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A MATHEMATICAL MODEL TO DETERMINE SAFE WEIGHT LIFT AMONG MANUAL MATERIALS HANDLING WORKERS IN NIGERIA.

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ABSTRACT

The low back pain (LBP) problem described as serious public health is observed to be prevalent among manual lifting workers. Despite various existing methods and equations there are still areas that needs to be explored in determining safe weight of lift. This study is contributing to filling the gap. The study objective is to identify some selected factors (worker's weight, age, gender, spine length, stature change, frequency of lift, and temperature) that may contribute to the safe weight of lift model formulation and determination for Nigeria manual construction workers. Purposive sampling technique was used to select twenty experienced male construction workers that reported no musculoskeletal disorder, lifting between 20 and 22.50*kg* blocks. A digital surgilac scale model ZT – 160 weight-height machine and Extech RH/Temperature pen 445580 device, tape rule and clock timer were requre instrument used for measurement. The measurements sample size was 140 at 20 per independent factor. The load weight of between 3.78 and 13.63*kg*, mean 6.99*kg* were obtained as safe weight deemed not capable of causing low back pain among manual lifting construction workers in Nigeria.

Keywords: Age, Gender, Body weight, Low Back Pain (LBP), Stature change, Temperature, spine length.

1.1 Introduction

Manual material handling is an unaided human activity that includes lowering, pushing, pulling, carrying, releasing, holding and lifting. Manual material handling task that normally happens include handling of heavy or bulky load, holding loads with arms distance from the trunk, lifting by snaking the back, neck, or upper body, reaching of object at low levels or beyond shoulder height, load handling on one side, postural and movement constraints during working in narrow and obstructed environment (Hamid and Tamrin, 2016; Ardiyanto *et al*, 2019). Manual material handling injuries such as low back pain do happen anywhere people are at work such as on construction, building sites, farms, factories, warehouses, hospitals, banks, laboratories, while making deliveries. The increase in automation has not stopped need for Manual Material Handling (MMH) activities especially, in the countries where labour are cheap (such as Nigeria) and in countries where automation is partially implemented or when automation is not economical. Therefore, the MMH still exists in under – developed, developing and in some area of work in developed countries (Mital and Manivasagan, 1983; Madiha *et al*, 2020).

Manual lifting is a widely performed manual material handling activity.The low back pain has been concomitant with manual lifting activities. Low back injuries to manual lifting workers caused by lifting remain a common occurrence not only in the developed countries, but also in the developing and under – developed nations. Manual Lifting has been observed to place high mechanical loads on the low back, which could lead to low back pain over period of time of lifting activities, if these loads surpass mechanical tolerance of the tissue (Marras, 2012; Antwi-Afari *et al*., 2017). The National Institute for Occupational Safety and Health (NIOSH, 1991) developed Recommended Weight Limit (RWL) having factors as; load constant (23*kg*), horizontal, vertical, distance, asymmetric, coupling, and frequency of lift multipliers (Water *et al*, 1993). In the opinion of Maiti and Ray (2004) the suitability of applying the RWL equation (NIOSH, 1991) to different race is doubtful as work related accidents are depended on different body size, anthropometry, and environmental conditions. Also Kamarudin *et al* (2013) aserted that application of the RWL is limited to those conditions for which it was designed. According to Hidalgo *et al* (1997) the need for equal employment opportunity for both able and disable American workers, and gender equality in American legislation made NIOSH (1991) to design an equation with absence of personal factors such as gender, age and fitness. Arjmand *et al* (2015) observed that the RWL generated spine loading exceeding recommended limits of 3400*N*. They came to conclusion that factors like body weight, height, age, and gender can play critical role in determine spine compression strength.

