

KNOWLEDGE OF ERGONOMICS AND ERGONOMIC RISK FACTORS FOR WORKERS IN THE CONSTRUCTION INDUSTRY

Ajayi O.O. and Adeoye D.O.

Department of Architecture, Faculty of Environmental Sciences,
Ladoke Akintola University of Technology, Ogbomosho, Nigeria

Email: ooajayi@lautech.edu.ng

ABSTRACT

Construction is a physically demanding and potentially hazardous profession. The construction industry is characterized by fragmentation, multiplicity of operation, multiplicity of crews and industry culture. Ergonomics is still a relatively new theme for the construction industry. Understanding the ergonomic issues in construction can play a critical role in ameliorating its risks among the construction workers. Sustained physical work can be the cause of bodily injury to workers, which in turn entails enormous losses to the industry in terms of money, time, and productivity. Each of these however contributes to unforeseen and unfamiliar hazards or the unsafe behavior of workers. Several safety and health organizations have proposed rules and regulations that limit workers' efforts in order to mitigate possible bodily injuries. Despite the advancement in technology the ergonomic knowledge has been slow in construction industry, however, physical efforts continue to cause serious damage to workers' health and, as a result, efforts are being directed towards a more ergonomic and safe working environment. The aim of the paper is to discuss various ergonomic risks encountered by construction workers on construction sites and develop various interventions to reduce those risks. The paper also advocates for participatory research ergonomics as an effective health and safety policy in the construction industry so as to achieve the positive safety culture in the workers daily operations.

Keywords: Ergonomics, construction sites, construction workers, work related musculoskeletal disorders (WMSDs), manual handling

INTRODUCTION

Construction works typically require the adopting of awkward postures, lifting of heavy materials, manual handling of heavy and irregular sized loads, frequent bending, bending and twisting of the body, working above the shoulder height, staying in one position (Schneider, 2001, Ajayi, 2012). The manner in which construction activities are executed adversely affects the health of building construction workers are exposed to excessive construction site danger that often results in injuries and even death. They are exposed to different hazardous and accident – prone working environments. The work sites exposes than to different safety and health prone conditions. Building construction is a physical process and presents numerous ergonomic related hazards. The site brings together skilled and unskilled construction workers. With increasing development of the construction process building construction workers exposure to unfavourable ergonomic risks makes it an extreme risk sector in regard to Work related Musculoskeletal Disorder (WMSDs) (Ajayi, 2013). One of the most effective approaches to preventing WMSDs is to evaluate ergonomics considerations early in the design and construction planning stage before the worker encounters the unsafe conditions. However, lack of tools for identifying potential ergonomic risks in a proposed workplace design has led to difficulties in integrating safety and health into workplace design practice

(Golabchi *et al.*, 2015). The Musculoskeletal Disorders (MSDs) remain in the most prevalent form of occupational ill health, prompting examination of the reason that has been less successful than perhaps hoped (In Ju, 2017).

The International Labour Organisation (ILO) classifies the construction industry as government and private firms erecting building for habitation and for commercial purposes (ILO, 2017). Construction work by its nature entails exposure to hazards and a high rate of occupational disease which traditional creates injuries, fatigue, strains, dull faculties and wears out the body system (Ajayi, 2013). The construction workers are manual labourers employed in the physical construction of the built environment and its infrastructure. The workers within this concept are primarily described by specific level of work they performed.

Based on the findings of ergonomics study among South African construction management and workers, the use of body force, reaching away from the body, reaching above the head, repetitive, movements; bending or twisting the back, climbing and descending were common and constitute work related job problems (Rawamamara *et al.*, 2007; Ajayi, 2012). The situation is worst in developing countries. Ajayi (2013) maintained that numerous construction tasks pose significant ergonomic risk to building construction workers. Construction in respect to innovation is at a

macro level that is of large scale changes to building process but conservative with innovation at micro level that involves low level method of design details or installations which depends on the capabilities of the construction worker. Construction is a field of work that is very physically demanding. The work can be performed at a variety of different sites ranging from buildings and highways to demolition sites and tunnel excavations. Many construction workers have to control machines, move heavy objects, repair equipment, as well as monitor processes. This job requires an individual who has great manual dexterity as well as the ability to think quickly and intelligently. Since construction jobs are so demanding physically on a person's body, a variety of injuries can occur (Rabia et al., 2015).

