



Ergonomic Evaluation of Post Biomechanical Effects of Lifting Maximum Loads Using Male Subjects

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Authors' contributions

This work was carried out in collaboration between all authors. Authors SPA and BOA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Author ORI helped in data collection. All authors read and approved the final manuscript.

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ABSTRACT

The post biomechanical effects of performing lifting tasks using male subjects was investigated to know the body parts most disposed to pains and the degree of pains and injuries that 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 could suffer spinal kyphosis and spinal lordosis.

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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. It is the science of designing facilities, work place and systems to enhance the health, safety and comfort of the people using them [3]. 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].

The objectives of ergonomics are those of achieving functional effectiveness of whatever physical equipment or facilities people use and of maintaining or enhancing human welfare or well-being (such as health, safety and satisfaction) by appropriate design of the equipment, facilities and environment [8].

The standards that are most widely used by ergonomist are ISO standard 11228-1 25 kg, Manual Material Handling (MMH) 27 kg and

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

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

2. METHODOLOGY

A field approach was adopted because of the nature of the research work. In order to collect relevant data for this work, different small scale industries (SMEs) – pallet, drinks depots, block moulding, cement depots, poultry feed depots and sachet water packaging industry –where manual lifting tasks are performed were visited. Only male worker seen in the locations visited were sampled as subjects in the study. The frequency of loading and lifting postures was

observed at the various sites where the questionnaires were administered. Work postures were analyzed using Ovako Working Postures Assessment System (OWAS) as adopted in [13]. Snapshots of the workers were taken as they performed various lifting tasks and the most frequent postures assumed while lifting were observed. The summary of tasks studied is presented in Table 1.

A well-structured questionnaire adapted from Lin et al. [6] (Fig. 1) was administered on subjects after performed lifting tasks at the various locations visited and relevant data collected. This was to assess the post biomechanical effects of performing occupational lifting tasks on the subjects. The questionnaire contains a body discomfort chart and an overall workload assessment scale. It was also used to obtain

other basic data such as age, height, and weight. The weight of the various materials lifted and lifting posture of the subjects were also obtained. Each subject was asked to rate the degree of discomfort for each listed body part as a result of performing the type of task being studied. Illiterate workers posed a great challenge during the field trip. This was however taken care of by educating them in their local dialect. The data obtained in the study was analyzed using Statistical Package for the Social Sciences (SPSS) version 17 to determine the mean, standard deviation as well as standard error of the age, height and weight of the subjects. Principal component factor analysis procedures were used to analyze the body discomfort scale (stress analysis). Kaiser's rule of retaining factors with eigen values larger than 1.00 was used.

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

Neck Upper Back
 Left Shoulder Right Shoulder
 Left Upper Arm Right Upper Arm
 Left Elbow Mid 10 Lower Back
 Left Forearm Right Elbow
 Buttocks Right Forearm
 Left Wrist Right Wrist
 Left Hand Right Hand
 Left Hand Fingers Right Hand Fingers
 Left Thigh Right Thigh
 Left Knee Right Knee
 Left Lower Leg Right Lower Leg
 Left Ankle or Foot Right Ankle or Foot

AGE: **HEIGHT:** **WEIGHT:** **POSTURE:**

Task description:

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 appropriate)

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].

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. 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.

Table 1. 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
Drinks Depots	31	3	37	Loading & offloading crates of drinks into trucks and warehouse and in breweries	Bending
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

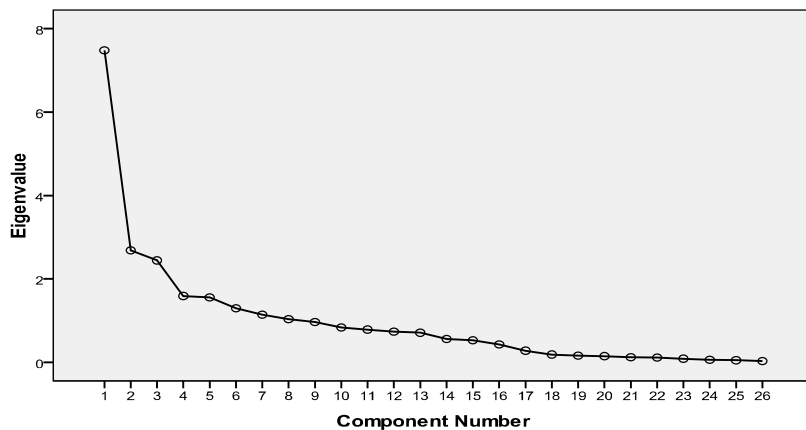


Fig. 2. Scree plot of the analysed data

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

A look at the workload rating by the subjects for the tasks they performed in Table 3 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 4, it can be seen that the average age, height and weight of subjects that participated in the study are 26.24 years, 169.59 cm and 65.08 kg respectively. The average weight of the materials lifted in the study is 32 kg 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.

In summary, with the right shoulder as the second most stressed part of the body among

the subjects used in this research beside the mid to lower back, there is no gain saying that these subjects are also predisposed to shoulder tendinitis (a medical disorder that may evoke due to work tasks involving repetitive arm movements) as reported in [14]. In addition, a work posture involving elevated arms may accelerate degeneration of shoulder tendons through impairment of circulation due to static tension and humeral compression against the coracoacromial arch [14].

Table 3. 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

Table 4. Results of analysed age, height and weight of subjects

Statistic	N	Mean		Std. deviation	Variance	Percentiles	
		Statistic	Std. error			Statistic	Statistic
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

4. CONCLUSION

The results of this study show that the level of body discomfort is dependent on the nature of the lifting task(s). However, the lifting posture employed when performing the task as well as the frequency of lift are also seen to determine the body parts that will likely experience more discomfort. Other factors can be identified as lifting duration, properties of the load, working 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. Repeated stress on the shoulder predisposes respondents to shoulder tendinitis. This can be ameliorated by rest, medication and corticosteroid injection. The connection between lower back pain and spinal kyphosis and spinal lordosis is inconclusive and is still a subject of research.

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) 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

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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