Modelling equation for safe weight to be lifted manually has been suggested to include gender and age as an input factor because significant difference has been observed between male and female (Stambough *et al*, 1995). In the findings of Hamid and Tamrin (2016) gender multiplier for male and female are 0.72 and 0.56 respectively. This can be used to determine gender lifting capability of manual lifting workers. Ismaila (2010) developed a model to determine safe weight lift by considering factors such as shrinkage, spine length, chest length and width, modulus of elasticity, velocity of lift, acceleration due to gravity, vertical location, and horizontal length of load from ankles, load vertical displacement, and lift angle. Stambough *et al* (1995) considered factors like weight base, horizontal distance, vertical distance, vertical travel distance, lifting frequency, task duration, trunk twisting angle, age group, heat stress and body weight multipliers but Hidalgo *et al*

(1997) modified and extended Stambough *et al* (1995) equation to determine base weight for manual lifting workers. Maiti and Ray (2004) developed a Working Heart Rate (WHR) to determine maximum load limit for adult Indian women by considering factors such as constant, frequency, weight and vertical distance multipliers. Ismaila (2006) considered parameters that comprised stature shrinkage (x), the value of length of spine from first thoracic to last lumbar vertebrae of the trunk (L), chest length (l_f) and chest width (l_s). The other parameters used in the equation were young modulus of elasticity of the articular cartilage (E), velocity of lift (u), acceleration due to gravity (g), vertical location of the load (V), horizontal length of the load from the ankles (H), vertical displacement of the load (D) and lift angle (θ) to determine weight safe to be lifted. The equation parameters did not include worker's weight, age, gender and temperature as it been considered in this present study.

The present study aim at developing a model to determine safe weight of lift by considering observed factors that can influence safe weight of lift. The observed factors identified in this study to be influencing lifting capability of manual lifting workers include workers' weight, spine length, age, stature change, gender, frequency of lift, and temperature. Other authors that have also observed and suggested one or two of the factors include Hafez (1984) frequency of lift and temperature; Maiti and Ray (2004) body size, anthropometry, and environmental conditions; Ismail, (2006) spine length and stature change; Kjellstrom *et al*, (2009) temperature; Choi *et al*, (2012) temperature; Arjmand *et al*, (2015) body weight, height, age, and gender; Hajihosseinal *et al*, (2015) body weight; Ghezelbash *et al*, (2016) sex, age, body height and weight; Al-Meanazel *et al*, (2021) physical characteristics (gender and percentile). This study objective is to use formulated model to determine safe weight of lift for manual lifting construction workers' in Nigeria.

1.2 Materials and Methods

1.2.1 Model development

The equation is formulated by modifying and extending Ismaila (2006) Safe Weight of Lift Model This present formulated equation considered observed factors that influence safe weight of lift among manual lifting workers in Nigeria. The observed selected factors considered in the equation are worker's weight, spine length, age, stature change, gender, temperature, and frequency of lift. In order to formulate the equation, following terms are adopted. Strain energy is the energy that causes deformation of the physical body. Therefore,

$S.E_T$ = the sum of strain energy due to upper body and weight of lift.
$S.E_b$= the upper body strain energy only, $S.E_l$ = the weight of lift strain energy only
m_T= sum of the upper body weight and load weight, m_b = upper body weight only
m_l = load weight only

$$S.E_T = S.E_b + S.E_l \quad (1)$$

$$m_T = m_b + m_l \quad (2)$$

From equation (1) the strain energy due to the upper body is:

$$S.E_b = S.E_T - S.E_l \quad (3)$$

By the conservation of energy principle, the sum of potential and kinetic energy is taking as total strain energy.

$$S.E = P.E + K.E \quad (4)$$

The total strain energy is the sum of potential energy of the body and kinetic energy of lift

$$K.E_T = \frac{1}{2} m_T u^2 \quad (5)$$

$$P.E_T = \frac{m_T g(D+V)}{sin\theta} \quad (6)$$

Where *D* is the vertical displacement of the load (*m*), *V* is the vertical location of the load (*m*), *g* is the acceleration due to gravity, *u* is the velocity of lift and θ is the angle between hip and thigh during lifting.

The total strain energy is given as:

$$S.E_T = \frac{m_T g(D+V)}{sin\theta} + \frac{1}{2} m_T u^2 \quad (7)$$

The strain energy of the load only (applied force) is given as:

$$S.E_l = \frac{m_l g(D+V)}{sin\theta} + \frac{1}{2} m_l u^2 \quad (8)$$

The strain energy due to upper body only is given as:

$$S.E_b = S.E_T - S.E_l \quad (9)$$

By substituting equation (7) and (8) into (9) we have:

$$S.E_b = \left[\frac{m_T g(D+V)}{sin\theta} + \frac{1}{2} m_T u^2\right] - \frac{m_l g(D+V)}{sin\theta} + \frac{1}{2} m_l u^2 \quad (10)$$

