LITERATURE REVIEW ON EXOSKELETONS IN WORK PLACE.

Abstract

This literature review of exoskeletons in the work place provides a brief history of its development, the current influence of exoskeletons in line with innate human-machine interface and the basic integration of exoskeletons for ergonomic intervention. It also provides a review of future work that is needed to be done in creation of a conducive environment for employees. Development of assistive exoskeletons began in the early 1960s whereas other designs which were more advanced were introduced later on. For instance, they lacked specific designs for human factors and ergonomics had low power energy density compared to ratios of power weight. Continuous advancements of technology has led to broader research whose main objectives are to enhance human performance. The review will perform extensive research and will offer a reflective article of the current state of exoskeleton design and its incorporation for ergonomic intervention. Some of the challenges that are still pending and will be studied include; power weight ratio of actuation, levels of variability between users and the energy density of exoskeleton power supplies. Most of the workers have been exposed to posture related risks which has facilitated the development of musculoskeletal disorders. This has also led to low production and incapacitation of work among the workers. With the gradual rise of technology, the use of exoskeletons provides opportunities for employees to be creative, flexible and make decisions appropriately while at the same time gain a less strenuous environment for working. The main objective of this study is to systematically research, assess factors qualitatively, make evaluations and offer literature on psychological health aspects that are associated with the use of exoskeletons in the work place. The outcome of this systematic review shall be used for

development of a survey that will be used for investigation of employees on their view towards the use of exoskeletons.

Introduction

Exoskeletons are electromechanical devices that are designed for human operation and increases the physical performance of the wearer. This kind of technology has developed massively over the past decade due to major improvements in robotics and mechatronics technology. Ergonomics on the other end is a process of designing a job that fits the worker which is safe and efficient. Implementation of ergonomic remedies makes the employees more comfortable and leads to increased productivity. Exoskeletons are currently produced by Ekso Bionics Holding (USA), Rex Bionics (New Zealand), ReWalk (Israel) and Parker Hannifin Corp (Indego). Evolution of other technologies such as computers, tablets and smartphones has shaped the workplace over the years. This kind of evolution has literarily transformed the workplace and led to improvements in the economic sector. At the same time employees are working for longer hours so as to meet the job requirements. Companies have higher expectations now that there are new technologies in the house. This has however impacted the health of workers in a negative way. It has led to certain illnesses and most specifically injuries as a result of exoskeleton. Studies conducted by various scholars have identified the potential health risks associated to exoskeleton in the work places. For instance, with reference to sixth European working conditions survey (Parent-Thirion et al., 2017) employees at the work places in the construction site are exposed to physical risks and most specifically posture-related risks which are the most prevalent risks in Europe. Studies showed that about 61% of the employees were reported to be suffering the risks of posture related factors. In Germany, studies conducted in various workplaces showed that approximately 56.4% of men and 48.6% of women employed worked in

a standing position whereas 19.2% men and 14.2% of women had forced posture (Bundesanstalt fur Arbeitsschutz and Arbeitsmedizin, 2017). The study showed that many employees in the work places were affected by multitasking, overworking and performance pressure as well as interruptions and disturbances at the work place. Remedy for reduction in the rise of musculoskeletal disorders that results from handling of objects such as lifting, lowering and transportation of manual material has been the use of mechanical aids such as carts, forklifts and hoists. Studies have however shown that employees did not utilize these tools when the objects to be lifted were within physical abilities (Bewick& Garderner, 2000). Furthermore, employees did not use these devices especially in cases where they found it to be time consuming, poorly positioned and difficult to handle (Hautekiet, Spaepen, Cobbaut, and Clerq 1999). The use of industrial robots that can handle both physical and psychological tasks is another solution that helps in reduction of physical and psychological strains that have been the lead cause of exoskeleton related diseases.

