

ERGONOMIC EVALUATION OF POST BIOMECHANICAL EFFECTS OF LIFTING MAXIMUM LOADS USING MALE SUBJECTS

ABSTRACT

The post biomechanical effects of performing lifting tasks using male subjects was investigated to know the degree and where pains and injuries occur as a result of lifting maximum loads. A field approach was adopted involving six industries performing different kinds of lifting tasks. A questionnaire showing a body discomfort chart was administered to 209 respondents. The data collected were analyzed using descriptive statistics to determine the mean and standard deviation while Kaiser's rule of retaining factors were used in determining the most affected body parts predisposed to discomfort and to analyze workload assessments. High values were reported for thigh discomfort. Shoulder discomforts were significantly prevalent while most respondents reported discomforts in the mid to lower back regions. 51% of the respondents consider their work to be hard while 23% consider their work very hard. The average mass of materials lifted in the study is 32 kg. The average age, height and weight of subjects are 26.24 years, 169.59 cm and 65.08 kg respectively. Subjects involved in lifting maximum loads are prone to shoulder tendinitis and are potential sufferers of spinal kyphosis and spinal lordosis.

Keywords: *Ergonomics, Biomechanics, Maximum loads, Male subjects*

1. INTRODUCTION

Manual material handling – such as lifting heavy loads- still play an important role in the industrial and service sectors of any economy in the world irrespective of the growing advancement in mechanization and automation [1]. According to Triano and Selby [2], manual material handling (MMH) entails lifting, but also usually includes climbing, pushing, pulling and pivoting, all of which pose the risk of injury to the back. Any job that involves heavy labour or MMH may be classified as high risk. This is corroborated by Elfeturi [1] who suggested that MMH tasks should be designed to take into account several risk factors related to the task being handled. When a person involved in manual materials handling sustains an injury in the course of performing a lifting task, it often results in wastage of both time and material resources which usually has a multiplier effect(s) on the profit margin of his employer [3].

Biomechanics is a branch of ergonomics that deals with the motion undergone by the human body. According to Tichauer [4] and Hedge [5], biomechanics is the study of body movements and the mechanical forces at work in a particular body. In this field, the musculoskeletal system of the human body is viewed as a mechanical structure that can undergo certain motions and stresses. Biomechanical effects can be analyzed from joint kinematics and dynamics, giving basic understanding of what happens to the body in terms of mechanical load such as force and moment [6]. This is done using laws of physics and engineering concepts to describe the motion undergone by various body segments and the forces acting on those body parts during normal daily activities [7].

45 The objectives of ergonomics are those of achieving functional effectiveness of whatever
46 physical equipment or facilities people use and of maintaining or enhancing human welfare or
47 well-being (such as health, safety and satisfaction) by appropriate design of the equipment,
48 facilities and environment[8]. It is the science of designing facilities, work place and systems to
49 enhance the health, safety and comfort of the people using them [3].
50

51 The standards that are most widely used by ergonomist are ISO standard 11228-1 25Kg,
52 Manual Material Handling (MMH) 27Kg and National Institute for Occupational Safety and
53 Health (NIOSH) 23Kg as presented in Patenaude [9]. The standards determine the maximum
54 weight that can be safely lifted by workers. According to Patenaude [9], the values need to be
55 adjusted according to five main factors affecting worker's health and safety namely: lifting
56 duration, lifting frequency, properties of the load, working environment and workers' posture.
57 Although there are standards set to quantify the weight of the material that can be safely lifted,
58 people involved in MMH still perform tasks involving lifting objects that are up to (and sometimes
59 more than) two-third (2/3) of their total body weight by virtue of their occupation which is grossly
60 un-ergonomic [10; 11] and [6]. When the maximum load that is acceptable to the body is lifted, it
61 results in a quantifiable strain, and stress acting on the spine. Depending on the posture of the
62 person performing the lifting task, the torque and bending moments as well as the force acting
63 on the body linkages during lifting can be determined using biomechanical models. [10], [6]
64 Lower Back Pain (LBP) has been identified as the most prominent of all the injuries related to
65 lifting tasks. It has been reported that tasks involving lifting account for 33% of all work-related
66 causes of back pain [12]. Low back pain is an injury that can occur at the L5/S1 compression
67 disc of the human spine when a heavy load is lifted and when bad lifting techniques are adopted
68 while performing the task.
69

70 The aim of this work is to investigate the predisposition of male subjects involved in lifting
71 maximum loads to discomfort and injuries and to determine the parts of the human
72 musculoskeletal frame most affected by lifting such loads based on the lifting posture and lifting
73 duration.
74