By substituting for m_T from equation (2) into (10) we have

$$S.E_b = \left[\frac{(m_l + m_b) g(D+V)}{sin\theta} + \frac{(m_l + m_b) u^2}{2}\right] - \left[\frac{m_l g(D+V)}{sin\theta} + \frac{m_l u^2}{2}\right] \quad (11)$$

By expansion and subtraction equation (11) becomes:

$$S.E_b = \frac{m_b (D+V)}{sin\theta} + \frac{m_b u^2}{2} \quad (12)$$

A property of material (rigidity measurement) known as spring constant (*k*) exists for an axial force that did not stress the material (spine) when at rest (Jorgen, 1986).

Hence,

$$k = \frac{F}{\Delta L} = \frac{AE}{L} \quad (13)$$

Since the spine is not stressed, $\Delta L = L$

Thererfore,

$$k = F = AE \quad (14)$$

Elliptical Truncal Area, $A = \frac{\pi l_f l_s}{4}$ (m^2), where *A* is the cross – sectional area (m^2)

E is Young Modulus of elasticity (N/m^2), *L* is the length of spine involved (*m*), l_f is the chest length, l_s is the chest width.

The strain energy of the body is given as:

$$S.E = \frac{1}{2} Fx \quad (15)$$

by substituting $F = AE$ in equation (15) strain energy of the body becomes:

$$S.E = \frac{AEx}{2} \tag{16}$$

x = stature change (m)

Therefore, by equating equation (16) with (12) we have

$$\frac{m_b g(D+V)}{sin\theta} + \frac{m_b u^2}{2} = \frac{AEx}{2} \tag{17}$$

By factorizing m_b equation (17) becomes:

$$m_b \left[\frac{g(D+V)}{sin\theta} + \frac{u^2}{2}\right] = \frac{AEx}{2} \tag{18}$$

By rearranging, equation (18) becomes:

$$\frac{2m_b}{x} = \frac{2AEsin\theta}{[2g(D+V) + u^2 sin\theta]} \tag{19}$$

The equation (19) becomes:

$$\frac{m_b}{x} = \frac{AEsin\theta}{[2g(D+V) + u^2 sin\theta]} \tag{20}$$

By substituting $sin\theta = \left(\frac{D+V}{H}\right) cos\theta$ in equation (20) we have:

$$\frac{m_b}{x} = \frac{AE\left(\frac{(D+V)}{H}\right)cos\theta}{\left[2g(D+V) + u^2\left(\frac{(D+V)}{H}\right)cos\theta\right]} \tag{21}$$

By substituting $A = \frac{\pi l_f l_s}{4}$ in equation (21) we have:

$$\frac{m_b}{x} = \frac{\pi l_f l_s E\left(\frac{(D+V)}{H}\right)cos\theta}{4\left[2gD + u^2\left(\frac{(D+V)}{H}\right)cos\theta\right]} \tag{22}$$

From Ismaila (2006)

$$m_l = \frac{\pi l_f l_s x^2}{4L}\left[\frac{E\left\{\frac{D+V}{H}\right\}cos\theta}{2gD + u^2\left\{\frac{D+V}{H}\right\}cos\theta}\right] \tag{23}$$

By comparing equation (22) with (23) we have:

$$m_l = \frac{x^2}{L} * \frac{m_b}{x} = \frac{x}{L} * m_b \tag{24}$$

Where x is the stature change; m_b is the worker's weight, L is the lifter's spine length

Note: $m_l = SWL$

Therefore, by multiplying SWL with factors multiplier of worker's age, gender, temperature, and frequency of lift (Stambough *et al*, 1995; Hidalgo *et al*, 1997) we have:

$$SWL * AG * TF * GN * FM = x * \frac{m_b}{L} \tag{25}$$

Therefore,

$$SWL = x * \frac{m_b}{L * AG * TF * GN * FM} \tag{26}$$

Therefore, equation 26 in general serves as Safe Weight of Lift (*SWL*) equation (dependent factor) to determine the weight safe to be lifted by manual lifting workers, where *x* is the stature change

(m), m_b is the worker's weight (kg), L is the lifter's spine length (m) and other factors such as AG is the age factor multiplier, TF is the temperature factor multiplier, FM is the frequency of lift factor multiplier and GN is the gender factor multiplier (independent factors).