Fig 1: An illustration of exoskeleton

These systems still encompass the use of exoskeletons such as robots and smart watches to execute tasks (Cernavin & Lemme 2018). Exoskeleton was derived from the biological exoskeleton where it operates as the shell of an animal. It provides for muscle attachment, offers water proof to the body and protects it from desiccation while enabling sensory interactions within the environment (Yang, Zhang, Chen, Dong & Zhang, 2008). This however was utilized in the formation of exoskeletons which are meant for supporting purposes. It's a wearable device that has structural mechanisms with sensors which are linked to the human body (Gopura, Kiguchi, Bandara, 2011). By using this exoskeletons workers can be able to combine human intelligence with the power of support in the device which enhances performance. Any organization that uses exoskeletons in the work place increases performance, flexibility, creativity and provides a less strenuous workplace environment for employees (Looze et al., 2016).

Literature review

A systematic literature review has been adopted and applied in the study of how exoskeletons affect workers in a workplace economically. This review can be defined as a means of identifying, making analysis and interpretation of data that is relevant to the research question in an unbiased way (Kitchenham & Charters, 2000). The study shall deal with physical and psychological health aspects that are associated with the use of exoskeletons at the workplace. Therefore the two main questions that this research will try to evaluate are; the effects of use of exoskeletons on the physical health of workers and the psychological effects of exoskeletons to the health of workers. The two key issues will be investigated thoroughly through appropriate accepted measures. The study will identify suitable survey to be used in measuring the attitude for employees towards the introduction and use of exoskeletons in the workplace. Exoskeletons

have been used in rehabilitation centers and military fields. Their effectiveness has been proven by studies conducted by scholars over the years. The effects of military and rehabilitative exoskeletons on physiological health aspects have so far been assumed and not done as expected. On top of that the use of exoskeleton for industrial purpose has gained more interest in the recent past (Yang et al., 2008).

Fig 2: Heavy lifting using exoskeleton

This development has been accompanied by several considerations regarding the physical and psychological effects on the wearer after some time. An overview of how tis exoskeletons have impacted employees in the work place shall be discussed. The use of exoskeletons for rehabilitative purposes began in 1883 being led by professor H. Wangenstein`s work who championed an active lower-limp exoskeleton while focusing on the paraplegic patients which will enable them to walk, run and jump(J.L. Pons, Ceres & Carldern, 2008 pp.4-5). Recent

studies by scholars have shown that the use of exoskeletons in rehabilitation is more effective and practical. Research scholars concluded in their systematic review that the use of exoskeletons in the bodies of individuals having spinal cord injuries is more useful since the exoskeleton will provide the patient with the ability to walk again at a considerable speed. Results showed that patients who participated in this improved significantly and their distance in 6miutes increased from 70.1 meters to 163.3 meters. The use of exoskeletons was also found to be safe and practical in this centers. It increased the rate of mobility and reduced any possible risk (Federici et al 2015). The developments and use of exoskeletons in the military has also impacted the workers in different ways. This began in the early 1960s with the US Department of Defense gaining interest in the development of exoskeletons for military purposes. Soldiers used exoskeletons to move to longer distances while carrying heavy military tools (Yang et al., 2008). An example of exoskeleton that was used by military forces in US is Berkeley Lower Extremity Exoskeleton (BLEEX) which is an autonomous tool that allows the wearer to carry extra loads of about 75kg on their backs while at the same time facilitating movement to far places (Zoss, Kazerooni & Chu, 2006). In the industries, exoskeletons are used to increase the performance and health of employees. The study conducted by scholars interviewed eight stakeholders in the field of industrial manufacturing sectors. Results collected showed that the expected trends for industries include mechanization and automation, reduced number of workers in the actual production and increased number of workers in the production planning and engineering stages. On top of that, due to age factor, there industries have opted to use exoskeletons to ensure high production and safety. The interviews conducted mentioned the need to tackle occupational skeletons through increase of flexibility of production, employees and increase in productivity of manual work. There is also need to reduce physical work load and

risks of any injury. Copenhagen Psychological Questionnaire (COPSOQ) for assessment purposes and analysis of psychological stressors and strains in the workplace. The purpose of the questionnaire was to discuss the occupational scientific model of the working situation of the employees. Musculoskeletal disorders which are rated at 23.1 %and psychological disorders rated at 11.6% in Germany (2015) has incapacitate the workplace environment of employees. The costs due to loss of production resulting from musculoskeletal disorders has increased significantly. Furthermore, the study conducted by Federal institute for occupational safety and health showed that most of the male as well as female employees have been affected by psychological strenuous working conditions and there was need for intervention. Preventive measures should therefore be taken to mitigate physical and psychological strains in the workplace.