75 2. METHODOLOGY

76 A field approach was adopted because of the nature of the research work. In order to collect
77 relevant data for this work, different small scale industries (SMEs) – pallet, drinks depots,
78 block moulding, cement depots, poultry feed depots and sachet water packaging industry –
79 where manual lifting tasks are performed were visited. Only male worker seen in the
80 locations visited were sampled as subjects in the study. The summary of tasks studied is
81 presented in Table 1.
82

83 **Table1: Summary of the Tasks Considered**

Tasks Categories	Load (Kg)	Freq of Lift (Mins)	No of Subjects	Description of Lifting Tasks Performed	Lifting Posture
Pallet Industry	20	2	25	Loading and offloading wooden pallets from trucks	Standing Bending
Drinks Depots	31	3	37	Loading & offloading crates of drinks into trucks and warehouse	Standing Bending

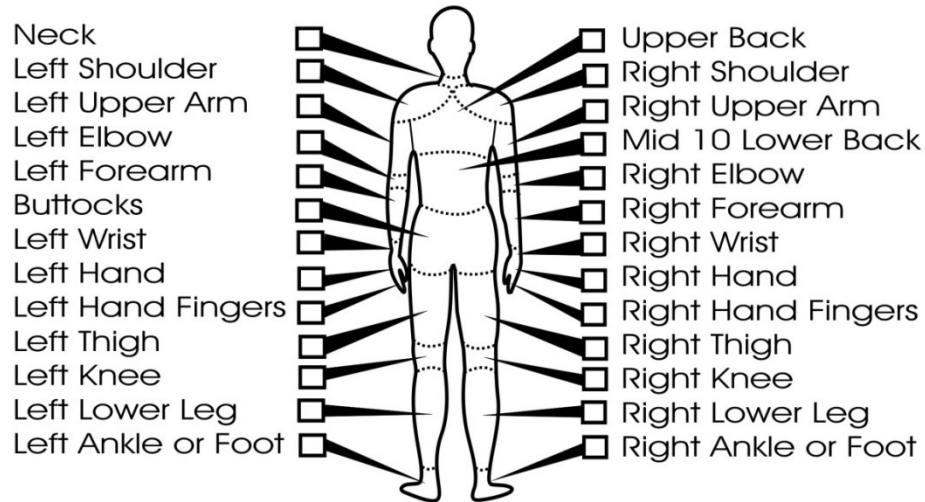
				and in breweries	
Block Molding Industry	30	2	60	Lifting and carrying molded block from machine and loading and offloading delivery trucks	Bending
Cement Depots	50	2	30	Loading & offloading bags of cement into trucks and warehouse	Bending
Poultry Feed Depots	25	2	26	Loading & offloading bags of poultry feed into delivery van and warehouse	Bending
Sachet Water Industry	36	3	31	Lifting and carrying bags of sachet water from packaging machine and loading and offloading delivery van	Standing Bending Kneeling

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85 A well-structured questionnaire adapted from Lin *et.al* [6] (Fig.1) was administered on subjects
86 that performed lifting tasks at the various locations visited and relevant data collected. This was
87 to assess the post biomechanical effects of performing occupational lifting tasks on the subjects.
88 The questionnaire contains a body discomfort chart and an overall workload assessment scale.
89 It was also used to obtain other basic data such as age, height, and weight. The weight of the
90 various materials lifted and lifting posture of the subjects were also obtained. Each subject was
91 asked to rate the degree of discomfort for each listed body part as a result of performing the
92 type of task being studied. Illiterate workers posed a great challenge during the field trip. This
93 was however taken care of by educating them in their local dialect. The data obtained in the
94 study was analyzed using Statistical Package for the Social Sciences (SPSS) version 17 to
95 determine the mean, standard deviation as well as standard error of the age, height and weight
96 of the subjects. Principal component factor analysis procedures were used to analyze the body
97 discomfort scale (stress analysis). Kaiser's rule of retaining factors with eigen values larger than
98 1.00 was used.
99

As a result of performing your current task, rate the degree of discomfort for each body part according to the following scale:

0: no feeling of pain and soreness 1: slight pain or soreness 2: pain or soreness
3: strong pain or soreness 4: extreme pain or soreness



AGE: HEIGHT: WEIGHT: POSTURE:
Task discription:

Rate the overall workload for the type of task(s) you performed
1: very light 2: light 3: some what hard 4: hard 5: very hard
(tick as appropaite)

Fig.1: A Whole Body Discomfort Questionnaire used in the Research

Source: Adapted from Lin *et. al* [6]

3. RESULTS AND DISCUSSION

The descriptive statistics shows the means and standard deviation for the twenty six variables on the body discomfort scale. From the descriptive information in Table 2 it is obvious that the mid to low back region of the body is the most stressed body part among these subjects that performed lifting tasks in the locations visited in this study with the highest mean value of 2.58. This is followed closely by discomforts reported in the right shoulder and the thighs with mean values of 1.33, 1.25(right thigh) and 1.24(left thigh) respectively. This agrees with the work of Arjmand and Shirazi [12] that tasks involving lifting account for 33% of all work-related causes of back pain [12].