1.2.2 Measurement procedure

Twenty measurement of experienced male construction workers lifting between 20 and 22.50kg blocks in an 8*hours* work, betweeen 9.00am and 5.00pm and shown no symptoms of musculoskeletal disorder were taken in Ibadan metropolis, Oyo state, Nigeria. The Extech RH/temperature 445580 was used to obtain temperature (^oC). The frequency of lifts (FM) was obtained by observing number of lifts performed by the construction workers and record was taken with aid of clock timer. The age (*years*), temperature (^oC) and frequency of lift (*lifts/min*) factor multipliers AG, FM, and TF were obtained from the tables in the appendix respectively. The gender (m*ale*) factor multiplier (GN) was taken as 0.72. The workers' weight $m_b(kg)$ and height were measured using surgilac scale model ZT – 160 equipment. The stature change $x(m)$ is the difference in the morning and evening height measurement of the workers, while tape rule was used to measure spine length $L(m)$ of the workers from the last cervical to lumbar end of the spine. Safe Weight of Lift (SWL) is the dependent factor while worker's weight, gender, spine length, age, stature change, frequency of lift, and temperature are the independent factors.

1.3 Theory and Calculation

The formulated equation (26) was used to determine safe weight of lift.

$$SWL = x * \frac{m_b}{L * AG * TF * GN * FM}$$

Below is an illustration of how the formulated equation (26) was used to calculate Safe Weight of Lift (SWL)

Stature change (x) = 0.03m
Worker's weight (m_b) = 55kg
Worker's spine length (L) = 0.46m
Age multiplier (AG) for 28*years* = 0.88
Frequency of lift multiplier (FM) for 1*lift/min* = 0.95
Temperature multiplier (TF) for temperature at 29.6^oC = 0.95
Gender (GN) (male) multiplier = 0.72.
By subtituting the values into equation (26):

$$SWL = (0.03) * \frac{55}{(0.46) * 0.88 * 0.95 * 0.95 * 0.72}$$

$$SWL = \frac{1.65}{0.263} = 6.27kg$$

$SWL = 6.27kg$ for one subject.

1.4 Results

1.4.1 Analysis of results

Figure 1 shows that 50% of the bricklayers and their assistants have weight of between 51.50 and 61.50*kg*, 20% weight of between 62 and 72*kg*, 20% weight of between 73 and 83*kg*, 5% weight of between 84 and 94*kg*, and 5% weight of between 95 and 105*kg*.

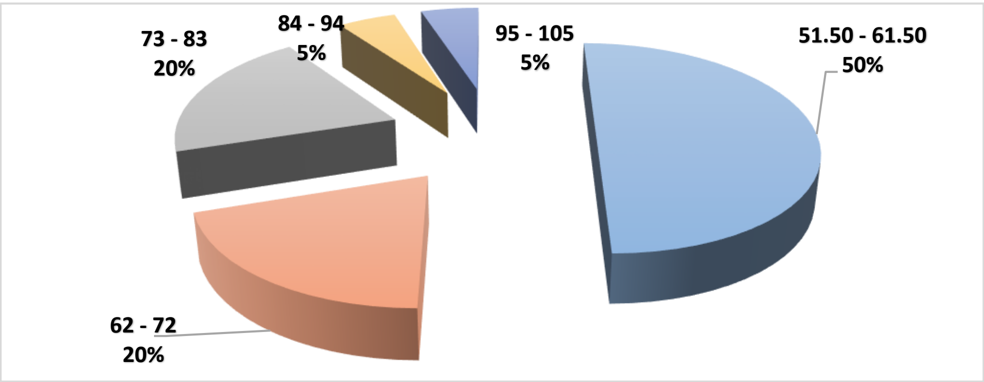

Figure 1. Workers' weight distribution
Source: Field data (2021)

Figure 2 shows that 15% of the bricklayers and their assistants have stature change of between 0.014 and 0.017*m*, 5% have stature change of between 0.018 and 0.021*m*, 30% have stature change of between 0.022 and 0.025*m*, 20% have stature change of between 0.026 and 0.029*m*, and 30% have stature change of between 0.030 and 0.033*m*.

