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I. Introduction

Construction industry is one of the more hazardous and risky occupations in terms of safety and health. Workers in the industry work under tough conditions to perform the desired task. The workers are frequently exposed to awkward work postures, physical demands and different types of diseases and accidents. They are more than twice as likely to be killed at work, than the average worker. Among the most common diseases is Work related Musculoskeletal Disorders (WMSDs) (Helen et al. 2008; Aman et al., 2011; David et al., 2010; BLES, 2010). The physical hazards always leading to increased risk of Musculoskeletal Disorders (MSDs) (NIOSH, 2011). Tasks that are either physically demanding or require repetitive lifting are at a high risk for accident-injuries. One situation that regularly cause worker to report back pains or to actually sustain injury is where an event that is not anticipated cause an injury while performing the task, example is the straining of back muscles by improper lifting (Articlesbase, 2011). Task may be considered hazardous if the imposed loads (forces) exceed the individual's strength and endurance/ tolerance (Chafin and Andersson, 1991). It was noted that the risk of injury is largely determined by the weight lifted (MHOR, 1992).

Basra and Crawford (1995) observed variety of different handling techniques within the 131 employees in one brick manufacturing plant of which some of the techniques were considered potentially harmful. Construction Industry Advisory Committee (CONIAC, 1993) stated that there is a high risk of injury in the single-handed, and repetitive manual handling techniques of blocks heavier than 20 kilograms. As emphasized by Kerst (2003), effects of repetitive motions coupled with the performance of the same tasks are increased when awkward postures and forceful exertions are involved.

It was however stated that ergonomics involvement tends to lower the physical demands of work tasks, thereby lowering the incidence and severity of injuries (Ajimotokan, 2008). Ergonomics must be targeted to each individual worker and the tasks that he or she performs. It is also important to take into account the physical abilities of each worker as well as their personal limitations (Articlesbase, 2011). One way to minimize risk to health or safety in construction work is by changing the way the work is done (WHSR, 2011). The Work Health and Safety (WHS) regulations place obligations on administrators carrying out of high risk construction work to ensure that a Safe Work Method Statement (SWMS) is prepared before the proposed work commences. The document should state among others the health and safety hazards and risks arising from the work to be carried out and describe how the risk control measures will be implemented, monitored and reviewed (CWCP, 2012). All employers are to devise safe working methods and communicate to all of the necessary workers on site and which have to be updated as the construction work progresses (TS, 2013). It is therefore the responsibility of site supervisor to supervise the safe work procedures and workers also are trained to follow such safe work techniques.

There has been a number of research works after the limits established by International Labour Office

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(ILO, 1964) to reduce injuries, especially Low Back Pain (LBP) associated with manual load lifting. Work Practices Guide for Manual Lifting was published in 1981 (NIOSH, 191). Load that nearly all healthy workers could perform in a specific set of task conditions over a substantial period of time without an increased risk of developing lifting-related low back pain was highlighted as Recommended Weight Limit (RWL) (Waters et al., 1993). This limit as described (Waters et al., 1994), proved useful for identifying certain lifting jobs that posed a risk to the musculoskeletal system for developing lifting related low back pain.

Using NIOSH equation involves calculating Single task Recommended Weight Limit (STRWL) and Single–task Lifting Index (STLI) Waters et al., 1993) (APPENDIX A1) for the factors in the equation for a particular lifting and lowering task. If the magnitude of the lifting index (LI) increases, the level of the risk for the worker performing the job would be increased and a greater percentage of the workforce is likely to be at risk for developing lifting-related low back pain. The goal should be to design all lifting jobs to achieve a LI of 1.0 or less (Waters et al., 1994).

a) *The aim and objectives of the study*

The aim of this study is to determine the level of inclusion of ergonomics in the work methods of some selected lifting related tasks in construction industry.

The objectives of the study are too;

1. Determine the prevailing ergonomics risk factors contributing to lifting–related injuries among the group of tasks.
2. Determine the cause of prevalence of lifting related pains among the group of workers.

