature change (*x*), spine length from the beginning of thoracic to lumbar end of the backbone (*L*), chest length (l_f) and width (l_s). Other factors included were Young Modulus of elasticity of articular cartilage (*E*), lifting speed (*u*), acceleration due to gravity (*g*), load-vertical position (*V*) and horizontal length from ankles (*H*), vertical displacement of load (*D*) and angle of lift (θ) to compute safe weight to be lifted.

However, parameters such as worker's age, body weight, gender and workplace temperature were not considered in the Ismaila (2006) model. These were considered in the present research developed model.

3.2 Model development

The developed model is based on the conceptual and theoretical review of the existing literature and the principle of strain energy. The personal characteristic factors considered in the present model development were the lifter's weight, length of the spine, age, gender, frequency of lift, spinal shrinkage and workplace varying temperatures. The deformation of the physical body is caused by strain energy.

From (3.23), making $S.E_b$ subject gives:

$$S.E_b = S.E_T - S.E_l \quad (3.40)$$

Substituting (3.26) and (3.31) into (3.40) gives:

$$S.E_b = \left[\frac{m_T g(D+V)}{sin\theta} + \frac{1}{2}m_T u^2\right] - \left[\frac{m_l g(D+V)}{sin\theta} + \frac{1}{2}m_l u^2\right] \quad (3.41)$$

Substituting (3.25) into (3.41) gives:

$$S.E_b = \left[\frac{(m_l + m_b)g(D+V)}{sin\theta} + \frac{(m_l + m_b)u^2}{2}\right] - \left[\frac{m_l g(D+V)}{sin\theta} + \frac{m_l u^2}{2}\right] \quad (3.42)$$

Expanding and subtracting (3.42) gives:

$$S.E_b = \frac{m_b g(D+V)}{sin\theta} + \frac{m_b u^2}{2} \quad (3.43)$$

A rigidity measurement (a material property) called spring constant (k) exists for an axial force (F) that did not tension the material (spine) L when at rest (Jorgen, 1986).

where

A = cross-sectional area

E = Young Modulus of elasticity

L = length of spine involved (morning measurement)

ΔL = length of spine involved (evening measurement)

Since the spine is not tensioned:

$$\Delta L = L \quad (3.44)$$

$$k = \frac{F}{\Delta L} = \frac{F}{L} = \frac{AE}{L} \quad (3.45)$$

Therefore,

$$k = F = AE \quad (3.46)$$

Body strain energy is expressed as:

$$S.E = \frac{1}{2}Fx \tag{3.47}$$

Substituting (3.46) into (3.47) gives:

$$S.E = \frac{AEx}{2} \tag{3.48}$$

Therefore (3.43) and (3.48) yield:

$$\frac{m_b g(D+V)}{sin\theta} + \frac{m_b u^2}{2} = \frac{AEx}{2} \tag{3.49}$$

Factorising m_b (3.49) gives:

$$m_b\left[\frac{g(D+V)}{sin\theta} + \frac{u^2}{2}\right] = \frac{AEx}{2} \tag{3.50}$$

Cross multiplying and rearranging (3.50) gives:

$$\frac{2m_b}{x} = \frac{2AEsin\theta}{[2g(D+V) + u^2 sin\theta]} \tag{3.51}$$

Multiplying (3.51) with $^1/_2$ gives:

$$\frac{m_b}{x} = \frac{AEsin\theta}{[2g(D+V) + u^2 sin\theta]} \tag{3.52}$$

Substituting (3.38) into (3.52) gives:

$$\frac{m_b}{x} = \frac{AE\left(\frac{(D+V)}{H}\right)cos\theta}{\left[2g(D+V) + u^2\left(\frac{(D+V)}{H}\right)cos\theta\right]} \tag{3.53}$$

Substituting (3.14) into (3.53) gives:

$$\frac{m_b}{x} = \frac{\pi l_f l_s E\left(\frac{(D+V)}{H}\right)cos\theta}{4\left[2gD + u^2\left(\frac{(D+V)}{H}\right)cos\theta\right]} \tag{3.54}$$

The RHS (3.54) were part of the factors considered in Ismaila's (2006) model (3.39). The LHS (3.54) was substituted into RHS (3.39).

Therefore (3.39) and (3.54) give:

$$m_l = \frac{x^2}{L} \times \frac{m_b}{x} \tag{3.55}$$

where

x = stature change

m_b = worker's weight

L = worker's spine length

m_l = load weight only.

Eq. (3.55) is expressed as:

$$m_l = \frac{x}{L} \times m_b \tag{3.56}$$

$$m_l = SWLwT \tag{3.57}$$

From (3.57)

$$SWLwT = \frac{x}{L} \times m_b \tag{3.58}$$

3.3 The model individual characteristic selection

Equation 3.58 is the biomechanical outcome of the developed model comprising spinal shrinkage (x), body weight (m_b) and spine length (L). Other selected factors, such as age (AG) and gender (GN), were based on physiological, while temperature (TF) and frequency (FM) were based on the psychophysical of the manual lifting workers.

3.4 Developed model and other factors

Multiplying (3.58) LHS with multiplier factors gives:

$$SWLwT \times AG \times TF \times GN \times FM = x \times \frac{m_b}{L} \tag{3.59}$$

Therefore,

$$SWLwT = x \times \frac{m_b}{L \times AG \times TF \times GN \times FM} \tag{3.60}$$

Equation 3.60 is the SWL with varying Temperature ($SWLwT$) model developed to compute the SWL that may reduce low back injuries for manual lifting workers.

where

x = stature change

m_b = lifter's weight

L = lifter's spine length

AG = age factor

TF = temperature factor

FM = frequency of lift factor

GN = gender factor.

The manual lifting capability of gender is 0.56 for females and 0.72 for males, as seen in Chapla (2004); Hamid and Tamrin (2016). The stature change (x), lifter's weight (m_b), spine length (L), age (AG), gender (GN), temperature (TF) and frequency of lift (FM) were independent factors. The model-dependent factor is the safe Weight of Lift with varying Temperatures ($SWLwT$).

Stambough *et al*. (1995). Hidalgo *et al*. (1997) lifting models were based on a multiplicative approach to determine Load Capacity (*LC*) by multiplying the base weight with six-factor multipliers. The revised National Institute for Occupational Safety and Health (NIOSH, 1991) model was based on the multiplicative approach to determine Recommended Weight Limit (RWL) by multiplying Load Constant (*LC*) with six-factor multipliers. Barim *et al*. (2019) modified the revised NIOSH lifting equation (RNLE) based on a multiplicative approach to determine the RWL. International Standards Organization (ISO) formulated model was based on a multiplicative approach. It was published as ISO standard 11228 (ISO 11228-1, 2003). A European Norm (EN) was published as Part 2 of European standard 1005 (BS EN 1005-2, 2003). These were based on multiplicative approaches. The factor multipliers of age (AG), temperature (TF), frequency of lift (FM) and gender (GN) found in the literature were adopted in this present study. This was done to maintain the original distribution of findings reported by the researchers, based on their experimental findings and for easy incorporation of future data without disrupting the structure of the developed model.

Table 3.1 shows age factor multipliers for males and females according to manual lifting workers' age (years).
Table 3.2 shows the frequency of lift (lifts/min) with the corresponding multiplier values for both male and female manual lifting workers.
Table 3.3 shows the temperature (°C) with the corresponding multiplier value of the recorded temperature.

3.5 Determining the safe weight of the lift

Equation 3.60 is the model developed to calculate the SWL that may not cause low back injury for manual lifting workers at Arulogun, Ibadan, Oyo state, Nigeria, by considering the six individual selected characteristic factors and varying workplace temperatures.

3.6 Developed Model Assumption

1. Male manual lifting worker spine behaves like a spring
2. Male manual lifting worker spinal shrinkage and body weight are the most important factors of determining safe weight of the lift.
3. Spring constant (k) existed for an axial force (F) did not tension the material (spine) L when at rest.

4. None of the selected male bricklayers were under any drug influencer while lifting the sandcrete blocks.

5. Selected male bricklayers were healthy.

3.6 Developed Model Limitation

1. No male manual worker above 60 years old would engaged in manual lifting.
2. No male manual worker frequency of lift aboved 16 lifts/minute.
3. No male manual worker would involve in lifting at temperature beyond 40℃

3.7 Require research equipment

1. Digital Extech RH/temperature pen *445580* to measure workplace temperature.
2. Surgilac model ZT-160 to measure worker's height and weight
3. A clock timer is used to aid in recording the observed frequency of lifts performed by the workers during manual lifting.
4. Measuring tape to measure spine length.

3.7 Sampling technique

In this study, a subjective sampling technique was used to select 50 experienced male bricklayers who were not experiencing musculoskeletal disorder and were lifting between 20.00 and 22.50 kg sandcrete blocks for 8 hours daily at Arulogun, Akinyele L.G.A., Ibadan, participated in this study.

3.8 Measurement procedure

The workers were asked to remove shoes, hats, and any other attachments to the extent possible. They were made to stand on a stadiometer footplate of surgilac model ZT-160 with their back against the stadiometer ruler. It has been reported that a stadiometer is an instrument with precision to determine the change in human stature (Yar, 2008). Rodacki *et al*. (2005) used factory-fabricated, while Ismaila (2006) used a locally fabricated stadiometer to determine stature change. Ismaila (2017) reverted to ZT-160 stadiometer for measurement. The scale of the surgilac model ZT-160 weight–height measuring instrument consisted of round tubes of three different calibrations. The outer tube is firmly secured into the dial column. The middle and inner tubes were firmly placed in each other and had metric and British units.

Table 3. 1. Age factor multiplier

Age (year)	Male	Female
20.00	1.00	1.00
25.00	0.91	0.95
30.00	0.88	0.90
35.00	0.88	0.87
40.00	0.86	0.82
45.00	0.78	0.79
50.00	0.69	0.72
55.00	0.62	0.64
60.00	0.59	0.49

Source: Stambough *et al*. (1995); Hidalgo *et al*. (1997)

Table 3. 2. Frequency factor multiplier

Frequency (lifts/min)	Male	Female
1.00	0.95	0.91
2.00	0.89	0.87
3.00	0.83	0.84
4.00	0.78	0.80
5.00	0.73	0.77
6.00	0.69	0.74
7.00	0.65	0.70
8.00	0.62	0.68
9.00	0.59	0.66
10.00	0.56	0.65
11.00	0.54	0.64
12.00	0.52	0.63
13.00	0.50	0.63
14.00	0.49	0.62
15.00	0.47	0.61
16.00	0.46	0.60

Source: Stambough *et al*. (1995); Hidalgo *et al*. (1997)

Table 3. 3. Temperature factor multiplier

Temperature °C	Multiplier
19.00 – 27.00	1.00
28.00	0.98
29.00	0.95
30.00	0.93
31.00	0.90
32.00	0.88
33.00	0.86
34.00	0.83
35.00	0.81
36.00	0.78
37.00	0.76
38.00	0.74
39.00	0.71
40.00	0.69

Source: Stambough *et al*. (1995); Hidalgo *et al*. (1997)

A movable headpiece on top of the inner tube has a standard measuring unit and can be pulled out at a right angle before use. The height of the male manual workers were measured using the ZT-160 scale. We make sure that the workers had their legs together and straight, arms by their flanks, and shoulders relaxed, and we ensured that the rear of the male manual workers' body make contact with the stadiometer while the heels, bottoms, upper back and head touched the measuring surface with their body in a straight line. We ensured that male manual worker's head was properly positioned (Frankfurt plane) before we took height and weight measurements. We measured male manual workers' heights twice in the morning/evening, and the average was found before the start of the day's work and after the day's work in an 8-hour daily job. The lifting activities after morning measurement were not standardised (this was to make the experiment more realistic and allow subjects to freely express themselves without restriction, thereby giving first–hand field data results). The lifting was done based on the self-pace of each subject and not at a fixed pace. The differences in the average morning and evening height measurements were taken as stature change values and recorded as x (metre). The worker's weight m_b (kilogram) was taken using the same surgilac model ZT-160 equipment, a weigh-height machine built with high accuracy and sensitivity (Yar, 2008). Its load-carrying installation comprised the lever mechanism, knife edges, and bearings. Also, the board allowed for stability, accuracy and durability. The board was protected with a rubber sheet to prevent slipping and offer shockproof to the internal mechanism. It had a self-indicating dial equipped with ease of reading, indicating accurate weight in metric. The British system uses a dial connected to a lever mechanism using gears and a coiled spring. Before and after use, we set the pointer to point at zero position by turning the screw under the dial. The male worker's spine length (metre) was taken twice, and the average was found with measuring tape from the beginning of the thoracic to the lumbar end of the worker's spine as precisely as possible.

Extech RH/temperature pen *445580* was used to measure workplace temperature (*TF*). The frequency of lift (*FM*) was recorded by observing several lifts performed by male manual lifting workers, and the record was taken with a clock timer. We obtained age (years) from the subjects, the corresponding age factor multiplier (*AG*) was obtained from Table 3.1, and the gender (Male) corresponding gender factor multiplier (*GN*) was taken as 0.72 for male manual lifting workers. The temperature (degree Celsius) and frequency (lifts per minute) corresponding factor multiplier values were obtained from Table 3.2 and 3.3, respectively.

Safe Weight of Lift with varying Temperature (SWLwT) as the dependent variable was computed while stature change (*x*), lifter's weight (m_b), spine length (*L*), age, gender, frequency of lift and workplace varying temperatures were independent factors.

3.9 Developed model validation by determining relationship between the selected factors and the safe weight of the lift model

The relationship of the independent, two-way and mutual interaction of six-individual characteristics of the observed selected factors (workers' age, spine length, spinal shrinkage, weight, lifts frequency and workplace temperatures) on the SWL were analysed using multiple linear regression (MLR) at the alpha level of 0.05.

The observed selected personal factors such as body weight, length of the spine, age, stature change, lift frequency, and varying workplace temperature of the fifty experienced male bricklayers were the independent factors. Safe Weight of Lift with varying Temperatures (SWLwT) is the dependent factor. The six selected independent male bricklayer characteristic factors were inputted into the *x*-axis and the dependent factor into the *y*-axis of multiple regression application in the SPSSv16 to determine the significance, relationship, strength and direction between independent and dependent factors. The R-square (coefficient of determination) indicated how much unique variance the selected factors contributed to the developed SWL model. The Beta (β) is the standardised coefficient that explains the strength and direction of the relationship between the selected factors (independent factors) and SWLwT (dependent factor), and B is the unstandardised coefficient factor. These were analysed at a significance alpha level of 0.05.

3.9.1 Hypothesis Testing in multiple regression

The hypothesis testing allowed for determining the statistical significance of each independent factor in the model. The test of significance of the model was a test to determine whether a linear relationship existed between independent factors and response variable (dependent) Safe Weight of Lift with varying Temperature (*SWLwT*).

3.9.2 Correlation analysis

Correlation is used to determine the strength and direction of the relationship between two factors by interpreting specific coefficients as a measure of the strength and direction of the relationship (Schober *et al.*, 2018).

Table 3.4 shows value ranges and interpretation of correlation values.

3.10 Descriptive Statistics

The sample size minimum, maximum, mean and standard deviation and the range values of the selected six-individual characteristic factors and varying temperatures were determined using SPSSv16, Microsoft Excel and presented graphically.

3.11 Validation studies

The developed model validations were carried out using Analysis of Variance (ANOVA) to study variations in the selected factors and T-test at an alpha level of 0.05.

3.12 Model comparison procedure

The compare means test, also known as t–test at the alpha level of 0.05, was used in comparing selected existing secondary and model SWL data at the same temperature.

Table 3. 4. Interpretation of correlation value

Value Ranges	Interpretation
0.00 – 0.10	Negligible
0.10 – 0.39	Weak
0.40 – 0.69	Moderate
0.70 – 0.89	Strong
0.90 – 1.00	Very strong

Source: Schober *et al*. (2018)

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Formulated safe weight of lift model

The comprehensive Lifting Model (CLM) developed by Stambough *et al.* (1995) was based on the conceptual approach of Drury and Pfeil (1975). It was done to allow the model to be based on findings generated in the literature. To avoid making any different assumptions on the distribution of factor multipliers of the considered factors such as base weight, horizontal and vertical travel distances, lifts frequency, period of the task, backbone twisting angle, coupling factor, heat stress, age group and body weight. Therefore maintaining the original distribution of the factor multipliers reported by the researchers in their experimental results was necessary. It allowed for the ease of incorporating factor multipliers into the developed model without disrupting the structure of the model.

The SWL with varying Temperature model incorporated individual characteristic factors and multipliers based on findings generated in scientific literature. Therefore, no distinct assumption was made in the distribution of each multiplier factor used in this study, as seen in some research (Drury and Pfeil, 1975; NIOSH, 1991; Stambough *et al.*, 1995; Maiti and Ray, 2004). The formulated model to determine the SWL is expressed as follows:

$$SWLwT = x \times \frac{m_b}{L \times AG \times TF \times GN \times FM} \quad (4.1)$$

where

x = stature change

m_b = lifter's weight

L = lifter's spine length

AG = age factor

TF = temperature factor

FM = frequency of lift factor

GN = gender factor.

The manual lifting capability of gender is 0.56 for females and 0.72 for males, as seen in Chapla (2004); Hamid and Tamrin (2016). The stature change (x), lifter's weight (m_b), spine length (L), age (AG), gender (GN), temperature (TF) and frequency of lift (FM) were independent factors. The model-dependent variable is the SWL with varying Temperatures ($SWLwT$).

4.2 Demographic representation of selected male bricklayers' characteristic factors data

Figure 4.1 shows that 46% of the male bricklayers had weights ranging from 51.50 to 61.50 kg, 22% weighed from 62.00 to 72.00 kg, 24% weighed from 73.00 to 83.00 kg, 6% weighed from 84.00 to 94.00 kg, and 2% weighed from 95.00 to 105.00 kg.

Figure 4.2 indicates that 16% of the male bricklayers had a stature change between 0.014 and 0.017 m, 10% had a stature change between 0.018 and 0.021 m, 28% had a stature change between 0.022 and 0.025 m, and from 0.026 to 0.029 m, and 28% for stature change of between 0.030 and 0.033 m.

Figure 4.3 shows that 34% of the male bricklayers worked at a temperature between 28.60 and 30.60°C, and also between 30.70 and 32.70°C, 20% worked at a temperature between 26.50 and 28.50°C, 8% worked at a temperature between 32.80 and 34.80°C, and 4% worked at a temperature between 37 and 39°C.

Figure 4.4 indicates that 14% of the male bricklayers had age ranging from 20.00 to 25.00 year, 30% age was between 26.00 and 31.00 years, 32% aged between 32.00 and 37.00 years, 16% age was between 38.00 and 43.00 years, 4% aged between 44.00 and 49.00 years, and between 50.00 and 55.00 years.

Figure 4.5 shows that 6% of the male bricklayers had spine lengths between 0.41 and 0.43 m, 34% of spine lengths were between 0.44 and 0.46 m, 42% of spine lengths were between 0.47 and 0.49 m, and 18% of spine lengths were between 0.50 and 0.52 m.

Figure 4.6 indicates the distribution of Safe Weight of Lift (SWL) for the sandcrete block to be lifted by the male bricklayers. Figure 4.6 shows that 30% of the male bricklayers should lift weights from 3.78 to 5.78 kg, 54% to lift weights between 5.79 and 7.79 kg, 10% were to lift weights between 7.80 and 9.80 kg, 2% were to lift weight between 9.81 and 11.81 kg, and 4% were to lift weight between 11.82 and 13.82 kg. It shows that 54% of the male bricklayers representing the highest percentage, can lift load weight from 5.78 to 7.79 kg instead of the maximum weight of 22.50 kg to reduce low back pains.

4.3 Demonstration of the developed model

Below is an illustration of how Safe Weight of Lift (SWL) can be calculated using obtained data from an experienced male bricklayer using the SWLwT-developed model.

Stature change (x) = 0.03 m
Worker's weight (m_b) = 55.00 kg
Worker's spine length (L) = 0.46 m
Age multiplier (AG) for 28.00 years = 0.88
Frequency of lift multiplier (FM) for 1.00 lift/min = 0.95
Temperature multiplier (TF) for the temperature at 29.60°C = 0.95
Gender (male) multiplier = 0.72.
Substituting the values into (4.1) yields:

$$SWLwT = (0.03) \times \frac{55.00}{0.46 \times 0.88 \times 0.95 \times 0.95 \times 0.72} \quad (4.2)$$

$$SWLwT = \frac{1.65}{0.263} = 6.27 \text{ kg} \quad (4.3)$$

$$SWL = 6.27 \text{ kg for one subject} \quad (4.4)$$

Table 4.1 shows the results of SWL for fifty experienced male bricklayers. The data obtained were; age (years) ranged between 20.00 and 52.00, gender factor's multiplier (*GN*) for males is 0.72, workplace temperature (degree Celsius) ranged between 26.50 and 33.80, frequency of lifts (lifts per minute) from 1.00 to 2.00, lifter's weight m_b (kilogram) ranged between 51.50 and 101.90, spine length L (metre) ranged between 0.41 and 0.52 and stature change x (metre) ranged between 0.014 and 0.033. The manual workers in this study lifted a maximum load weight of 22.50 kg. The SWL calculated were between 3.78 and 12.77 kg.

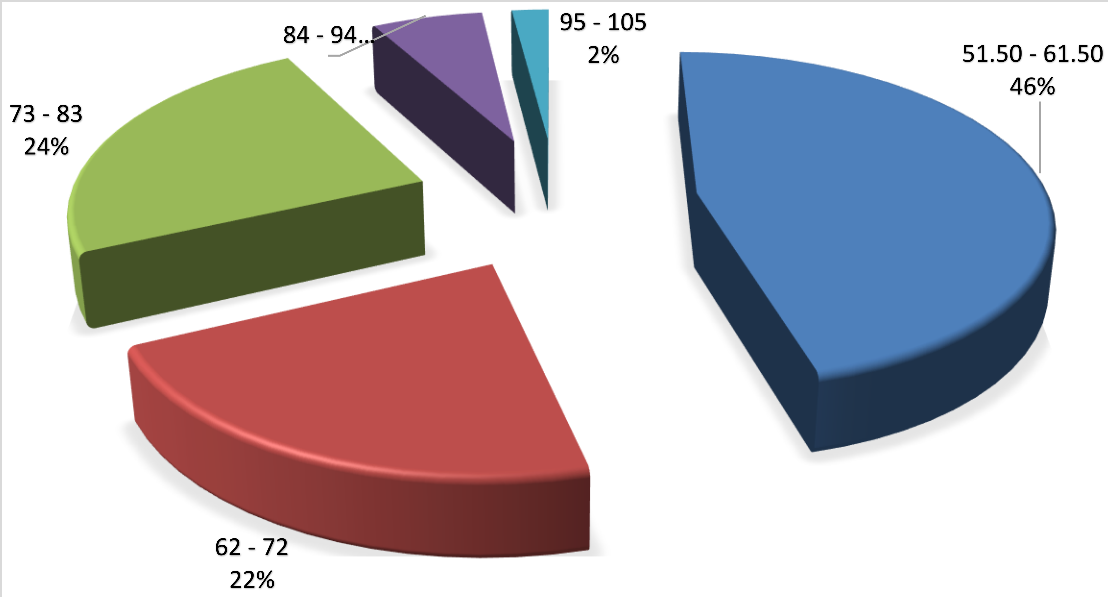

Figure 4. 1. Male bricklayers' weight distribution in kilograms

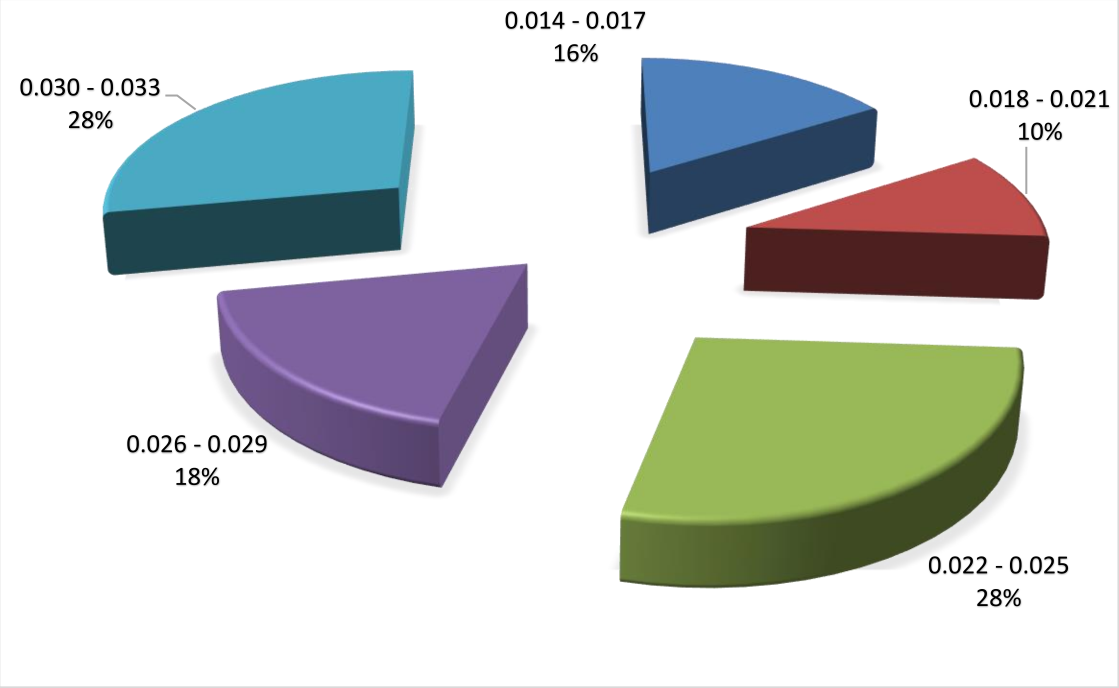

Figure 4. 2. Male bricklayers' stature change distribution in metres

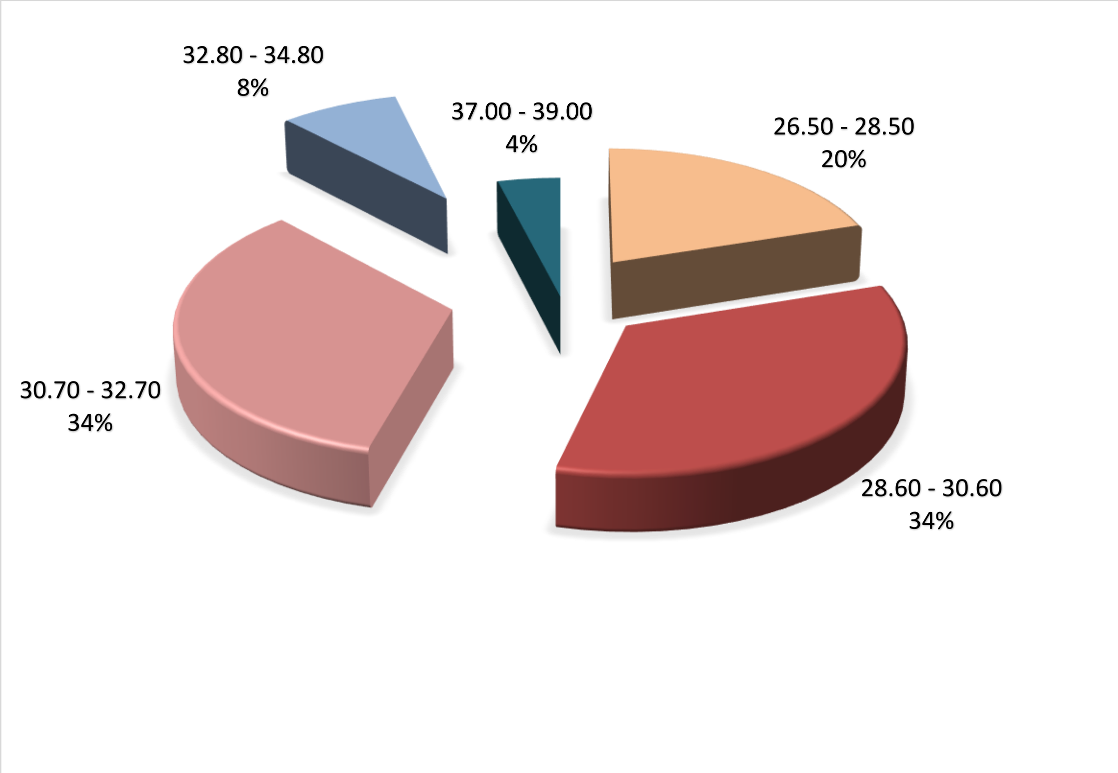

Figure 4. 3. Male bricklayers' workplace temperature distribution in degree Celsius