Bureau of Labor Statistics shows that overall days-lost by injuries and illness of construction was higher than any other industry sector. In Great Britain, 3% of workers in construction industry suffer from work related illness which leads to 1.2 million days lost. Annually, around 69,000 construction workers in Great Britain were suffering from an illness in which 65% were cases of musculoskeletal disorders that are harmed by Ergonomic hazard and only 35% were cases are harmed by other hazards (Kim 2017). The current statistics illustrate construction labors to be at major threat of musculoskeletal injury; particularly linked to the job they do. Countless injuries that happen in the construction industry are owing to the physical working activities that is necessary in the construction industry. Workers illness and injuries leads to delay in project progress and decrease the productivity in construction. Usually workers safety is not considered in the initial phase of the project (Rabia *et. al.*, 2015).

However, these exposures usually make workers in the building construction industry to experiences a high rate of Work-related Musculoskeletal Disorders (WMDs) resulting from a number of unfavourable construction activities and body movements.

Ergonomics in Construction Industry

Ergonomics involves the way the body is used to work and fitting the job or task for the reduction of risk of injury. According to the International Ergonomics Association (IEA), ergonomics is defined as the understanding interactions among humans and other elements of a system in order to make them compatible with the needs, abilities, and limitations of people (Ajayi and Thwala, 2012). Defined by the Board of Certification for Professional Ergonomists (BCPE), "is a body of knowledge about human abilities, human limitations and human characteristics that are relevant to design. 'Ergonomics is fitting the task to the person. Too often employees perform job tasks that expose them to potential injuries and illness due to the poor design of a workstations or tool they are using. Ergonomics involves the assessment of job tasks to identify

ergonomic risk factors and appropriate engineering or work practices controls to reduce or eliminate the identified risk factors. Generally, ergonomic changes are made to improve the fit between the demands of the job tasks and the capabilities of the employees' (Ayat and Adnan, 2012). The Occupational and Industrial Orthopedic Center, NYU Hospital for Joint Diseases Orthopedic Institute, Graduate Program in Ergonomics and Biomechanics (2003) said that 'Ergonomics is the science that looks at the interaction between the laborer and the work that they do'. Michigan Occupational Safety and Health Administration (MISOHA) (2015) submitted that Ergonomics is the study of people while they use equipment in specific environments to perform certain tasks. Ergonomics seeks to minimize adverse effects of the environment upon people and thus to enable each person to maximize his or her contribution to a given job' [8]. Ergonomics involves the application of knowledge about physiological psychological and biomechanical capabilities and limits of the human body (Ayat and Adnan, 2012). 'Ergonomics can be defined simply as the study of work. Ergonomic is the science of designing the job to fit the worker, rather than physically forcing the worker's body to fit the job'. Ergonomics is a significant factor in achieving and maintaining high levels of worker productivity and one of the procedures that eliminate the hazards and risk in construction industry. Ergonomics resolutions have contributed to preventing injuries and fatalities and facilitate safety and health practices for the construction workers (Kim, 2017). Increase in construction works leads to constant exposure of unfavourable ergonomic challenges. Thus, construction works represents a challenge in that it requires work above shoulder height or below knee level. Furthermore, the materials used in construction may be heavy and inconveniently sized or shaped.