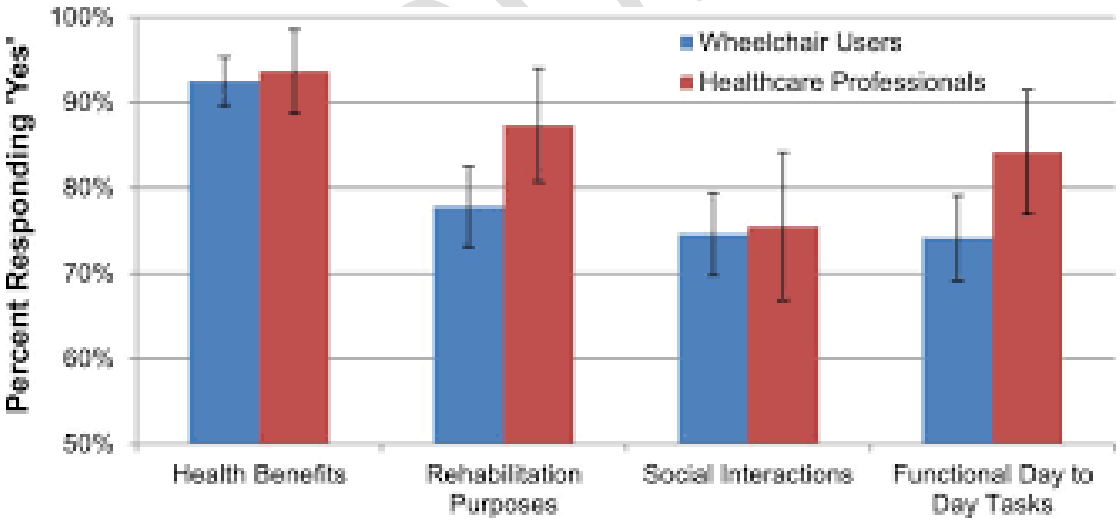

Fig 3: A survey of stakeholder perspective

The companies should implement possible solutions in the industries that will help in implementation of exoskeletons that will eventually offer support to the employee physically

strenuous activities e.g. lifting of heavy loads, carrying heavy weights and working overhead. Exoskeletons are applied to minimize the risk of musculoskeletal disorders such as low back pain. This reduction in physical strain will at the same time lead to decrease in the psychological stress factors. Employees will not worry again about their physical health and psychological concerns once this is implemented. The management and all the stakeholders in the industries concerned should s make regular tests on the physical and psychological effects of these exoskeletons. This will enable them develop appropriate control measures and how to mitigate any possible arising issues in use of exoskeletons. By focusing on the utilization of wearable in the workplaces. This study discusses the main categories such as monitoring, augmenting, tracking and assisting. This scientific study will develop ways of studying exoskeletons in the work places and their impact to employees. The study will focus on two main goals. First it seeks to identify and qualitatively assess and evaluate studies that will help in measurement of health aspect s such as physical and psychological factors that results from the use of occupational exoskeletons in the work place. Secondly the study will formulate a survey that will in turn investigate the attitudes of employees toward s the use of exoskeletons in the workplace.

Scope and limitations

This study focuses on the physical and psychological health aspects that are associated with the use of exoskeletons at the work place. The study shall elaborate more on different fields such as rehabilitation centers, military and industrial places. The outcomes shall be utilized and later harmonized for creation of better work environments. Part of the research materials used are sourced from studies conducted in Europe, Germany, USA and other countries.