II. Material and Methods

a) *Study Site and Task*

A worker participatory approach was used in this study. Two hundred and fifty male workers from ten construction sites in the Southwestern Nigeria volunteered to participate in the study. All participants were experienced workers in manual material lifting jobs and the tasks selected for the study were tasks performed regularly, for a long time without major changes and that conform to the application of the RWL. Thirty two lifting-related jobs which involved two-handed and none required of significant amount of non-lifting physical demands were included in the study. Some of the tasks included; brick setting, kern setting, lowering bricks from truck bed, loading wheelbarrow with bricks, Lifting head pans filled with mortars, lifting and fixing window blade, ceiling fan, fluorescent holders, setting perforated bricks, wall tilling, lifting and fixing wooden doors, Stacking concrete bricks, among others. Weight of materials lifted ranged from 2kg to 42kg.

b) *Data Collection*

i. *Demographic Information and Assessment of Work Outcomes*

A structured interview which followed a set of standardized questionnaires was conducted at the workers by trained personnel. Data collection was conducted at the construction sites during the working period and at a time agreed by the workers and the site managers. Data collection procedures consist of the assessment of demographic information of the workers, data related to level of ergonomics training received by the workers and the health outcome for workers who spent at least 2 years on the current lifting jobs. Workers were asked of their age and the number of years spent on the current job. Inclusion of ergonomics in the job methods was verified by the frequency of ergonomics related information/training made available to workers through their supervisors. Workers' responses to introduction of new methods of lifting were also examined. Nordic Musculoskeletal Symptom Survey (Kuorinka et al.,1987) was also used, inform of a questionnaire, taking into consideration the information concerning the subjective pain/discomfort so as to record the presence or absence of any lifting related pains in lower back, upper back, hips/upper legs, knees/lower legs, ankles/feet, neck, shoulders, elbows/forearms, wrists /hands, and fingers within the past 12 months.

ii. *Assessment of Lifting Task Parameters*

Reliable measurements are obtained if standardized measurement methods are used(Kuorinka et al., 1987). For reliability, personnel trained to make measurement in a standardized manner were involved in the measurement of variables of the selected tasks. In each of the selected job the following variables were recorded: weight of the lifted object (kg) using a weighing scale, frequency of the lift (lift/min) with the use of stop watch, task duration (hour) with wrist watch, vertical and horizontal distances (cm) both at the origin and destination of the lift with meter rule, coupling rating by observation, asymmetry angle (degree) both at the origin and destination of the lift with the use of goniometer. The frequency of lift was counted within the sample period of 15minutes.

Data obtained from the workers were used for the calculations of STLI using the revised National Institute for Occupational Safety and Health (NIOSH) lifting equation. Horizontal Multiplier (HM), Vertical Multiplier (VM), Distance Multiplier (DM) and Asymmetric Multiplier (AM) were obtained with the use of equations as stated in APPENDIX A1 while Coupling Multiplier (CM) and Frequency Multiplier (FM) were derived using tables in APPENDIX A2 and A3 respectively. All the tasks were analyzed both at the origin of lift and at the destination.

III. Results

Two hundred and thirty three (93.2%) of the two hundred and fifty (250) workers that participated in the study completed the questionnaire all of which have spent not less than 2 years on the current job. The demographics of the workers who participated in the studies are presented in Table 1.

Table 1 : Description of Demographic Information for Workers studied in ten constructions sites

Lifting Index Category				
Demographic Variable	0<LI ≤1	1<LI≤ 2	2<LI ≤ 3	LI>3
Mean age (yr)	39.78	36	33.67	36.12
Mean time at current job (yr)	6.78	4.68	5.25	5.84
No. of workers	63	51	53	66

Table 2 presents the variables and multiplier values of the studied tasks. The outcome measure of STLI was greater than 1.0 for 23 (71.9%) out of 32 jobs analyzed and the highest value of the mean lifting index was 4.49 with a standard deviation of 2.19. All multipliers values are below the value of 1.0 with horizontal and frequency multipliers as worse cases.

It appears that the average STRWL values in the four categories of LI are similar in magnitude (6.86, 6.42, 7.83, and 6.23 kg) and there are wide variability in the magnitude of the weight lifted (3.50, 9.32, 19.73, and 25.42 kg).