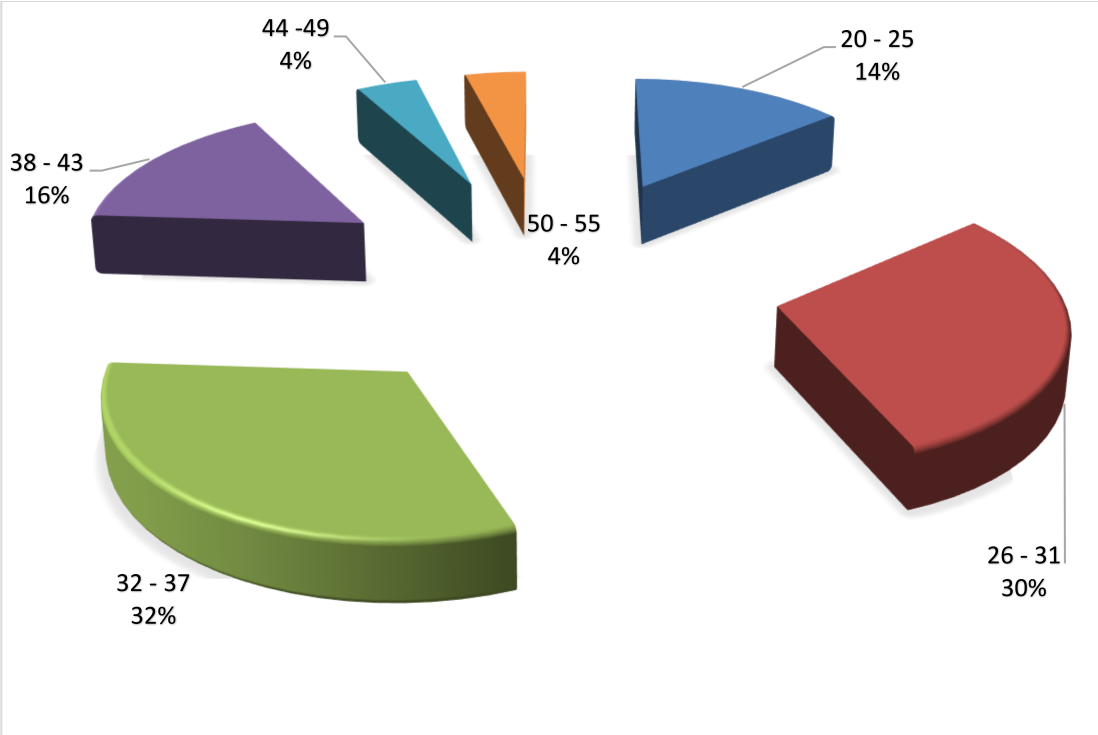

Figure 4. 4. Male bricklayers' age distribution in years

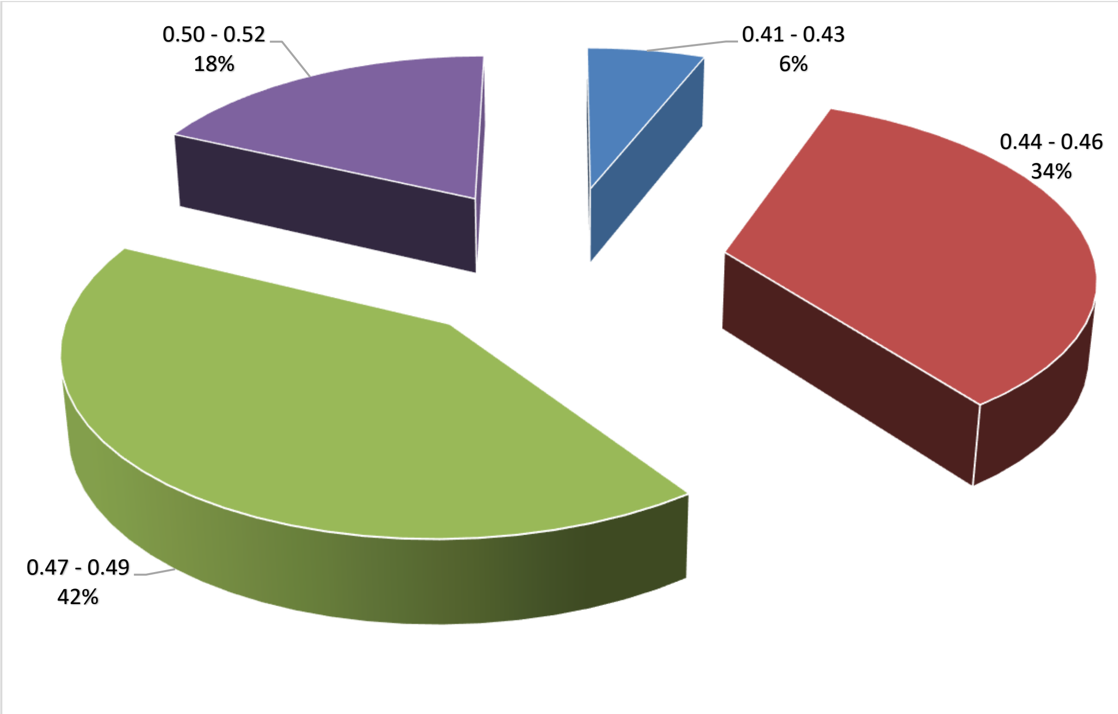

Figure 4. 5. Male bricklayers' spine length distribution in metres

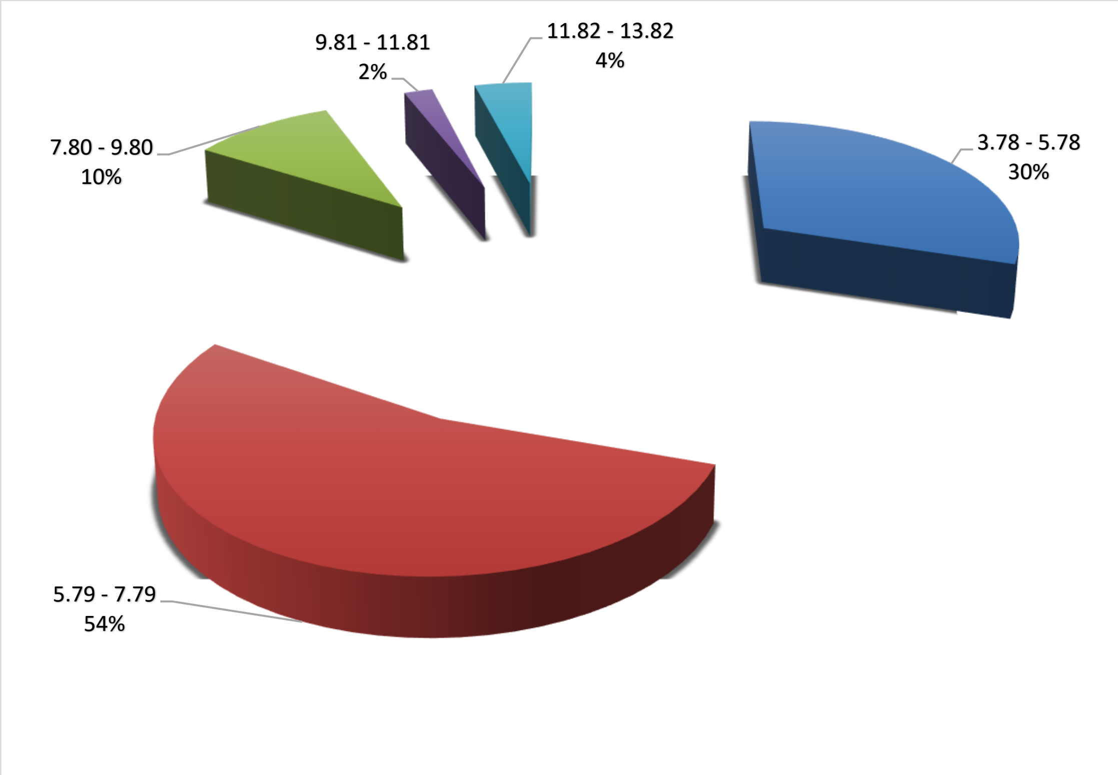

Figure 4. 6. Safe Weight of Lift distribution in kilograms for the selected male bricklayers'

Table 4. 1. Safe Weight of Lifts (SWL) results

Age (year)	*AG*	*GN*	Temperature (°C)	*TF*	Frequency of lifts (lifts/min)	*FM*	m_b (m)	*L*(m)	*x*(m)	SWL (kg)
30.00	0.88	0.72	31.20	0.90	2.00	0.89	55.00	0.43	0.015	3.78
37.00	0.86	0.72	28.45	0.98	1.00	0.95	72.00	0.49	0.015	3.82
20.00	1.00	0.72	29.43	0.95	1.00	0.95	79.00	0.50	0.017	4.13
28.00	0.88	0.72	29.50	0.93	2.00	0.89	81.70	0.51	0.014	4.27
46.00	0.78	0.72	28.61	0.95	2.00	0.89	70.20	0.48	0.014	4.31
42.00	0.86	0.72	32.30	0.88	2.00	0.89	55.40	0.52	0.021	4.61
45.00	0.78	0.72	28.71	0.95	2.00	0.89	68.70	0.47	0.016	4.92
33.00	0.88	0.72	26.80	1.00	2.00	0.89	70.60	0.45	0.018	5.00
31.00	0.88	0.72	29.30	0.95	2.00	0.89	57.20	0.46	0.022	5.10
42.00	0.86	0.72	27.30	1.00	1.00	0.95	73.00	0.47	0.020	5.28
29.00	0.88	0.72	29.20	0.95	2.00	0.89	54.10	0.47	0.025	5.37
30.00	0.88	0.72	29.10	0.71	1.00	0.95	75.00	0.45	0.014	5.46
39.00	0.86	0.72	27.30	1.00	1.00	0.95	62.00	0.51	0.027	5.58
35.00	0.88	0.72	30.10	0.95	1.00	0.95	59.00	0.46	0.026	5.83
35.00	0.88	0.72	37.20	0.76	2.00	0.89	66.00	0.42	0.016	5.87
22.00	1.00	0.72	30.30	0.93	2.00	0.89	59.00	0.47	0.028	5.90
29.00	0.88	0.72	31.40	0.90	1.00	0.95	59.00	0.46	0.025	5.91
40.00	0.86	0.72	34.30	0.83	2.00	0.89	60.00	0.44	0.020	5.96
30.00	0.88	0.72	26.50	1.00	1.00	0.95	74.00	0.47	0.023	6.01
28.00	0.88	0.72	31.40	0.90	2.00	0.89	51.50	0.45	0.027	6.09
28.00	0.88	0.72	30.10	0.93	1.00	0.95	63.40	0.50	0.027	6.11
32.00	0.88	0.72	29.50	0.93	1.00	0.95	59.00	0.49	0.029	6.24
28.00	0.88	0.72	29.60	0.95	1.00	0.95	55.00	0.46	0.030	6.27
50.00	0.69	0.72	32.30	0.88	2.00	0.89	55.00	0.51	0.023	6.37
41.00	0.86	0.72	27.50	0.98	2.00	0.89	77.20	0.51	0.023	6.45
36.00	0.88	0.72	26.90	1.00	2.00	0.89	71.80	0.46	0.024	6.64
32.00	0.88	0.72	27.10	1.00	2.00	0.89	60.00	0.48	0.030	6.65
25.00	0.91	0.72	29.60	0.95	2.00	0.89	54.00	0.44	0.030	6.65
30.00	0.88	0.72	31.30	0.90	2.00	0.89	80.30	0.45	0.019	6.68
22.00	1.00	0.72	29.30	0.95	2.00	0.89	61.40	0.45	0.030	6.72
25.00	0.91	0.72	30.20	0.93	2.00	0.89	61.00	0.51	0.031	6.83
26.00	0.88	0.72	31.40	0.90	2.00	0.89	59.00	0.44	0.026	6.86
29.00	0.88	0.72	29.30	0.95	2.00	0.89	65.70	0.41	0.023	6.88
24.00	0.91	0.72	31.10	0.90	2.00	0.89	58.00	0.48	0.030	6.90
23.00	0.91	0.72	31.30	0.90	2.00	0.89	55.00	0.45	0.030	6.98
43.00	0.78	0.72	27.80	0.98	2.00	0.89	75.00	0.48	0.022	7.01
34.00	0.88	0.72	31.80	0.88	1.00	0.95	55.00	0.47	0.032	7.07
27.00	0.88	0.72	31.40	0.90	1.00	0.95	60.00	0.49	0.032	7.23
34.00	0.88	0.72	27.50	0.98	2.00	0.89	60.50	0.47	0.032	7.45
33.00	0.88	0.72	33.80	0.83	2.00	0.89	74.50	0.48	0.023	7.63
38.00	0.86	0.72	30.84	0.93	1.00	0.95	83.20	0.49	0.025	7.76
37.00	0.86	0.72	31.80	0.88	2.00	0.89	69.00	0.47	0.027	8.17
27.00	0.88	0.72	29.60	0.95	2.00	0.89	70.00	0.48	0.030	8.17
52.00	0.69	0.72	32.32	0.88	1.00	0.95	57.30	0.50	0.030	8.28
40.00	0.86	0.72	33.80	0.83	2.00	0.89	83.60	0.47	0.022	8.55
37.00	0.86	0.72	29.53	0.93	2.00	0.89	90.00	0.49	0.024	8.60
35.00	0.88	0.72	31.23	0.90	1.00	0.95	85.30	0.46	0.028	9.58
35.00	0.88	0.72	31.80	0.88	2.00	0.89	87.60	0.45	0.025	9.80
33.00	0.88	0.72	31.34	0.90	2.00	0.89	82.00	0.44	0.033	12.11
36.00	0.86	0.72	33.80	0.83	1.00	0.95	101.90	0.49	0.030	12.77

Table 4.2 shows the lowest, highest, mean and standard deviations of descriptive statistics of the selected factors and the Safe Weight Lift of 50 experienced male bricklayers obtained at Arulogun, Akinyele L.G.A., Ibadan. The lowest and highest age was 20.00 and 52.00 years, respectively, with a mean value of 33.26 and a standard deviation of 7.22. Lifters' lowest and highest weights were 51.50 and 101.90 kg, respectively, mean of 67.27 kg and a standard deviation of 13.43. Stature change had 0.014 as the lowest and 0.033 as the highest, a mean of 0.024 and a standard deviation of 0.06. Temperature lowest and highest were 26.50 and 37°C with a mean of 30.46°C and a standard deviation of 2.51. Lifters' lowest and highest spine lengths were 0.41 and 0.52 m, with a mean of 0.47 m and a standard deviation of 0.03. The frequency of lifts lowest and highest were 1.00 and 2.00 lifts/min with a mean of 1.66 lifts/min and a standard deviation of 0.48. The SWL lowest and highest were 3.78 and 12.77 kg, with a mean of 6.60 kg and a standard deviation of 1.83.

4.4 Relationship between independent selected male bricklayers' characteristic factors and SWL model

Table 4.3 shows the results of the main effect of the independent factors (age, weight, stature change, temperature, and spine length and lift frequency) on the dependent variable (Safe Weight Lift). This presented coefficient of determination (R-square), standardised coefficient (beta, β), unstandardised coefficient (B) and level of significance (p-value) for independently selected male bricklayer characteristic factors of the developed model. Workers' age explained 1% of the total variance of the SWLwT model and had a negligible positive relationship (β =0.08) with the model. The age contributed insignificantly to the model ($p>0.05$). The male bricklayers' weight explained 26% of the total variance of the SWL model and had a moderate positive relationship (β =0.51) with the SWLwT. The male bricklayers' weight factor contributed significantly to the developed safe weight of the lift model ($p<0.05$). The stature change explained 33% of the total variance in the SWLwT and had a moderate positive relationship (β =0.58) with the model. The stature change contributed significantly to the model ($p<0.05$). The temperature explained 6% of the total variance in the SWLwT model and had a weak positive relationship (β=0.25) with the safe weight lift model. It contributed insignificantly ($p>0.05$) to the model. The male bricklayers' spine length explained 0% of the total variance in the model and had a negligible negative relationship (β=0.-06) with the model. The male bricklayers' spine length contributed insignificantly to the SWLwT model (p>0.05). The frequency of lift explained 0% of the total variance in the model and had a negligible positive relationship (β=0.00) with the SWLwT model, contributed insignificantly to the model (p>0.05).

Table 4.4 shows the ascending order arrangement of the male bricklayers' age and Safe Weight Lift (SWL). At a given male bricklayers' age corresponding value of the SWL can be observed at SWL (kilogram). It should be noted that the increase in the SWL did not follow ascending order arrangement of male bricklayers' age. It was due to the overlapping of the male bricklayers' age factor with other factors in determining the SWL.

Table 4.5 shows the ascending order arrangement of the male bricklayers' weight (m_b) and Safe Weight Lift (SWL). At a given male bricklayer weight, the corresponding value of the safe weight to be lifted can be observed at the SWL (kilogram). It should be noted that the increase in the SWL did not follow ascending order arrangement of male bricklayers' weight. This was due to the overlapping of male bricklayers' weight factor with other factors in determining the SWL.

Table 4.6 shows the ascending order arrangement of the male bricklayers' stature change (x) and SWL. At a given stature change, the corresponding weight value safe to be lifted can be observed at SWL (kilogram). It should be noted that the increase in the SWL did not follow the ascending order arrangement of stature change. It was due to the overlapping of other factors in determining the SWL.

Table 4.7 shows the ascending order arrangement of the male bricklayers' temperature and SWL. At a given temperature, the corresponding value of weight safe to be lifted can be observed at the SWL (kilogram). It should be noted that the increase in the SWL did not follow ascending order arrangement of the temperature. The reason was that in determining the SWL, other factors were involved in the method used.

Table 4.8 shows the ascending order arrangement of the male bricklayers' spine length (L) and SWL. The corresponding weight value safe to be lifted at a given spine length can be observed at SWL (kilogram). It should be noted that the increase in the SWL did not follow ascending order arrangement of the spine length. It was due to the spine-length overlapping and other factors involved in the method.

The relationship between the lifting frequency and SWL is shown in Table 4.9. The corresponding value of safe weight to lift can be observed at the SWL (kilogram) at a given lift frequency. It should be noted that the increase in the SWL did not follow ascending order arrangement of the frequency of lifts. It was due to the overlapping of the frequency of the lift factor with other factors involved in the model.

Table 4. 2. Descriptive statistics of selected male bricklayer characteristic factors

Factors	N	Lowest	Heighest	Mean	Std. Deviation
Age (year)	50	20.00	52.00	33.26	7.22
Lifter’s weight (kg)	50	51.50	101.90	67.46	11.58
Stature change (m)	50	0.014	0.033	0.02	0.06
Temperature (°C)	50	26.50	37.00	30.46	2.51
Spine length (m)	50	0.41	0.52	0.47	0.03
Frequency of lifts (lifts/min)	50	1.00	2.00	1.66	0.48
SWL (kg)	50	3.78	12.77	6.60	1.83
Valid N (list-wise)	50				

Table 4. 3. Main effect of independent factors on Safe Weight of Lift

Independent factors	Safe Weight Lift			
	R square	Beta	B	p-value
Age (year)	0.01	0.08	0.02	0.60
Worker's weight (kg)	0.26	0.51	0.08	0.00
Stature change (m)	0.33	0.58	191.54	0.00
Temperature (°C)	0.06	0.25	0.18	0.08
Spine length (m)	0.00	-0.06	-4.61	0.66
Lifts frequency (lifts/min)	0.00	0.00	0.01	0.98

Table 4. 4. Age vs Safe Weight Lift (SWL)

Age (year)	*AG*	*GN*	Temperature (°C)	*TF*	Frequency of lifts (lifts/min)	*FM*	m_b (kg)	*L*(m)	*x*(m)	SWL (kg)
20.00	1.00	0.72	29.43	0.95	1.00	0.95	79.00	0.50	0.017	4.13
22.00	1.00	0.72	30.30	0.93	2.00	0.89	59.00	0.47	0.028	5.90
22.00	1.00	0.72	29.30	0.95	2.00	0.89	61.40	0.45	0.030	6.72
23.00	0.91	0.72	31.30	0.90	2.00	0.89	55.00	0.45	0.030	6.98
24.00	0.91	0.72	31.10	0.90	2.00	0.89	58.00	0.48	0.030	6.90
25.00	0.91	0.72	29.60	0.95	2.00	0.89	54.00	0.44	0.030	6.65
25.00	0.91	0.72	30.20	0.93	2.00	0.89	61.00	0.51	0.031	6.83
26.00	0.88	0.72	31.40	0.90	2.00	0.89	59.00	0.44	0.026	6.86
27.00	0.88	0.72	31.40	0.90	1.00	0.95	60.00	0.49	0.032	7.23
27.00	0.88	0.72	29.60	0.95	2.00	0.89	70.00	0.48	0.030	8.17
28.00	0.88	0.72	29.50	0.93	2.00	0.89	81.70	0.51	0.014	4.27
28.00	0.88	0.72	31.40	0.90	2.00	0.89	51.50	0.45	0.027	6.09
28.00	0.88	0.72	30.10	0.93	1.00	0.95	63.40	0.50	0.027	6.11
28.00	0.88	0.72	29.60	0.95	1.00	0.95	55.00	0.46	0.030	6.27
29.00	0.88	0.72	29.20	0.95	2.00	0.89	54.10	0.47	0.025	5.37
29.00	0.88	0.72	31.40	0.90	1.00	0.95	59.00	0.46	0.025	5.91
29.00	0.88	0.72	29.30	0.95	2.00	0.89	65.70	0.41	0.023	6.88
30.00	0.88	0.72	31.20	0.90	2.00	0.89	55.00	0.43	0.015	3.78
30.00	0.88	0.72	29.00	0.71	1.00	0.95	75.00	0.45	0.014	5.46
30.00	0.88	0.72	26.50	1.00	1.00	0.95	74.00	0.47	0.023	6.01
30.00	0.88	0.72	31.30	0.90	2.00	0.89	80.30	0.45	0.019	6.68
31.00	0.88	0.72	29.30	0.95	2.00	0.89	57.20	0.46	0.022	5.10
32.00	0.88	0.72	29.50	0.93	1.00	0.95	59.00	0.49	0.029	6.24
32.00	0.88	0.72	27.10	1.00	2.00	0.89	60.00	0.48	0.030	6.65
33.00	0.88	0.72	26.80	1.00	2.00	0.89	70.60	0.45	0.018	5.00
33.00	0.88	0.72	33.80	0.83	2.00	0.89	74.50	0.48	0.023	7.63
33.00	0.88	0.72	31.34	0.90	2.00	0.89	82.00	0.44	0.033	12.11
34.00	0.88	0.72	31.80	0.88	1.00	0.95	55.00	0.47	0.032	7.07
34.00	0.88	0.72	27.50	0.98	2.00	0.89	60.50	0.47	0.032	7.45
35.00	0.88	0.72	30.10	0.95	1.00	0.95	59.00	0.46	0.026	5.83
35.00	0.88	0.72	37.20	0.76	2.00	0.89	66.00	0.42	0.016	5.87
35.00	0.88	0.72	31.23	0.900	1.00	0.95	85.30	0.46	0.028	9.58
35.00	0.88	0.72	31.80	0.88	2.00	0.89	87.60	0.45	0.025	9.80
36.00	0.88	0.72	26.90	1.00	2.00	0.89	71.80	0.46	0.024	6.64
36.00	0.86	0.72	33.80	0.83	1.00	0.95	101.90	0.49	0.030	12.77
37.00	0.86	0.72	28.45	0.98	1.00	0.95	72.00	0.49	0.015	3.82
37.00	0.86	0.72	31.80	0.88	2.00	0.89	69.00	0.47	0.027	8.17
37.00	0.86	0.72	29.53	0.93	2.00	0.89	90.00	0.49	0.024	8.60
38.00	0.86	0.72	30.84	0.93	1.00	0.95	83.20	0.49	0.025	7.76
39.00	0.86	0.72	27.30	1.00	1.00	0.95	62.00	0.51	0.027	5.58
40.00	0.86	0.72	34.30	0.83	2.00	0.89	60.00	0.44	0.020	5.96
40.00	0.86	0.72	33.80	0.83	2.00	0.89	83.60	0.47	0.022	8.55
41.00	0.86	0.72	27.50	0.98	2.00	0.89	77.20	0.51	0.023	6.45
42.00	0.86	0.72	32.30	0.88	2.00	0.89	55.40	0.52	0.021	4.61
42.00	0.86	0.72	27.30	1.00	1.00	0.95	73.00	0.47	0.020	5.28
43.00	0.78	0.72	27.80	0.98	2.00	0.89	75.00	0.48	0.022	7.01
45.00	0.78	0.72	28.71	0.95	2.00	0.89	68.70	0.47	0.016	4.92
46.00	0.78	0.72	28.61	0.95	2.00	0.89	70.20	0.48	0.014	4.31
50.00	0.69	0.72	32.30	0.88	2.00	0.89	55.00	0.51	0.023	6.37
52.00	0.69	0.72	32.32	0.88	1.00	0.95	57.30	0.50	0.030	8.28

Table 4. 5. Weight (m_b) vs Safe Weight Lift (SWL)

Age (year)	*AG*	*GN*	Temperature (°C)	*TF*	Lifts frequency (lifts/min)	*FM*	m_b (kg)	*L*(m)	*x*(m)	SWL (kg)
28.00	0.88	0.72	31.40	0.90	2.00	0.89	51.50	0.45	0.027	6.09
25.00	0.91	0.72	29.60	0.95	2.00	0.89	54.00	0.44	0.030	6.65
29.00	0.88	0.72	29.20	0.95	2.00	0.89	54.10	0.47	0.025	5.37
23.00	0.91	0.72	31.30	0.90	2.00	0.89	55.00	0.45	0.030	6.98
28.00	0.88	0.72	29.60	0.95	1.00	0.95	55.00	0.46	0.030	6.27
30.00	0.88	0.72	31.20	0.90	2.00	0.89	55.00	0.43	0.015	3.78
34.00	0.88	0.72	31.80	0.88	1.00	0.95	55.00	0.47	0.032	7.07
50.00	0.69	0.72	32.30	0.88	2.00	0.89	55.00	0.51	0.023	6.37
42.00	0.86	0.72	32.30	0.88	2.00	0.89	55.40	0.52	0.021	4.61
31.00	0.88	0.72	29.30	0.95	2.00	0.89	57.20	0.46	0.022	5.10
52.00	0.69	0.72	32.32	0.88	1.00	0.95	57.30	0.50	0.030	8.28
24.00	0.91	0.72	31.10	0.90	2.00	0.89	58.00	0.48	0.030	6.90
22.00	1.00	0.72	30.30	0.93	2.00	0.89	59.00	0.47	0.028	5.90
26.00	0.88	0.72	31.40	0.90	2.00	0.89	59.00	0.44	0.026	6.86
29.00	0.88	0.72	31.40	0.90	1.00	0.95	59.00	0.46	0.025	5.91
32.00	0.88	0.72	29.50	0.93	1.00	0.95	59.00	0.49	0.029	6.24
35.00	0.88	0.72	30.10	0.95	1.00	0.95	59.00	0.46	0.026	5.83
27.00	0.88	0.72	31.40	0.90	1.00	0.95	60.00	0.49	0.032	7.23
32.00	0.88	0.72	27.10	1.00	2.00	0.89	60.00	0.48	0.030	6.65
40.00	0.86	0.72	34.30	0.83	2.00	0.89	60.00	0.44	0.020	5.96
34.00	0.88	0.72	27.50	0.98	2.00	0.89	60.50	0.47	0.032	7.45
25.00	0.91	0.72	30.20	0.93	2.00	0.89	61.00	0.51	0.031	6.83
22.00	1.00	0.72	29.30	0.95	2.00	0.89	61.40	0.45	0.030	6.72
39.00	0.86	0.72	27.30	1.00	1.00	0.95	62.00	0.51	0.027	5.58
28.00	0.88	0.72	30.10	0.93	1.00	0.95	63.40	0.50	0.027	6.11
29.00	0.88	0.72	29.30	0.95	2.00	0.89	65.70	0.41	0.023	6.88
35.00	0.88	0.72	37.20	0.76	2.00	0.89	66.00	0.42	0.016	5.87
45.00	0.78	0.72	28.71	0.95	2.00	0.89	68.70	0.47	0.016	4.92
37.00	0.86	0.72	31.80	0.88	2.00	0.89	69.00	0.47	0.027	8.17
27.00	0.88	0.72	29.60	0.95	2.00	0.89	70.00	0.48	0.030	8.17
46.00	0.78	0.72	28.61	0.95	2.00	0.89	70.20	0.48	0.014	4.31
33.00	0.88	0.72	26.80	1.00	2.00	0.89	70.60	0.45	0.018	5.00
36.00	0.88	0.72	26.90	1.00	2.00	0.89	71.80	0.46	0.024	6.64
37.00	0.86	0.72	28.45	0.98	1.00	0.95	72.00	0.49	0.015	3.82
42.00	0.86	0.72	27.30	1.00	1.00	0.95	73.00	0.47	0.020	5.28
30.00	0.88	0.72	26.50	1.00	1.00	0.95	74.00	0.47	0.023	6.01
33.00	0.88	0.72	33.80	0.83	2.00	0.89	74.50	0.48	0.023	7.63
30.00	0.88	0.72	29.00	0.71	1.00	0.95	75.00	0.45	0.014	5.46
43.00	0.78	0.72	27.80	0.98	2.00	0.89	75.00	0.48	0.022	7.01
41.00	0.86	0.72	27.50	0.98	2.00	0.89	77.20	0.51	0.023	6.45
20.00	1.00	0.72	29.43	0.95	1.00	0.95	79.00	0.50	0.017	4.13
30.00	0.88	0.72	31.30	0.90	2.00	0.89	80.30	0.45	0.019	6.68
28.00	0.88	0.72	29.50	0.93	2.00	0.89	81.70	0.51	0.014	4.27
33.00	0.88	0.72	31.34	0.90	2.00	0.89	82.00	0.44	0.033	12.11
38.00	0.86	0.72	30.84	0.93	1.00	0.95	83.20	0.49	0.025	7.76
40.00	0.86	0.72	33.80	0.83	2.00	0.89	83.60	0.47	0.022	8.55
35.00	0.88	0.72	31.23	0.90	1.00	0.95	85.30	0.46	0.028	9.58
35.00	0.88	0.72	31.80	0.88	2.00	0.89	87.60	0.45	0.025	9.80
37.00	0.86	0.72	29.53	0.93	2.00	0.89	90.00	0.49	0.024	8.60
36.00	0.86	0.72	33.80	0.83	1.00	0.95	101.90	0.49	0.030	12.77