The main challenges for development of exoskeletons to be used in the work place is less weight, grip force, low power consumption and high speed of operation. The design of the desired structure is one of the key areas whereby imaginative design may help to reduce a lot of stress from weight constraint. Most of the studies conducted in the past indicated that there was a small size sample that consisted of young healthy male participants who had not been employed in the occupational exoskeleton industries. The research however was not intended for them but rather those who have had previous experience on the use of exoskeleton wearables. Furthermore, most of the results obtained could be experimental laboratory studies that simulates work which is considered as a reflection of the real world work tasks. The results therefore cannot be generalized to the entire population especially if the women and other employees who have medical history on the influence of musculoskeletal diseases participate. Another limitation that may be witnessed in the research process is the imbalance in the results obtained from measurement of both physical and psychological factors. In most cases it is very rare to obtain psychological results of any phenomenon since they are immeasurable. However, the results obtained will be more of physical facts than psychological facts. This will be counted as a limitation to the research team. Another limitation is the length of measurement. The study conducted will only measure short term effects of the use of occupational exoskeletons. Long term effects of this will be difficult to achieve unless organized for a longer period of time. Measurement is only done without considering the possible long-term side effects such as muscular atrophy. The study might not allow researcher to conduct qualitative pilot interviews which could have given more information about the topic. The use of closed questionnaires in the study might hinder individuals from expressing themselves fully. Some of them might think that they are being limited and eventually give biased results. Companies and organization which

use exoskeletons are quite different and operate in their own capacities hence it is quite difficult to use the same questionnaire while conducting the survey. Participants who have gathered knowledge on occupational exoskeletons through friends, media or family might have a different opinion that will eventually result in worse personal rating of the effectiveness of the result in the study. The results from the survey might therefore be considered as biased and might not offer the real picture.

EXOSKELETONS IN WORK PLACE

As described in the previous section, exoskeletons can be utilized for many uses and most especially by the companies. Exoskeleton tools are used to monitor physical and psychological factors of the employees. Most of the employees' physical and psychological stress levels vary depending on the organization they work for. There is need to conduct regular studies on how this wearable's are impacting the individuals physically and psychologically. Wearable technology can be utilized here by monitoring and refining the health fitness of the employees. Most of these devices have been used to track physic-social stress and physical stress which is stress in line with equipment used in the work place. One of the main benefits of this technology is that it offers accurate data on the progress of employees while analyzing both physical and psychological factors. This will however help the managers to formulate ways and key steps towards assisting their workers either through discussion about issues or by developing other physical activities. This will eventually help them to reduce tension and stress among the workers in the company. Another benefit with this technology is that it enhances operational efficiency. Wearable devices such as Microsoft HoloLens can be used remotely to provide guidance. This gadget makes communication more accurate and efficient thus increasing the performance.

Fig 4: Man using exoskeleton in the work place

Exoskeletons can also be modified to provide safety and security. For instance, employees' safety which is so important especially for an individual who is working in dangerous environment, should be looked into. Safety can be improved by using exoskeleton technologies which will help in monitoring progress of the work being done (Yang et al 2006). It is very possible for the company to detect danger in the working spots at any given time while using these wearable technologies. Sensors can be attached to the workers feet so that they are in contact with the skin. The sensors will be used to detect the users' body and their behaviors. If the user approaches a certain dangerous place, it warns the user not to proceed. This is an indication of how wearable technologies can be used for safety and security purposes. The wearables can also be utilized for industrial designing. It can be used to develop construction

plans, building information and aircraft cabins at any given time. Study conducted by scholars identified that wearables can be used to assist in manufacturing purposes and maintenance. This saves a lot of time and reduces the cost of production. Exoskeletons can also be used to improve workers health. Working posture is always a challenge to employees in any organization especially for those who do much of the manual work. This is as a result of physical strain which may lead to backside of the body. If such persists for many years it will lead to disorders. The use of these wearable will help the workers by reducing strain from the posture sitting and prevents any possible back disorder. The kind of support offered by this devices will help workers as they handle their tasks and prevents musculoskeletal disorders. It however improves efficiency and prevents muscular diseases.

