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Review

A Review of Ergonomics Interventions to Reduce Injury Risks and Improve Human Performance; Lessons for the Development of the Science in Nigeria

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ABSTRACT

Human Factors and Ergonomics (HFE) is one of the disciplines in Nigeria that require greater attention for its development despite having existed in other parts of the world for quite some time. The discipline has remained in its developmental stage in the developing countries for far too long due to a number of factors. This paper provides up-to-date commentary (using specific examples of HFE-based interventions) of the applications of HFE in various works of life. Studies show that HFE is applicable in a variety of industries-steel production, oil and gas, automobile, garments manufacturing etc. It is also applicable in healthcare, agriculture, education and has great potential for ecosystem redesign in the future. Although, the useful applications of HFE cannot be exhausted in one writing, it is expected that the carefully-selected interventions can stimulate the development of HFE as an academic discipline in institutions of higher learning and as a profession in Nigeria.

Keywords: Ergonomics education; Musculoskeletal disorders

INTRODUCTION

Human factors and ergonomics, HFE, as a recognized body of knowledge and endeavor took center stage in the 1940s during World War II [1]. Succeeding the World War II was a growing concern over how to consistently study the nature of human work and apply that knowledge to the design of workplaces in countries like Japan which was faced with challenges of reconstruction. The central focus was on subjects like physiology, anthropometry, and human biomechanics and the use of ordered observatory studies to develop ergonomics technology. Presently, the scope of study and principles and procedures for developing and applying human factors and ergonomics technology are synonymous, following years of integrated and expanded approaches in places like Europe and the US. Therefore, ergonomics and human factors have become formally recognized by the International Ergonomics Association (IEA) as the same discipline.

A number of definitions have existed for the science of ergonomics over the years but a universally patronized definition is that of the IEA. An updated definition by the IEA (2020), describes ergonomics as the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize well-being and overall performance. This definition highlights certain keywords in the training and practice of the science of ergonomics as well as the significance of the interaction that must take place between man and his environment (such as tools, machines, jobs/tasks, workplaces). It is important that these interactions do not compromise performance and the overall health of humans. The IEA did not only describe the science, but also has a description of the roles of the practitioners. It states as follows: ergonomists contribute to the planning, design, implementation, evaluation, redesign and continuous improvement of tasks, jobs, products, technologies, processes, organizations, environments and systems in order to make them compatible with the needs, abilities and limitations of people. An ergonomists is generally expected to have certain attributes such as knowledge (not just theoretical but equally practical), abilities, skills and other factors considered important to be an expert.

Another definition of ergonomics worth highlighting here for its simplicity is that of [2]. It describes ergonomics as the science concerned with the relationship between human beings, the

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machines they use and their working environment. Although simple, this definition captures the essence of the science and is not in any way different from that of the IEA. It recognizes the major components which are man and the interaction with his work environment. Two important outcomes of fitting the environment to the human are improved performance (in the form of productivity, efficiency and effectiveness, quality and so on) and well-being in the form of health and safety, satisfaction, learning etc. [3]. Human Factors Engineering, Human Factors (HF) or Ergonomics are often interchangeably used and generally refers to the combination of various fields such as anthropometrics, biomechanics, psychology, physiology, management, and industrial design, including multiple engineering disciplines [4] and has three important domains – physical, cognitive and organizational ergonomics. Ergonomics also is concerned with the adjustment and modification of workstations, processes and the working environment to suit human psychophysical capabilities. This definition of ergonomics derives from the definition of health which, according to the world health organization (WHO), is a state of full physical, mental and social wellbeing and not merely a lack of disease or disability [5].

An important strategy for addressing short-comings in ergonomics is often through designs and redesigns. In fact, design is the most popular application domain of ergonomics, followed by health, safety and systems, in that order [6]. Ergonomic interventions through design can be realized among other means through active practice and often requires the guidance and supervision of experts [7]. User-friendly designs are often based on the participatory engagement of the end-users in the planning and implementation stages. Although, it is a given that such users are adults, children and teenagers can provide interesting perspectives useful for ergonomic designs [8, 9]. Other than being participatory in nature, user-friendly designs (tools, furniture and workstations) rely on the physical shape and size of the target users. Anthropometric data therefore becomes essential for applying ergonomic principles to the design and improvement of a wide range of products for different users [10].