Table 2 : Description of Mean (Standard Deviation) Lifting Equation Values for Jobs with Workers on Current Job ≥ 2 year, by Lifting Index (LI) category

Lifting Index Category				
Demographic Variable	0<LI≤1	1<LI≤2	2<LI≤ 3	LI>3
No. of Jobs	9	7	8	8
Single Task Recommended Weight Limit (STRWL)	6.864(2.088)	6.42(2.24)	7.83(3.41)	6.23(2.34)
Mean Lifting index	0.52(0.27)	1.48(0.33)	2.64(0.27)	4.49(2.19)
Weight	3.50(2.14)	9.32(3.35)	19.73(7.96)	25.42(6.3 8)
Horizontal multiplier (HM)	0.65(0.16)	0.65(0.21)	0.61(0.24)	0.56(0.15)
Vertical multiplier (VM)	0.87(0.07)	0.93(0.06)	0.80(0.25)	0.87(0.09)
Distance multiplier (DM)	0.91(0.07)	0.91(0.03)	0.92(0.07)	0.94(0.07)
Asymmetric multiplier (AM)	0.86(0.06)	0.92(0.07)	0.92(0.08)	0.89(0.07)
Coupling multiplier (CM)	0.92(0.03)	0.90(0.01)	0.92(0.04)	0.92(0.03)
Frequency multiplier (FM)	0.70(0.17)	0.62(0.20)	0.63(0.13)	0.62(0.19)

a) *Response of workers to ergonomics related training*

Regarding ergonomics related training-/information organized by supervisors/managers to introduce workers to new method(s) of safe lifting (Figure 1), about 146 workers (63%) confirmed that there is no regular ergonomics training that could expose them to any better method(s) of lifting than the one they are used to. While 87 of the workers (37%) reported receiving regular training/information from their supervisors, 56 workers (64.4%) in this category could not confirm learning any new method of lifting during the said training.