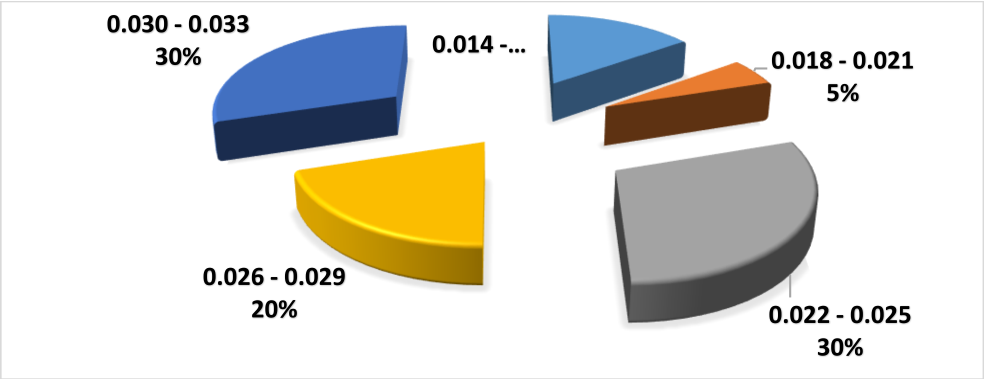

Figure 2. Workers' stature change distribution
Source: Field data (2021)

Figure 3 shows that 40% of the bricklayers and their assistants worked at temperature of between 29.30 and 31.30^oC, 30% worked at temperature of between 31.40 and 33.40^oC, 20% worked at temperature of between 33.50 and 35.50^oC, 5% worked at temperature of between 35.60 and 37.60^oC, and 5% worked at temperature of between 37.70 and 39.70^oC.

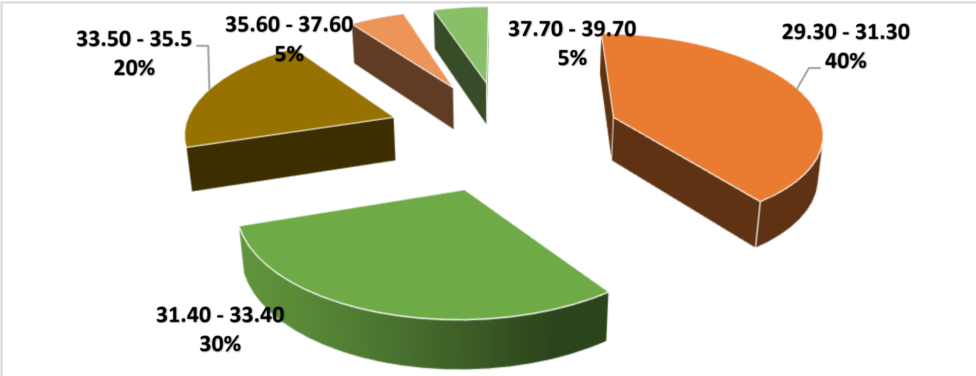

Figure 3. Workers' working temperature distribution
Source: Field data (2021)

Figure 4 shows that 10% of the bricklayers and their assistants have age of between 22 and 25*years*, 30% age of between 26 and 29*years*, 15% age of between 30 and 33*years*, 30% age of between 34 and *37years*, and 15% age of between *38* and 41*years*.

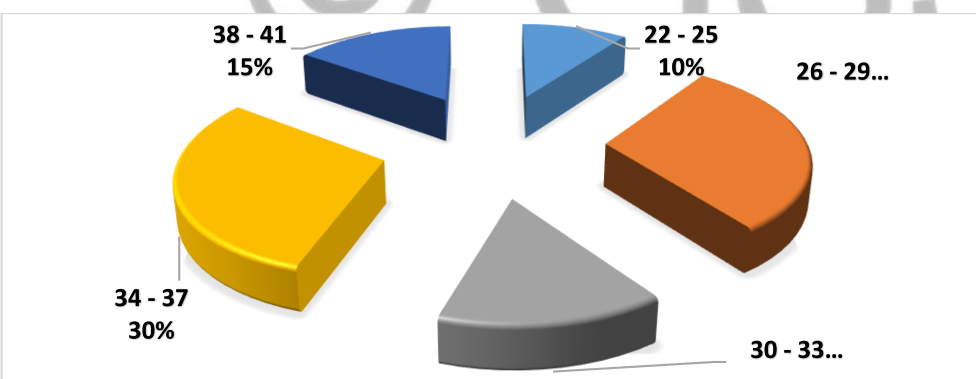

Figure 4. Workers' age distribution
Source: Field data (2021)

Figure 5 shows that 15% of the bricklayers and their assistants have spine length of between 0.41 and 0.43*m*, 50% have spine length of between 0.44 and 0.46*m*, and 35% have spine length of between 0.47 and 0.49*m*.