Table 4. 6. Stature change (x) vs Safe Weight Lift (SWL)

Age (year)	*AG*	*GN*	Temperature (°C)	*TF*	Frequency of lifts (lifts/min)	*FM*	m_b(kg)	*L*(m)	*x*(m)	SWL (kg)
46.00	0.78	0.72	28.61	0.95	2.00	0.89	70.20	0.48	0.014	4.31
30.00	0.88	0.72	29.00	0.71	1.00	0.95	75.00	0.45	0.014	5.46
28.00	0.88	0.72	29.50	0.93	2.00	0.89	81.70	0.51	0.014	4.27
30.00	0.88	0.72	31.20	0.90	2.00	0.89	55.00	0.43	0.015	3.78
37.00	0.86	0.72	28.45	0.98	1.00	0.95	72.00	0.49	0.015	3.82
35.00	0.88	0.72	37.20	0.76	2.00	0.89	66.00	0.42	0.016	5.87
45.00	0.78	0.72	28.71	0.95	2.00	0.89	68.70	0.47	0.016	4.92
20.00	1.00	0.72	29.43	0.95	1.00	0.95	79.00	0.50	0.017	4.13
33.00	0.88	0.72	26.80	1.00	2.00	0.89	70.60	0.45	0.018	5.00
30.00	0.88	0.72	31.30	0.90	2.00	0.89	80.30	0.45	0.019	6.68
40.00	0.86	0.72	34.30	0.83	2.00	0.89	60.00	0.44	0.020	5.96
42.00	0.86	0.72	27.30	1.00	1.00	0.95	73.00	0.47	0.020	5.28
42.00	0.86	0.72	32.30	0.88	2.00	0.89	55.40	0.52	0.021	4.61
31.00	0.88	0.72	29.30	0.95	2.00	0.89	57.20	0.46	0.022	5.10
43.00	0.78	0.72	27.80	0.98	2.00	0.89	75.00	0.48	0.022	7.01
40.00	0.86	0.72	33.80	0.83	2.00	0.89	83.60	0.47	0.022	8.55
50.00	0.69	0.72	32.30	0.88	2.00	0.89	55.00	0.51	0.023	6.37
29.00	0.88	0.72	29.30	0.95	2.00	0.89	65.70	0.41	0.023	6.88
30.00	0.88	0.72	26.50	1.00	1.00	0.95	74.00	0.47	0.023	6.01
33.00	0.88	0.72	33.80	0.83	2.00	0.89	74.50	0.48	0.023	7.63
41.00	0.86	0.72	27.50	0.98	2.00	0.89	77.20	0.51	0.023	6.45
36.00	0.88	0.72	26.90	1.00	2.00	0.89	71.80	0.46	0.024	6.64
37.00	0.86	0.72	29.53	0.93	2.00	0.89	90.00	0.49	0.024	8.60
29.00	0.88	0.72	29.20	0.95	2.00	0.89	54.10	0.47	0.025	5.37
29.00	0.88	0.72	31.40	0.90	1.00	0.95	59.00	0.46	0.025	5.91
38.00	0.86	0.72	30.84	0.93	1.00	0.95	83.20	0.49	0.025	7.76
35.00	0.88	0.72	31.80	0.88	2.00	0.89	87.60	0.45	0.025	9.80
26.00	0.88	0.72	31.40	0.90	2.00	0.89	59.00	0.44	0.026	6.86
35.00	0.88	0.72	30.10	0.95	1.00	0.95	59.00	0.46	0.026	5.83
28.00	0.88	0.72	31.40	0.90	2.00	0.89	51.50	0.45	0.027	6.09
39.00	0.86	0.72	27.30	1.00	1.00	0.95	62.00	0.51	0.027	5.58
28.00	0.88	0.72	30.10	0.93	1.00	0.95	63.40	0.50	0.027	6.11
37.00	0.86	0.72	31.80	0.88	2.00	0.89	69.00	0.47	0.027	8.17
22.00	1.00	0.72	30.30	0.93	2.00	0.89	59.00	0.47	0.028	5.90
35.00	0.88	0.72	31.23	0.90	1.00	0.95	85.30	0.46	0.028	9.58
32.00	0.88	0.72	29.50	0.93	1.00	0.95	59.00	0.49	0.029	6.24
25.00	0.91	0.72	29.60	0.95	2.00	0.89	54.00	0.44	0.030	6.65
23.00	0.91	0.72	31.30	0.90	2.00	0.89	55.00	0.45	0.030	6.98
28.00	0.88	0.72	29.60	0.95	1.00	0.95	55.00	0.46	0.030	6.27
52.00	0.69	0.72	32.32	0.88	1.00	0.95	57.30	0.50	0.030	8.28
24.00	0.91	0.72	31.10	0.90	2.00	0.89	58.00	0.48	0.030	6.90
32.00	0.88	0.72	27.10	1.00	2.00	0.89	60.00	0.48	0.030	6.65
22.00	1.00	0.72	29.30	0.95	2.00	0.89	61.40	0.45	0.030	6.72
27.00	0.88	0.72	29.60	0.95	2.00	0.89	70.00	0.48	0.030	8.17
36.00	0.86	0.72	33.80	0.83	1.00	0.95	101.90	0.49	0.030	12.77
25.00	0.91	0.72	30.20	0.93	2.00	0.89	61.00	0.51	0.031	6.83
34.00	0.88	0.72	31.80	0.88	1.00	0.95	55.00	0.47	0.032	7.07
27.00	0.88	0.72	31.40	0.90	1.00	0.95	60.00	0.49	0.032	7.23
34.00	0.88	0.72	27.50	0.98	2.00	0.89	60.50	0.47	0.032	7.45
33.00	0.88	0.72	31.34	0.90	2.00	0.89	82.00	0.44	0.033	12.11

Table 4. 7. Temperature vs Safe Weight Lift (SWL)

Age (year)	*AG*	*GN*	Temperature (°C)	*TF*	Frequency of lifts (lifts/min)	*FM*	m_b (kg)	*L*(m)	*x*(m)	SWL (kg)
30.00	0.88	0.72	26.50	1.00	1.00	0.95	74.00	0.47	0.023	6.01
33.00	0.88	0.72	26.80	1.00	2.00	0.89	70.60	0.45	0.018	5.00
36.00	0.88	0.72	26.90	1.00	2.00	0.89	71.80	0.46	0.024	6.64
32.00	0.88	0.72	27.10	1.00	2.00	0.89	60.00	0.48	0.030	6.65
42.00	0.86	0.72	27.30	1.00	1.00	0.95	73.00	0.47	0.020	5.28
39.00	0.86	0.72	27.30	1.00	1.00	0.95	62.00	0.51	0.027	5.58
41.00	0.86	0.72	27.50	0.98	2.00	0.89	77.20	0.51	0.023	6.45
34.00	0.88	0.72	27.50	0.98	2.00	0.89	60.50	0.47	0.032	7.45
43.00	0.78	0.72	27.80	0.98	2.00	0.89	75.00	0.48	0.022	7.01
37.00	0.86	0.72	28.45	0.98	1.00	0.95	72.00	0.49	0.015	3.82
46.00	0.78	0.72	28.61	0.95	2.00	0.89	70.20	0.48	0.014	4.31
45.00	0.78	0.72	28.71	0.95	2.00	0.89	68.70	0.47	0.016	4.92
29.00	0.88	0.72	29.20	0.95	2.00	0.89	54.10	0.47	0.025	5.37
31.00	0.88	0.72	29.30	0.95	2.00	0.89	57.20	0.46	0.022	5.10
29.00	0.88	0.72	29.30	0.95	2.00	0.89	65.70	0.41	0.023	6.88
22.00	1.00	0.72	29.30	0.95	2.00	0.89	61.40	0.45	0.030	6.72
20.00	1.00	0.72	29.43	0.95	1.00	0.95	79.00	0.50	0.017	4.13
28.00	0.88	0.72	29.50	0.93	2.00	0.89	81.70	0.51	0.014	4.27
32.00	0.88	0.72	29.50	0.93	1.00	0.95	59.00	0.49	0.029	6.24
37.00	0.86	0.72	29.53	0.93	2.00	0.89	90.00	0.49	0.024	8.60
25.00	0.91	0.72	29.60	0.95	2.00	0.89	54.00	0.44	0.030	6.65
28.00	0.88	0.72	29.60	0.95	1.00	0.95	55.00	0.46	0.030	6.27
27.00	0.88	0.72	29.60	0.95	2.00	0.89	70.00	0.48	0.030	8.17
35.00	0.88	0.72	30.10	0.95	1.00	0.95	59.00	0.46	0.026	5.83
28.00	0.88	0.72	30.10	0.93	1.00	0.95	63.40	0.50	0.027	6.11
25.00	0.91	0.72	30.20	0.93	2.00	0.89	61.00	0.51	0.031	6.83
22.00	1.00	0.72	30.30	0.93	2.00	0.89	59.00	0.47	0.028	5.90
38.00	0.86	0.72	30.84	0.93	1.00	0.95	83.20	0.49	0.025	7.76
24.00	0.91	0.72	31.10	0.90	2.00	0.89	58.00	0.48	0.030	6.90
30.00	0.88	0.72	31.20	0.90	2.00	0.89	55.00	0.43	0.015	3.78
35.00	0.88	0.72	31.23	0.90	1.00	0.95	85.30	0.46	0.028	9.58
30.00	0.88	0.72	31.30	0.90	2.00	0.89	80.30	0.45	0.019	6.68
23.00	0.91	0.72	31.30	0.90	2.00	0.89	55.00	0.45	0.030	6.98
33.00	0.88	0.72	31.34	0.90	2.00	0.89	82.00	0.44	0.033	12.11
29.00	0.88	0.72	31.40	0.90	1.00	0.95	59.00	0.46	0.025	5.91
26.00	0.88	0.72	31.40	0.90	2.00	0.89	59.00	0.44	0.026	6.86
28.00	0.88	0.72	31.40	0.90	2.00	0.89	51.50	0.45	0.027	6.09
27.00	0.88	0.72	31.40	0.90	1.00	0.95	60.00	0.49	0.032	7.23
35.00	0.88	0.72	31.80	0.88	2.00	0.89	87.60	0.45	0.025	9.80
37.00	0.86	0.72	31.80	0.88	2.00	0.89	69.00	0.47	0.027	8.17
34.00	0.88	0.72	31.80	0.88	1.00	0.95	55.00	0.47	0.032	7.07
42.00	0.86	0.72	32.30	0.88	2.00	0.89	55.40	0.52	0.021	4.61
50.00	0.69	0.72	32.30	0.88	2.00	0.89	55.00	0.51	0.023	6.37
52.00	0.69	0.72	32.32	0.88	1.00	0.95	57.30	0.50	0.030	8.28
40.00	0.86	0.72	33.80	0.83	2.00	0.89	83.60	0.47	0.022	8.55
33.00	0.88	0.72	33.80	0.83	2.00	0.89	74.50	0.48	0.023	7.63
36.00	0.86	0.72	33.80	0.83	1.00	0.95	101.90	0.49	0.030	12.77
40.00	0.86	0.72	34.30	0.83	2.00	0.89	60.00	0.44	0.020	5.96
35.00	0.88	0.72	37.20	0.76	2.00	0.89	66.00	0.42	0.016	5.87
30.00	0.88	0.72	29.00	0.71	1.00	0.95	75.00	0.45	0.014	5.46

Table 4. 8. Spine length (L) vs Safe Weight Lift (SWL)

Age (year)	*AG*	*GN*	Temperature (°C)	*TF*	Frequency of lifts (lifts/min)	*FM*	m_b (kg)	*L*(m)	*x*(m)	SWL (kg)
29.00	0.88	0.72	29.30	0.95	2.00	0.89	65.70	0.41	0.023	6.88
35.00	0.88	0.72	37.20	0.76	2.00	0.89	66.00	0.42	0.016	5.87
30.00	0.88	0.72	31.20	0.90	2.00	0.89	55.00	0.43	0.015	3.78
25.00	0.91	0.72	29.60	0.95	2.00	0.89	54.00	0.44	0.030	6.65
33.00	0.88	0.72	31.34	0.90	2.00	0.89	82.00	0.44	0.033	12.11
26.00	0.88	0.72	31.40	0.90	2.00	0.89	59.00	0.44	0.026	6.86
40.00	0.86	0.72	34.30	0.83	2.00	0.89	60.00	0.44	0.020	5.96
33.00	0.88	0.72	26.80	1.00	2.00	0.89	70.60	0.45	0.018	5.00
22.00	1.00	0.72	29.30	0.95	2.00	0.89	61.40	0.45	0.030	6.72
30.00	0.88	0.72	31.30	0.90	2.00	0.89	80.30	0.45	0.019	6.68
23.00	0.91	0.72	31.30	0.90	2.00	0.89	55.00	0.45	0.030	6.98
28.00	0.88	0.72	31.40	0.90	2.00	0.89	51.50	0.45	0.027	6.09
35.00	0.88	0.72	31.80	0.88	2.00	0.89	87.60	0.45	0.025	9.80
30.00	0.88	0.72	29.00	0.71	1.00	0.95	75.00	0.45	0.014	5.46
36.00	0.88	0.72	26.90	1.00	2.00	0.89	71.80	0.46	0.024	6.64
31.00	0.88	0.72	29.30	0.95	2.00	0.89	57.20	0.46	0.022	5.10
28.00	0.88	0.72	29.60	0.95	1.00	0.95	55.00	0.46	0.030	6.27
35.00	0.88	0.72	30.10	0.95	1.00	0.95	59.00	0.46	0.026	5.83
35.00	0.88	0.72	31.23	0.90	1.00	0.95	85.30	0.46	0.028	9.58
29.00	0.88	0.72	31.40	0.90	1.00	0.95	59.00	0.46	0.025	5.91
30.00	0.88	0.72	26.50	1.00	1.00	0.95	74.00	0.47	0.023	6.01
42.00	0.86	0.72	27.30	1.00	1.00	0.95	73.00	0.47	0.020	5.28
34.00	0.88	0.72	27.50	0.98	2.00	0.89	60.50	0.47	0.032	7.45
45.00	0.78	0.72	28.71	0.95	2.00	0.89	68.70	0.47	0.016	4.92
29.00	0.88	0.72	29.20	0.95	2.00	0.89	54.10	0.47	0.025	5.37
22.00	1.00	0.72	30.30	0.93	2.00	0.89	59.00	0.47	0.028	5.90
37.00	0.86	0.72	31.80	0.88	2.00	0.89	69.00	0.47	0.027	8.17
34.00	0.88	0.72	31.80	0.88	1.00	0.95	55.00	0.47	0.032	7.07
40.00	0.86	0.72	33.80	0.83	2.00	0.89	83.60	0.47	0.022	8.55
32.00	0.88	0.72	27.10	1.00	2.00	0.89	60.00	0.48	0.030	6.65
43.00	0.78	0.72	27.80	0.98	2.00	0.89	75.00	0.48	0.022	7.01
46.00	0.78	0.72	28.61	0.95	2.00	0.89	70.20	0.48	0.014	4.31
27.00	0.88	0.72	29.60	0.95	2.00	0.89	70.00	0.48	0.030	8.17
24.00	0.91	0.72	31.10	0.90	2.00	0.89	58.00	0.48	0.030	6.90
33.00	0.88	0.72	33.80	0.83	2.00	0.89	74.50	0.48	0.023	7.63
37.00	0.86	0.72	28.45	0.98	1.00	0.95	72.00	0.49	0.015	3.82
32.00	0.88	0.72	29.50	0.93	1.00	0.95	59.00	0.49	0.029	6.24
37.00	0.86	0.72	29.53	0.93	2.00	0.89	90.00	0.49	0.024	8.60
38.00	0.86	0.72	30.84	0.93	1.00	0.95	83.20	0.49	0.025	7.76
27.00	0.88	0.72	31.40	0.90	1.00	0.95	60.00	0.49	0.032	7.23
36.00	0.86	0.72	33.80	0.83	1.00	0.95	101.90	0.49	0.030	12.77
20.00	1.00	0.72	29.43	0.95	1.00	0.95	79.00	0.50	0.017	4.13
28.00	0.88	0.72	30.10	0.93	1.00	0.95	63.40	0.50	0.027	6.11
52.00	0.69	0.72	32.32	0.88	1.00	0.95	57.30	0.50	0.030	8.28
39.00	0.86	0.72	27.30	1.00	1.00	0.95	62.00	0.51	0.027	5.58
41.00	0.86	0.72	27.50	0.98	2.00	0.89	77.20	0.51	0.023	6.45
28.00	0.88	0.72	29.50	0.93	2.00	0.89	81.70	0.51	0.014	4.27
25.00	0.91	0.72	30.20	0.93	2.00	0.89	61.00	0.51	0.031	6.83
50.00	0.69	0.72	32.30	0.88	2.00	0.89	55.00	0.51	0.023	6.37
42.00	0.86	0.72	32.30	0.88	2.00	0.89	55.40	0.52	0.021	4.61

Table 4. 9. Frequency of lifts vs Safe Weight Lift (SWL)

Age (year)	*AG*	*GN*	Temperature (°C)	*TF*	Frequency of lifts (lifts/min)	*FM*	m_b (kg)	*L*(m)	*x*(m)	SWL (kg)
30.00	0.88	0.72	29.00	0.71	1.00	0.95	75.00	0.45	0.014	5.46
28.00	0.88	0.72	29.60	0.95	1.00	0.95	55.00	0.46	0.030	6.27
35.00	0.88	0.72	30.10	0.95	1.00	0.95	59.00	0.46	0.026	5.83
35.00	0.88	0.72	31.23	0.90	1.00	0.95	85.30	0.46	0.028	9.58
29.00	0.88	0.72	31.40	0.90	1.00	0.95	59.00	0.46	0.025	5.91
30.00	0.88	0.72	26.50	1.00	1.00	0.95	74.00	0.47	0.023	6.01
42.00	0.86	0.72	27.30	1.00	1.00	0.95	73.00	0.47	0.020	5.28
34.00	0.88	0.72	31.80	0.88	1.00	0.95	55.00	0.47	0.032	7.07
37.00	0.86	0.72	28.45	0.98	1.00	0.95	72.00	0.49	0.015	3.82
32.00	0.88	0.72	29.50	0.93	1.00	0.95	59.00	0.49	0.029	6.24
38.00	0.86	0.72	30.84	0.93	1.00	0.95	83.20	0.49	0.025	7.76
27.00	0.88	0.72	31.40	0.90	1.00	0.95	60.00	0.49	0.032	7.23
36.00	0.86	0.72	33.80	0.83	1.00	0.95	101.90	0.49	0.030	12.77
20.00	1.00	0.72	29.43	0.95	1.00	0.95	79.00	0.50	0.017	4.13
28.00	0.88	0.72	30.10	0.93	1.00	0.95	63.40	0.50	0.027	6.11
52.00	0.69	0.72	32.32	0.88	1.00	0.95	57.30	0.50	0.030	8.28
39.00	0.86	0.72	27.30	1.00	1.00	0.95	62.00	0.51	0.027	5.58
29.00	0.88	0.72	29.30	0.95	2.00	0.89	65.70	0.41	0.023	6.88
35.00	0.88	0.72	37.20	0.76	2.00	0.89	66.00	0.42	0.016	5.87
30.00	0.88	0.72	31.20	0.90	2.00	0.89	55.00	0.43	0.015	3.78
25.00	0.91	0.72	29.60	0.95	2.00	0.89	54.00	0.44	0.030	6.65
33.00	0.88	0.72	31.34	0.90	2.00	0.89	82.00	0.44	0.033	12.11
26.00	0.88	0.72	31.40	0.90	2.00	0.89	59.00	0.44	0.026	6.86
40.00	0.86	0.72	34.30	0.83	2.00	0.89	60.00	0.44	0.020	5.96
33.00	0.88	0.72	26.80	1.00	2.00	0.89	70.60	0.45	0.018	5.00
22.00	1.00	0.72	29.30	0.95	2.00	0.89	61.40	0.45	0.030	6.72
30.00	0.88	0.72	31.30	0.90	2.00	0.89	80.30	0.45	0.019	6.68
23.00	0.91	0.72	31.30	0.90	2.00	0.89	55.00	0.45	0.030	6.98
28.00	0.88	0.72	31.40	0.90	2.00	0.89	51.50	0.45	0.027	6.09
35.00	0.88	0.72	31.80	0.88	2.00	0.89	87.60	0.45	0.025	9.80
36.00	0.88	0.72	26.90	1.00	2.00	0.89	71.80	0.46	0.024	6.64
31.00	0.88	0.72	29.30	0.95	2.00	0.89	57.20	0.46	0.022	5.10
34.00	0.88	0.72	27.50	0.98	2.00	0.89	60.50	0.47	0.032	7.45
45.00	0.78	0.72	28.71	0.95	2.00	0.89	68.70	0.47	0.016	4.92
29.00	0.88	0.72	29.20	0.95	2.00	0.89	54.10	0.47	0.025	5.37
22.00	1.00	0.72	30.30	0.93	2.00	0.89	59.00	0.47	0.028	5.90
37.00	0.86	0.72	31.80	0.88	2.00	0.89	69.00	0.47	0.027	8.17
40.00	0.86	0.72	33.80	0.83	2.00	0.89	83.60	0.47	0.022	8.55
32.00	0.88	0.72	27.10	1.00	2.00	0.89	60.00	0.48	0.030	6.65
43.00	0.78	0.72	27.80	0.98	2.00	0.89	75.00	0.48	0.022	7.01
46.00	0.78	0.72	28.61	0.95	2.00	0.89	70.20	0.48	0.014	4.31
27.00	0.88	0.72	29.60	0.95	2.00	0.89	70.00	0.48	0.030	8.17
24.00	0.91	0.72	31.10	0.90	2.00	0.89	58.00	0.48	0.030	6.90
33.00	0.88	0.72	33.80	0.83	2.00	0.89	74.50	0.48	0.023	7.63
37.00	0.86	0.72	29.53	0.93	2.00	0.89	90.00	0.49	0.024	8.60
41.00	0.86	0.72	27.50	0.98	2.00	0.89	77.20	0.51	0.023	6.45
28.00	0.88	0.72	29.50	0.93	2.00	0.89	81.70	0.51	0.014	4.27
25.00	0.91	0.72	30.20	0.93	2.00	0.89	61.00	0.51	0.031	6.83
50.00	0.69	0.72	32.30	0.88	2.00	0.89	55.00	0.51	0.023	6.37
42.00	0.86	0.72	32.30	0.88	2.00	0.89	55.40	0.52	0.021	4.61

Figure 4.7 shows the relationship between the SWL and male bricklayers' age. There was a negligible positive relationship between the SWL and male bricklayers' age (β=0.08). It means a slight increase in the SWL as workers' age increased.

Figure 4.8 shows the relationship between the SWL and male bricklayers' weight. There was a moderate positive relationship between the SWL and male bricklayers' weight (β =0.51). The moderate positive relationship means that an increase in male bricklayers' weight led to a gradual increase in the SWL.

Figure 4.9 shows the relationship between male bricklayers' stature change and SWL. There was a moderate positive relationship between the SWL and male bricklayers' stature change (β =0.58). The moderate positive relationship means a gradual increase in the SWL as stature change increases. Figure 4.10 shows the relationship between the SWL and temperature. There was a weak positive relationship between the SWL and temperature (β =0.25). The weak positive relationship means that increased temperature led to a minimal increase in the SWL.

Figure 4.11 shows the association between the SWL and the male bricklayers' spine length. There was a negligible negative relationship between the SWL and spine length (β= -0.06). The negligible negative relationship means that an increase in spine length led to a slight decrease in the SWL. The relationship between SWL and frequency of lift is shown in Figure 4.12. There was a negligible positive relationship between SWL and the frequency of lifts (β=0.00). The negligible positive relationship means that an increase in the frequency of lifts led to a slight increase in the SWL.