Rationale

The significance of Ergonomics and the role it plays in everyday life is much too enormous that the science requires much greater attention than it already has particularly in developing nations. It is important that Ergonomics is not only taught in academic institutions but is adopted as a way of life. In many developing nations (specifically Nigeria), little or no attention is paid to this field. For example, no institution of higher learning in the country has academic programmes in the area of ergonomics. While, this is in part due to the multidisciplinary nature of the subject (where elements of Ergonomics exist in other science and engineering subjects), the present situation does not bode well for the country. Till date, a huge gap still exist for the application of ergonomics in the industries, schools, hospitals and many more public places. It is expected that this paper will achieve two things – call the attention of stakeholders to the gap in training of Ergonomists and also highlight the many benefits of having a culture of ergonomics consciousness, especially in a developing nation. Ergonomics has been widely applied in many industrially developed countries in designing better methods and tools to improve work conditions and productivity. However, this common practice is still scarce in many developing countries [11]. Many ergonomics experts and international organizations have urged the promotion of ergonomics in developing countries in order to improve work conditions and demonstrate the capacity of ergonomics applications in improving work condition and productivity [12]. Therefore, it may be necessary to provide applied ergonomics knowledge and expertise to local researchers in developing countries in order to build some successful showcases of ergonomics interventions and to stimulate ergonomics applications in these countries.

RELEVANCE TO HUMAN FACTORS/ERGONOMICS THEORY

The application of ergonomics theories and principles not only improves productivity on the job but also ensures safety and wellbeing. One way to ensure wider practice of the science of ergonomics is through ergonomics education. This article captures various applications of ergonomics theories and principles in multiple industries and is intended to stimulate stakeholders and policy makers, especially in developing countries such as Nigeria, to favour extensive and far-reaching training in the field of human factors and ergonomics.

METHODOLOGY

In the present review, research papers discussing different applications of ergonomics for improving human performance in different industries and environments were identified and selected, and the published information was reviewed. SciVerse Scopus, Google Scholar as well Taylor and Francis Online, were used to find relevant published papers in the field of applied ergonomics. The following keywords were used to identify relevant papers: 'ergonomics' or 'ergonomic design', 'human safety' or 'human performance" or 'learning environment' or 'anthropometrics' or 'anthropometric measures'. To avoid papers not relevant to the topic under study, the search was performed using the Boolean operator 'AND', together with the search terms 'ergonomics' or 'ergonomic', 'design' or 'designing' or 'redesign' or 'redesigning'. Articles resulting from the literature search were initially screened on the basis of their titles and abstracts. In the event that the title and abstract was not sufficient to determine the eligibility of an article, the full text was screened [13]. The references cited within all of the relevant retrieved papers were also reviewed to identify additional articles. The following additional inclusion criteria were also adopted:

Original and review articles written in English and published or accepted for publication in peer-reviewed journals; Articles published or in press between January 2000 and April 2020, except in few cases where an earlier published article which is referenced in a more recent article was seen to be of great relevance; Papers with specific approaches to ergonomic product, job/task and/or system design or redesign. To be included in the review, the paper had to meet all of the above-mentioned inclusion criteria. The application considered in this

review is the use of ergonomics to address issues in workplaces, learning environment, hospitals and even in agriculture.

RESULTS

A total of 1,107 articles were initially recovered from the first search. Upon screening the titles, abstracts and years of publication, the number of papers were reduced to only 393. Reviewing the corresponding full text further reduced the number of articles reviewed to 60; excluding papers written in languages other than English and papers that were not direct applications of Ergonomic theories and principles. Four (4) additional papers were included; being older articles sited in more recent ones but quite relevant to the current study. A total of 64 journal articles were reviewed in the present study; these presented ergonomics interventions applied to workplaces and learning environments and intended to improve human performance and/or prevent injury. The remaining part of this paper is presented under nine subtitles – as well as future applications of ergonomics and human factors.