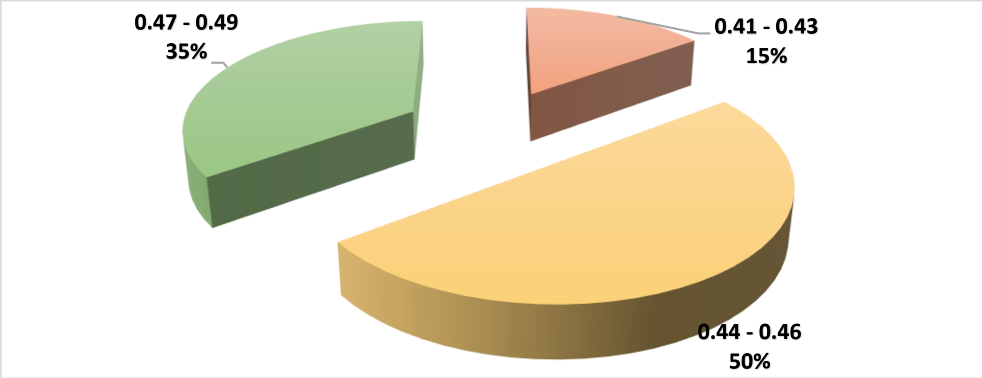

Figure 5. Workers' spine length distribution
Source: Field data (2021)

Figure 6 shows calculated Safe Weight of Lift (*SWL*) to be lifted instead of 22.50*kg* block weight been lifted by the bricklayers and their assistants. Table 4.6 shows that 15*%* of the bricklayer and their assistant should lift weight of between 3.78 and 5.78*kg*, 70*%* to lift weight of between 5.79 and 7.79*kg*, 5*%* to lift weight between 7.80 and 9.80*kg*, 5*%* to lift weight of between 9.81 and 11.81*kg*, and 5*%* to lift weight of between 11.82 and 13.82*kg*.

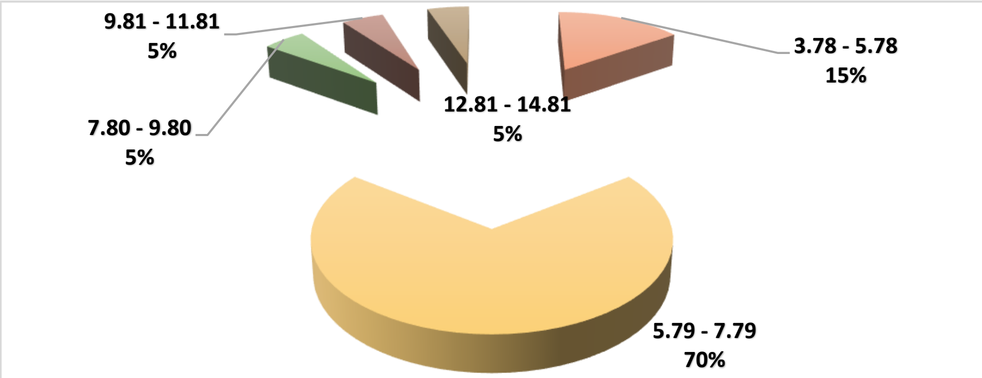

Figure 6. Safe weight of lift distribution
Source: Field data (2021)

1.4.2 Presentation of results

Table 1 shows that all the expected data were valid and used in the equation.