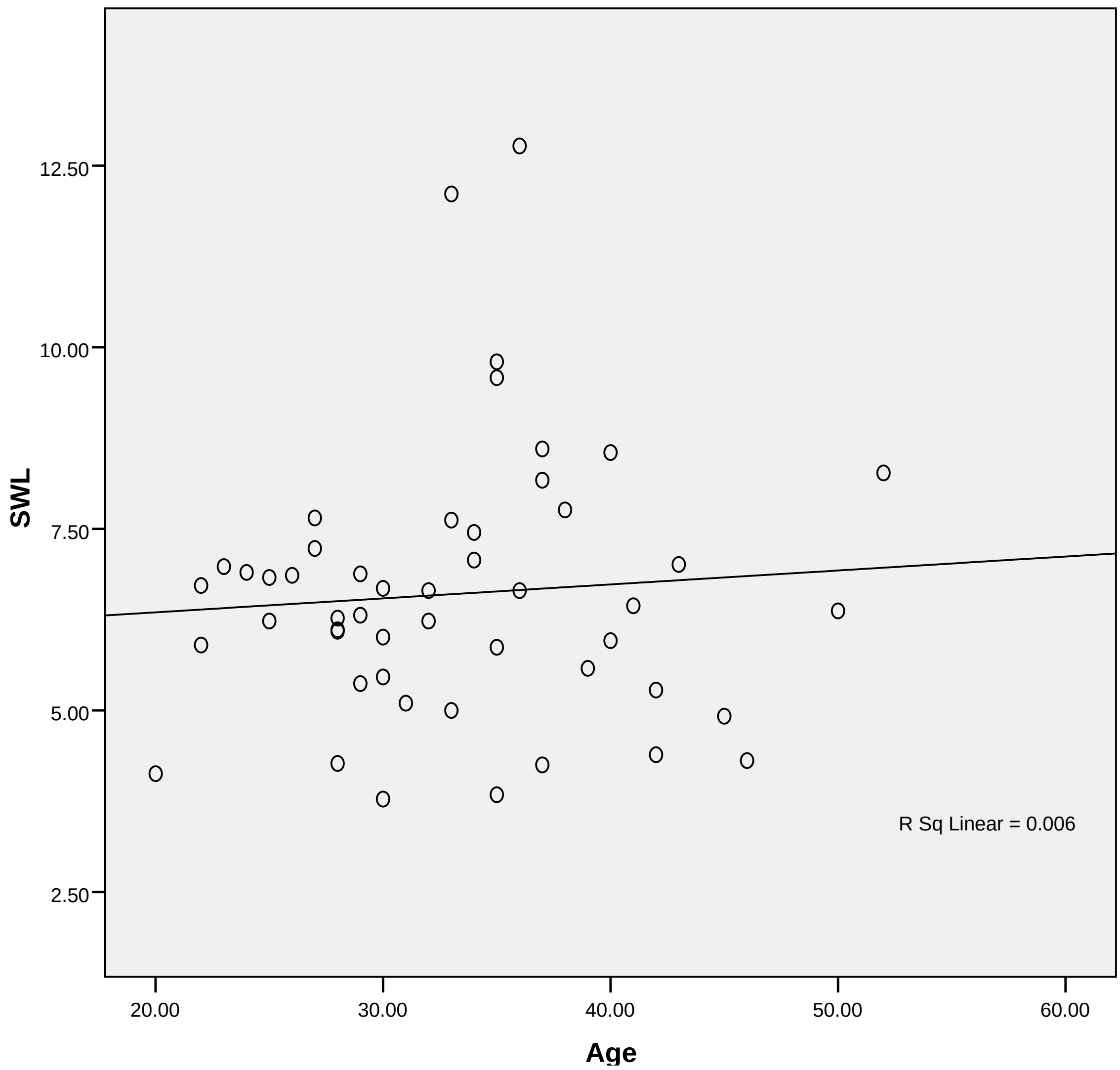

Figure 4. 7. Safe Weight of Lift vs Age

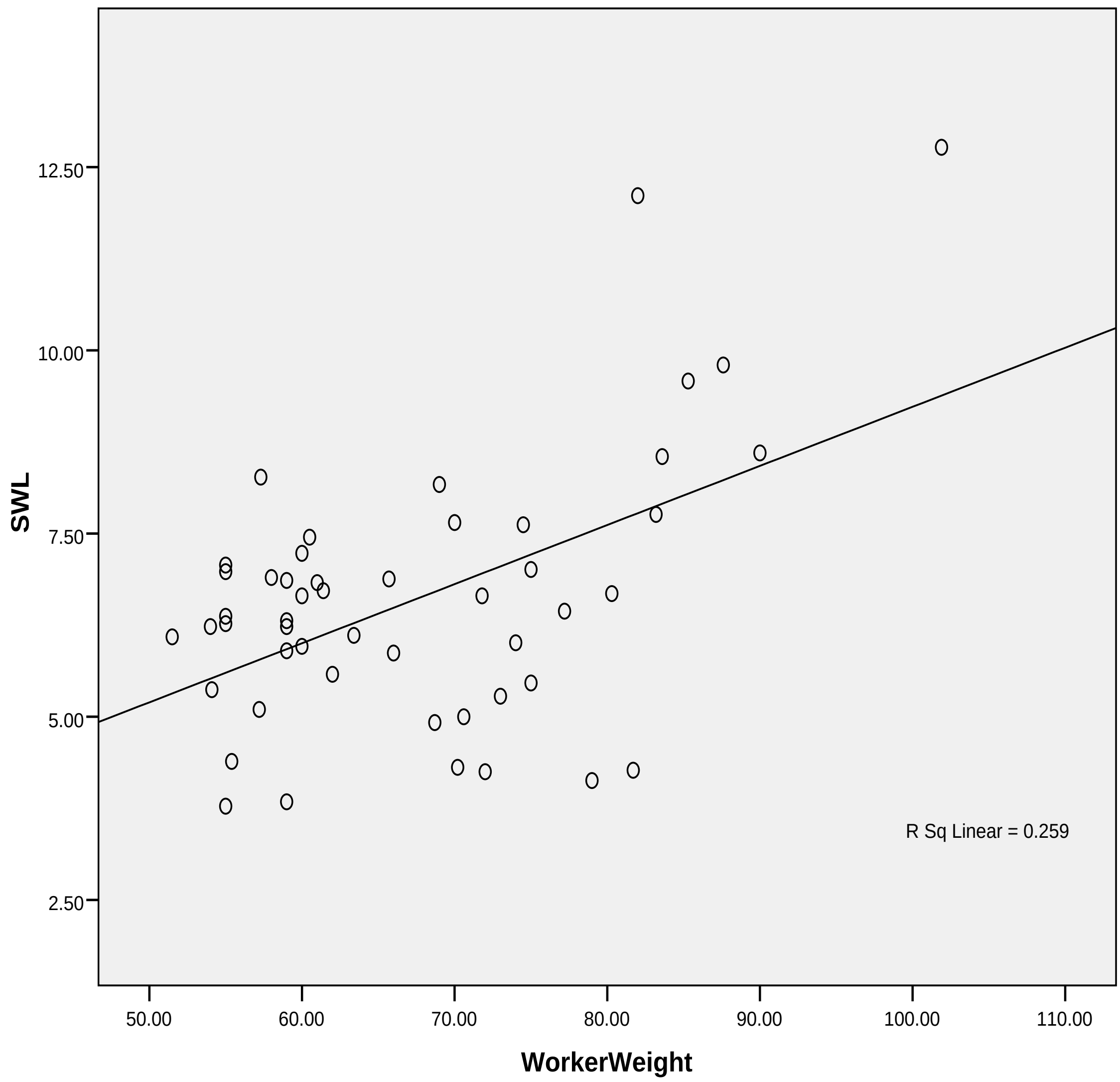

Figure 4. 8. Safe Weight of Lift vs Weight

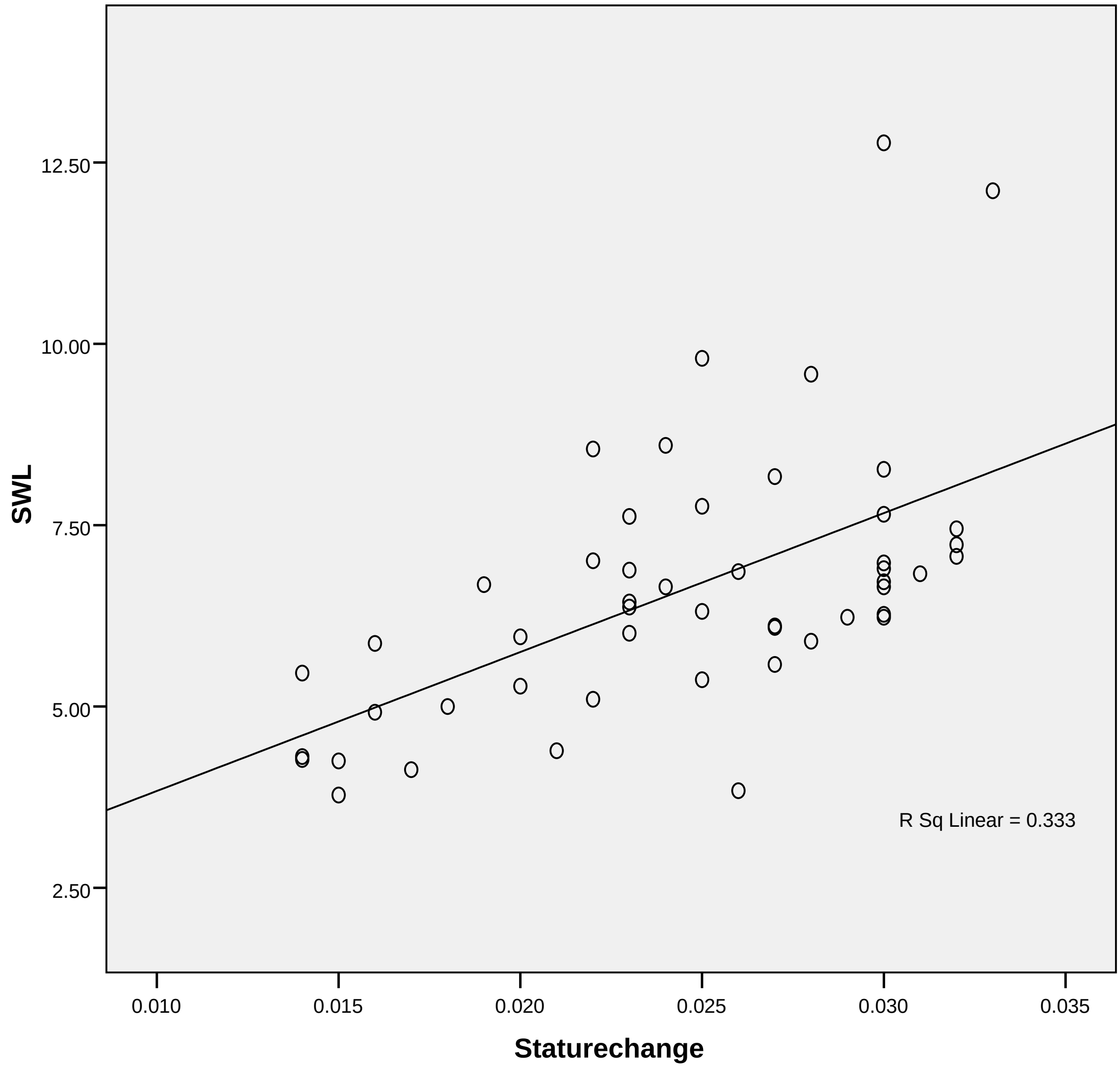

Figure 4. 9. Safe Weight of Lift vs Stature change

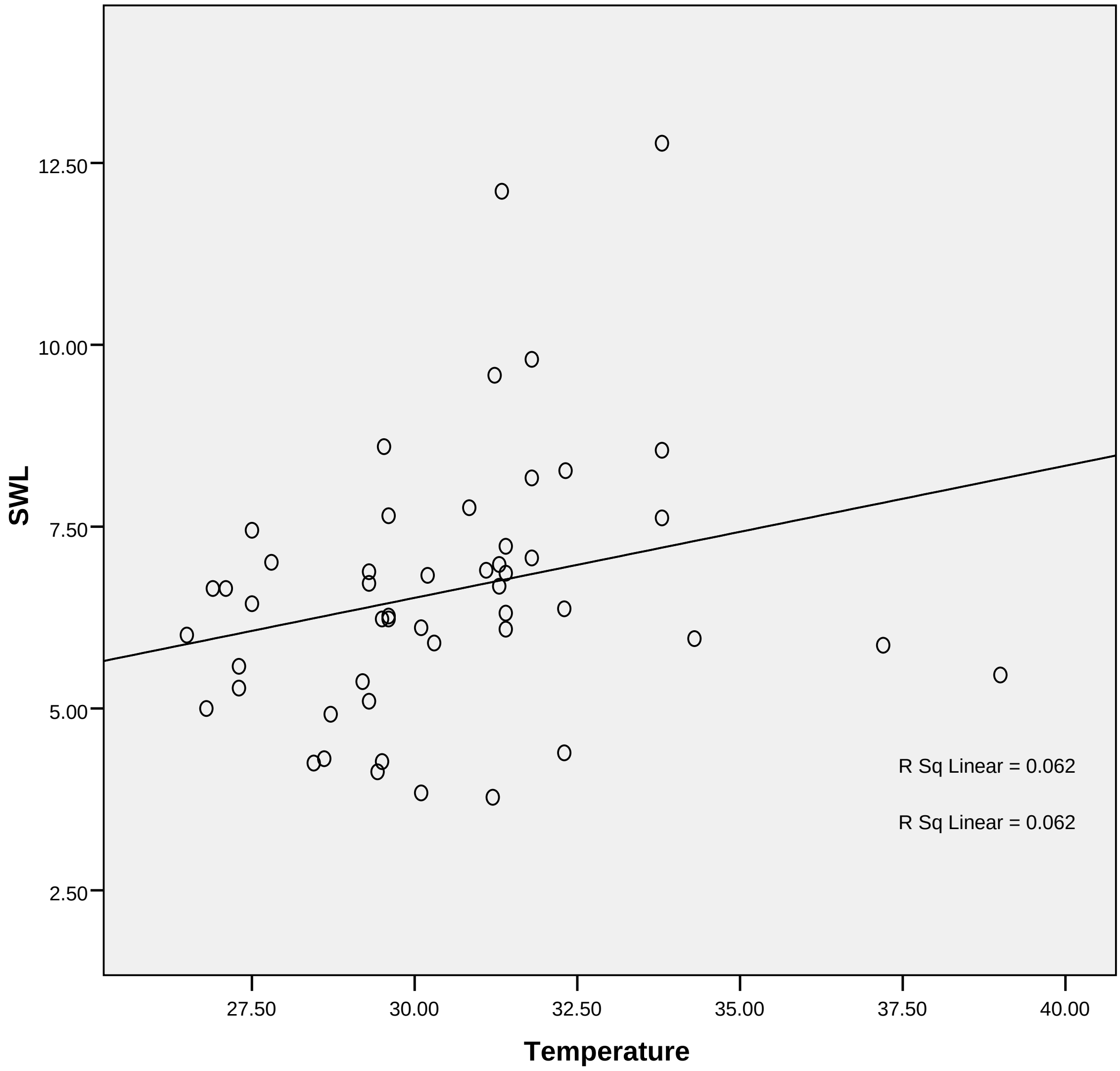

Figure 4. 10. Safe Weight of Lift vs Temperature

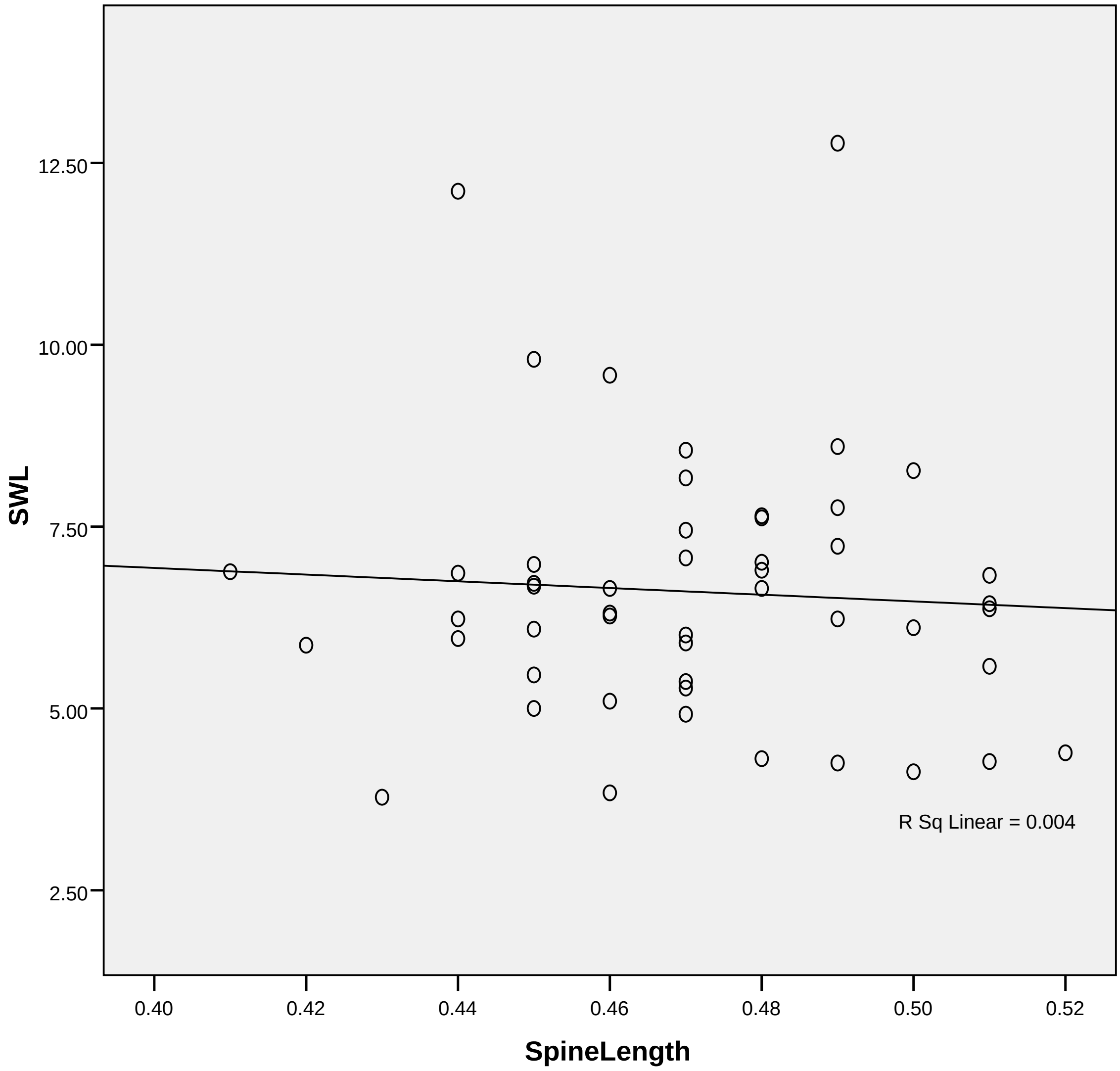

Figure 4. 11. Safe Weight of Lift vs Spine length

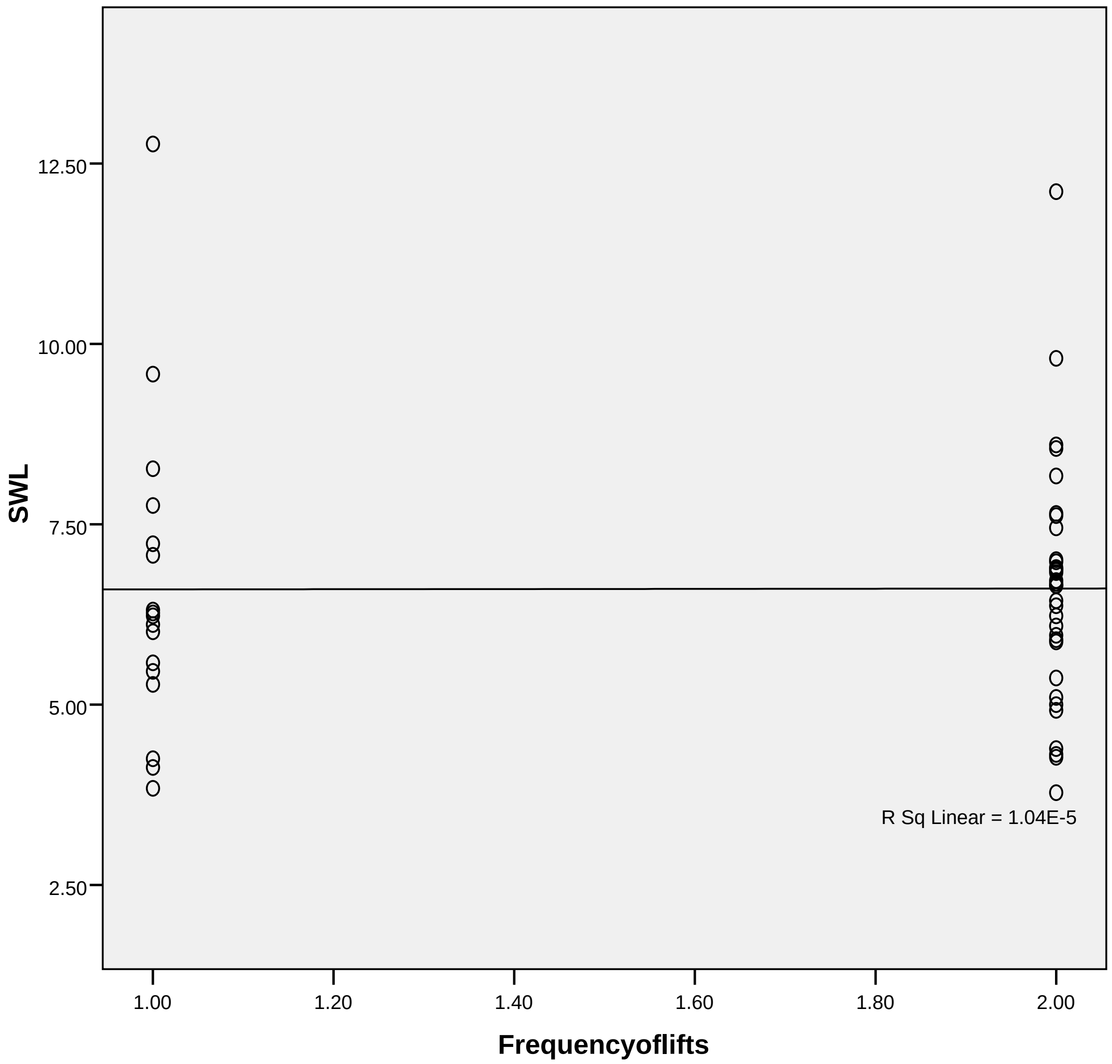

Figure 4. 12. Safe Weight of Lift vs Frequency of lifts

4.5 R**elationship between two-ways interactions of independently selected male bricklayer characteristic factors and safe weight of the lift**

Table 4.10 shows the results of two-ways interaction of independently selected male bricklayer characteristic factors to explain the SWL model interrelationship of the selected factors. The interaction between male bricklayers' age (*AG*) and temperature (*TF*) (*AGTF*) explained 6% of the total variance in the model. It had a weak negative relationship (β = -0.24) with the SWL. The *AGTF* contributed insignificantly ($p>0.05$) to the model. The insignificant contribution of the *AGTF* was a result of the overlapping of their interaction with other independent factors in the model. The interaction between male bricklayers' age (*AG*) and frequency of lifts (*FM*) (*AGFM*) explained 1% of the total variance in the *SWLwT*. It had a negligible negative relationship (β = -0.08) with the SWL. The *AGFM* contributed insignificantly ($p>.05$) to the *SWLwT*. The overlap of *AGFM* and other independent factors in the model caused the insignificant contribution. Interaction between male bricklayers' age (*AG*) and weight (*AGWEIGHT*) explained 21% of the total variance in the developed model. It had a moderate positive relationship (β = 0.46) with the SWL. The *AGWEIGHT* contributed significantly ($p<0.05$) to the *SWLwT*. The *AGL* was the interaction between male bricklayers' age and spine length factor.

The AGL explained 1% of the total variance in the *SWLwT*. It had a weak negative relationship (β = -0.12) with the SWL. The *AGL* contributed insignificantly ($p>0.05$) to the model. The insignificant contribution was attributed to the overlap of the *AGL* and other independent factors in the model. The interaction between male bricklayers' age and stature change (*AGx*) explained 26% of the total variance in the model. It had a moderate positive relationship (β = 0.51) with the SWL. The *AGx* contributed significantly ($p<0.05$) to the SWL model. The *FMTF* was the interaction between the frequency of lifts and temperature. The *FMTF* explained 6% of the total variance in the *SWLwT*. The *FMTF* had a weak positive relationship (β =-0.25) with the SWL. It contributed insignificantly to the model ($p>0.05$).

The insignificant contribution of the interaction between the frequency of lift and temperature resulted from the overlap of the *FMTF* factor with other independent factors in the model. The interaction between temperature and male bricklayers' weight (*TF*WEIGHT) explained 14% of the total variance in the *SWLwT* model. It had a weak positive relationship (β =0.37) with the SWL and contributed significantly ($p<0.05$) to the model. The *TFL* was the interaction between temperature and male bricklayers' spine length. The TFL explained 6% of the total variance in the *SWLwT* and had a weak negative relationship (β = -0.24) with the SWL. The *TFL* contributed insignificantly ($p>0.05$) to the model. The insignificant contribution of the interaction between temperature and male bricklayers' spine length (*TFL*) was attributed to the overlap of the *TFL* and other independent factors in the *SWLwT*. The interaction between temperature and stature change (*TFx*) explained 22% of the total variance in the *SWLwT*. The *TFx* had a moderate positive relationship (β =0.46) with the SWL. It contributed significantly ($p<0.05$) to the model. The interaction between the frequency of lifts and spine length of the selected male bricklayers' (FML) explained 0% of the total variance in the model. It had a moderate negative relationship (β = -0.05) with the SWL. The *FML* contributed insignificantly ($p>0.05$) to the SWLwT. The insignificant contribution of the *FML* was attributed to the interface that occurred with other independent factors in the model. The *FMx* was the interaction between the frequency of lifts and stature change and explained 32% of the total variance in the *SWLwT* model. It had a moderate positive relationship (β =0.56) with the SWL, contributing significantly ($p<0.05$) to the model. The interaction between male bricklayers' weight (WEIGHT) and stature change (*x*) (WEIGHT*x*) explained 81% of the total variance in the model. It had a strong positive relationship (β = 0.90) with the SWL. It contributed significantly ($p<0.05$) to the model. The *Lx* was the interaction between male bricklayers' spine length (*L*) and stature change (*x*). The *Lx* explained 29% of the total variance in the model. It had a moderate positive relationship (β = 0.54) with the SWL. It made a significant ($p<0.05$) contribution to the model. The frequency of lifts (*FM*) interaction with male bricklayers' weight (WEIGHT) (*FM*WEIGHT) explained 24% of the total variance in the *SWLwT*. It had a moderate positive relationship (β = 0.49) with the SWL. It contributed significantly ($p<0.05$) to the SWLwT. The interaction between male bricklayers' weight (WEIGHT) and spine length (L) (WEIGHTL) explained 20% of the total variance in the model. The WEIGHT*L* had a moderate positive relationship (β = 0.45) with the SWL and contributed significantly ($p<0.05$) to the model.

Table 4.11 shows the ascending order arrangement of the interactions between male bricklayers' age and temperature (*AGTF*) with the SWL result. At given *AGTF* corresponding value of the weight safe to be lifted is observed at SWL (kg) column. Table 4.12 shows the ascending order arrangement of the interaction between male bricklayers' age and frequency of lifts (*AGFM*). At given *AGFM* corresponding value of the weight safe to be lifted can be observed at SWL (kg) column.

Table 4.13 shows the ascending order arrangement of the interactions between male bricklayers' age and weight factors (*AG*WEIGHT). At given *AG*WEIGHT corresponding value of the weight safe to be lifted is observed as SWL (kg). Table 4.14 shows the ascending order arrangement of the interaction between male bricklayers' age and spine length factor (*AGL*). At given *AGL* corresponding value of the weight safe to be lifted can be seen at SWL (kg) column.

Table 4.15 shows the ascending order arrangement of the interactions between male bricklayers' age and stature change factor (*AGx*). At given *AGx* corresponding value of the weight safe to be lifted is observed as SWL (kg). Table 4.16 shows the chronological arrangement of the SWL with the interaction between male bricklayers' frequency of lifts and temperature (*FMTF*). At given *FMTF* corresponding value of the weight safe to be lifted can be seen at SWL (kg) column.

Table 4.17 shows the ascending order arrangement of the interactions between temperature and male bricklayers' weight factor (*TF*WEIGHT). At given *TF*WEIGHT corresponding value of the weight safe to be lifted is observed as SWL (kg). Table 4.18 shows the ascending order arrangement of the interaction between temperature and male bricklayers' spine length factor (*TFL*). At given *TFL* corresponding value of the weight safe to be lifted is observed as SWL (kg).

Table 4.19 shows the ascending order arrangement of the interactions between temperature and stature change factor (*TFx*). At given *TFx* corresponding value of the weight safe to be lifted can be gotten at SWL (kg) column. Table 4.20 shows the ascending order arrangement of the interaction between the frequency of lifts and the male bricklayers' spine length factor (*FML*). At given *FML* corresponding value of the weight safe to be lifted can be obtained at SWL (kg) column.

Table 4.21 shows the ascending order arrangement of the interactions between frequency of lifts and stature change factor (*FMx*). At given *FMx* corresponding value of the weight safe to be lifted is seen at SWL (kg) column. Table 4.22 shows the ascending order arrangement of the interaction between male bricklayers' weight and spine length factor (WEIGHT*L*). At given WEIGHT*L* corresponding value of the weight safe to be lifted can be traced to SWL (kg) column.

Table 4.23 shows the ascending order arrangement of the interactions between male bricklayers' weight and stature change factor (WEIGHT*x*). At given WEIGHT*x* corresponding value of the weight safe to be lifted is observed as SWL (kg). Table 4.24 shows the ascending order arrangement of the interaction between the male bricklayers' spine length and stature change factor (*Lx*). At given *Lx* corresponding value of the weight safe to be lifted is observed as SWL (kg).

Table 4.25 shows the ascending order arrangement of the interactions between the frequency of lifts and male bricklayers' weight factor (*FM*WEIGHT). At a given *FM*WEIGHT corresponding value of the weight safe to be lifted can be gotten from SWL (kg) column. The relationship between the SWL and more than two-way independent characteristic factors' interaction were not possible because of repetition in the combination of the factors.