ERGONOMICS INTERVENTIONS IN DIFFERENT SECTORS OF WORK

The global economic change in the last couple of decades has resulted in a significant shift in the types of work that occur in different regions of the world. These changes will continue into the future both in developed and developing nations and the need to review ergonomic viewpoints from time to time to ensure that the environment fits the user will be inevitable [3]. A consequence of the otherwise will be icky experiences some of which are broadly categorized as musculoskeletal disorders (MSDs) or work-related musculoskeletal disorders (WMSDs). WMSDs comprise a wide range of inflammatory and degenerative conditions which are a major cause of work-related disabilities and injuries in many occupations [14, 15]. Together, these disorders reduce workers' productivity, the quality of their work and increase production costs. WMSDs arise due to physical factors such as awkward postures, repetitive movements, manual materials handling, vibration and mechanical load on the human body. This section presents the major findings from the review of ergonomic interventions in various industries.

Ergonomic interventions in agriculture

In [11] the authors applied the principles of ergonomics to implement a participatory ergonomics intervention among coffee harvesting workers in Nicaraguan, and to subsequently improve their work conditions through the design of a novel harvesting bag. The application was partly intended to showcase ergonomics studies in developing countries and partly demonstrate that simple solutions can make a difference in terms of improving work conditions. Electromyography (EMG) was recorded from four different muscles (left and right upper trapezius, right infraspinatus, and right erector spine) to quantify muscle loading during the four different coffee harvesting activities and to compare the muscle loading between the three different methods used. In addition to the EMG signals, a questionnaire was administered to capture the extent of perceived pain in the four different muscles under study. Most workers reported that they liked the new bag over the conventional baskets and felt more comfortable using the bag. Although there are areas of improvement to the job tasks, the study presents a prospect for the application of ergonomics principles to job activities on a coffee farms.

Ergonomic interventions in job redesign in the garment industry

Sewing machine operation is characterized by sitting for long periods of time, repetitive tasks and muscular load on the back, neck, shoulders, arms, wrists and fingers [16] and as such, WMSDs such as rigid vertebral column are common among workers [17-19]. The study in [20] was aimed at investigating the effectiveness of ergonomics education among sewing machine operators in Turkey. The strategy deployed in the study was the use of ergonomics education to improve the machine operators' knowledge of ergonomic risk factors and WMSDs, working posture, preventive exercises and adaptation of workstations. All participants received an ergonomics education brochure, which consisted of information about ergonomic risk factors, WMSDs, importance of prevention, suitable warm up exercises at the beginning and in-between execution of work, workstation adjustments and advice on correct working posture and load carrying procedures. The results indicate that ergonomics education helped to significantly reduce exposure to risk factors for WMSDs among the sewing machine operators who participated in the study.

[21] was designed to investigate the prevalence of work-related shoulder pain (SP) and the associated risk factors with work-related SP among informal garment workers. The contributing factors for SP were noted to include the length of garment work experience, work posture (no change of posture in each hour), and a poor seat at workstations (i.e., an inappropriate seat width). In order to help reduce or prevent SP in this occupational group, it was proposed that the dimension of seats at workstations should be redesigned and seating should be more appropriately fitted to workers. A process of routine ergonomics education was recommended for implementation to help improve workplace behaviour and work conditions among informal workers.

Ergonomics interventions in oil and gas industry

In the oil and gas industry, ergonomics is a significant subject to be explored since the industry's facilities sometimes consist of many complex technologies that require human intervention during operation and maintenance, hence, requires mitigating potential physical hazards towards workers [4]. Another critical issue in a working facility is the mismatch of design specifications and end-users' body dimensions [22,23]. Therefore, facility design should accommodate the variability of body measurements according to the region of the workplace, and consider the limitations and capabilities of the human body such as reading level, hearing level, and reaching parameters [24]. Poor workplace design could lead to awkward work conditions in lifting and using heavy tools (force), risky body movement (posture), and long-term exposure to bad posture and excessive load (fatigue). These factors – force, posture, fatigue – are considered as the causes of MSDs and injury within oil and

gas industry and eliminating these can result in better work conditions and improved wellbeing and performance of workers.