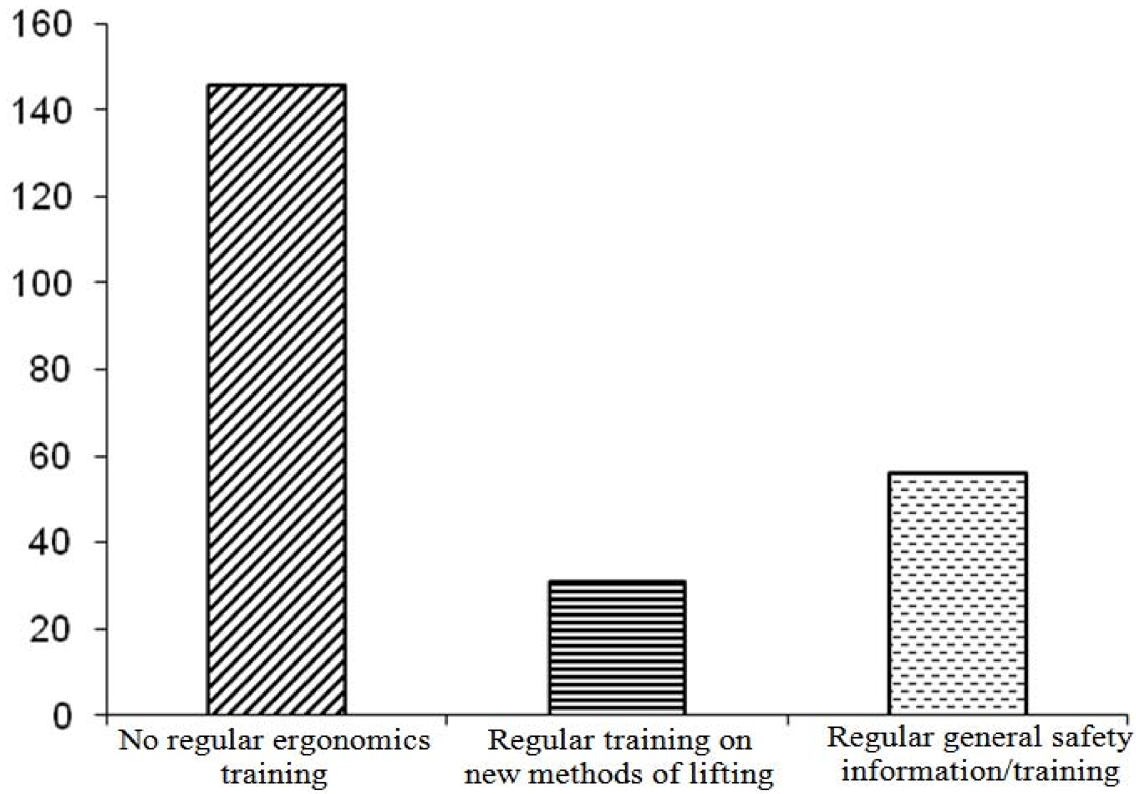

Figure 1 : Description of the Response of workers to ergonomics related training

Therefore through regular information/training, only thirty-one workers representing 13.3 percent of the total workers who participated in the study are probably exposed to ergonomics/ safe method of lifting.

b) Work-related pain prevalence among the workers

Regarding work-related pain prevalence among the workers, 170 workers (73%) out of 233 workers fall into categories of LI>1 (Table 3). In the study 40 (63.5%) out of 63 workers that fall into category of 0<LI≤1 complained of neck pain as compared to 11 (16.4%) out of 67 workers in the category of LI>3 who complained of pain in the same body region. Category of 0<LI≤1 workers have the least complaint of lower back pain with 8 (12.7 %) out of 63 workers. The major reported LBP are from workers in the category of LI>3 where 50 (74.6%) out of 67 workers reported having lower back pain lasting more than one week in the past 12months.

Table 3 : Description of Percentage (Number of workers) reported health outcome for Workers on current Job≥1 year, by Lifting Index (LI) Category

Lifting Index Category				
Demographic Variable	0<LI≤1	1<LI≤2	2<LI≤ 3	LI>3
No. of workers	63	49	54	67
% Pain in the neck	63.6 (21)	19.0(4)	18.2(4)	16.7(6)
% Pain in the lower back	12.1(4)	47.6(10)	59.1(13)	75(27)
% Pain in the upper back	0	9.5(2)	18.2(4)	8.3(3)
% Pain in the hips/upper legs	0	0	9.1(2)	38.9(14)
% Pain in the knees/lower legs	0	0	0	22.2(8)
% Pain in the ankles/feet	0	0	0	0
% Pain in the shoulders	54.5(18)	33.3(7)	40.9(9)	30.6(11)
% Pain in the elbows/forearms	27.3(9)	23.8(5)	18.2(4)	8.3(3)
% Pain in the wrists /hands	0	0	0	0
% Pain in the fingers.	0	0	0	0
% Workers missed work due to back pain from repeated activities in the last 12months	0	4.8(1)	36.4(8)	58.3(21)

Pains at the shoulder region of the body were reported by workers fixing window blade, ceiling fan and fluorescent holder with 54.5% of the workers in the category 0<LI≤1 complained of pain in the region and 40.9% of workers in the category 2<LI≤3, 33.3% of workers in the category 1<LI≤2 and 30.6% of workers in the category LI>3 were also reported suffering from shoulder pain as a result of the repetitive work. About twenty seven percent (27.3%) of workers in the category of 0<LI≤1 had pains in the elbows/forearms region of their body. Among all the complaints, lower back, shoulder and neck pain take predominant in decreasing order (Figure 2).

In all the categories, 62 (26.6%) out of the total 233 workers interviewed of which 39 (58.2%) out of 67 workers are in the category of LI>3 and 20 (37.0%) of 54 workers are in the category of 2<LI ≤3 reported to have missed work due to back pain in the last 12 months. When the reported pain was associated with their job, 55 (90.2%) of 61 workers who reported having LBP lasting more than a week in the past 12months thought that their back pain was caused by their works. Forty-six workers (68.7%) that fall into this group were from the category of LI>3. No worker in the categories of 0<LI≤1 and 1<LI≤2 however reported missing their job schedule in the past 12months because of back pain.

IV. Discussion

Workers in the category 0<LI≤1 had the longest tenure on the current job and followed closely by LI>3 category which were also the youngest among the group. Workers in the category of 0<LI≤1 were older than other categories. The outcome indicated that this group of workers stays longer in the job more than other groups. For the population included in this study, as the LI value increases, the mean age of the workers reduces.