Table 4. 10. Two-ways interaction of independently selected male bricklayer characteristic factors effect on Safe Weight Lift (SWL)

Two-way independent factors interaction	**Safe Weight of Lift (SWL)**			
	R square	Beta	B	p-value
AGTF	0.06	-0.24	-5.76	0.10
AGFM	0.01	-0.08	-2.46	0.61
*AG*WEIGHT	0.21	0.46	0.08	0.00
AGL	0.01	-0.12	-6.99	0.43
AGx	0.26	0.51	177.95	0.00
FMTF	0.06	-0.25	-7.54	0.08
*TF*WEIGHT	0.14	0.37	0.06	0.01
TFL	0.06	-0.24	-11.04	0.10
TFx	0.22	0.46	158.82	0.00
FML	0.00	-0.05	-3.02	0.74
FMx	0.32	0.56	200.14	0.00
WEIGHT*x*	0.81	0.90	3.86	0.00
Lx	0.29	0.54	366.61	0.00
*FM*WEIGHT	0.24	0.49	0.08	0.00
WEIGHT*L*	0.20	0.45	0.14	0.00

Table 4. 11. ***AGTF* vs SWL**

AGTF	*AGFM*	*AG*WEIGHT	*AGL*	*AGx*	*FMTF*	*TF*WEIGHT	*TFL*	*TFx*	*FML*	*FMx*	WEIGHT*L*	WEIGHT*x*	*Lx*	*FM*WEIGHT	SWL
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25

0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13

Table 4. 12. *AGFM* vs SWL

AGTF	*AGFM*	*AG*WEIGHT	*AGL*	*AGx*	*FMTF*	*TF*WEIGHT	*TFL*	*TFx*	*FML*	*FMx*	WEIGHT*L*	WEIGHT*x*	*Lx*	*FM*WEIGHT	SWL
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28

0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13

Table 4. 13. *AG*WEIGHT vs SWL

AGTF	***AGFM***	***AG*WEIGHT**	***AGL***	***AGx***	***FMTF***	***TF*WEIGHT**	***TFL***	***TFx***	***FML***	***FMx***	**WEIGHT*L***	**WEIGHT*x***	***Lx***	***FM*WEIGHT**	**SWL**
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01

0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77

AGTF	*AGFM*	*AG*WEIGHT	*AGL*	*AGx*	*FMTF*	*TF*WEIGHT	*TFL*	*TFx*	*FML*	*FMx*	WEIGHT*L*	WEIGHT*x*	*Lx*	*FM*WEIGHT	SWL
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25
0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76

0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13

Table 4. 14. *AGL* vs SWL

Table 4. 15. *AGx* vs SWL

AGTF	***AGFM***	***AG*WEIGHT**	***AGL***	***AGx***	***FMTF***	***TF*WEIGHT**	***TFL***	***TFx***	***FML***	***FMx***	**WEIGHT*L***	**WEIGHT*x***	***Lx***	***FM*WEIGHT**	**SWL**
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13

0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90

Table 4. 16. *FMTF* vs SWL

AGTF	*AGFM*	*AG*WEIGHT	*AGL*	*AGx*	*FMTF*	*TF*WEIGHT	*TFL*	*TFx*	*FML*	*FMx*	WEIGHT*L*	WEIGHT*x*	*Lx*	*FM*WEIGHT	SWL
0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23

0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58

Table 4. 17. *TF*WEIGHT vs SWL

AGTF	*AGFM*	*AG*WEIGHT	*AGL*	*AGx*	*FMTF*	*TF*WEIGHT	*TFL*	*TFx*	*FML*	*FMx*	WEIGHT*L*	WEIGHT*x*	*Lx*	*FM*WEIGHT	SWL
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25

0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13

Table 4. 18. *TF*WEIGHT vs SWL

AGTF	*AGFM*	*AG*WEIGHT	*AGL*	*AGx*	*FMTF*	*TF*WEIGHT	*TFL*	*TFx*	*FML*	*FMx*	WEIGHT*L*	WEIGHT*x*	*Lx*	*FM*WEIGHT	SWL
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45

0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58

Table 4. 19. *TFx* vs SWL

AGTF	*AGFM*	*AG*WEIGHT	*AGL*	*AGx*	*FMTF*	*TF*WEIGHT	*TFL*	*TFx*	*FML*	*FMx*	WEIGHT*L*	WEIGHT*x*	*Lx*	*FM*WEIGHT	SWL
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13

0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11

Table 4. 20. *FML* vs SWL

AGTF	***AGFM***	***AG*WEIGHT**	***AGL***	***AGx***	***FMTF***	***TF*WEIGHT**	***TFL***	***TFx***	***FML***	***FMx***	**WEIGHT*L***	**WEIGHT*x***	***Lx***	***FM*WEIGHT**	**SWL**
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65

0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25
0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13

Table 4. 21. *FMx* vs SWL

AGTF	*AGFM*	*AG*WEIGHT	*AGL*	*AGx*	*FMTF*	*TF*WEIGHT	*TFL*	*TFx*	*FML*	*FMx*	WEIGHT*L*	WEIGHT*x*	*Lx*	*FM*WEIGHT	SWL
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13

0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83

Table 4. 22. WEIGHT*L* vs SWL

AGTF	*AGFM*	*AG*WEIGHT	*AGL*	*AGx*	*FMTF*	*TF*WEIGHT	*TFL*	*TFx*	*FML*	*FMx*	WEIGHT*L*	WEIGHT*x*	*Lx*	*FM*WEIGHT	SWL
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31

0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25
0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77

Table 4. 23. WEIGHT*x* vs SWL

AGTF	*AGFM*	*AG*WEIGHT	*AGL*	*AGx*	*FMTF*	*TF*WEIGHT	*TFL*	*TFx*	*FML*	*FMx*	WEIGHT*L*	WEIGHT*x*	*Lx*	*FM*WEIGHT	SWL
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27

0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77

Table 4. 24. *Lx* vs SWL

AGTF	AGFM	*AG*WEIGHT	*AGL*	*AGx*	*FMTF*	*TF*WEIGHT	*TFL*	*TFx*	*FML*	*FMx*	WEIGHT*L*	WEIGHT*x*	*Lx*	*FM*WEIGHT	SWL
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.73	0.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90

0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83

Table 4. 25. *FM*WEIGHT vs SWL

AGTF	*AGFM*	*AG*WEIGHT	*AGL*	*AGx*	*FMTF*	*TF*WEIGHT	*TFL*	*TFx*	*FML*	*FMx*	WEIGHT*L*	WEIGHT*x*	*Lx*	*FM*WEIGHT	SWL
0.79	0.78	45.32	0.40	0.02	0.80	46.35	0.41	0.02	0.40	0.02	23.18	1.39	0.012	45.84	6.09
0.86	0.81	49.14	0.40	0.03	0.85	51.30	0.42	0.03	0.39	0.03	23.76	1.62	0.013	48.06	6.23
0.84	0.78	47.61	0.41	0.02	0.85	51.40	0.45	0.02	0.42	0.02	25.43	1.35	0.012	48.15	5.37
0.79	0.78	48.40	0.38	0.01	0.80	49.50	0.39	0.01	0.38	0.01	23.65	0.83	0.006	48.95	3.78
0.82	0.81	50.05	0.41	0.03	0.80	49.50	0.41	0.03	0.40	0.03	24.75	1.65	0.014	48.95	6.98
0.61	0.61	37.95	0.35	0.02	0.78	48.40	0.45	0.02	0.45	0.02	28.05	1.27	0.012	48.95	6.37
0.76	0.77	47.64	0.45	0.02	0.78	48.75	0.46	0.02	0.46	0.02	28.81	1.16	0.011	49.31	4.39
0.84	0.78	50.34	0.40	0.02	0.85	54.34	0.44	0.02	0.41	0.02	26.31	1.26	0.010	50.91	5.10
0.82	0.81	52.78	0.44	0.03	0.80	52.20	0.43	0.03	0.43	0.03	27.84	1.74	0.014	51.62	6.90
0.84	0.84	48.40	0.40	0.03	0.90	52.25	0.44	0.03	0.44	0.03	25.30	1.65	0.014	52.25	6.27
0.77	0.84	48.40	0.41	0.03	0.84	48.40	0.41	0.03	0.45	0.03	25.85	1.76	0.015	52.25	7.07
0.79	0.78	51.92	0.39	0.02	0.80	53.10	0.40	0.02	0.39	0.02	25.96	1.53	0.011	52.51	6.86
0.93	0.89	59.00	0.47	0.03	0.83	54.87	0.44	0.03	0.42	0.02	27.73	1.65	0.013	52.51	5.90
0.71	0.77	51.60	0.38	0.02	0.74	49.80	0.37	0.02	0.39	0.02	26.40	1.20	0.009	53.40	5.96
0.88	0.78	52.80	0.42	0.03	0.89	60.00	0.48	0.03	0.43	0.03	28.80	1.80	0.014	53.40	6.65
0.86	0.78	53.24	0.41	0.03	0.87	59.29	0.46	0.03	0.42	0.03	28.44	1.94	0.015	53.85	7.45
0.85	0.81	55.51	0.46	0.03	0.83	56.73	0.47	0.03	0.45	0.03	31.11	1.89	0.016	54.29	6.83
0.61	0.66	39.54	0.35	0.02	0.84	50.42	0.44	0.03	0.48	0.03	28.65	1.72	0.015	54.43	8.27
0.95	0.89	61.40	0.45	0.03	0.85	58.33	0.43	0.03	0.40	0.03	27.63	1.84	0.014	54.65	6.72
0.79	0.84	51.92	0.40	0.02	0.86	53.10	0.41	0.02	0.44	0.02	27.14	1.48	0.012	56.05	6.31
0.84	0.84	51.92	0.40	0.02	0.90	56.05	0.44	0.02	0.44	0.02	27.14	1.53	0.012	56.05	3.84
0.82	0.84	51.92	0.43	0.03	0.88	54.87	0.46	0.03	0.47	0.03	28.91	1.71	0.014	56.05	6.23
0.79	0.84	52.80	0.43	0.03	0.86	54.00	0.44	0.03	0.47	0.03	29.40	1.92	0.016	57.00	7.23
0.84	0.78	57.82	0.36	0.02	0.85	62.42	0.39	0.02	0.36	0.02	26.94	1.51	0.009	58.47	6.88
0.67	0.78	58.08	0.37	0.01	0.68	50.16	0.32	0.01	0.37	0.01	27.72	1.06	0.007	58.74	5.87
0.86	0.82	53.32	0.44	0.02	0.95	62.00	0.51	0.03	0.48	0.03	31.62	1.67	0.014	58.90	5.58
0.82	0.84	55.79	0.44	0.02	0.88	58.96	0.47	0.03	0.48	0.03	31.70	1.71	0.014	60.23	6.11
0.74	0.69	53.59	0.37	0.01	0.85	65.27	0.45	0.02	0.42	0.01	32.29	1.10	0.008	61.14	4.92
0.76	0.77	59.34	0.40	0.02	0.78	60.72	0.41	0.02	0.42	0.02	32.43	1.86	0.013	61.41	8.17
0.84	0.78	61.60	0.42	0.03	0.85	66.50	0.46	0.03	0.43	0.03	33.60	2.10	0.014	62.30	7.65

0.74	0.69	54.76	0.37	0.01	0.85	66.69	0.46	0.01	0.43	0.01	33.70	0.98	0.007	62.48	4.31
0.88	0.78	62.13	0.40	0.02	0.89	70.60	0.45	0.02	0.40	0.02	31.77	1.27	0.008	62.83	5.00
0.88	0.78	63.18	0.40	0.02	0.89	71.80	0.46	0.02	0.41	0.02	33.03	1.72	0.011	63.90	6.65
0.73	.78	65.56	0.42	0.02	0.74	61.83	0.40	0.02	0.43	0.02	35.76	1.71	0.011	66.31	7.62
0.76	0.69	58.50	0.37	0.02	0.87	73.50	0.47	0.02	0.43	0.02	36.00	1.65	0.011	66.75	7.01
0.84	0.82	61.92	0.42	0.01	0.93	70.56	0.48	0.01	0.47	0.01	35.28	1.08	0.007	68.40	4.25
0.84	0.77	66.39	0.44	0.02	0.87	75.66	0.50	0.02	0.45	0.02	39.37	1.78	0.012	68.71	6.44
0.86	0.82	62.78	0.40	0.02	0.95	73.00	0.47	0.02	0.45	0.02	34.31	1.46	0.009	69.35	5.28
0.88	0.84	65.12	0.41	0.02	0.95	74.00	0.47	0.02	0.45	0.02	34.78	1.70	0.011	70.30	6.01
0.62	0.84	66.00	0.40	0.01	0.67	53.25	0.32	0.01	0.43	0.01	33.75	1.05	0.006	71.25	5.46
0.79	0.78	70.66	0.40	0.02	0.80	72.27	0.41	0.02	0.40	0.02	36.14	1.53	0.009	71.47	6.68
0.82	0.78	71.90	0.45	0.01	0.83	75.98	0.47	0.01	0.45	0.01	41.67	1.14	0.007	72.71	4.27
0.79	0.78	72.16	0.39	0.03	0.80	73.80	0.40	0.03	0.39	0.03	36.08	2.71	0.015	72.98	12.11
0.71	0.77	71.90	0.40	0.02	0.74	69.39	0.39	0.02	0.42	0.02	39.29	1.84	0.010	74.40	8.55
0.95	0.95	79.00	0.50	0.02	0.90	75.05	0.48	0.02	0.48	0.02	39.50	1.34	0.009	75.05	4.13
0.77	0.78	77.09	0.40	0.02	0.78	77.09	0.40	0.02	0.40	0.02	39.42	2.19	0.011	77.96	9.80
0.80	0.82	71.55	0.42	0.02	0.88	77.38	0.46	0.02	0.47	0.02	40.77	2.08	0.012	79.04	7.76
0.80	0.77	77.40	0.42	0.02	0.83	83.70	0.46	0.02	0.44	0.02	44.10	2.16	0.012	80.10	8.60
0.79	0.84	75.06	0.40	0.02	0.86	76.77	0.41	0.03	0.44	0.03	39.24	2.39	0.013	81.04	9.58
0.71	0.82	87.63	0.42	0.03	0.79	84.58	0.41	0.02	0.47	0.03	49.93	3.06	0.015	96.81	12.77

The relationship of SWL with the interactions between factors of male bricklayers' age (*AG*) and temperature (*TF*) (*AGTF*) is shown in Figure 4.13. There was a weak negative relationship between the SWL and *AGTF* (β = -.24). The weak negative relationship means that an increase in the *AGTF* led to a minimal decrease in the SWL. Figure 4.14 indicates the relationship of SWL with the interaction between factors of male bricklayers' age and lift frequency (*AGFM*). Figure 4.14 shows a negligible negative relationship between the SWL and *AGFM* (β = -0.08). The negligible negative relationship means a slight decrease in the SWL as *AGFM* increases.

The relationship of SWL with the interaction between male bricklayers' age and weight (*AG*WEIGHT) factor is shown in Figure 4.15. It shows a moderate positive relationship between the SWL and *AG*WEIGHT (β = 0.46). The moderate positive relationship means a gradual increase in the SWL as *AG*WEIGHT increases. The relationship of SWL with the interaction between male bricklayers' age and spine length (*AGL*) factor is shown in Figure 4.16. It shows a weak negative relationship between the SWL and AGL (β = -0.12). The weak negative relationship means that an increase in the *AGL* led to a slight decrease in the SWL. Figure 4.17 shows the relationship of SWL with the interaction between male bricklayers' age and stature change factor (*AGx*). It shows a moderate positive relationship between the SWL and *AGx* (β = 0.51). The moderate positive relationship means that an increase in the *AGx* led to a gradual increase in the SWL.

The relationship of SWL with the interaction between frequency of lifts and temperature factors (*FMTF*) is shown in Figure 4.18. It shows weak negative relationship between the SWL and *FMTF* (β = -0.25). The weak negative relationship means that an increase in *FMTF* led to a minimal decrease in the SWL.

Figure 4.19 shows the relationship of SWL with the interaction between temperature and male bricklayers' weight factors. There was weak positive relationship between the SWL and *TF*WEIGHT (β =0.37). The weak positive relationship means that as *TF*WEIGHT increases SWL minimally increase.

The relationship of SWL with the interaction between temperature and male bricklayers' spine length factors (*TFL*) is shown in Figure 4.20. It shows weak negative relationship between the SWL and *TFL* (β = -0.24). The weak negative relationship means that as *TFL* increases there was a minimal decrease in the SWL.

Figure 4.21 shows the relationship of SWL with the interaction between temperature and stature change factors (*TFx*). It shows moderate positive relationship between the SWL and *TFx* (β = 0.46). The moderate positive relationship means that an increase in *TFx* led to a gradual increase in the SWL.

Figure 4.22 shows the relationship of Safe Weight Lift (SWL) with the interaction between frequency of lift and male bricklayers' spine length factor (*FML*). It shows negligible negative relationship between the SWL and *FML* (β = -0.05). The negligible negative relationship means that an increase in the *FML* led to a slight decrease in the SWL.

Figure 4.23 shows the relationship of Safe Weight Lift (SWL) with the interaction between the frequency of lifts and stature change factor (*FMx*). It shows moderate positive relationship between the SWL and *FMx* (β = 0.56). The moderate positive relationship means that an increase in *FMx* corresponded to a gradual increase in the SWL.

The relationship of SWL with the interaction between male bricklayers' weight and stature change factor (WEIGHT*x*) is shown in Figure 4.24. There was a very strong positive relationship between the SWL and WEIGHT*x* (β = 0.90). The very strong positive relationship means that an increase in WEIGHT*x* led to a corresponding increase in the SWL.

Figure 4.25 shows the relationship of SWL with the interaction between male bricklayers' spine length and stature change factors. There was moderate positive relationship between the SWL and *Lx* (β = 0.54).

The moderate positive relationship means an increase in *Lx* led to a gradual increase in the SWL. The relationship of SWL with the interaction between the frequency of lifts multiplier and worker's weight factors (*FM*WEIGHT) is shown in Figure 4.26.

There was moderate positive relationship between the SWL and *FM*WEIGHT (β = 0.49). The moderate positive relationship means that as *FM*WEIGHT increase the SWL increase gradually. Figure 4.27 shows the relationship of SWL with the interaction between worker's weight and spine length factors. There was moderate positive relationship between the SWL and WEIGHT*L* (β = 0.45). The moderate positive relationship means that an increase in WEIGHT*L* led to a gradual increase in the SWL.