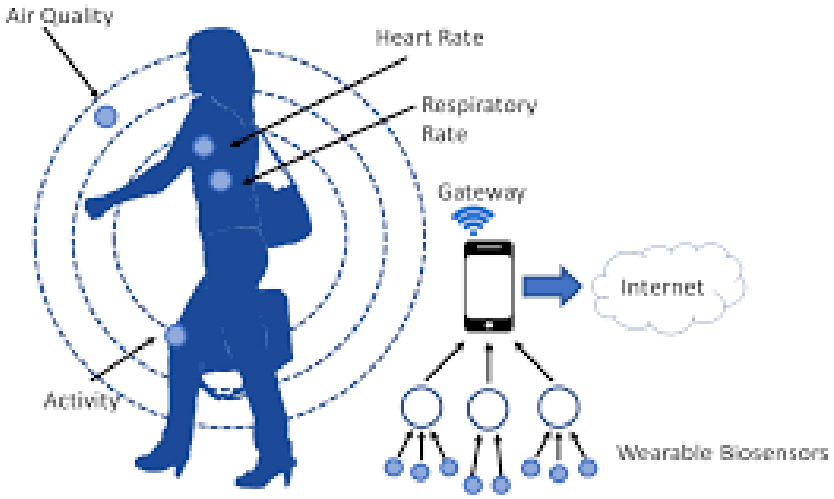

Fig 5: A woman with wearable sensors for health fitness

There are challenges related to these exoskeletons and researchers need to do more investigations and suggest possible solutions for efficiency of these devices. There is need to increase the usability of these wearable devices such that factors like size, battery life and other modalities are enhanced. Researchers should further investigate how the size of the device and energy

consumption can be minimized by raising the size of the memory. The other limitation in the study is privacy of information. There were reports from the study that data generated from this devices can reveal very important information about the organization and most specifically details about the e employee. It can reveal information on the heart rate of the employee and the number of steps taken at any point. This is violation of privacy and there is need for researchers to come up with new ways and procedures that will be used to minimize the exposure of data. They should however discover the types of wearables to be used by employees and regulate the kind information available in the gadgets. Another issue with this devices is adoption. Both employees and employers have found it difficult to adopt the use of these gadgets. Some of the employers are not willing to use the exoskeletons while others are not aware of the benefit of this devices. Further research should be conducted to formulate new ways that will motivate both employees and employers while at the same time enhance the use of these gadgets in the workplace. Another key factor here is the accuracy of the devices. Studies conducted found out that information delivered by these devices are not 100% as expected (Khakurel, et al 2009). This calls for innovation and development of more accurate sensors to ensure quality of the data. These gadgets can be hacked any time. This threatens the security of the information contained by the device. Studies reveal that cyber-attacks can lead to breaching of security data in the gadgets. Much has to be done to obtain more systematic secure devices. The results obtained from studies conducted by various scholars explained how exoskeleton and its use has impacted the workers in different organizations. The study on work at overhead level was an experimental laboratory study whose aim was to identify the effects of a wearable robot assistant carpentry (Naito, et al 2006). The study sought to evaluate the effectiveness of the gadget and to further explain the effects on the worker. The lifting of theses loads by the employees will in the long

run lead to health risks .The field of exoskeleton is wide and tries to reach out to several areas of life such as rehabilitation, military and in industries (Looze, et al. 2015). The purpose of this study is to point out benefits as well as the possible challenges in use of this exoskeletons.

Conclusion

The systematic review has showed how the use of exoskeletons to help employees during various handling tasks has become of major concern across the nations. The experimental laboratory studies conducted showed positive effects on the use of occupational exoskeletons with regard to both physical and psychological factors. However these studies cannot be applied generally as they did not reflect actual tasks in the work environment. The small sample sizes of young healthy participants' calls for other research studies to be conducted. The studies conducted by scholars also showed that so far few scholars have investigated the psychological health factors with regard to occupational exoskeletons this is because there are no appropriate ways to use in measurement of psychological health factors. For any scholar endeavoring to do future research on this, they should conduct studies at the actual workplace and investigate the effects of exoskeleton used in the actual tasks. The team should also access both short term and long term effects of occupational exoskeletons.

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