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Table 2: The Results of the Descriptive Statistics of the Analyzed Data

Body Part	Mean	Std. Deviation	Analysis N	Communalities	
				Initial	Extraction
Neck	0.49	0.807	209	1.000	0.575
Upper back	0.79	0.872	209	1.000	0.630
Left Shoulder	1.20	0.995	209	1.000	0.838
Right Shoulder	1.33	0.983	209	1.000	0.799
Left Upper Arm	1.01	0.980	209	1.000	0.897
Right Upper Arm	1.06	1.003	209	1.000	0.908
Left Elbow	0.47	0.782	209	1.000	0.706
Right Elbow	0.47	0.724	209	1.000	0.677
Mid To Lower Back	2.58	1.358	209	1.000	0.518
Left Forearm	0.65	0.887	209	1.000	0.751
Right Forearm	0.59	0.814	209	1.000	0.721
Buttocks	0.16	0.489	209	1.000	0.465
Left Wrist	0.76	0.893	209	1.000	0.734
Right Wrist	0.81	0.941	209	1.000	0.748
Left Hand	0.65	0.841	209	1.000	0.699
Right Hand	0.58	0.779	209	1.000	0.687
Left Hand Fingers	0.53	0.769	209	1.000	0.726
Right Hand Fingers	0.57	0.840	209	1.000	0.696
Left Thigh	1.24	1.317	209	1.000	0.882
Right Thigh	1.25	1.344	209	1.000	0.854
Left Knee	0.96	1.181	209	1.000	0.779
Right Knee	1.03	1.259	209	1.000	0.773
Left Lower Leg	0.79	0.963	209	1.000	0.833

Right Lower Leg	0.79	0.921	209	1.000	0.775
Left Ankle or Foot	0.47	0.812	209	1.000	0.767
Right Ankle or Foot	0.45	0.781	209	1.000	0.789

The principal component communalities extracted range from 0.465 to 0.908 revealing an obvious variance in the response of all the subjects to these variables related to their body discomfort as presented in Table 2. The communalities show how much of the variance in the variables has been accounted for by the extracted factors. For instance, over 90.08% of the variance in right upper arm is accounted for while 46.5% in buttocks is accounted for. Eight factors were extracted using Kaiser's rule of retaining factors with eigen values larger than 1.00. The eigen values for eight principal components were retained and their variance as presented in Table 3. The scree plot of the eigen values against the components number shows support for Kaiser's rule opting for eight factors as can be seen in Fig. 2. A look at the scree plot shows that eight among the twenty six variables have eigen values greater than one.

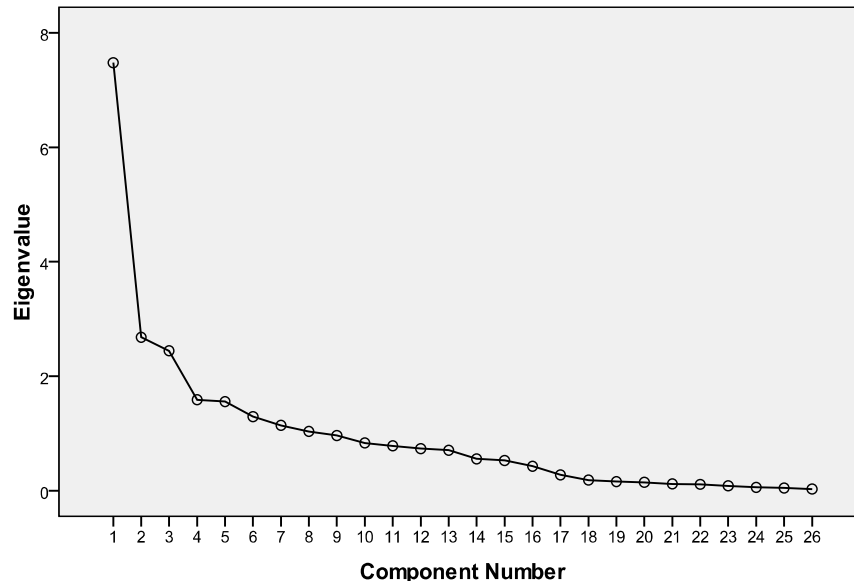


Fig. 2: Scree Plot of the Analysed Data

A look at the workload rating by the subjects for the tasks they performed in Table 4 reveals that 51% of them consider their workload to be HARD while 23.44% opted for VERY HARD. It thus follows that their unemployment status and other economic factors might have compelled them to be performing occupational tasks that most of them refer to as "hard work".