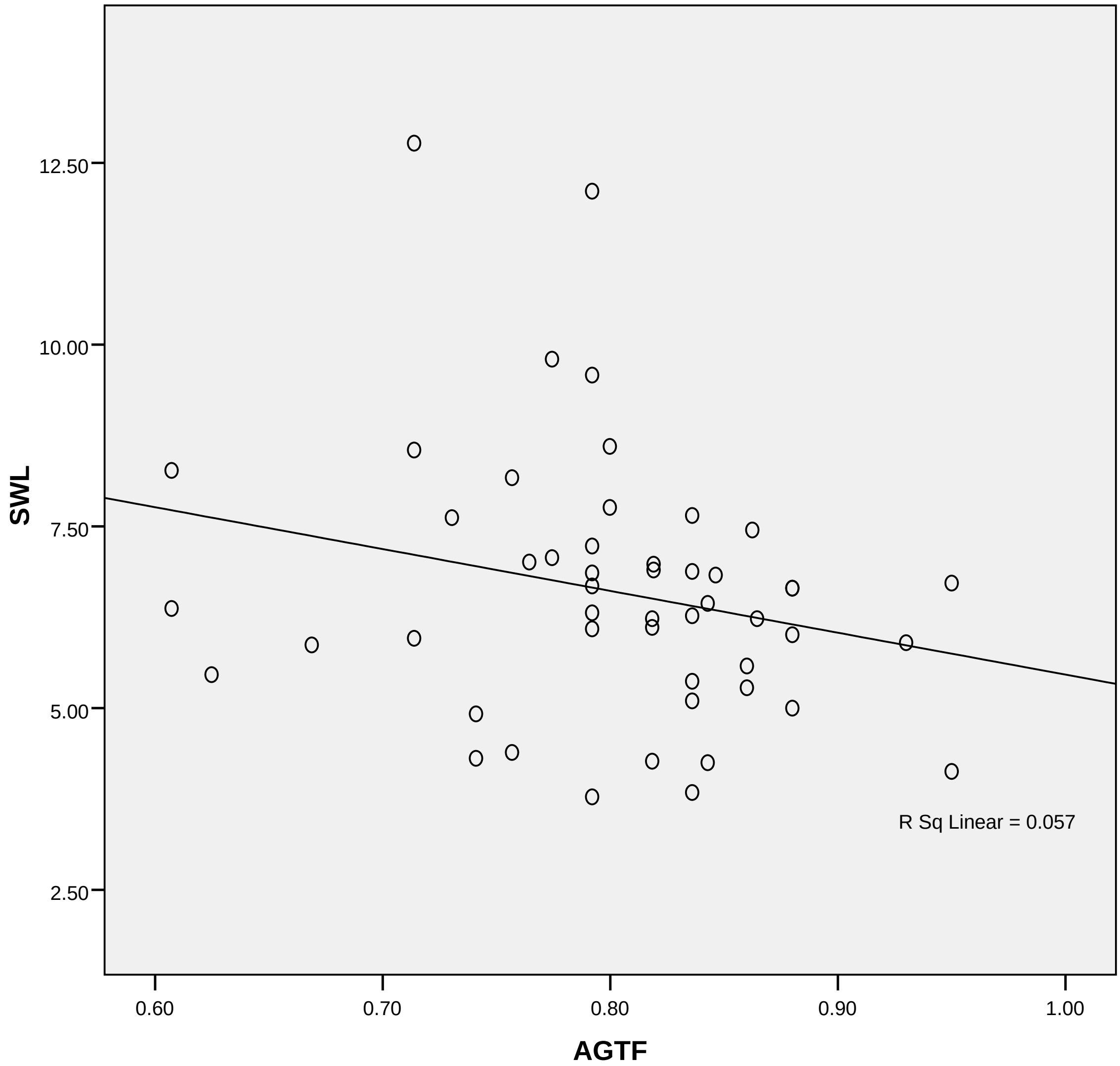

Figure 4. 13. SWL vs *AGTF*

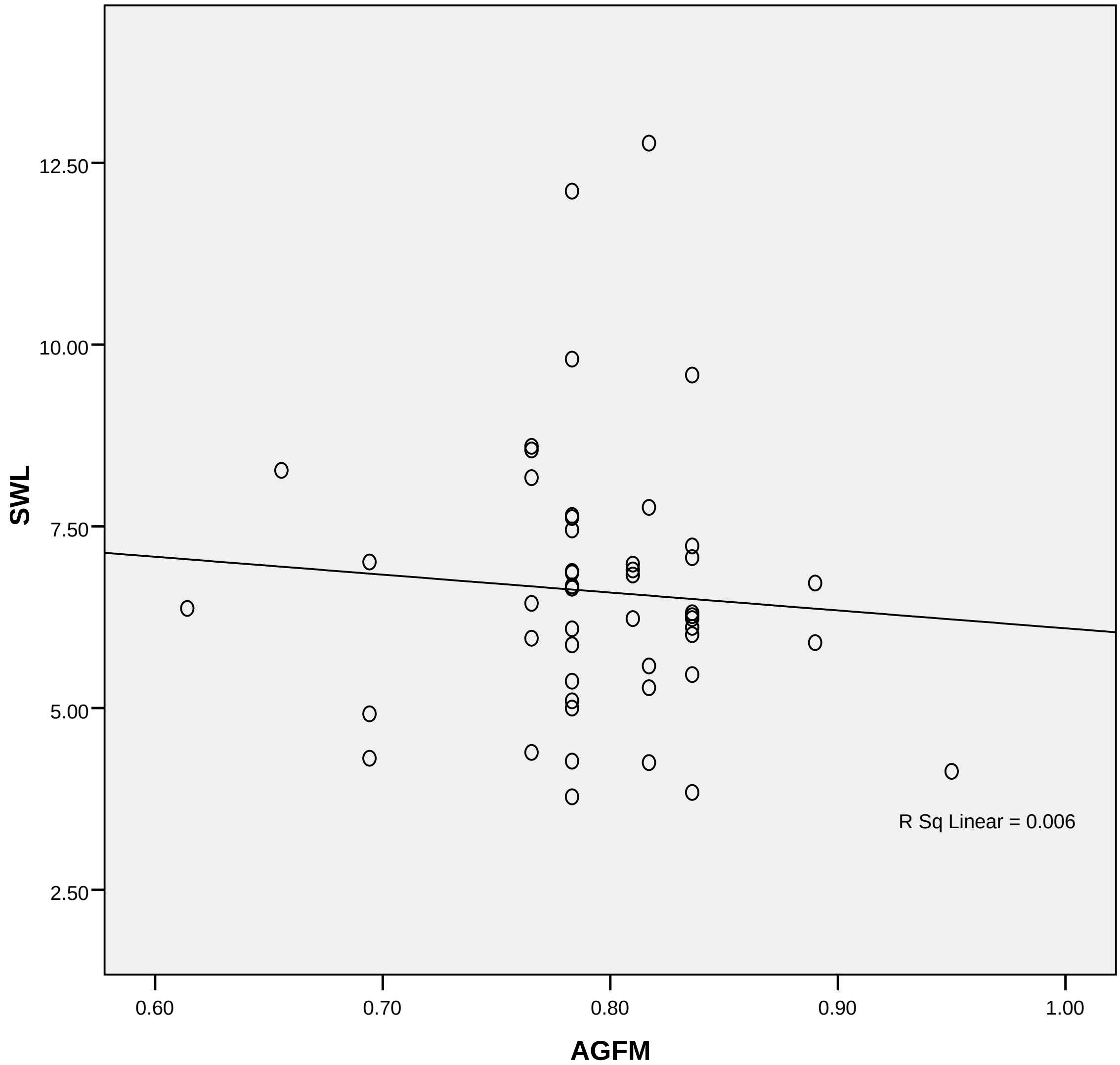

Figure 4. 14. SWL vs AGFM

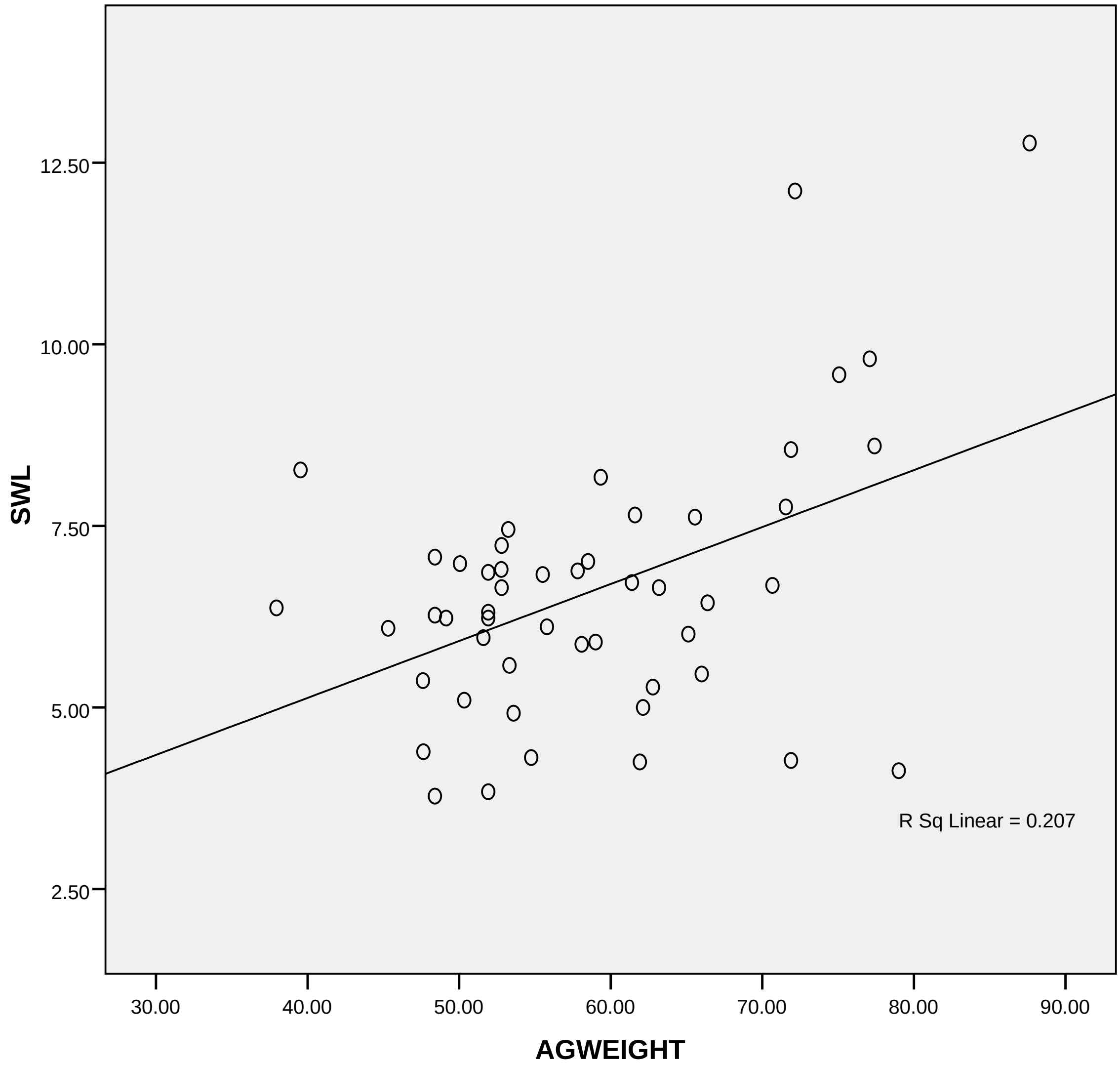

Figure 4. 15. SWL vs *AG*WEIGHT

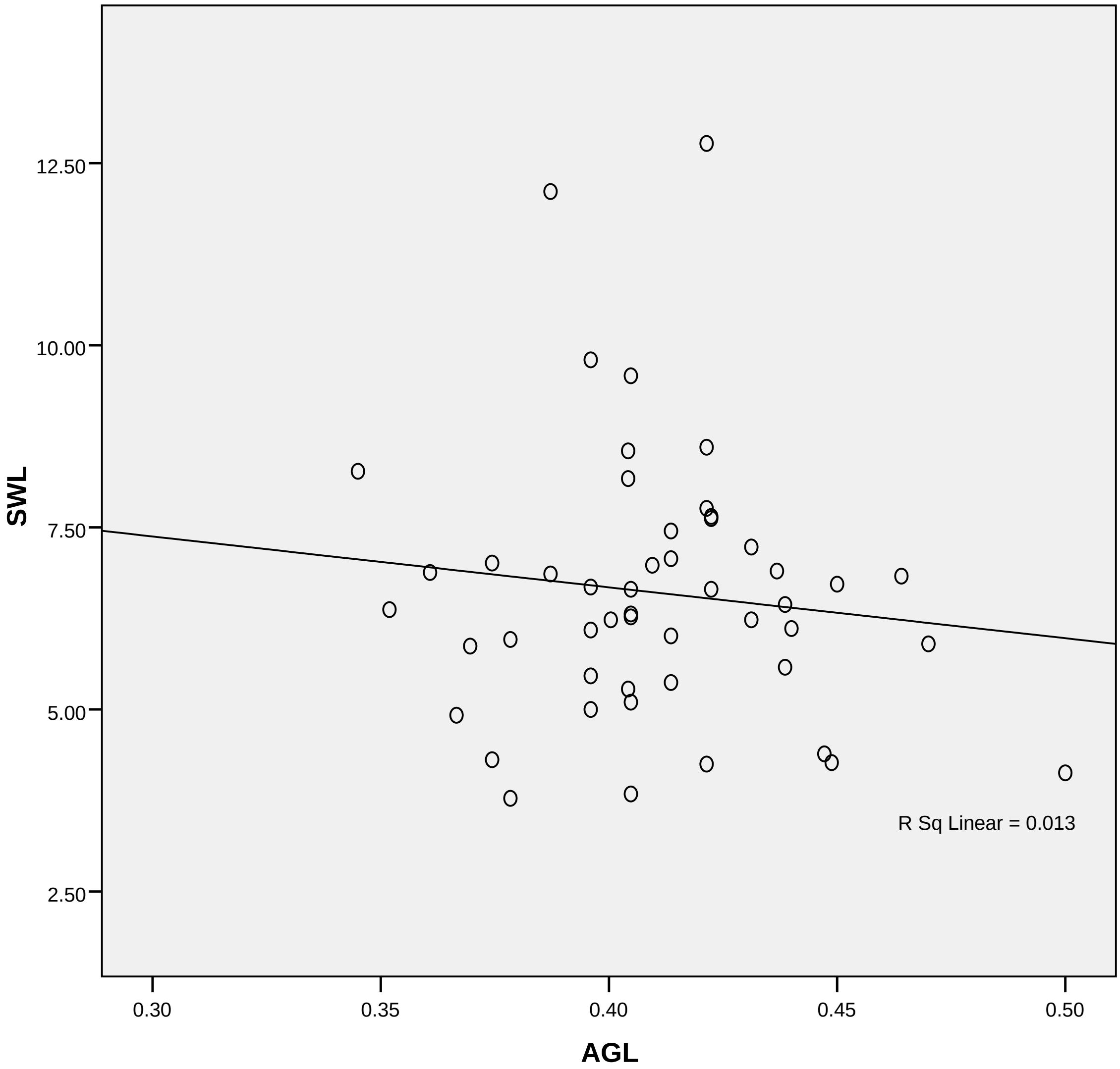

Figure 4. 16. SWL vs *AGL*

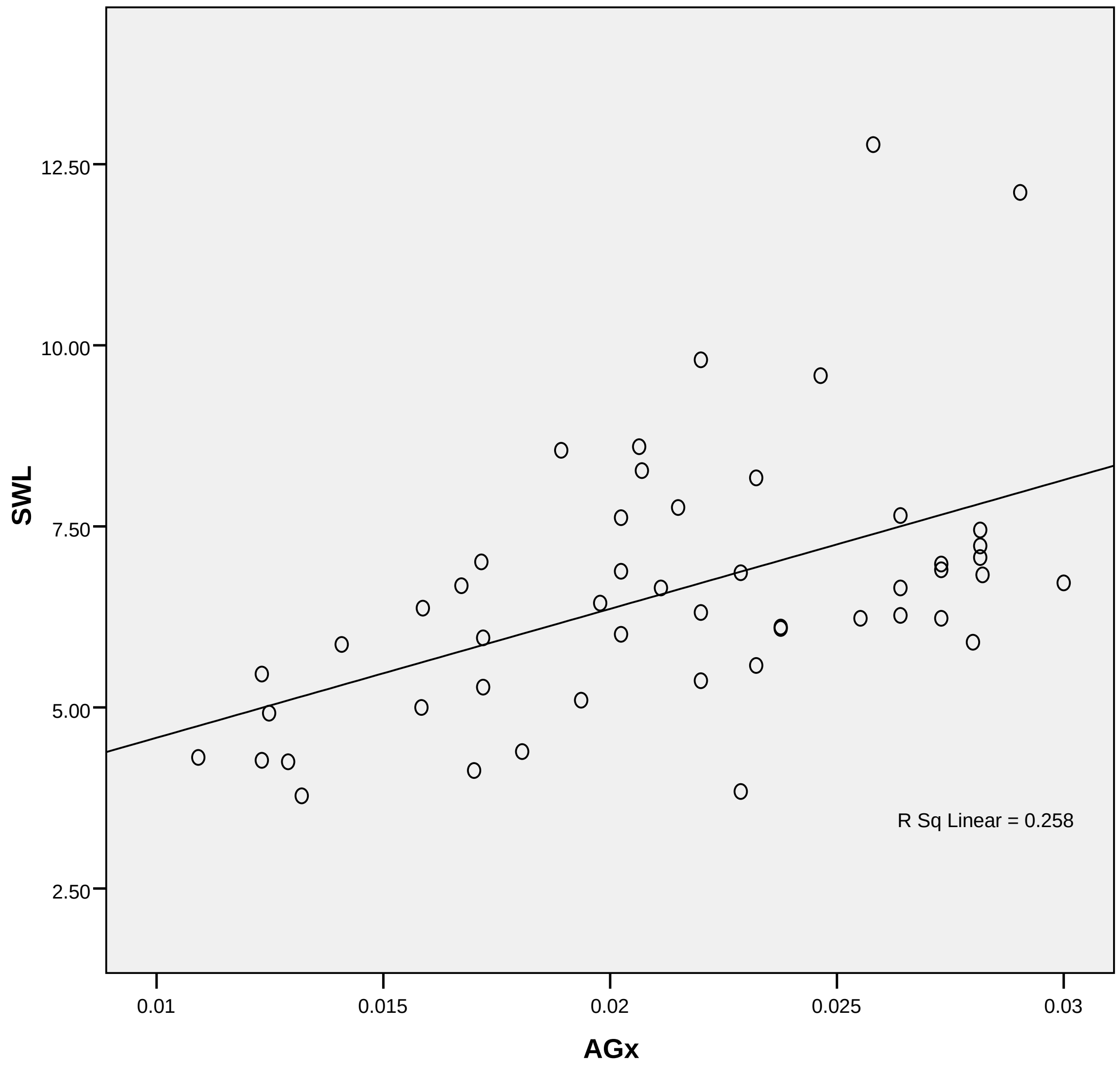

Figure 4. 17. SWL vs *AGx*

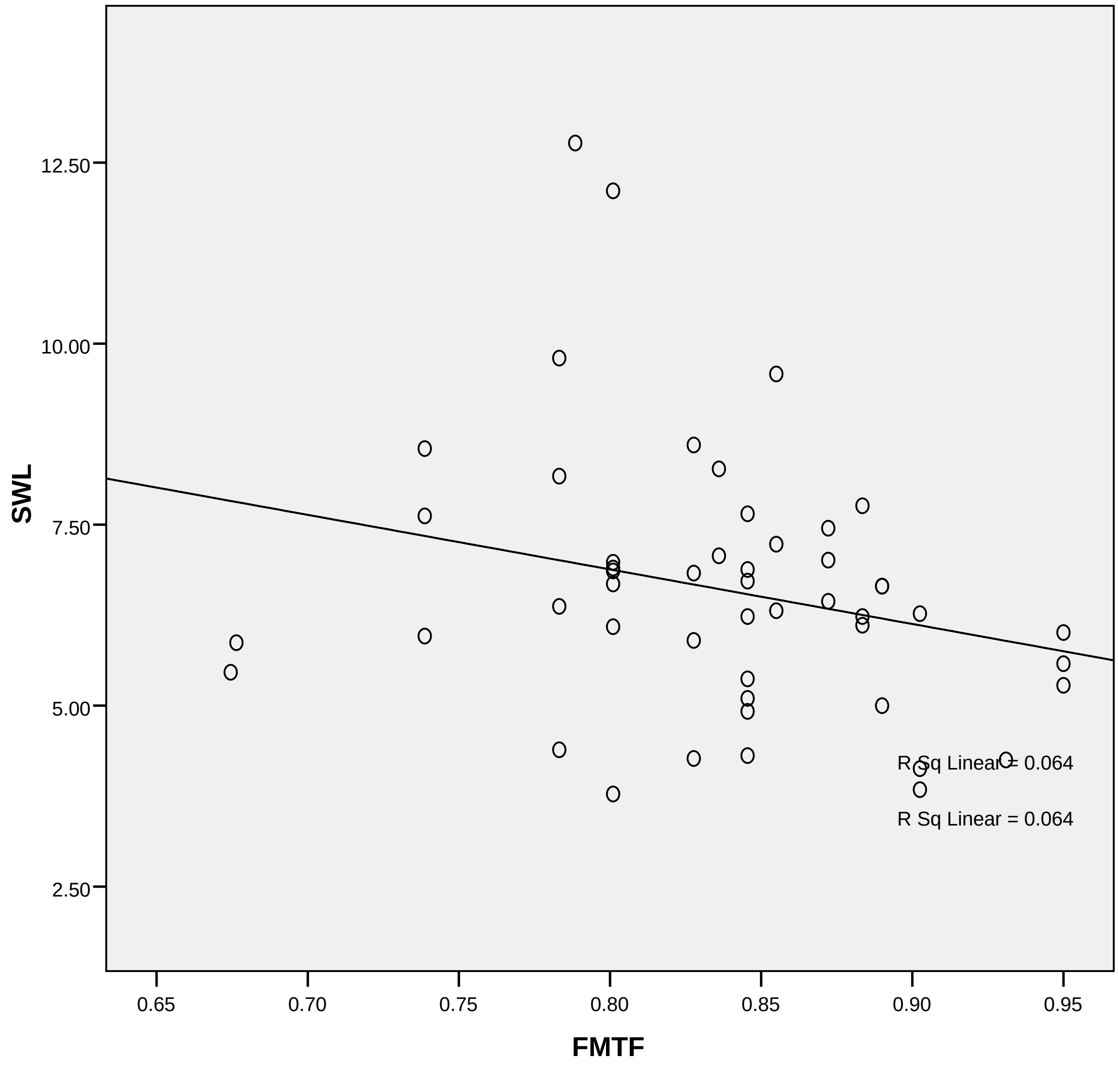

Figure 4. 18. SWL vs *FMTF*

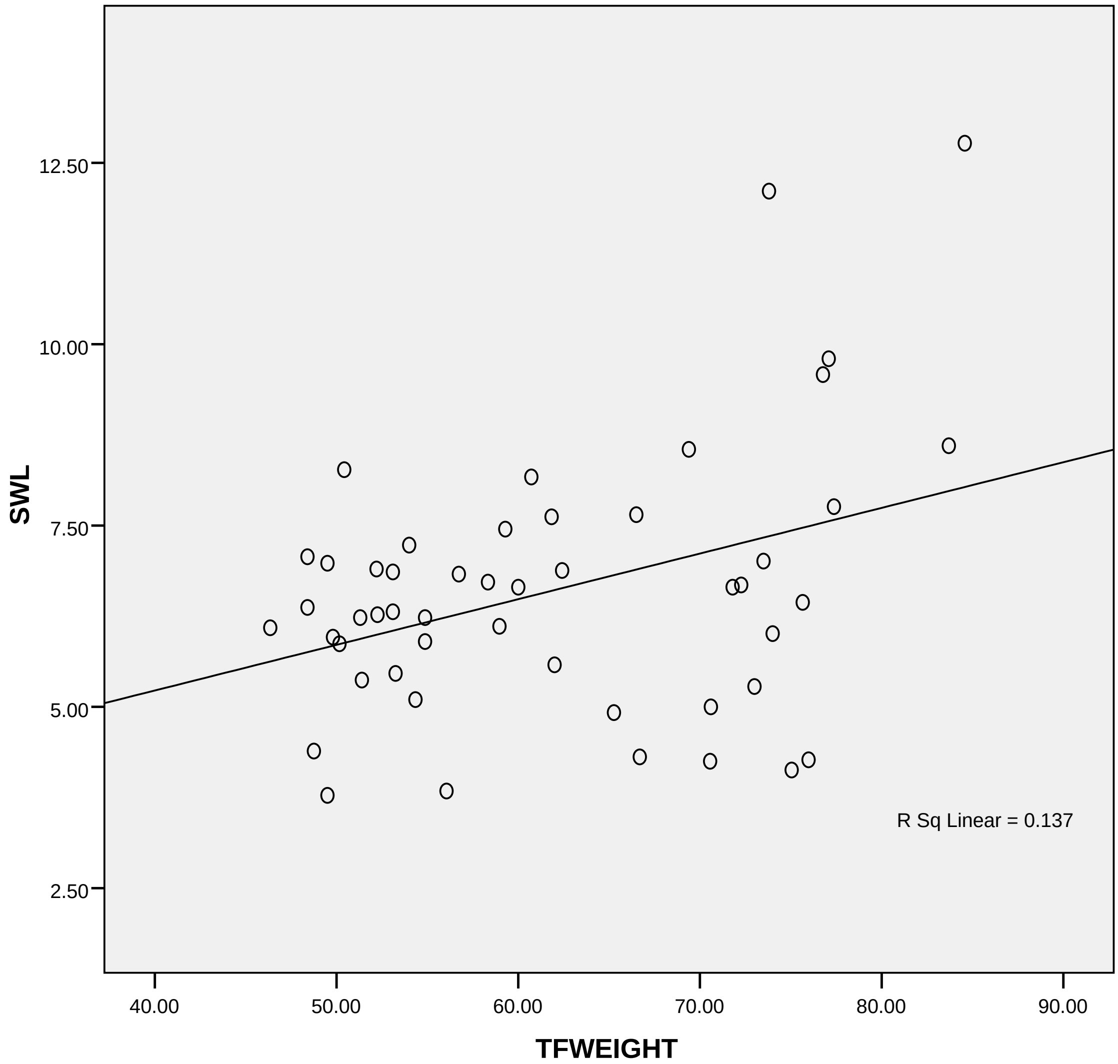

Figure 4. 19. SWL vs *TF*WEIGHT

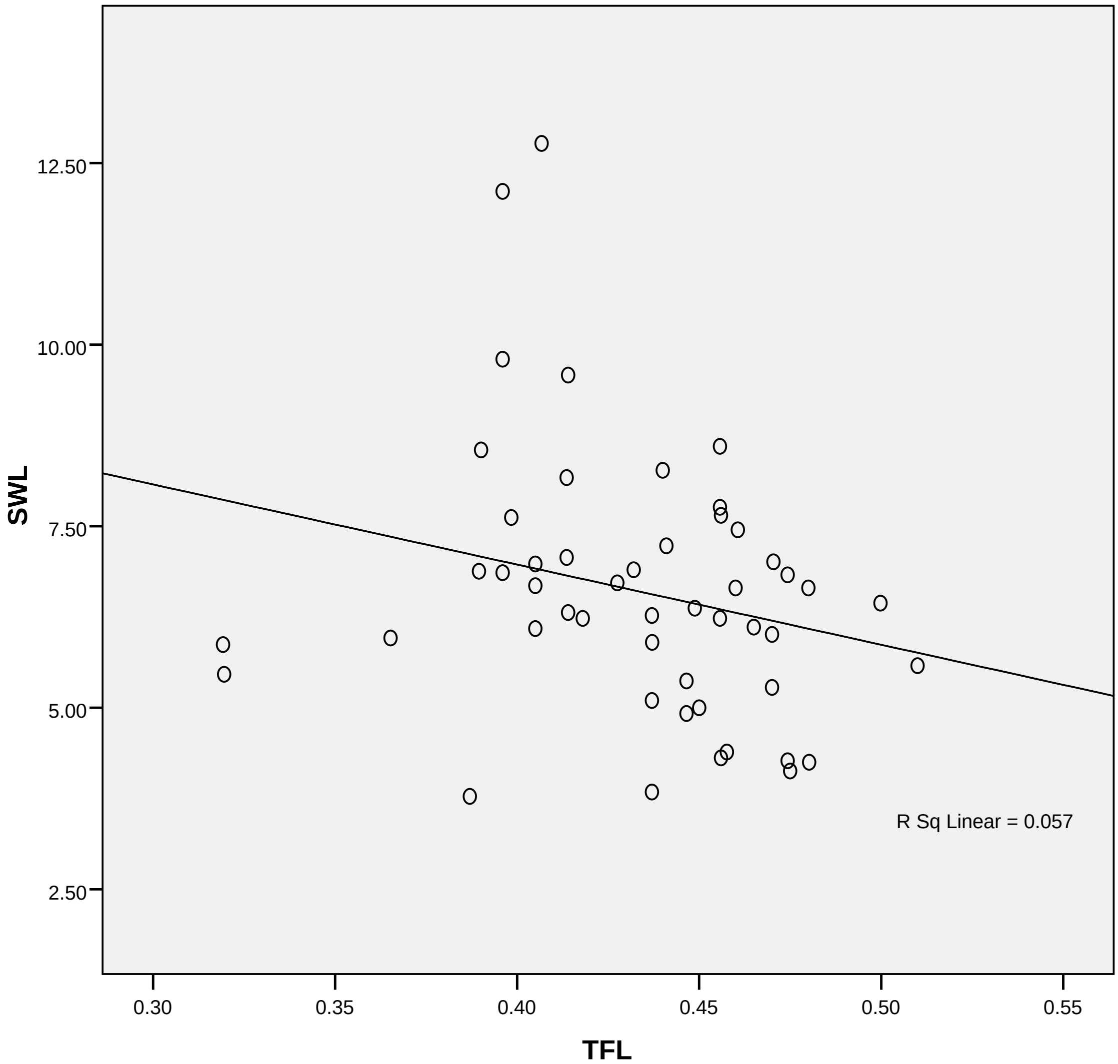

Figure 4. 20. SWL vs *TFL*

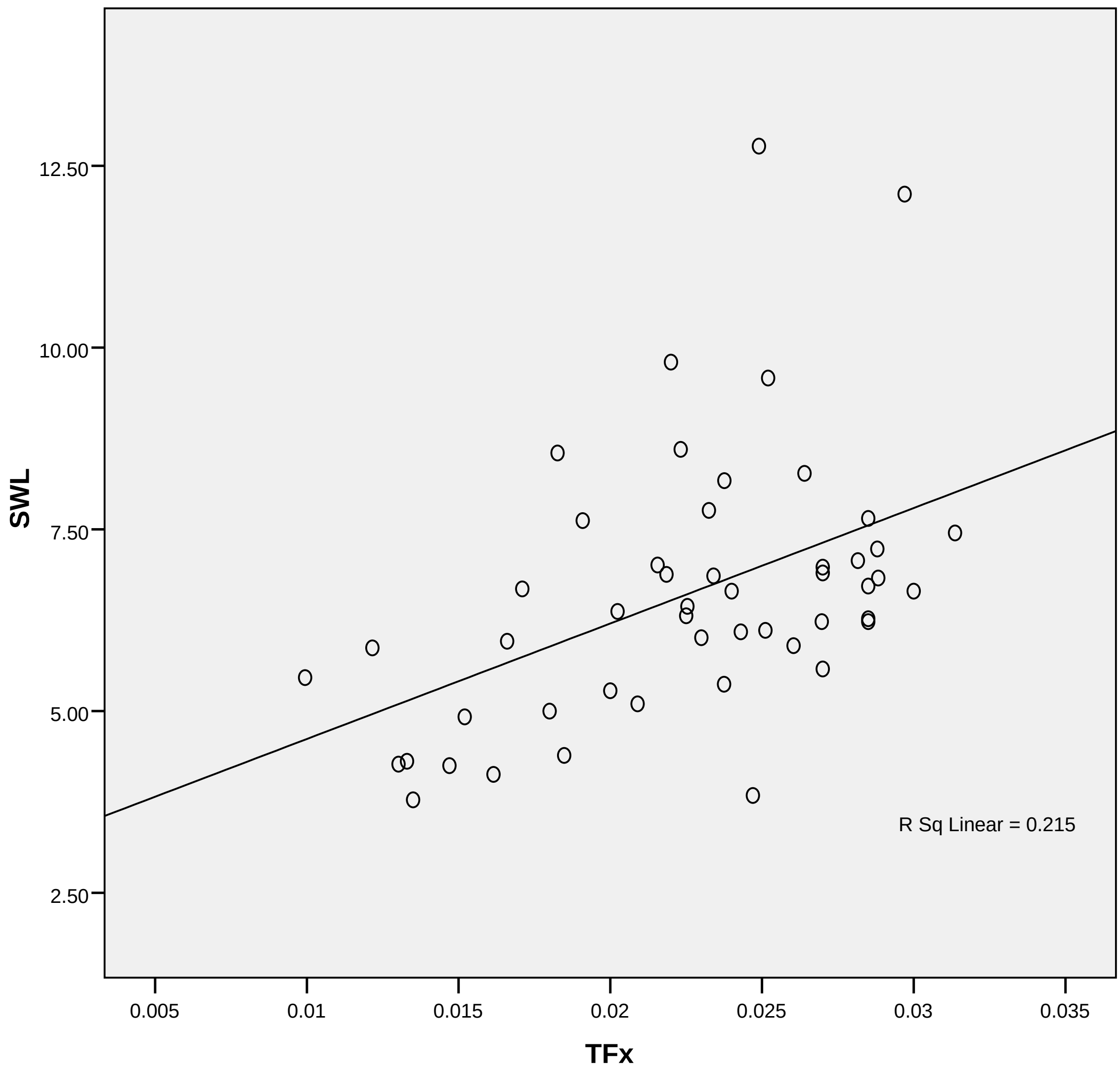

Figure 4. 21. **SWL vs** ***TFx***

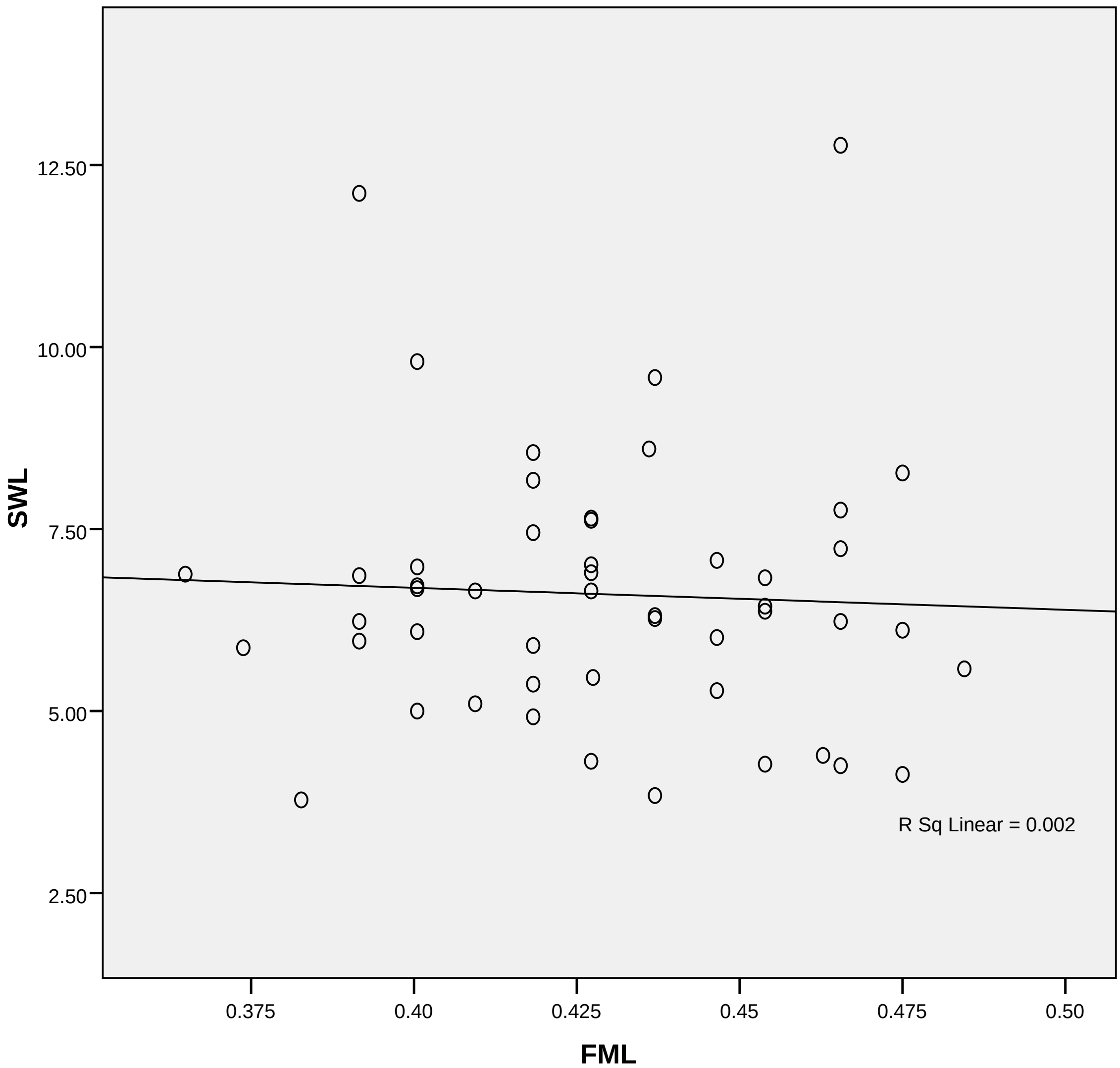

Figure 4. 22. SWL vs *FML*

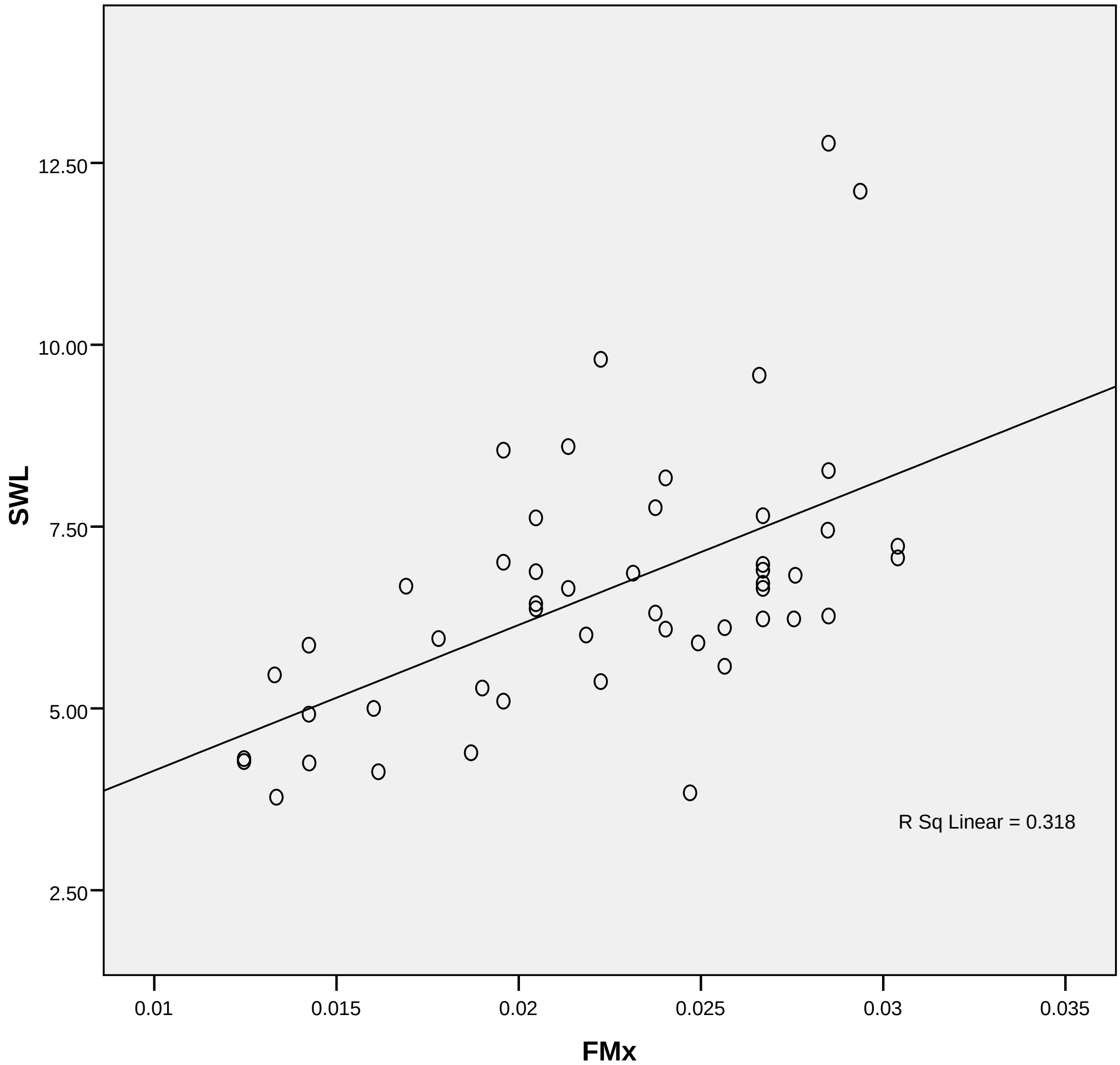

Figure 4. 23. SWL vs *FMx*

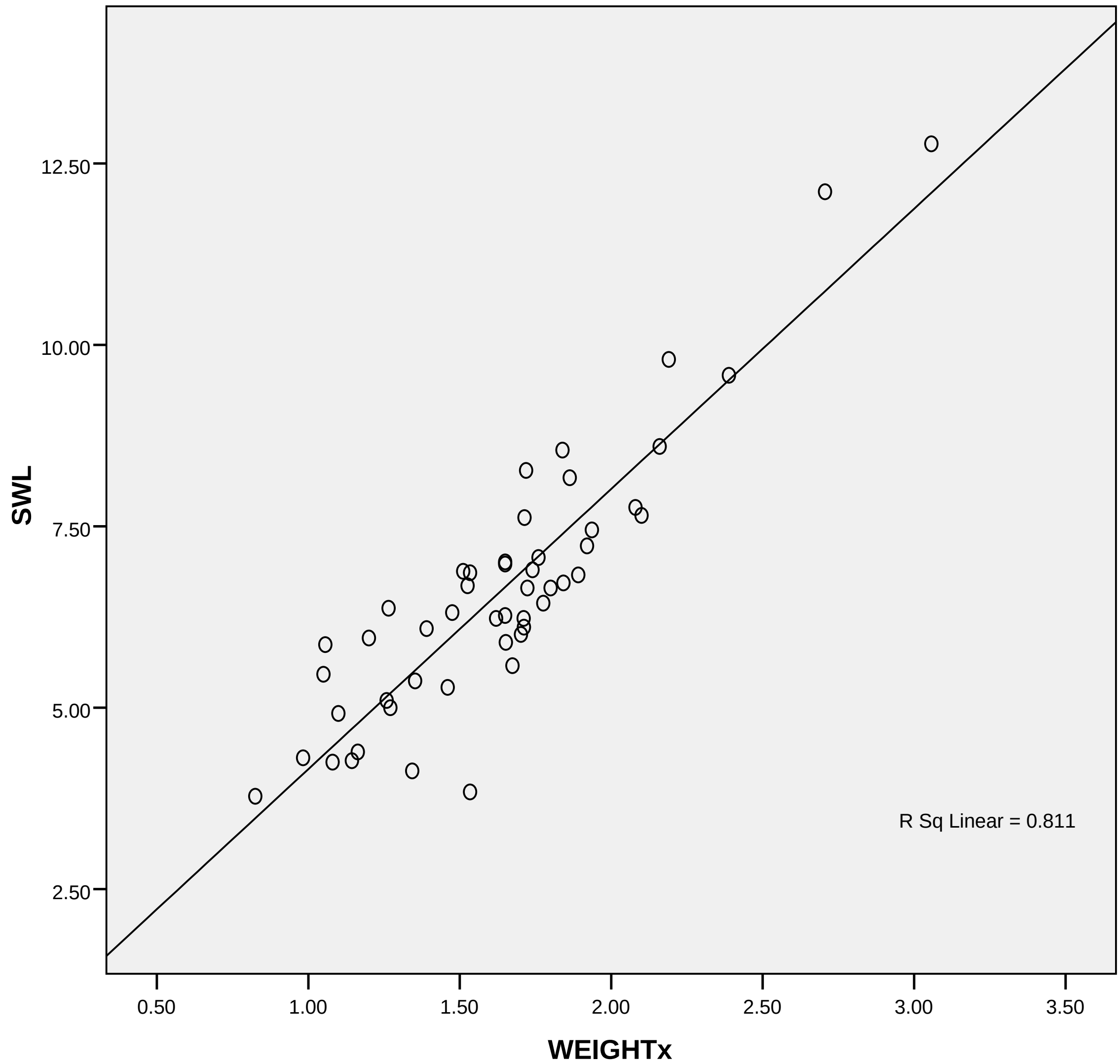

Figure 4. 24. **SWL vs WEIGHT*x***

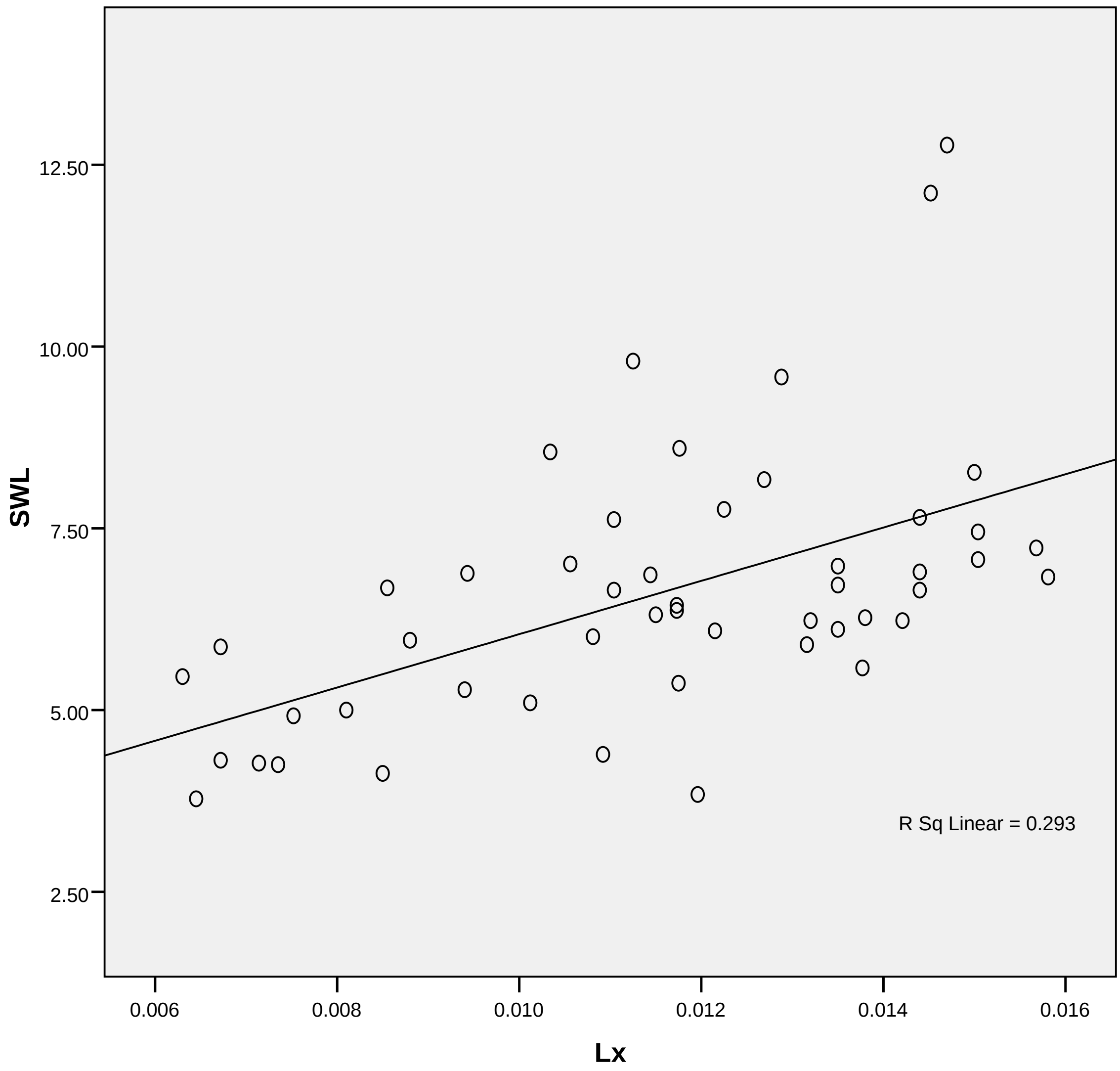

Figure 4. 25. SWL vs *Lx*

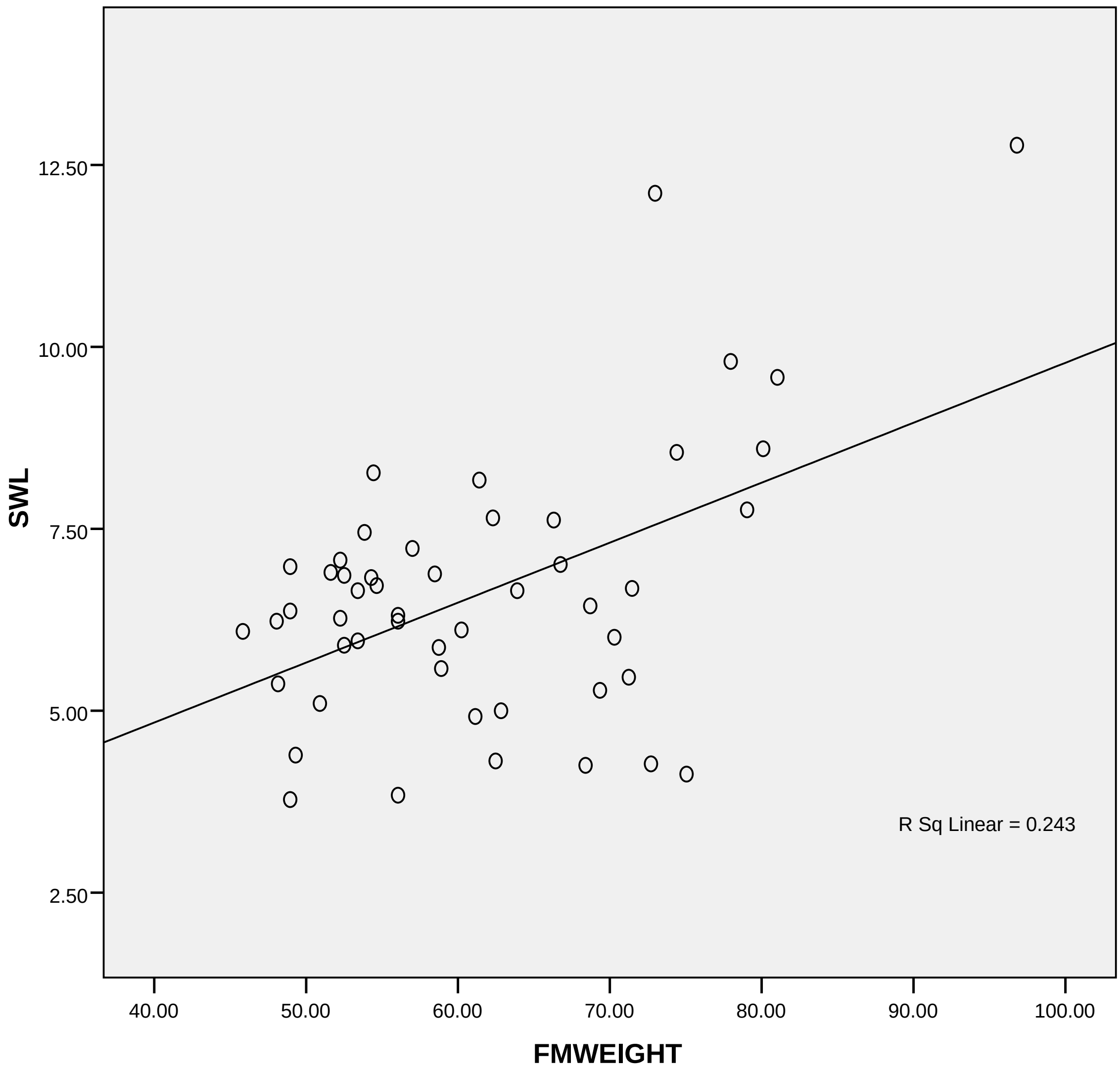

Figure 4. 26. SWL vs *FM*WEIGHT

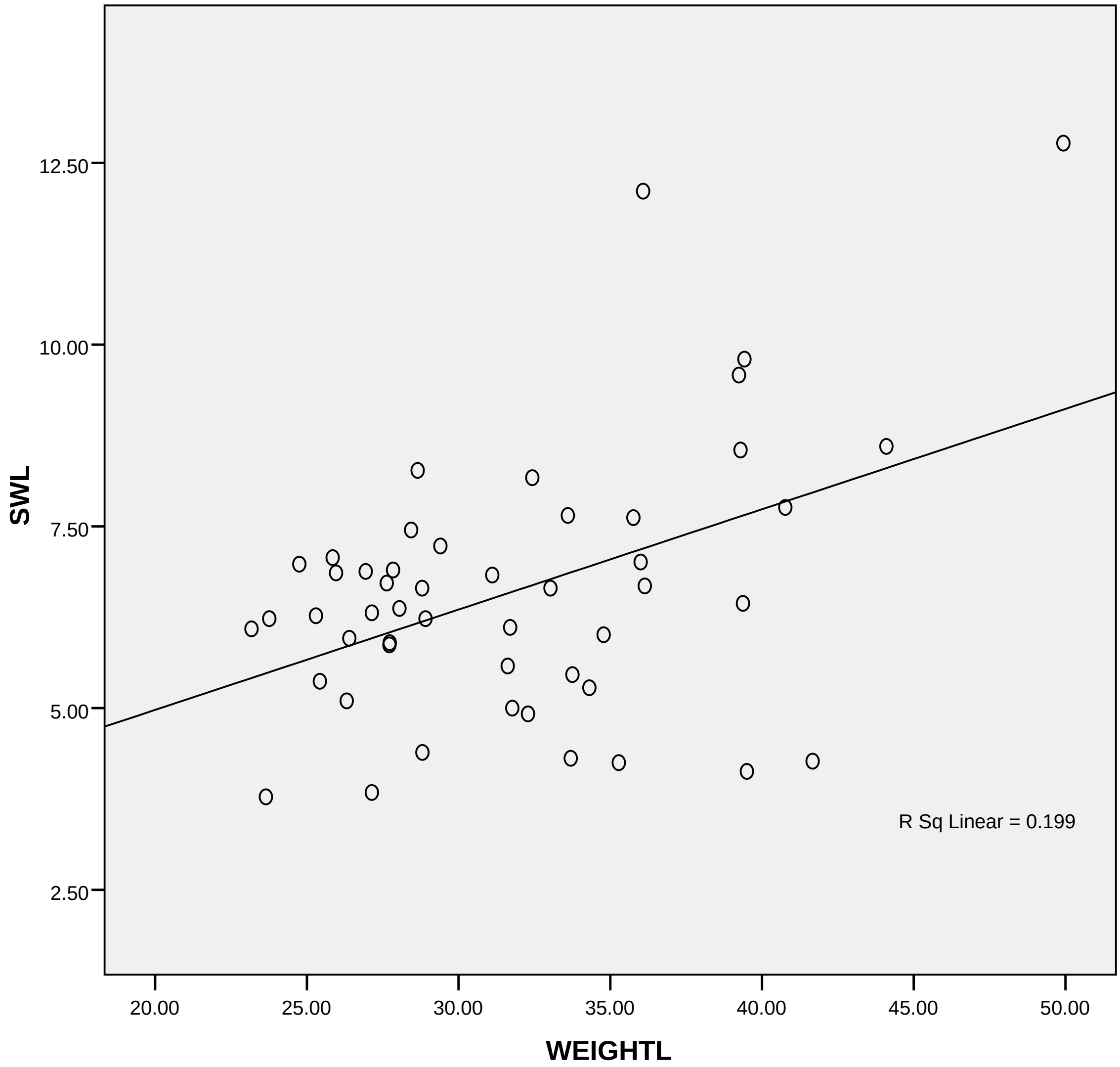

Figure 4. 27. SWL vs WEIGHT*L*

4.6 Relationship between independently selected male bricklayer characteristic factors' mutual interactions and safe weight of lift

The relationships of mutual interactions between independently selected male bricklayer characteristic factors and the safe weight of lift were investigated using multiple linear regression at significance alpha level of 0.05. Table 4.26 shows the results of independent male characteristic factors' interaction (workers' weight, age, change in stature, length of the spine, and lifts frequency) and workplace temperature. The independent factors interactions gave coefficient of determination of 0.94, explained 94% variance in the SWLwT model and they were statistically significant at $p<0.05$. There is a weak positive relationship between age (β =0.23), temperature (β =0.25), frequency of lifts (β =0.14) and SWL, while spine length (β = -0.18) indicated weak negative relationship. The male bricklayers' weight (β =0.69) showed moderate positive relationship, while stature change (β =0.86) showed strong positive relationship with the SWL.

4.7 Analysis of Variance of the SWL model result

Table 4.27 shows the result of the model's Analysis of Variance (ANOVA) at an alpha level of 0.05. The result shows that the factors considered were statistically significant at p<0.05. The F – test result means that the model-selected factors and environmental temperature estimated good reliability characteristics as factors in the prediction of the safe weight of lift and safety management of male manual lifting workers considered in this study.

4.8 Safe Weight Lift and model-independent characteristic factors

Table 4.28 presents a model summary and parameter estimates of the sample data used as input into the regression curve estimation to determine the relationship between the SWL and developed model-independent factors by considering linear and quadratic equations. The quadratic predicts the much better relationship between the SWL and developed model independent factors as nonlinear better than linear if their coefficient of determination (R^2) is compared. The quadratic, R^2 is 0.38, while the linear R^2 is 0.28. The coefficient of determination of the quadratic is higher than the linear. The quadratic F – statistics is 14.65 and $p<0.05$.

These implied that sample data used as input into the model provided enough evidence to show that the model fitted the data better than the model with no independent variables considered in this study to develop a safe weight of lift model that can minimise the problem of low back pain among manual load handling workers.

4.9 Comparison of model SWL with existing secondary SWL

Table 4.29 shows the results of compared means test of the SWL of the model compared with the existing secondary SWL. The mean of the two groups of six selected SWL at the same temperatures from existing secondary and model SWL were 16.34±6.40 kg and 6.10±1.29 kg.