Ergonomic interventions in automobile and tire manufacturing

In [25], a participatory ergonomics programme was implemented in an automotive parts manufacturing factory in which an ergonomics change team was formed. The objective of the study was to investigate the effectiveness of a participatory ergonomics programme in decreasing WMSDs. Workers at the intervention plant reported enhanced communication regarding ergonomics issues following the participatory ergonomics intervention. The psychosocial elements of the participatory ergonomics intervention were found to enhance worker perceptions of communication dynamics related to ergonomic issues. These findings support the need for careful consideration of the timing of, and circumstances surrounding, the implementation of participatory ergonomics processes.

In another study, [26] investigated the use of participatory ergonomics to redesign jobs in the tire industry and the effectiveness of the intervention (in the form of regular training and workshops) on wellbeing and performance of workers. The topics covered during the trainings include MSDs and their risk factors; observational methods for assessing risk of developing MSDs; manual materials handling; ergonomics and design; applied anthropometry; workstation design; ergonomics hand tool design; and physiology of work. During the three-year study, some (re)designs were implemented in the company including the design of a pneumatic lifting mechanism for tires, portable/fixed foot rests, a loading station, ergonomic chairs and a handle for easy pulling/pushing of pallets. Defining new solutions and improving working conditions became the team's routine activity. The prevalence of musculoskeletal symptoms also decreased considerably. The result of the study shows that implementation of ergonomics solutions decreased prevalence of musculoskeletal complaints.

Ergonomic in steel manufacturing industry

In [27], the ergonomic interventions in the steel industry was described as having metamorphosed from mainly oriented on physical workload and environmental working conditions to redesign of equipment and activities. A number of ergonomic criteria were set out for the design including: (1) clear sight lines during receiving, driving and discharge of coke, (2) avoidance of the necessity for the driver's torso to be twisted or his head to be turned during operation and (3) improving the controllability of the operator devices by redesign. The systematic and ergonomic approach which involved the participation of the end-users, yielded a cabin which met all expectations (for example, diesel motor exhaust which previously hindered the view was hidden behind a window frame where it was no longer visible from the cabin). By involving the drivers in the redesign followed by timely training in the new cabin, no problems developed during commissioning. The overall process improved the quality of coke produced and consequently the profit gained.

Ergonomics applied to promoting safety and wellbeing among computer operators

In [28], ergonomics interventions (such as worksite adjustment to individual anthropometrics, stretching and muscle-relaxing exercises, breaks during working hours and the ergonomics intervention accompanied by biofeedback programme) were used to effectively reduce MSDs relating to computer use among computer workers in hi-tech companies. The participants were consecutively assigned to one of three groups – ergonomics with biofeedback intervention, ergonomics intervention without biofeedback and control groups. The major finding of the study was the significant reduction of the MSDs scores of participants in the intervention groups compared to the control. The intervention programmes were based on a combination of commonly recommended training factors that in agreement with other studies presenting ergonomic interventions, showed significant decrease in MSD. As reported in [29], the use of notebook accessories (external keyboard, ergonomic computer work- station chair, external monitor, external mouse and a notebook riser) combined with ergonomic training (such as proper sitting posture) may be a solution to the occurrence of upper extremity MSDs in notebook computer users, reducing the incidence of musculoskeletal symptoms by as much as 15 percent.