The low values of HM recorded in the course of performing the tasks showed that

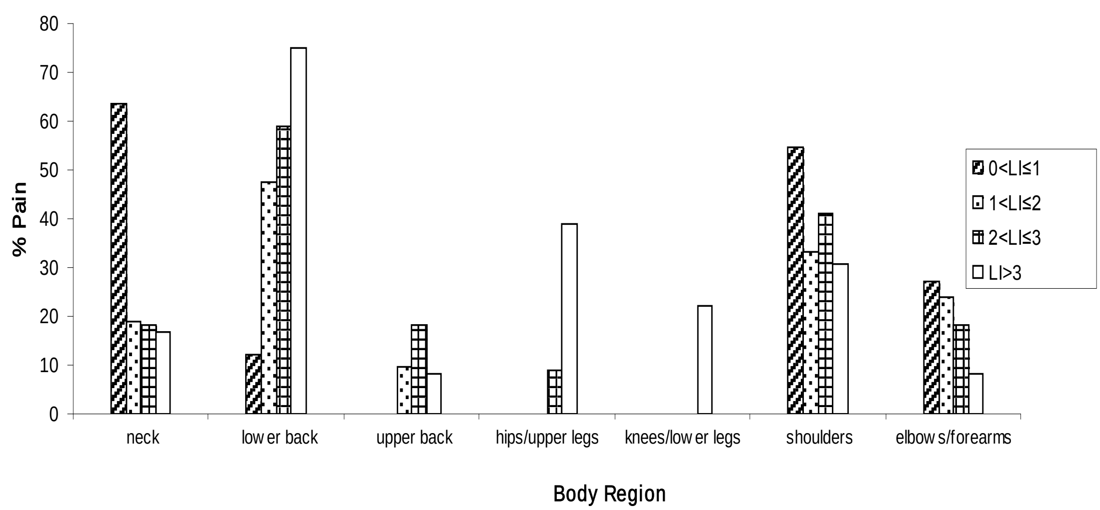

Figure 2 : Description of the reported pain in body regions within the past 12 months

the loads are not positioned where workers can conveniently access them. The values of FM obtained suggested that workers are subjected to a high frequency of lift to probably meet up with the demand of their service. This was common in mortar lifting jobs. High frequencies of lift as well as location of load are therefore suspected as potential factors capable of causing lifting related pain.

Twisting and bending of body parts are also frequent in the lifting processes. Workers sometimes had to lift loads from the origin by bending sides asymmetrically and/or delivered the load at the destination at angles deviated from the natural as witnessed nearly in all the jobs studied. Most workers (in stacking and dies-stacking jobs) preferred quick lift from Sides instead of repositioning the body to lift directly from the front.

Though some times may be gained to complete their tasks earlier as envisaged by the workers, but the increases in frequency of lift in an awkward posture subjected the workers to more risks.

A larger percentage of the workers are ignorant of the negative effects of the awkward lifting because they were not properly informed/ trained by the concern supervisors on the ergonomics techniques of performing the tasks. It could also be suggested that LI are sensitive to the magnitude of weight lifted. Among other multipliers the horizontal and frequency multipliers had the greatest effects on the STRWL values in all the categories.

Though the calculated LIs for workers in the category 0<LI≤1 were less than 1.0, majority of the workers complained of neck pain most especially those who are involved in fixing wall tiles and fluorescent lamb

holders. This could be as a result of prolonged inclination of head/neck during the tasks. This category of workers also had the least complaint of lower back pain. The major reported LBP among workers lasting more than one week in the past 12 months are from the category of LI>3, the same group also suffered from shoulder pain because the nature of their jobs required having the load sustained at hands for some times at a height above the head. Mortar lifting, brick lifting, brick setting and fixing wooding doors tasks are mostly affected in this group. The high LBP complaints could be as a result of the magnitude of load lifted and the low variable multiplies recorded among the category of workers.