The developed model (SWLwT) mean is lower than the existing secondary mean. There was a statistical significance difference (p<0.05) between the model and the existing secondary SWL. This could be attributed to differences between the factors and environmental temperatures considered in the literature compared to the model. It can be deduced from comparing means test results that the model can be used as a decision-making tool in the safety management of male labourers involved in manual load handling to estimate safe weight lift that can be lifted for 8 hours daily without increasing the threat of developing low back pain.

Figure 4.28 shows that a non-linear relationship existed between the SWL and the Safe Weight of Lift with Temperature model that comprised worker's weight, age, spinal shrinkage, gender, length of the spine, lift frequency and workplace temperature.

Table 4. 26. Independent factors mutual interactions effect on Safe Weight Lift

Independent factors interaction	**Safe Weight of Lift (SWL)**		
	Beta	B	p-value
Age (year)	0.23	0.06	0.00
Lifters' weight (kg)	0.69	0.11	0.00
Stature change (m)	0.86	285.08	0.00
Temperature (°C)	0.25	0.18	0.00
Spine length (m)	-0.18	-13.29	0.00
Frequency of lifts (lifts/min)	0.14	0.52	0.00
R-square 0.94			

Table 4. 27. Analysis of Variance (ANOVA)

Model		Sum of squares	df	Mean square	F	Significance
1	Regression	157.96	6	26.34	404.53	0.00
	Residual	2.80	43	0.07		
	Total	160.76	49			

Table 4. 28. SWLwT Regression curve estimate summary and parameters

Equation	Model summary					Parameters estimates		
	R^2	F	df1	df2	Sig.	Constant	b1	b2
Linear	0.28	18.75	1	48	0.00	2.11	0.02	
Quadratic	0.38	14.65	2	47	0.00	16.98	-0.09	0.00

Table 4. 29. Compared samples of SWL at assumed equal temperatures

		Existing Secondary	Present Model
Sample		6	6
Mean		16.34	6.10
Standard deviation		6.40	1.29
Standard error mean		2.61	0.53
t		6.25	11.56
df		5	5
Significance (2 – tailed)		0.00	0.00
Mean difference		16.34	6.10
95% Confidence interval of the difference	Lower	9.62	4.74
	Upper	23.06	7.46

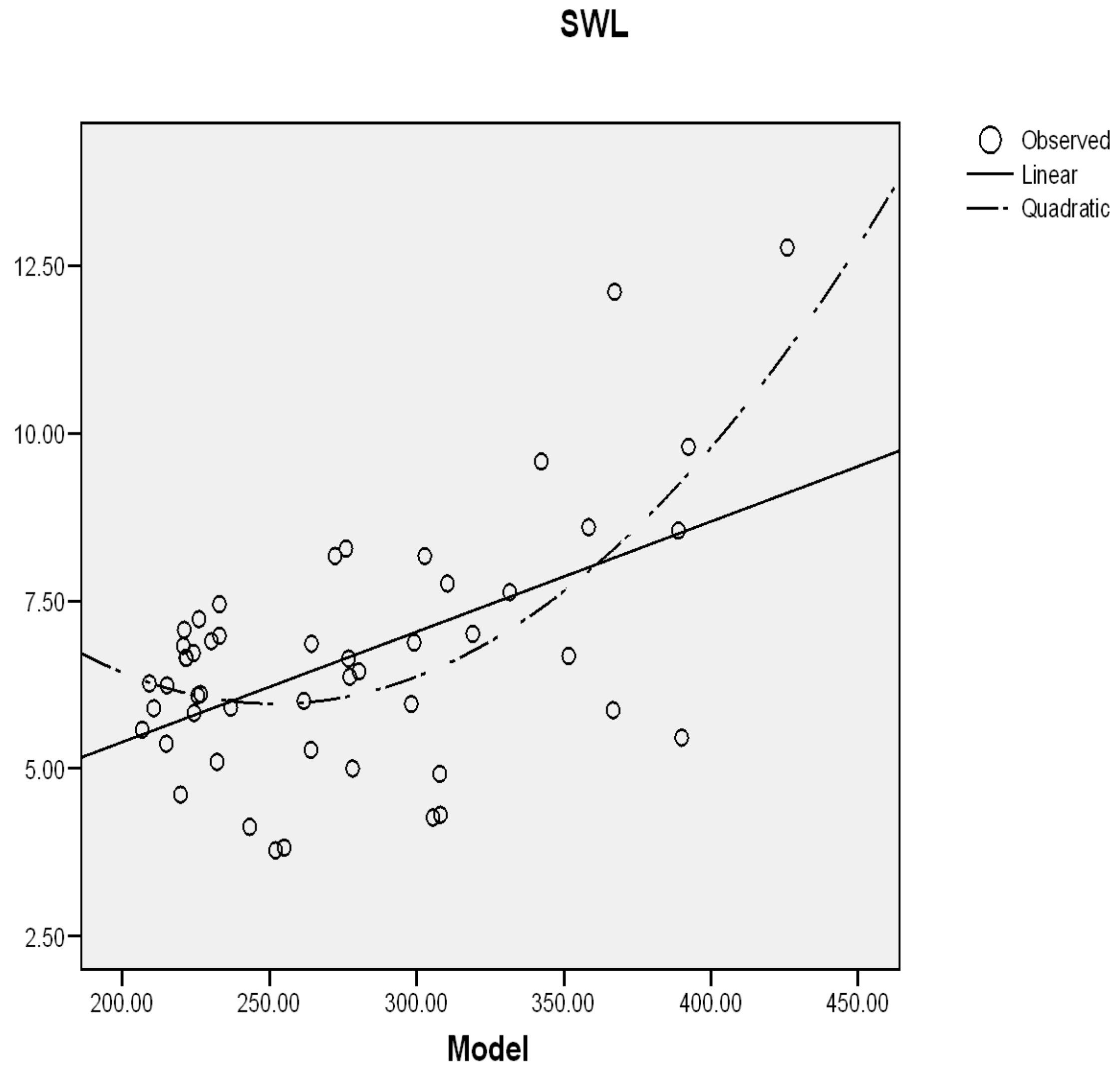

Figure 4. 28. Safe Weight Lift relationships effect on Safe Weight of Lift with a Temperature model

4.10 Discussion

The Safe weight of lift with varying Temperature (SWLwT) model developed was presented in equation 4.1. An example of using the developed model to calculate the safe weight lift was presented using six-individual characteristic data of a male bricklayer from equations 4.2 to 4.4.

The male bricklayers' weights from 51.50 to 61.50, 62.00 to 72.00, 73.00 to 83.00, 84.00 to 94.00, and 95.00 to 105.00 kg were at 46, 22, 24, 6, and 2%, respectively shown in Figure 4.1. The male bricklayers' change in stature measurement from 0.014 to 0.017, 0.018 to 0.021, 0.022 to 0.025, 0.026 to 0.029, and 0.030 to 0.033 m were at 16, 10, 28, 18, and 28%, respectively shown in Figure 4.2. The measurement of workplace temperature ranged between 26.50 and 28.50, 28.60 and 30.60, 30.70 and 32.70, 32.80 and 34.80, and 37.00 and 39.00℃ were at 20, 34, 34, 8, and 4%, respectively shown in Figure 4.3. Figure 4.4 shows male bricklayers' age distribution. The age ranged between 20 and 25, 26 and 31, 32 and 37, 38 and 43, 44 and 49, and 50 and 55 years at 14, 30, 32, 16, 4, and 4%, respectively. The male bricklayers' spine length distribution was shown in Figure 4.5, which was from 0.41 to 0.43, 0.44 to 0.46, 0.47 to 0.49, and 0.50 to 0.52 m at 6, 34, 42, and 18%, respectively. The safe weight of lift distribution among the selected 50 experienced male bricklayers at Arulogun, Ibadan, Nigeria, is shown in Figure 4.6. The safe weight lift was from 3.78 to 5.78, 5.79 to 7.79, 7.80 to 9.80, 9.81 to 11.810, and 11.82 to 13.82 kg at 30, 54, 10, 2, and 4%, respectively.

Table 4.1 presented computed safe weight lift results based on the six-individual characteristic factors collected data from the 50 experienced male bricklayers at Arulogun, Ibadan, Oyo state. Table 4.4 to 4.9 shows the chronological arrangement of independent six-individual characteristic factors of male bricklayers' age, weight, stature change, workplace temperature, spine length and frequency of lift to the Safe Weight Lift (SWL). Figures 4.7 to 4.12 showed the scatter plot graph relationship between the safe weight lift and six-individual characteristic factors of the male bricklayers.