Ergonomic interventions in the design of classroom and learning environments

As it is with industries, when education benefits from the field of ergonomics, it leads to an increase in quality and in productivity; this is because ergonomic factors such as sitting posture and positioning have been reported to significantly affect performance in classroom activities [30]. Most classroom activities involve sitting for long periods, therefore, effort should be made to ensure that young children do not experience back pain and other musculoskeletal disorders due to prolonged sitting on poorly designed classroom furniture. Studies [31-34] have proposed methods and guidelines for the design of ergonomic-oriented classroom furniture for students of various school ages. A number of models have also been reported for ergonomic products designs notably design for an adjustable range and design for extreme individuals. School furniture must fit student anthropometric characteristics, and the desk must have the possibility of a tilt angle and a slight concave curve in the front, with a high saddle chair [35] The use of furniture which promotes proper posture is important particularly among younger populations because postural problems often develop at those ages and could lead to serious consequences in the future [37, 38].

Computers represent one of the most important gadgets today (ranging from desktops to laptops and notebooks), and the extensive use of computers among young people may have come with a price as higher levels of MSDs relating to computer use have been reported among students [38, 39] observed that children in elementary schools often use computers in groups of three or more at schools. The implication is that the children often do not assume static positions during the computer lessons as they often have to move their limbs and/trunk to

point out things on the computer screens. A study by Jacobs and Baker (2002) found that 58% of 6th grade US children reported musculoskeletal discomfort in at least one body part that was associated with computer use. Although a majority of the teachers in the study had taken some sort of computer training, a large percentage of this group never had any training in the ergonomics of computer use and therefore, were not equipped to instruct the children on the ergonomics of computer use. This is one area ergonomics intervention could benefit both school children and the teachers.

Ergonomics in healthcare and hospital engineering

Quite a number of studies have reported the incidence and prevalence of MSDs among healthcare workers due to poorly designed work environment and work tasks [40-42]. MSDs are reported to be common among many professional groups and disciplines in healthcare with nursing as one of the highest MSD-risk occupations [43]. The physical environment of the clinic and equipment have been identified as two of the several performance obstacles experienced by intensive care unit (ICU) nurses and can affect nurses' quality of working life and their perceptions of quality and safety of care [44, 45] A similar study among sonographers in Guangdong [46] revealed the ergonomics of the examination room was poor in the province compared with industry standards [47]. The study suggests that ergonomic improvement of workstations was one of the preventive measures for WMSDs among sonographers and recommended ergonomics education as a key factor in helping sonographers learn to improve occupational health. When human factors aspects are not adequately considered in the design and management of healthcare systems (HCS), it often affect the work environment of personnel, leading to excess workloads that increase injury risks for staff [48].

HFE-based healthcare system redesign applies a systems approach which highlights interactions among work system elements and levels, the impact of individual work system element on the whole system, and links between work system, care processes and system outcome [49]. It differs from general quality improvement interventions because it largely combines the three core characteristics of HFE vis-a-viz, the use of a systems approach; design-driven approach and focus on both system performance and well-being [3]. In [49], HFE-based healthcare system redesign was studied to assess the impact of HFE on quality of care and patient safety. The study revealed evidence of the effectiveness of HFE in improving quality of care, such as reduced task completion time, decreased error rate, and improved compliance with best practices. There was also evidence of the impact of HFE-based interventions on patient safety, such as decreased complication rate, decreased in-hospital mortality, and increased self-efficacy of patients. HFE can be applied in the design and implementation of health IT; the physical design of operating rooms to address and minimize infection-control problems, safety and effective patient monitoring as well as to identify and categorize patient safety hazards in operating rooms [50, 51].

Ergonomics in pregnancy and child care

Several researches have been conducted to investigate back pain in pregnant women. Some of these have been on the effectiveness of ergonomics education for reducing back pain in the women. Compelling evidence subsist as proof for the significant effect of ergonomics education in the reduction of low back pain in women during pregnancy [52, 53] conducted a comparative study of telephone-supported ergonomic education against standard face-to-face ergonomics education in the management of pregnancy-related low back pain (LBP). The result showed that telephone-supported ergonomic education over three weeks during pregnancy was more effective than standard ergonomic education for relieving pregnancy-related LBP. The pregnant women in the study who received weekly telephone support had less pain, lower disability levels, and higher quality of life compared to the group who received only a single session of face-to-face ergonomic education. The success of the telephone-based method of education and support was attributed to higher rate of compliance compared to the outcome of the face-to-face method.