One of the important proposed applications of the lifting equation is as a tool for estimating the percentage of workers involving in lifting related jobs that is likely to be at risk for developing lifting-related low back pain (LBP). It has been raised that most of the working population should be able to perform jobs with LIs less than 1.0 without a significant risk of LBP and that the risk begins to increase as the LI exceeds 1.0. It is therefore necessary to consider possible ways of reducing the values of LI for all the jobs evaluated. A total redesign of workplace and job methods is very essential. Administrators in the industry need to incorporate ergonomics into the job methods most especially by intensifying efforts in training the workers on safe methods of manual material lifting among other safety trainings. All the multipliers must be given attention most importantly HM and FM in all categories to bring the values to 1.0 and less. The weight lifted by workers can be reduced by ensuring the containers are not fully loaded at the lifting point. Possibility of resizing the lifting containers can be conceived. Vertical multiplier can be increased by raising the origin of lift most especially while working above. This will increase the VM making it better than lifting from the lowest layer. Bringing the load as close as between the workers' leg could make a significant positive change. The angle of twist should be reduced to increase AM by moving the origin and destination closer together. The physiological demands can decrease by reducing the frequency rate of lift. Increasing number of mortar carriers, for instance, can be helpful in this measure so that demand on one worker will reduce. These corrections will decrease the values of LI below 1.0, reduce the risk of work related injuries and increase the quality of the task.

V. Conclusion

Seventy-six percent (76%) of the lifting-related jobs studied had LI greater than 1.0 showing that the entire individual tasks in the groups have excessive physical stress that is connected with the jobs for nearly all healthy workers performing them and will result in physical fatigue. It is significant from this present study that most of the stress related complaints in construction works are engineered by poor work methods leading to high frequency of lift, lifting heavy loads at awkward postures among other factors.

It can be concluded that manual handling in construction industries still have a significant level of higher physical stress associated with the jobs. There is a wide gaps in information related to the prevention of construction site injuries and illnesses among the workers. The tasks analysis results indicated that the involvement of ergonomics in studied construction sites is very low. Most workers performing the manual lifting job will be at an increased risk of a work-related injury. Among all the jobs analyzed, the highest LI values were recorded in mortar lifting tasks.

References References References

1. Ajimotokan H. A. 2008. *System Dynamics Approach for Managing Magnitude and Risk Factors of Injuries in a Manufacturing Industry.* Match Seminar Report, Dept. of Mechanical Engineering, Ladoke Akintola University of Technology, Ogbomoso , Nigeria.
2. Articlesbase (online). *Back Injuries at Work and Your Office Chair* Available from. http://-www.articles base.com/ health-articles. Accessed 19-04-2012.
3. Ayoub M. M., Dampsey P. G., Karwowski W., 1997. *Manual Material Handling,* Solvendy, G. (Ed.). Handbook of Human factors and Ergonomics (2nd Ed.). New York: John Wiley and Son, p. 1085-1123.
4. Basra G., Crawford J.O. 1995. *Assessing Work-related upper limb Disorders in a brick-making factory.* In: Robertson, S.A. (Ed.), Contemporary Ergonomics. Taylor & Francis, London: p. 480-485.
5. Chafing D.B., Andersson G.B., 1991. *Occupational Biomechanics,* 2nd ed. John Wiley, New York.
6. Construction Industry Advisory Committee (CONIAC), 1993. *Handling building blocks.* Published by Health and Safety Commission. Construction sheet No. 37 NIS/06/37 C40 Available fromhttp://www.ibstock.com/pdfs/health-and-safety /blocks-info.pdf (accessed 02-08-2010).
7. Construction Work Code of Practice (CWCP). 2012. "*Safe Work Australia*" Available from www. safeworkaustralia.gov.au accessed 09-09-2012.
8. Health and Safety Executive (HSE). 2000. *Injuries and ill health caused by handling in the food and drink industries,* Food Information Sheet 23.
9. Helen, L., Nick, B., Ron, W., David, J., Tim, F., 2008. *"Safer Construction: the development of a guide to best practice".* In : Third International Conference of the Cooperative Research Centre (CRC) for Construction Innovation, Gold Coast, Australia.
10. International Labour Office (ILO), 1964. *Maximum permissible weight to be carried by one worker.*

Geneva. Available from www.worldcat.org/.../ max-mum-permissible- weight-to-be-car... accessed 02-06-2010.