Table 1. Valid data values

		Age	Workers weight	Stature change	Temperature	Spine length	Frequency of lifts
N	Valid	20	20	20	20	20	20
	Missing	0	0	0	0	0	0

Source: Field data (2021)

Table 2 shows descriptive statistics for minimum, maximum, mean and standard deviation of selected factors and safe weigth of lift of twenty experienced male construction workers. The minimum and maximum age were 20 and 40*years* respectively with the mean of 31.85*years* and standard deviation 5.15. Workers' weight minimum and maximum were 51.50 and 101.90*kg* respectively with the mean of 67.27*kg* and standard deviation 13.43. Temperature minimum and maximum were 29.30 and 39^{o}C respectively with the mean of 32.05^{o}C and standard deviation 0.01. Workers' spine length minimum and maximum were 0.41 and 0.49*m* respectively with the mean of 0.46*m* and standard deviation 0.02. Frequency of lift minimum and maximum were 1.00 and 2.00*lifts/min* respectively with the mean of 1.45*lift/min* and standard deviation 0.51. The Safe Weight of Lift (*SWL*) minimum and maximum were 3.78 and 13.63*kg* with the mean of 6.99*kg* and standard deviation 2.17.

Table 2. Descriptive statistics of selected factors

Factors	N	Minimum	Maximum	Mean	Std. Deviation
Age (*year*)	20	22.00	40.00	31.85	5.15
Workers weight (*kg*)	20	51.50	101.90	67.27	13.43
Stature change (*m*)	20	0.014	0.032	0.025	0.01
Temperature (^{o}C)	20	29.30	39.00	32.05	2.61
Spine length (*m*)	20	0.41	0.49	0.46	0.02
Frequency of lifts (*lifts/min*)	20	1.00	2.00	1.45	0.51
SWL (*kg*)	20	3.78	13.63	6.99	2.17
Valid N (listwise)	20				

Source: Field data (2021)

Table 3 shows Safe Weight of Lift (*SWL*) for twenty experienced male construction workers. The obtained data include age (*years*) with multiplier factor (*AG*), gender multiplier factor (*GN*), temperature (^oC) with multiplier factor (*TF*), frequency of lifts (*lifts/min*) with multiplier factor (*FM*), worker's weight $m_b(kg)$, lifter's spine length $L(m)$ and stature change $x(m)$. The studied subjects were lifting maximum load of 22.50*kg*. The obtained Safe Weight of Lift (*SWL*) ranged from 3.78 to 13.63*kg*.

Table 3. Safe weight of lifts results

Age (*years*)	*AG*	*GN*	Temperature (^oC)	*TF*	Frequency of lifts (*lifts/min*)	*FM*	m_b (*kg*)	$L(m)$	$x(m)$	*SWL(kg)*
30	0.88	0.72	31.02	0.90	2	0.89	55.00	0.43	0.015	**3.78**
35	0.88	0.72	30.05	0.95	2	0.89	59.00	0.46	0.026	**3.84**
30	0.88	0.72	39.00	0.71	1	0.95	75.00	0.45	0.014	**5.46**
35	0.88	0.72	37.20	0.76	1	0.95	66.00	0.42	0.016	**5.87**
40	0.86	0.72	34.10	0.83	1	0.95	60.00	0.44	0.020	**5.96**
28	0.88	0.72	31.40	0.90	2	0.89	51.50	0.45	0.027	**6.09**
25	0.91	0.72	29.60	0.95	1	0.95	54.00	0.44	0.030	**6.23**
28	0.88	0.72	29.60	0.95	1	0.95	55.00	0.46	0.030	**6.27**
29	0.88	0.72	31.40	0.90	2	0.89	59.00	0.46	0.025	**6.31**
26	0.88	0.72	31.40	0.90	1	0.95	59.00	0.44	0.026	**6.44**
22	1.00	0.72	29.30	0.95	2	0.89	61.40	0.45	0.030	**6.72**
29	0.88	0.72	29.30	0.95	2	0.89	65.70	0.41	0.023	**6.88**
34	0.88	0.72	31.80	0.88	1	0.95	55.00	0.47	0.032	**7.07**
33	0.88	0.72	33.80	0.83	1	0.95	74.50	0.48	0.023	**7.15**
27	0.88	0.72	29.60	0.95	1	0.95	70.00	0.48	0.030	**7.65**
37	0.86	0.72	31.80	0.88	1	0.95	69.00	0.47	0.027	**7.67**
38	0.86	0.72	30.84	0.93	1	0.95	83.20	0.49	0.025	**7.76**
40	0.86	0.72	33.80	0.83	1	0.95	83.60	0.47	0.022	**8.02**
35	0.88	0.72	31.80	0.88	2	0.89	87.60	0.45	0.025	**10.91**
36	0.86	0.72	33.80	0.83	2	0.89	101.90	0.49	0.030	**13.63**