The most important safety, health, and ergonomically related problems in construction: accidents with construction tools; falling and tripping; manual handling, lifting, and carrying; noise; vibration; dust exposure; and poor design of tool interfaces (Agumba and Haupt, 2008). Of the job factors which constituted major ergonomically related problems, the following were the top four (i) Bending or twisting the back (ii) Staying in the same position for long periods(iii) Working in the same position for long periods (iv) Handling heavy materials or equipment (Ajayi,2012; In Ju,2017). Ergonomic techniques typically focus on an assessment process followed by interventions that can reduce the potential for musculoskeletal strains and sprains. While this methodology is shown to be effective and widely used within manufacturing and warehouse settings, construction ergonomics is very much in its infancy. Research conducted among construction workers representing six trades in the USA investigated inter alia, the extent to which 15 job factors constituted a problem on a scale of: minor-problem, minor-moderate problem, and major problem. Based upon a score out of 10, the following were determined to be the

top five work-site problems resulting from little or no ergonomics input: working in the same position for long periods (5.7), bending or twisting the back in an awkward way (5.5), working in awkward or cramped positions (5.0), working when injured or hurt (4.7), and handling heavy materials or equipment (4.6) (Muhammad *et al.*, 2013).

According to (IEA) ergonomics is of three (3) broad domains which are physical, cognitive and organizational. The physical ergonomics is concerned with human anatomical, anthropometric physiological, and biomechanical characteristics as they relate to physical activity. This is the ergonomics that is most concern with the workplace activity (Vikram *et al.*, 2017). Cognitive ergonomics is concern with mental processes, such as perception memory, reasoning and motor response as it affects interactions among humans and other elements of a system, while organizational ergonomics is concern with the optimization of sociotechnical systems, including their organizational structures; policies and processes. Ergonomics is an approach to deal with number of problems among them is (WMDs) work related musculoskeletal disorders. Currently, construction industries have focused more on improving productivity over ensuring safety and health issues of the construction workers such as conducting ergonomic analysis (In Ju, 2017). As a result, project managers should be aware that the economic outcome of increased productivity may be counterweighed by the increased medical and compensation costs caused from WMSDs. But, ergonomic analysis for the WMSDs is not sufficiently being addressed by construction companies Agumba and Haupt, 2008; Ajayi, 2013).

The principle of ergonomics involves work in neutral postures (proper posture is necessary, working too long with 'C' curve as it causes strain, and keeping the proper alignment of neck hands wrist are also necessary), Reduce excessive force(excessive pressure or force at the joints can cause injury, better to minimize the work that requires more physical labor), Keep everything in reach(Keeping everything in reach would help in avoiding unneeded stretching and strain, More or less this principle is related with maintaining good posture), Work at proper height(working at right makes things way easier, sometimes height can be maintained by adding extensions or avoiding extensions on the chair or tables) Reduce excessive motions(Repetitive motion needs to be avoided as this can cause disorder and numbness in long run, Motion scan be reduced by the use of power tools), Minimize fatigue and static load(fatigue is common in strenuous work, Having to hold things for longer period is example of static load, fatigue can be reduced by the intervals and the breaks between the works), Minimize pressure points(One needs to be aware of pressure points), Provide clearance (work area should have enough clearance), Move, exercise and stretch (Move and stretch when you can,

Stretching technique may differ and depend on the work one does), Maintain a comfortable environment(This principle is focused on the other component of the working environment) (In Ju, 2017).

In construction, site is of physical ergonomics domain in which the work place ergonomics need to be accentuated as it concerns with job demands to the capabilities of the working population. Therefore, when jobs are designed to match the capabilities of people, it results in better work being produced and a better experience for the person doing it (safety culture). Intent of changing work and finding solution is beyond human comprehension as, recreation, learning and living applications are very challenging to construction industry. Thus a macro ergonomic approach that considers both organisation and technological context is a way of meeting these challenges (Mohamed *et al.*, 2013; Abdul- Tharim *et al.*, 2013).

Ergonomic resolutions have contributed to preventing injuries and fatalities, facilitate safety and health practices for construction workers but there seems to be great potentials for more in widespread applications. The definitions of ergonomics is user-centered design or user centered engineering expressing focus on human being and at the same time emphasizing prevention by design. Therefore unsafe, unhealthy, uncomfortable or inefficient work situations can be avoided by taking into account the limitation of human beings.