11. Kerst J. 2003. *An Ergonomics Process for the and use of Research Animals.* Institute for Laboratory Animal Research Journal. 44 (1), p. 3-12.
12. Kivi P, Mattila M. 1991.*Analysis and improvement of work postures in the building industry: application of the computerized OWAS method.* Applied Ergonomics. 22, p. 43–48.
13. Kuorinka L, Johnsson B, Kilo A, et al. 1987. *Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms*. Applied Ergonomics.18, p. 233–7.
14. Manual Handling Operations Regulations (MHOR). 1992 (online), *Safe Manual Handling of Bariatric/Heavyweights Patients Policy.* Available from www.tamesidehospital.nhs.uk/.../Safe Manual Handling of Bariatric Patients Policy. Accessed 09-04-2011.
15. National Institute for Occupational Safety and Health (NIOSH). 1981. *Work Practices Guide for Manual Lifting (WPG),* NIOSH Technical Report. U.S. Department of Health and Human Services, National Institute for Occupation, p. 81 122.
16. National Institute for Occupational Safety and Health (NIOSH) (online), *Program Portfolio.* Available from http://www.cdc.gov/niosh/programs/msd/projects.html. Accessed 19-04-2012.
17. Punnett L, Fine LJ, Keyserling W.M, Herrin G.D and Chaffin D.B. 1991. *Back disorders and non-neutral trunk postures of automobile assembly workers*. Scandinavian Journal of Work, Environment and Health, 17, p 337–346.
18. Safety and Health Administration (OSHA). 1999. *Draft ergonomics requirements.* Feature Articles - ISHN Article tools.
19. Snook S.H. 1978. *The Design of Manual Material Handling Tasks, Ergonomics*, London, Taylor and Francis.
20. Thompsons Solicitor (TS). 2013. *"Construction Site and Building Site Accident Compensation Claims*" Available from http://www.thompsons.law.co.uk/ workplace accidents/ accidents-work-construction-building-sites.htm. Accessed 03-03-2013.
21. Waters T.R., Putz-Anderson V., Garg A., Fine L.J., 1993. *Revised NIOSH equation for the design and evaluation of Manual lifting tasks*, Ergonomics, 36, p. 749-776.
22. Waters T. R, Puts-Anderson, V., Gag, A. 1994. *Applications manual for the revised NIOSH Lifting Equation.* Publication no. 94-110. Cincinnati, OH: DHHS (NIOSH).
23. Work Health and Safety Regulation (WHSR), 2011. *Safe work method statement for demolition work.* Available from Www.workcover.nsw.gov.au. Accessed 01-07-2012.

Appendix

Appendix A1: NIOSH Lifting Equation

Calculation for single-Task Recommended Weight Limit
STRWL = LC * HM * VM * DM * AM *FM * CM
(* indicates multiplication)
STLI = Laverage/STRWL
Hours: or≤8 hours assuming appropriate recovery allowances

Recommended Weight Limit	
Components	ic
LC = Load Constant	3kg
HM=Horizontal Multiplier	25/H
VM=Vertical Multiplier	1-0.003(|V– 75|)
DM=Distance Multiplier	0.82 + 4.5/D
AM=Asymmetric Multiplier	1-0.0032A
CM=Coupling Multiplier	From Table A2
FM=Frequency Multiplier	From Table A3

Appendix A2: Coupling Multiplier: NIOSH Lifting Equation

Couplings	Coupling Multiplier	
	V<75 cm	V>75cm
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

Where
H= horizontal location of hands from midpoint between the ankles; measure at the origin and the destination of the lift (cm)
V = vertical location of the hands from the floor; measured at the origin and destination of the lift (cm)
D = vertical travel distance between the origin and the destination of the lift (cm)
A = angle of asymmetric-angular displacement of the load from the sagittal plane; measure at the origin and destination of the lift (degree)
F = average frequency rate of lifting measured in lift/min
Duration is defined to be: ≤1 hour: ≤2

Appendix A3: Frequency Multiplier (FM): NIOSH Lifting Equation*

Frequency lift/min.	Work Duration					
	< 1 hour		<2 hours		<8 Hours	
	V<75	V>75	V<75	V>75	V<75	V>75
.2	.1.00	1.00	1.00	.95	.85	.85
.5	1.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.31	.00	.00	.00	.00
14	.00	.00	.00	.00	.00	.00
15	.00	.00	.00	.00	.00	.00