Source: Field data (2021)

1.5 Discussion of results

This study used the formulated model that considers observed factors like worker's weight, age, gender, stature change, spine length, frequency of lift, and temperature that can influence safe weight of lift among manual lifting construction workers in Nigeria and determined safe weight to be lifted that will not cause low back pain. The result showed that 15% of the workers are to lift weight of between 3.78 and 5.78kg, 5% are to lift between 11.82 and 13.82*kg*, while the largest percentage 70% of the workers are to lift between 5.79 and 7.79*kg* at 1*lift/mins* and 2*lifts/mins* instead of maximum load of 22.50*kg* being lifted manually by the construction workers in Nigeria. The working temperature of the construction workers in Nigeria of between 29.30 and 32.05^oC were higher than Recommended Weight Limit (RWL) temperature given by (NIOSH, 1991) of between 19 and 26^oC to apply the RWL model. Therefore, 100% of the construction workers were working under temperature above NIOSH (1991), recommended weight limit temperature, this makes the application of the RWL model by NIOSH (1991) to manual lifting workers in Nigeria doubtful as it was suggested by Maiti and Ray (2004). This present study obtained safe weight to be lifted by the male construction workers with body weight ranged of between 51.50 to 101.90*kg* to be between 3.78 and 13.63*kg*. The obtained safe weight in this present study is less than 19.80*kg* observed by Hajihosseinal *et al*, (2015). In their study, there was no increase in spinal loading of workers of body weight of between 51kg and 112kg. However, in our study, thirty percent (30%) aged between 26 and 29 years, and 30% also aged between 38 and 41 years. For the highest stature change 30% were between 0.030 and 0.033, also between 0.022 and 0.025 respectively. Fifty percent (50%) of the workers have highest spine length of between 0.44 and 0.46m. The SWL result of between 3.78 and 13.63*kg* obtained in this present study is lower than; Hafez (1984) Maximum Acceptable Weight Limit (MAWL) of 25.30*kg*, Recommended Weight Limit (NIOSH, 1991) 23*kg* when all the multiplier factors are constant, Pinder *et al* (2001) 18*kg* recommended weight, Maiti and Ray (2004) Maximum Load Limit (MLL) 15.40*kg* for India women, Vandermolen *et al* (2008) of between 14 and 16*kg*, Ismaila and Aderele (2015) of 15.50*kg*, minimum value of 3.78*kg* of this present study is lower than minimum of 4.19*kg* of Ismaila (2006). Therefore, any weight above this present obtained value of between 3.78 and 13.63*kg* is considered unsafe to lift manually and such lifting should be automated if it cannot be reduced. The contribution of observed selected factors to the formulated SWL model by the values obtained in this present proposed model has shown that the model is useful in determining weight safe to be lifted, that will not cause low back pain among manual lifting workers in Nigeria.

1.6 Conclusion

It can be concluded that the SWL of between 3.78 and 13.63*kg* with mean 6.99*kg* were the weight deemed not capable of causing low back pain among participating manual lifting workers in the study. Therefore, any manual lifting above this safe weight of lift should be automated. The present proposed model is suggested to be adopted to determine weight safe to be lifted to safe guide health of manual lifting workers in Nigeria.

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Appendix

Age Multiplier Factor

Age (*years*)	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**
Multiplier	1.00	0.91	0.88	0.88	0.86	0.78	0.69	0.62	0.59

Source: Stambough *et al* (1995)

Frequency of lifts Multiplier Factor

Frequency (lifts/min)	**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	**6.00**	**7.00**	**8.00**	**9.00**	**10.00**	**11.00**	**12.00**
Multiplier	0.95	0.89	0.83	0.78	0.73	0.69	0.65	0.62	0.59	0.56	0.54	0.52

Source: Stambough *et al* (1995)

Temperature Multiplier Factor

Temperature (°*C*)	**19 - 27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**
Multiplier	1.00	0.98	0.95	0.93	0.90	0.88	0.86	0.83	0.81	0.78	0.76	0.74

Source: Stambough *et al* (1995)