From Table 5, it can be seen that the average age, height and weight of subjects that participated in the study are 26.24years, 169.59cm and 65.08kg respectively. The average weight of the materials lifted in the study is 32kg which is above the ergonomic standards discussed earlier. It can be seen that the average weight of material lifted in this research is about half the weight of the person that lifted it instead of Load $\leq \frac{1}{3}$ weight of subject.

142 In summary, with the right shoulder as the second most stressed part of the body among the
 143 subjects used in this research beside the mid to lower back, there is no gainsaying that these
 144 subjects are also predisposed to shoulder tendinitis (a medical disorder that may evoke due to
 145 work tasks involving repetitive arm movements) as reported in [13]. This is because according to
 146 [13], a work posture involving elevated arms may accelerate degeneration of shoulder tendons
 147 through impairment of circulation due to static tension and humeral compression against the
 148 coracoacromial arch.
 149

150 **Table 3: Explained Variance of the analyzed data**

Comp.	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.479	28.765	28.765	7.479	28.765	28.765	3.344	12.862	12.862
2	2.683	10.318	39.083	2.683	10.318	39.083	3.137	12.064	24.926
3	2.444	9.398	48.481	2.444	9.398	48.481	2.564	9.862	34.787
4	1.590	6.115	54.596	1.590	6.115	54.596	2.551	9.813	44.600
5	1.558	5.993	60.589	1.558	5.993	60.589	2.024	7.786	52.386
6	1.296	4.986	65.575	1.296	4.986	65.575	1.950	7.502	59.887
7	1.143	4.396	69.970	1.143	4.396	69.970	1.883	7.242	67.129
8	1.035	3.982	73.952	1.035	3.982	73.952	1.774	6.823	73.952
9	0.966	3.715	77.667						
10	0.834	3.209	80.876						
11	0.784	3.016	83.893						
12	0.735	2.828	86.721						
13	0.709	2.727	89.448						
14	0.557	2.143	91.591						
15	0.530	2.039	93.630						
16	0.428	1.648	95.277						
17	0.277	1.067	96.344						
18	0.186	0.715	97.059						

19	0.161	0.621	97.680						
20	0.146	0.563	98.243						
21	0.120	0.462	98.705						
22	0.112	0.431	99.136						
23	0.086	0.331	99.467						
24	0.060	0.232	99.699						
25	0.050	0.191	99.890						
26	0.029	0.110	100.000						

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153 **Table 4: Workload Rating by Subjects**

Code	Description	Frequency	Percentage
1	Very Light	0	0
2	Light	9	4.31
3	Somewhat Hard	44	21.05
4	Hard	107	51.20
5	Very Hard	49	23.44

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155 **Table5: Results of Analysed Age, Height and Weight of Subjects**

Statistic	N	Mean		Std. Deviation	Variance	Percentiles	
	Statistic	Statistic	Std. Error	Statistic	Statistic	5 th	95 th
Age (Years)	209	26.24	0.507	7.328	53.692	14.18	38.29
Height (Cm)	209	169.59	0.378	5.461	29.819	160.60	178.57
Weight (Kg)	209	65.08	0.505	7.308	53.402	53.05	77.10

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158 **4. CONCLUSION**

159 The results of this study show that the nature of the lifting task(s) and the body parts
160 complement that particular task play a predominant role in the nature of body discomfort for
161 that task. However, the lifting posture employed when performing the task as well as the
162 frequency of lift are also seen to determine the body parts that will likely experience more
163 discomfort. Other factors can be identified as lifting duration, properties of the load, working
164 environment, physiological factors (stature, height, weight of subject), psychological factors

(like economic pressure) etc. The results of this study implies that people performing lifting tasks in the locations investigated in this research are predisposed to lower back pain and lower back injury (spinal kyphosis and spinal lordosis). Repeated stress on the shoulder predisposes respondents to shoulder tendinitis. This can be ameliorated by rest, medication and corticosteroid injection.

All tasks involving weights above the set ergonomic standards must be redesigned to incorporate engineering controls. Similarly, worker selection criteria should be used to identify workers who can perform potentially stressful lifting tasks without significantly increasing their risk of work-related injury. Those selection criteria, however, must be based on research studies, empirical observations, or theoretical considerations that include job-related strength testing and/or aerobic capacity testing. It is also necessary to employ the procedures of Job severity Index (JSI) discussed in [14] when allocating manual lifting tasks to employees in industries. Finally, further work should be carried out on this research to include female subjects for the purpose of gender equality

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