Nature of Construction Industry and Ergonomics Impact

Despite the sophisticated safety and health regulations in most countries, it is no secrets that the industry is responsible for relatively high occupational injury rate the industry faces many occupational injuries and fatality risks, making it challenging to study. The physical working environment varies with seasons and job site conditions as highlighted in Table 1. Ajayi (2012) submits that a healthy and safety construction environment and healthy people are required to produce a product or service at a profit. Though, the sector is characterised by the mobility of workers, charge of work places, tremendous diversity in regard to the importance and type of work being performed in an extreme sensitivity for economic instability and large cyclical and sensational variations in activity level. As a significant employer of labour the large proportions of its activities and operations are labour intensive (Rabia *et al.*, 2015). The physical work activities and conditions as related to construction sites which cover the basic physical aspects of jobs and workstations are:

- Physical demands of work;
- Workplace and workstation conditions and layout;
- Characteristics of object(s) that are handled or used; and

- Environmental conditions.

The following table shows the physical work activities and workplace conditions that are associated with those physical aspects:

Table 1: Physical work activities and conditions

PHYSICAL ASPECTS OF JOBS AND WORKSTATIONS	EXAMPLES OF PHYSICAL WORK ACTIVITIES AND CONDITIONS ASSOCIATED WITH THE PHYSICAL ASPECT
Physical demands of work	<ul style="list-style-type: none"> • Exerting considerable physical effort to complete a motion • Doing the same motion over and over again • Performing motions constantly without short pauses or breaks in between • Maintaining same position or posture while performing tasks • Sitting for a long time • Using hand as a hammer • Using hands or body as a clamp to hold object while performing tasks • Objects or people are moved significant distances
Layout and condition of the workplace or workstation	<ul style="list-style-type: none"> • Performing tasks that involve long reaches • Working surfaces too high or too low • Vibrating working surfaces, machinery or vehicles • Workstation edges or objects press hard into muscles or tendons • Horizontal reach is long • Vertical reach is below knees or above the shoulders • Floor surfaces are uneven, slippery or sloped

Characteristics of the object(s) handled	<ul style="list-style-type: none"> • Using hand and power tools • Gloves bulky, too large or too small • Objects or people moved are heavy • Object is slippery or has no handles
Environmental Conditions	<ul style="list-style-type: none"> • Cold temperatures

Source: <https://www.ehs.iastate.edu>

The complexity and instability inherent to this sector have repercussions on health and safety of construction workers. The construction/tasks are physically very strenuous and the incidence of work related injuries and illnesses among construction workers are considerably higher than in most other occupations, the construction site tasks are often carried out in unfavourably postures with highly repetitive movements thus generating a load believed to increase the risk of injury.

Ergonomic Risk Factors

The risk factors are characterised by construction job which stresses the body. There are many risk factors that affect workers in construction via construction tasks. The knowledge of ergonomics is needed in executing different construction tasks as risk factors occurs at different job and tasks. Job activities involving any of the ergonomic risk factors contributes or results in an increased risk of strain and injury. The greater exposed to these risk factors the greater probability of ergonomics injury and this is what is called Work-related Musculoskeletal Disorder (WMDs). The five ergonomic risk factors are:

- **Forceful exertions:** This involve, lifting, pushing pulling using excessive force to perform tasks. These tasks which required forceful exertions, place higher loads on the muscle, tendons, ligaments and joints. The force requirement may increase with:
 - Increase weight of bad handled or lifted
 - Increase bulkiness of the load handled or lifted
 - Use of awkward posture
 - The speed of movement
 - Increased slipperiness of the objects handled
 - The presence of vibrations
- **Repetition:** This is repeating the same movement through the workday. Many work tasks and cycles are repetitive and are frequently controlled by hourly and daily production targets and work process. Repetitive actions also depend on the body area and specific act being performed. A job is

considered highly repetitive if the cycle time is 30 seconds or less. Therefore eliminating excessive force and awkward posture requirement will reduce worker fatigue and allow high repetition tasks to be performed without significant increase in MSD risk for workers.