Closely related to pregnancy is child care which can be physically demanding [54, 55]. This is because the role includes carrying heavy equipment and furniture; regularly sitting on child-size furniture and spending most of the day sitting on the floor with no backrest. Some problems associated with caring for children at child centers include incorrect posture while lifting children, toys, supplies, equipment etc.; inadequate work heights, e.g. child-size tables and chairs; difficulty in lowering infants in and out of cribs; frequently sitting on the floor with back unsupported; excessive reaching above shoulder height to obtain stored supplies; frequent lifting of infants and toddlers on and off diaper changing tables; forceful movements combined with awkward posture required to open windows; carrying garbage and diaper bags to the dumpster. These actions require that the care-giver makes a variety of postures, putting the intervertebral disc of the spine under a lot of pressure and leading to back pain. Ergonomics-based solutions have also been recommended to the problems which include education of the teachers on proper body mechanics particularly for lifting and sitting as well as modification of the work environment to accommodate furniture and equipment as well as provide space for both child and caregiver [54].

ERGONOMICS IN THE FUTURE AND ON GLOBAL ISSUES

Although it is difficult, if not impossible, to predict future events with accuracy in most circumstances, it is understandable to say that ergonomics will continue to exist for a long time. This is due in part to the fact that work will continue to exist, although may take different form, and will continue to require that humans develop new competencies and capabilities. Unless work suddenly changes and become oversimplified in every form (physical and cognitive) ergonomics will continue to be a requirement to ensure human wellbeing and productivity on the job. Work in the future is likely to evolve and as it does, ergonomics will evolve with it. Therefore, ergonomics will be in a constant state of catchup with work, and will thus be required [55]. In the future, sub-disciplines like forensic ergonomics will

receive much more attention globally than it already does. This kind of work will require proficiencies beyond simply being an expert in HFE because the role of an expert witness involves a different skill set than is usually taught, and often not even considered, in the vast majority of academic graduate programs. While the circumstances surrounding each case will be unique, forensic HFE professionals will make use of well-known theories and principals derived from research that includes data from thousands of studies and a multitude of observations on how people interact with things such as controls and displays for equipment [56].

One of the greatest challenges now facing humankind involves understanding how to deal with the degradation of our natural environment. In the future, more resources will be committed to research in the area of green ergonomics. Green ergonomics acknowledges that the planet (as a whole) is a closed system and that a disruption in one part of the system will inevitably have repercussions for other parts of the system [57, 58].

Other than these, the science of ergonomics is likely to enjoy bigger patronage as scientists explore the possibility of more ergonomics interventions in solving global challenges such as food security and water issues, energy, urbanization, violence and terrorism, pollution and waste as well as health and medicine [59-63].

CONCLUSION

In this paper, different application of ergonomics principles for addressing and solving human problems relating to work has been presented. Many of the applications and interventions discussed in the current review present with a short-coming in work and workplace designs and operations in developing countries. It is expected that a collection of several applications in one article can stimulate stakeholders in developing countries like Nigeria to appreciate the significance of ergonomics in society and therefore favour the consideration of the science in institutions of higher learning as well as increased application of ergonomics principles and theories in industries; not leaving out collaborations between academics and industries. It is obvious that the various industries and workplaces covered in the current review are in existence in many developing nations, Nigeria inclusive. However, what is missing is the application of ergonomic principles in these areas for improving human performance, preventing WMSDs and mitigating against loss of productive time arising from absence due to injury. An immediate step towards building a culture of ergonomics awareness in countries such as Nigeria is the commencement of Ergonomics programmes as academic disciplines in our Universities. Disciplines such as Nursing, Engineering/Design and Psychology must deliberately include a substantial amount of Ergonomics topics in their curricula. Industries must begin to recruit and train Ergonomics specialists for the purpose of improving human performance at work and preventing workplace injuries. In a short time, research collaboration between the academic institutions and the industries can result in increased awareness for Ergonomics as well as Ergonomics research outputs.

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