The main effect Multiple Linear Regression (MLR) analysis results for the independently selected male bricklayer characteristic factors presented in Table 4.3 revealed that body weight and stature change were significant ($p<0.05$), also explained the highest total variance of 26 and 36% in the SWLwT model and had a moderate positive relationship with the developed model. This means that body weight and stature change of the worker characteristic factors can be used independently to determine safe load weight for manual workers. Hajihosseinal *et al*. (2015); Ghezelbash *et al*. (2016) found that changes in body weight affected spinal loading. Also, Ismaila (2006) used stature change as one of the factors in a developed model to determine load weight and safe backpacks for secondary students. Brackley and Stevenson (2004); Al-Hazzaa (2006) recommended safe backpacks for school children as between 10 and 15% of their body weight. Song and Qu (2014) among other factors found significant ($p<0.05$) in the main effect analysis of age, load magnitude, destination height was the age. However, there were other human characteristics and environmental factors identified to be contributing to the influence of low back injury during manual lifting as seen in this present study. The body weight and stature change had been suggested as influencing factors to determine safe load weight to be lifted for manual workers (Arjmand *et al*., 2015; Ismaila *et al*., 2017; Barim *et al*., 2019). The other factors in the present model that had been identified as an influencing factors in the literature were: Body weight (Maiti and Ray, 2004; Arjmand *et al*., 2015; Barim *et al*., 2019); Workplace temperature (Hafez, 1984; Kjellstrom *et al*., 2009; Blazejczyk *et al*., 2014); Age (Song and Qu, 2014; Ghezelbash *et al*., 2016; Girish *et al*., 2018; Barim *et al*., 2019); Gender (Sheppard *et al*., 2016; Barim *et al*., 2019); Spine length (Ismaila, 2016; Reilly *et al*., 2006; Ismaila, 2017); Stature change (Ismaila, 2016; Reilly *et al*., 2006; Ismaila, 2017); Frequency of lifts (Hafez, 1984; Maiti and Ray, 2004; Ardiyanto *et al*., 2019). These factors had not been compounded to develop an ergonomic model in the literature as it had been done in this study to determine safe weight lift that can minimise occurrence of low back pain among male manual workers in the construction industry.

The Multiple Linear Regression (MLR) analysis results of the two–ways interaction of the six-individual characteristic factors of the safe weight of lift model were presented in Table 4.10. The MLR results revealed that interactions between male bricklayers' weight and workplace temperature, weight and spine length, age and weight, stature change and workplace temperature, frequency of lift and weight, age and stature change, spine length and stature change, frequency of lift and stature change, and weight and stature change were significant ($p<0.05$) and explained 14, 20, 21, 22, 24, 26, 29, 32, and 89% variance in the safe weight of lift model. The two–ways interaction of the six-individual characteristic factors revealed that each other factor that interacted with stature change and body weight was found significant. Song and Qu (2014) found two-ways interaction of the factors of age with load magnitude and destination height to be significant ($p<0.05$).

The ascending order arrangement of the results of the male bricklayers' six-individual characteristic factors and lifts' safe weight were presented in Tables 4.11 to 4.25. The scatter plot graph showing the relationship of the two–ways interaction of the six-individual characteristic factors of the male bricklayers and safe weight lift were presented in Figures 4.13 to 4.26. The deduction from the interactions of the compounded six-individual characteristic factors of the male bricklayers using Multiple Linear Regression (MLR) was that the compounded six-individual characteristic factors were significant ($p<0.05$), and the coefficient of determination (R^2) was 0.94. This explained the 94% variance in the SWLwT model.

The model validation was done using ANOVA at an alpha level of 0.05 and presented in Table 4.27. This revealed that the compounded six-individual characteristic factors were significant ($p<0.05$), and the F-test result was 404.53. The high F-test result means that the compounded six-individual characteristic factors were good reliability characteristic factors for predicting safe weight lift for male bricklayer manual workers that participated in the study.

Regression Curve Estimate (RCE) was used to determine the relationship between the compounded six-individual characteristic factors and the safe weight of the lift model. Table 4.28 presents the result of the RCE estimate summary and parameters for the SWLwT model. It was deduced from Table 4.28 that linear and non–linear (quadratic) relationship nature existed in the SWLwT model and were significant ($p<0.05$). However, the coefficient of determination of linear relationship was 0.28 and non–linear relationship was 0.38. Therefore, non – the linear relationship explained 38%, while the linear relationship explained 28% variance in the SWLwT model. The scatter plot graph of the relationship of the model is presented in Figure 4.28. Hence, the compounded six-individual characteristic factor nature of the relationship with the SWLwT was non–linear.

Six existing secondary SWL values were selected at the temperature range of 27.00 – 32.00°C and six values of the SWL of the present model at temperature ranges of 26.00 – 27.90, 28.00 – 29.90, 30.00 – 31.90, 32.00 – 33.90, 34.00 – 35.90 and 36.00 – 37.00°C for the comparison of the model result with the existing secondary SWL. Data were analysed using t – a test at an alpha level of 0.05. Table 4.29 shows the results of the t–test used to compare the selected six SWL values of the model and existing secondary from the literature. The compared mean test revealed that the existing secondary SWL mean of 16.34±6.40 was higher than the present model SWL of 6.10±1.29, and both were significantly different as the alpha level was less than 0.05. This could be attributed to a possible difference in the workplace temperature at which the existing secondary SWL were obtained compared to the model.

Hafez (1984) determined the Maximum Acceptable Weight of Limit (MAWL) by considering temperature values of 22, 27 and 32°C at the frequency of 1.00, 3.00 and 6.00 lifts/min, respectively. The MAWL of 25.34, 15.49 and 13.06 kg was obtained at 22°C at 1.00, 3.00 and 6.00 lifts/min, respectively. The MAWL of 25.34, 14.56 and 12.02 kg were obtained at 27°C at 1.00, 3.00 and 6.00 lifts/min, respectively. The MAWL of 23.41, 12.54 and 10.19 kg were obtained at 32°C at 1.00, 3.00 and 6.00 lifts/min, respectively. The MAWL is reduced as the frequency and temperature increase. The least MAWL of 10.19 kg was obtained at six lifts/min at 32°C, and the highest MAWL of 25.30 kg was obtained at 1.00 lift/min at 22 and 27°C, respectively. The present study recorded 3.78 kg as the least SWL having considered factors such as lifter's weight (55.00 kg), age (30.00 years), gender (male), change in stature (0.02 m), length of the spine (0.43 m), temperature (31°C) and frequency of lift (2.00 lifts/min) and 12.77 kg as highest SWL for factors such as worker's weight (60.00 kg), age (27.00 years), gender (male), stature change (0.032 m), spine length (0.49 m), temperature (31.40°C) and frequency of lift (one lift/min). The lower limit of the SWL value of 3.78 is lower than the value of 10.19 kg at 3.00 lifts/min at 32°C, and the upper limit of the SWL value of 12.77 kg is lower than 24.34 kg at 1.00 lifts/min at 27°C but higher than 10.19 kg at 3.00 lifts/min at 32°C obtained by Hafez (1984). The differences in values were attributed to variations in factors considered. Hafez (1984) considered only two factors (temperature and frequency of lifts) while in this study, consideration was given to six personal characteristic factors (weight of the worker, age, gender, length of the spine, stature change, and frequency of lifts) and workplace varying temperature. The values obtained in this study are deemed incapable of causing low back injuries and therefore seem safe for manual lifting workers involved in the experiment at Arulogun, Akinyele L.G.A., Ibadan, Oyo state. The research by Vandermolen *et al*. (2008) to determine block mass consequence on work difficulties and physical workload on masons. Five male masons of three groups that were similar in age, body height and weight carried block weights of 11.00, 14.00 and 16.00 kg for 8 hours daily.

The researchers observed that block weights of 11.00, 14.00 and 16.00 kg did not lead to any form of musculoskeletal disorder (low back pain). This was observed by monitoring the masons' heartbeat rate and oxygen ingestion on the site. The spine loads on the lower back were presumed by calculating cumulated elastic energy deposited in the lumbar using activities duration and existing data on forces of the corresponding compression. Therefore, the present study's safe weight of the lift, between 3.78 and 12.77 kg, can be deemed safe for manual lifting workers involved in the experiment. Jomoah (2014) determined the Acceptable Weight of Lift (AWL) by considering workers' age, height, body mass index and body angle. The observed AWL carried by the worker for 8 hours daily was 11.80 kg. The determined AWL was lower than this present study's upper limit computed SWL value of 12.77 kg but higher than the lower limit SWL value of 3.78 kg. Maiti and Ray (2004) computed Maximum Load Limit (MLL) for adult Indian women.

The MLL was determined by computing Working Heart Rate (WHR) by multiplying the constant (Load), Frequency of Lift Multiplier (FM), Weight Multiplier (WM) and vertical Distance Multiplier (DM). The MLL determined it safe for an Indian woman to lift 15.40 kg. The MLL obtained was higher than the safe weight of the upper lift limit of 12.77 kg of the present result. Hence, this study's obtained value of 12.77 kg can be considered safe to be lifted manually without increasing workers' threat of developing low back pain.

Ismaila (2006) computed the SWL by considering shrinkage (x), chest length (l_s), chest width (l_f), Young modulus of elasticity (E), lifting velocity (u), acceleration due to gravity (g), vertical height (v), horizontal length (H), vertical displacement (D), spine length (L) and an angle of lift (θ). The researcher calculated safe weight of lifts was between 4.91 and 12.40 *kg*. The SWL calculated in this study by considering workers' weight (m_b), spine length (*L*), stature change (*x*), age (*AG*), gender (*GN*), temperature (*TF*) and frequency of lift (*FM*) is between 3.78 and 12.77 kg. There was a 23% decrease in the present lower limit value of 3.78 kg of SWL when it was compared to the existing lower limit value of Ismaila's (2006) SWL of 4.91 kg and a 2.98% increase in the present upper limit value of 12.77 kg of the SWL when it was compared to the existing upper limit value of 12.40 kg of Ismaila (2006) SWL. The variation in results can be attributed to differences in factors and areas of application to experiment with the model. The present SWL value between 3.78 and 12.77 kg may be considered the safe weight to be lifted by manual lifting workers lifting a maximum load weight of 22.50 kg at Arulogun, Akinyele Local Government Area (LGA), Ibadan, Oyo State without leading to low back pain.

Ismaila and Aderele (2015) adopted Ismaila's (2006) SWL model in determining the safe weight to be lifted by block moulders. The SWL values obtained by the researchers were between 7.90 and 15.50 kg, with a mean of 11.21 kg. The SWL obtained in this present study among bricklayers is between 3.78 and 12.77 kg with a mean of 6.60 kg. The obtained values of SWL in this present study are lower than obtained values of Ismaila and Aderele (2015) in their research. The present study has a lower limit value of 3.78 kg than the SWL. Therefore, the SWL value in this present study can be deemed a safe load weight capable of reducing lower backache among manual lifting workers involved in this experiment.

Adeyemi *et al*. (2013) developed an expert fuzzy logistic model that investigated the impact of lower back pain among construction workers. The expert system involving fuzzy set theory made decisions about the level of threat of low back injury associated with selected workers. The areas of concern were workers position at work, lifting frequency and weight of load lifted. Recommended Weight Limit (RWL) of between 2.23 and 11.47 kg were obtained for the selected workers lifting load weight between 2.50 and 28kg at a frequency between 1.00 and 2.00 lifts/min and at a degree of postures between 0.00 and 60.00 degrees. If the SWL between 3.78 and 12.77 kg with a mean of 6.60 kg obtained in this study is interpolated into the RWL as obtained by Adeyemi *et al*. (2013). the SWL results obtained can be seen as weight that can reduce the effect of low back injuries among manual lifting workers lifting maximum load weight of 22.50 kg.

Stambough *et al*. (1995) used formulated Comprehensive Lifting Model (CLM) to determine the lifting Capacity (LC) for male and female manual lifting workers at the age of 20.00, 25.00, 30.00, 35.00, 40.00, 45.00, 50.00, 55.00 and 60.00 year, the corresponding lifting capacity obtained for male manual lifting workers were 25.00, 24.00, 23.00, 23.00, 22.00, 20.00, 18.00, 15.00 and 15.00 kg respectively. In this study, the SWL was determined for 50 experienced males in bricklaying jobs. The SWL calculated were between 3.78 and 12.77 kg. The calculated SWL values in this study for male manual lifting workers were lower than the values determined by Stambough *et al*. (1995) for male manual lifting workers in their study.

Drury and Pfeil (1975) determined Lifting Capacity (LC) for manual lifting workers irrespective of gender by adopting a task-centred model of manual lifting performance. The manual lifting workers' ages were 20.00, 25.00, 30.00, 35.00, 40.00, 45.00, 50.00, 55.00 and 60.00 years, with the corresponding lifting capacity as 38.00, 48.00, 45.00, 45.00, 41.00, 37.00, 34.00, 32.00 and 31.00 kg respectively. The lifting capacity obtained by Drury and Pfeil (1975) was higher than the safe weight of lifts between 3.78 and 12.77 kg obtained in this study for male manual lifting workers aged between 20.00 and 52.00 years with age approximate mean of 33.00 years. Hence, the SWL obtained can be deemed a safe weight capable of reducing low backaches for manual lifting workers.

The NIOSH (1991) recommended weight limit of 23.00 kg provided other multiplier parameters such as Horizontal (*HM*), Vertical (*VM*), Distance (*DM*), Asymmetric (*AM*), Frequency (*FM*) and Coupling (*CM*) were constant. When multipliers were not constant, it is expected that when the Load Constant (*LC*) of 23.00 kg is multiplied with factor multipliers, the load constant should be reduced. By assumption, if the factor multipliers were constant Recommended Weight Limit (RWL) of 23.00 kg is higher than the present calculated SWL between 3.78 and 12.77 kg using the SWLwT model.

The research carried out by Pinder *et al*. (2001) showed that the block used in constructing interiors in the Netherlands was made up of gypsum and weighed between 23.00 and 25.00 kg. The researchers suggested that the weight was above their recommended weight lift of 18.00 kg. Hence it can cause low back pain if it is not reduced. Pinder *et al*. (2001) recommended a weight lift of 18.00 kg for Netherlands gypsum interior wall construction manual lifting workers. This was higher than the upper limit of the safe weight of lift of 12.77 kg obtained in this present study to reduce low back injury amid manual lifting workers.

The lifting prediction capacity model developed by considering factors such as age, BMI, grip strength, flexibility (sit and reach height), core stability (prone plank), and trunk lateral flexor endurance gave a coefficient of determination of 0.65 (Mohapatra *et al*., 2022). Thereby, the model explained the 65% lifting capacity of the participating subjects. However, the present developed safe weight of lift with varying temperatures –SWLwT) the model gave a coefficient of determination of 0.94. Hence, the SWLwT model explained 94% safe weight of lift of the participated subjects. The developed model determines the safe weight that may minimise low back pain for manual lifting workers because it provides a better coefficient of determination.

This present study computed a safe weight to be lifted by experienced male bricklayers whose body weight ranged from 51.50 to 101.90 kg to be between 3.78 and 12.77 kg. The safe weight gotten in this present study is less than 19.80 kg suggested by Hajihosseinal *et al*. (2015), which did not cause an increase in spinal loading at the increase in body weight of male subjects of between 51.00 and 112.00 kg.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Manual lifting is the most widely practised manual loads handling engagement and it has been discovered to be associated with lower back pain among manual lifting workers. Low back pain has remained a usual happening in less technologically advanced nations and developing and technologically advanced countries.

The unaided human lifting jobs have been suggested to place high load mass on workers' lower back, leading to lower back injuries over an extended time of lifting activities. It may also lead to significant incapacitation by restricting common activity involvement, such as the ability to work effectively.

The adopted approaches in the literature to intervene in the problem of low back pain among manual lifting workers include biomechanical, physiological and psychophysical. Equations and models have been formulated, such as Recommended Weight Limit (RWL) equation (NIOSH, 1991), the Mathematical Lifting Model (Stambough *et al*., 1995), the Comprehensive Lifting Model (Hidalgo *et al*., 1997), the Safe Weight of Lift model using Young modulus with anthropometric dimensions of the workers' (Ismaila, 2006), Maximum Acceptable Weight of Lift (Maiti, 2001), Working Heart Rate equation (Maiti and Ray, 2004). However, in the literature, few ergonomics models considered personal characteristic factors and workplace temperature to determine safe load weight to minimise the problem of low back pain for manual lifting workers. Therefore, by adding to the area of knowledge in reducing the problem of lower back pain among manual lifting workers, consideration was given to six-individual characteristic factors (weight, age, spine length, gender, change in stature and frequency of lifts) and workplace varying temperature in this present study. In this study, a safe weight of lift with varying temperature (SWLwT) model was developed.

The formulated SWL model was based on the conceptual and theoretical review of the existing models in the literature and the principle of strain energy. The data used to validate the model were obtained from fifty experienced male bricklayers at Arulogun, Akinyele L.G.A., Ibadan. The data points of fifty experienced male bricklayers selected subjects having six-individual characteristic factors and workplace varying temperature gave three-hundred and fifty datasets.

The contribution, variance, significance, and relationship between the developed model and selected factors of lifter's weight, age, length of the spine, change in stature, frequency of lifts and workplace varying temperature were investigated.

The contribution of individual independent factors to the Safe Weight Lift with varying Temperature (SWLwT) model shows that change in stature(x) gave the highest coefficient of determination of 0.33 and explained 33% variance in the SWLwT model. Factors such as male bricklayers' age, spine length, frequency of lift and temperature contributed insignificantly ($p>0.05$). However, male bricklayers' weight and stature changes contributed significantly ($p<0.05$) to the model. The male bricklayers' weight and stature change factors were statistically important to the model.

The relationship between SWL and independently selected factors of male bricklayers' age was negligibly positive (β =0.08). Also, the frequency of lifts was negligibly positive (β =0.00). These relationships mean a possible slight increase in the SWL as male bricklayers' age and frequency of lift increased. The spine length relationship is negligibly negative (β = -0.06), meaning that an increase in spine length led to a slight decrease in the SWL. Male bricklayers' weight (β =0.51) and stature changes (β =0.58) relationships were moderately positive. This means there was a gradual increase in the SWL as male bricklayers' weight and stature changes increased.

The contribution of interactions of independent factors to the SWLwT model shows that male bricklayers' weight, age, and change in stature, spine length, frequency of lift and workplace varying temperature gave a coefficient of determination of 0.94 and explained 94% of the variance in the model. The interacted factors contributed significantly ($p<0.05$) to the model. Therefore, when they interacted, all six individual characteristic factors and workplace varying temperatures were statistically significant in the model.

The relationship between the SWL and interactions of independent factors of male bricklayers' age (β = 0.23), temperature (β = 0.25), and frequency of lift (β =0.14) were weak and positive. This relationship means that as male bricklayers' age, temperature, and lift frequency increased, there was a minimal increase in the SWL. Spine length (β = -0.18) was weak and negative. The relationship means that as spine length increased, there was a minimal decrease in the SWL. Male bricklayers' weight (β =0.69) was moderately positive. The relationship means that as male bricklayers' weight increased, there was a gradual increase in the SWL. Stature change (β = 0.86) was a strong positive relationship, meaning that as stature change increased, there was a corresponding strong increase in the SWL.

The contribution of two-way independent factors interaction to Safe Weight of Lift with varying Temperature (SWLwT) model shows that interaction between male bricklayers' weight and stature change (WEIGHT*x*) gave the highest coefficient of determination of 0.81 thereby, explained 81% variance in the SWLwT model. The interaction between male bricklayers' age and temperature (*AGTF*), male bricklayers' age and frequency of lift (*AGFM*), male bricklayers' age and spine length factors (*AGL*), frequency of lift and temperature (*FMTF*), temperature and spine length factors (*TFL*), frequency of lift and spine length factors (*FML*) contributed insignificantly (p>0.05). However, the interaction between male bricklayers' age and weight (*AG*WEIGHT), male bricklayers' age and stature change (*AGx*), temperature and male bricklayers' weight (*TF*WEIGHT), temperature and change in stature (*TFx*), lifts frequency and stature change (FMx), male bricklayers' weight and stature change (WEIGHT*x*), spine length and stature change (Lx), frequency of lift and male bricklayers' weight (*FM*WEIGHT), and male bricklayers' weight and spine length (WEIGHT*L*) contributed significantly (p<0.05) to the model.

The relationship between SWL and two-way independent factors interaction between male bricklayers' age and temperature (*AGTF*), male bricklayers' age and spine length (*AGL*), frequency of lift and temperature (*FMTF*), and temperature and spine length (*TFL*) (β = -0.24), (β = -0.12), (β = -0.25), and (β = -0.24), respectively were weak and negative, this relationship means that as *AGTF*, *AGL*, *FMTF* and *TFL* increased, there was a minimal decrease in the SWL. The interaction between temperature and male bricklayers' weight (*TF*WEIGHT) was weak and positive (β =0.37). This relationship means that an increase in *TF*WEIGHT led to a minimal increase in the SWL. The interaction between male bricklayers' age and weight (*AG*WEIGHT), male bricklayers' age and stature change (*AGx*), temperature and change in stature (*TFx*), lifts frequency and stature change (*FMx*), spine length and stature change (*Lx*), lifts frequency and male bricklayers' weight (*FM*WEIGHT), and male bricklayers' weight and spine length (WEIGHT*L*) (β = 0.46), (β= 0.51), (β = 0.46), (β = 0.56), (β = 0.54), (β = 0.49) and (β = 0.45), respectively were moderately positive, this relationship means that as *AG*WEIGHT, *AGx*, *TFx*, *FMx*, *Lx*, *FM*WEIGHT, and WEIGHT*L* increased, there were gradually increase in the SWL. The interaction between male bricklayers' age and frequency of lift (*AGFM*) and frequency of lift and spine length (*FML*) (β = -0.08) and (β = -0.05), respectively, were negligibly negative, these relationship means that as *AGFM* and *FML* increased, there was a slight decrease in the SWL. The interaction between male bricklayers' weight and stature change (WEIGHT*x*) (β=0.90) was strong and positive. This relationship means that as WEIGHT*x* increased, there was a corresponding strong increase in the SWL.

The safe weight of lift with varying temperature model (SWLwT) can be defined as the ratio of multiplied stature change and weight to spine length, age, gender, lifts frequency factors and workplace varying temperature. Therefore, the obtained safe weight of lift values were weights that a healthy male bricklayer could lift for 8 hours daily without increasing the threat of developing low back injuries.

5.2 Conclusion

The present formulated SWLwT model gave a safe weight of lift results ranging from 3.78 to 12.77 kg. These are load weights deemed safe to lift by manual lifting male bricklayers' that were lifting a maximum load weight of 22.50 kg that participated in this study. The load weight between 3.78 and 12.77 kg is deemed incapable of increasing the threat of low back injury for male bricklayers involved in this experiment. The SWL of between 3.78 and 12.77 kg obtained in this present study is lower than the Maximum Acceptable Weight Limit (MAWL) of between 10.19 and 25.30 kg (Hafez, 1984), Recommended Weight Limit of 23.00 kg if all the multiplier factors were constant

(NIOSH, 1991), recommended load weight of 18.00 kg (Pinder *et al*., 2001), Maximum Load Limit (MLL) of 15.40 kg for India women (Maiti and Ray, 2004), load weight of 11.00, 14.00 and 16.00 kg (Vandermolen *et al*., 2008), load weight from 7.90 to 15.50 kg (Ismaila and Aderele, 2015), load weight of 19.80 kg (Hajihosseinal *et al*., 2015), load weight between 7.10 and 17.80 kg (Antwi-Afari *et al*., 2017). The lower limit value of 3.78 kg of this present study is 23% lower than the lower limit value of 4.19 kg of Ismaila (2006), while the upper limit value of 12.77 kg of this present study is 2.98% higher than 12.40 kg upper limit of Ismaila (2006). Ardiyanto *et al*. (2019) obtained 12.67 kg as the MAWL for inexperienced Indonesian female manual material handlers, which is close to this present study's obtained upper limit for the safe weight of lift of 12.77 kg for experienced male bricklayer manual lifting workers at Arulogun, Akinyele Local Government Area (LGA) in Ibadan.

In conclusion, a safe weight lift with a workplace-varying temperature model has been developed by considering six-individual characteristic factors and workplace temperature. The developed model gave a good estimate of the safe lift weight at a construction site. The statistically significant contribution of the considered factors when interacting and obtaining SWL in this present study using the developed model has shown that the model can determine the safe weight of lift for unaided human lifting jobs in industries or organisations if adopted. It can be used as a decision-making tool to safely manage manual lifting labourers.

5.3 Recommendations

1. The occupational safety and health hazard of manual lifting should be a concern in implementing this safe weight-of-lift model in places where manual lifting is still practised.
2. The model can be applied by obtaining different measurements of the six-individual characteristics of different racial populations and genders involved in manual load handling to determine their safe lift weight.
3. The model should be used as a decision-making tool to manage the safety of manual labourers.
4. As a generic model, it can be used to determine SWL for either male or female manual lifting worker.

5.4 Contributions to Knowledge

1. The safe weight of lift model for manual tasks (sandcrete block lifting) in varying temperatures condition has been developed.
2. Establishment of normative data for optimum performance for sandcrete blocks lifting task.
3. A tool of effective musculoskeletal disorders risk planning and management in manual material handling task has been developed.
4. The model developed can help in pre-placement or return-to-work appraisal decision-making in order to minimise the problem of low back pain.

5.5 Area of further research

1. The gender based personal characteristic factors of weight, age, length of the spine, change in stature, lift frequency and workplace temperature should be used to determine the safe weight of lift for female manual lifting workers who are also involved in manual lifting.
2. The factors considered in this research should be investigated on manual material handling workers that are involved in carrying, pushing, pulling or holding load weight to understand the implications of the developed model and determine the safe weight of lift for workers involved in these types of manual material handling method as these are beyond the scope of this present research.
3. The proposed model should be subjected to manual lifting involving multiple people. This is to investigate the possibility of applicability of this model to determine the safe weight for lifting involving multiple persons, as the model in this present research was only applied to a person lifting load weight.
4. Since the safe weight of the lift determined may require changes to the work system and probably redesign of the work environment or equipment, there is a need to study the implication of the result of the developed model in terms of cost to the industry or organisation involved. It will help properly prepare for implementing the developed model results in the industries. The cost implication was not considered in this present study. It is out of the scope of the study.

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APPENDICES

Appendix 1. Factors Research gaps

Author's Names and Year	**Methods**	**Factors**																								
		AG	*GN*	*TF*	*L*	*FM*	m_b	*x*	l_s	l_f	*BMI*	*IVD*	*HM*	*VM*	*LC*	*WH*	*LV*	*PO*	*AM*	*CM*	*LH*	*LL*	*g*	*E*	*SH*	*A*
Hafez (1984)	Model	no	no	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
NIOSH equation (1991)	Equation	no	no	no	no	yes	no	no	no	no	no	no	yes	yes	yes	no	no	no	yes	yes	no	no	no	no	no	no
Maiti and Ray (2004)	Equation	yes	no	no	no	yes	yes	no	no	no	no	no	no	yes	yes	no	no	no	no	no	yes	no	no	no	no	no
Ismaila (2006)	Model	no	no	no	yes	no	no	yes	yes	yes	no	no	yes	no	no	yes	yes	yes	no	no	no	no	yes	yes	no	no
Kjellstrom *et al*. (2009)	Wet Bulb Global Temperature	no	no	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
Jomoah (2014)	Empirical study and Psychophysical	yes	no	no	no	no	no	no	no	no	yes	no	no	no	no	yes	no	no	yes	no	no	no	no	no	no	no
Ismaila and Aderele (2015)	Model	no	no	no	yes	no	no	yes	yes	yes	no	no	yes	yes	no	yes	yes	yes	no	no	no	no	yes	yes	no	no
Arjmand *et al*. (2015)	Equation	yes	no	no	no	no	yes	no	no	no	no	no	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no
Sheppard *et al*. (2016)	Principal Component Analysis and Single Component Reconstruction	no	yes	no	no	no	no	no	no	no	no	no	no	no	yes	yes	no	no	no	no	no	no	no	no	no	no
Ghezelbash et al. (2016)	Model	yes	yes	no	no	no	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Antwi-Afari *et al*. (2017)	Psychophysical and Physiological	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no	no	no	no	no	no	no
Ismaila (2017)	Model	no	no	no	yes	no	no	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	yes	yes	yes	yes
Girish *et al*. (2018)	Progressive Isoinertial lifting evaluation and semi-squat techniques	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no	no	no	no	no	no	no
Aghazadeh *et al*. (2019)	Artificial Neural Network	no	no	no	no	no	yes	no	no	no	no	no	yes	yes	yes	no	no	no	yes	yes	no	no	no	no	no	no
Ardiyanto *et al*. (2019)	Psychophysical and Physiological	no	no	no	no	yes	no	no	no	no	no	no	no	no	yes	no	no	no	no	no	no	no	no	no	no	no
Barim *et al*. (2019)	Equation	yes	yes	no	no	no	no	no	no	no	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no
Corbeil *et al*. (2019)	Empirical Study	yes	no	no	no	no	yes	no	no	no	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
Monteiro *et al*. (2019)	Transversal study	no	no	no	no	no	no	no	no	no	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
Mediha *et al*. (2020)	Questionnaire	yes	no	no	no	no	yes	no	no	no	yes	no	no	no	no	yes	no	no	no	no	no	no	no	no	no	no
Firouzabadi *et al*. (2021)	Model	no	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
Ramani and Shubha (2021)	Empirical study	yes	no	no	no	yes	no	no	no	no	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no	No
Mohapatra *et al*. (2022)	Model	yes	no	no	no	no	no	no	no	no	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
Present study	Model	yes	yes	yes	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no