- **Awkward Postures:** This involve the body position which impacts in the joints and muscles in an activity and amount of force used (spinal discs exposed to more stress when lifting heavy object, other tasks require repeated or sustained bending of the wrists, knees, hips, or shoulders also increase stress on these joints). These are common ergonomic hazards that occur in the construction trades. Awkward postures, means working with the various parts of the body rather than in a straight or neutral position. In general the extreme the posture the more force is needed to complete the task.
- **Vibration:** This occurs when specific part of the body contact with vibration tool like operating heavy duty vehicles or large machinery. Repeated exposure to high levels of vibration is known to cause injury to workers over time. Studies on construction workers found that exposure to whole body vibration or local vibration was significantly associated to stiff shoulders or neck and upper extremities disorder (Luenda *et al.*, 2018).
- **Duration:** This the amount of time person is continually expose to risk factor and using the same muscle or motion thereby increasing the probability of (WRMDs) (Ayat and Adnan, 2012).

Process of Ergonomics in Construction

Starting an ergonomics process may mean that changes have to be made in the construction project site and in work practices so that the workers interact most efficiently and safely with the “things” they’re using. As construction companies put the ergonomics process in place, they may have to modify project layout and planning, alter work methods and stations, and/or change equipment and tools so that they do not exceed the capabilities of their workers. Many changes can be made without significantly increasing costs; moreover many ergonomic interventions result in increased efficiency by reducing the time needed to perform a task. The process involves the following:

Assessment of Risk: Conducting an ergonomic assessment is a foundational element of ergonomics process. The ergonomic improvements efforts will not be established without being able to effectively assess jobs in construction workplace for musculoskeletal disorders risk factors.

Plan Improvements: The core goal of the ergonomic process is to make changes that reduces risks at construction workplace. This however, requires, significant planning effort that includes prioritizing jobs to be improved, identifying effective improvement ideas, and cost justifying the improvements.

Assure Management Support

Management should consistently communicate the importance of employee safety and health. They should commit resources to the process, and lead by example as well as Integrate production processes, schedules, and improvements with safety and health concerns. To ensure the process works all managers and employees should be held accountable for carrying out their responsibilities safely.

Measure Progress

The measurement is an important component of any successful process. High performing ergonomic programmes are constantly measured using both leading and lagging indicators.

Involve Employees

Encourage employees to report injuries early. Set up a procedure that encourages prompt and accurate reporting of WMSDs. Develop a system that involves employees in the design or arrangement of work, equipment, procedures, project planning/layout, and training to reduce exposure to ergonomic risk factors.

Scale Solutions

By establishing a common set of tools to train your work force, assess risks, plan improvements, measure progress and design network process. Provide Training to Managers, Supervisors, Engineers, and Employees the training should include: Reviewing of ergonomic concerns in each of their work environments, Ways to minimize the risk factors in each work environment, Procedures for reporting work-related injuries and illnesses, Proper work practices and use of tools/equipment. The scale ergonomic best practice will be established.

Control for ergonomics in Construction

Therefore, there are lots of controlling factors that can be taken into consideration in implementing ergonomics in construction site. Ergonomic controls are used to help fit the workplace to the worker. They seek to place the body in a neutral position and reduce the other ergonomic risk factors. Control measures starts with most effective stage called engineering controls for ergonomics while it fit workers to working environment which can isolate people from hazards.

The advantage of implementing design concepts in initial stage of ergonomics is, workers can know how to work or handle the task they perform before they reach and they can decide what kind of safety precautions should be taken while doing that task. To reduce the workers injury and illness, work tasks should be

designed out in the initial stage of the project for ergonomic factors to improve the workers safety.

As listed below, there are few design guidelines that should be taken into consideration in designing the most ergonomic design for workers:

- Avoid design that incur static (isometric) muscle tension if static muscle tension cannot be avoided, ensure that the muscular load remains less than 15% of the maximal muscle force.
- Design the work system to prevent overloading of the muscular system Forces necessary for dynamic activities should be kept less than 30% of the maximal forces that the muscles are capable of generating, forces over 50% are acceptable only when kept to short duration.
- Use postures for the limbs and body that provide the best lever arms for muscle used Use footrests, wrist rests, proper backrests, and other ergonomic features to prevent fatigue Design for allowing changes in posture
- Work surface heights should depend on the size (anthropometry) of the worker and the type of task performed (precision, light assembly or heavy manual) in general work within 30% of one's maximum voluntary contraction (strength).
- Avoid overloading of muscular system. Aim at dynamic work; avoid static work (work where there is no movement). Static work or static loading of the muscles is inefficient and accelerates fatigue. Static work can occur when holding a weight in one's arms for an extended period, or constant bending of the back to perform some task. Primary controls, devices and workplaces should be placed within the normal working area. Work with both hands.
- Do not use one hand (non preferred hand) as a biological holding device. Hands should move in symmetrical and opposite directions, and use the feet as well as the hands.
- Design knowing the capacity of the fingers, and do not overload the fingers. Counter balance tools when possible to reduce the weight and forces.
- Train the individual to use the workplace facility and equipment properly. Workstation can be designed to accommodate workers to work without any obstacles. Ensure functioning and position of lightning so that obstacles and spills can be clearly seen. Poor housekeeping cause slips and trips to workers so remove rubbish regularly in site. Keep routes visible and access for workers. Workers needs should also be prioritized and it can be considered for keeping them away from ergonomic hazards.

- Equipments should be designed and it should be easy for workers to access. Working methods must be designed within the workers abilities so that repetitive movements, static and awkward posture and external forces can be minimized. Limit the amount of reaching and twisting required in handling materials.
- Workers should be allowed to do their tasks in rotations to reduce fatigue and also it reduces static postures, unnecessary movements and repetitive motions of workers. The rotation of the workers will also increase the rotation of the different muscles group of the workers. Work load for an overloaded task should be distributed by increasing a number of workers
- Employer should conduct stretching and strengthens program for workers before and after they perform the tasks. Annual training and daily pre-task planning are the educational training of administrative control will increase the workers knowledge about tasks.
- Personal protective equipment's will reduce ergonomics related risk factors. Using proper gloves, wearing good clothes can protect them from unexpected ergonomic hazards. By addressing workers safety in design, the worker will come to know about risks from task and they can take safety precautions before they reach it, to keep them away from hazards.

Conclusion

Construction activity is an important area of development for the economy; its labour intensiveness is key to economic development as it provides employment to more than 35 million people. However, physical efforts continue to cause serious damage to workers' health and, as a result, managers' efforts should be directed towards a more ergonomic and safe working environment from the literature the construction industry is accident prone and many risk factors are involved. Workers are often exposed to unfavourable ergonomic hazards without the knowledge of its effect on their productivity life. Many exposures to ergonomic risks have their roots in decisions in planning, scheduling and sequencing of work, which workers and even contractors often have little control over. These must be brought into the ergonomics discussions with adequate information's of workplace health and safety, continued education and training are also needed to mitigate these risks.

Exposure assessment in construction should primarily be used to demonstrate the efficacy of interventions and here the precision is not as important as the relative risk (Schneider 2001; Kazys *et al.*, 2010). More precise measurements are required in the grey areas where exposures may pose a risk, depending on the length or intensity of exposure. But in construction there are so many tasks posing a high risk, they can be attacked without a significant investment in exposure assessment to prove the level of risk, knowing that any exposure

reduction will lower overall risk. There will always be residual risk in construction it will never be a risk free environment for WMSD. But we can reduce the risk significantly through interventions and demonstrate it through simple assessments.

Furthermore, the ergonomists and ergonomic research should advocate the importance of ergonomics in the construction sector and established its relationship with the negative impact on the workers health. The work system and workplace should be studied to create a balance between the requirements of the work and the capacity of the working person. This can be best achieved by the design of the specific work or by developing the capacity of humans to undertake the work after training and vocational adjustments. Baseline knowledge on the prevention of injuries and fatalities from construction works suggests that Architects, builders and safety researchers need to consider in their design how to mitigate the onset of work related injuries in construction workers (In Ju, 2017). An effective health and safety policy is needed in the construction industry, monitored and implemented by the stakeholders so as to achieve the positive safety culture in the construction workers daily operations.

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