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A Conceptual Approach for Developing an Ergonomic Intervention for Preventing Work-Related Musculoskeletal Disorders (WMSD) amongst Workforce at Power Plants

(Pendekatan Konseptual untuk Membangunkan Intervensi Ergonomik untuk Mencegah Kerja - Gangguan Muskuloskeletal Berkaitan (WMSD) di kalangan Tenaga Kerja di Loji Tenaga)

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ABSTRACT

Work at fossil-fuelled power plant is physically strenuous and could expose workers to Work-related Musculoskeletal Disorder (WMSD) such as Carpal Tunnel Syndrome (CTS), low-back pain (LBP), or shoulder tendonitis. WMSDs are considered as a leading factor in disabilities and absenteeism, reduced production, and increased costs. WMSDs in the workplace have been studied extensively and it is a common notion that the work itself is a major cause of MSDs. Work environment contributed to these types of disorders and are made worse by the working conditions or workplace risk factors. All those mentioned common occupational injuries are related with the ergonomic field of study. By implementing appropriate ergonomic interventions, the above-mentioned work-related injuries and resulting disability is potentially preventable. The major workforce in these plants are either associated with handling of machineries or serving as control room operators. Hence, this category of manpower is subjected to physical stress and workplace injuries if there is no form of ergonomic interventions. Previous studies have shown that common tasks performed by workers in the electric power industry often involve the use of a manual tool and revealed that less than 1% of the general population has sufficient strength to manually perform the task resulting in decreased productivity and worker injury. Departing from the aforementioned need, this study embarks to assess exposure to risk factors for WMSDs and to provide a basis for ergonomic intervention at the workplace. Therefore, by focusing on health and safety matter of workers at our power plants, we are actually applying a form of business risk management (BRM) to consider possible impacts of related foreseeable significant risks on any electricity utilities performance. It is envisaged that this study could identify the ergonomics interventions which will reduce staff medical bills, compensation, and lost time injury from MSDs.

Keywords: Ergonomics; occupational safety and health; power plant

ABSTRAK

Bekerja di stesen janakuasa yang mengendalikan bahan fosil bakar yang mendedahkan diri kepada kerja fizikal yang berat telah menjadikan para pekerja mudah berhadapan kepada symptom Muskeletal Disorder (WMSD) seperti Carpal Tunnel Syndrom (CTS), Lower Back Pain (LBP) atau dentonitis bahu. WMSD dianggap sebagai factor utama yang menjurus kepada ketidakupayaan, ketidakhadiran, pengurangan daya kecekapan, dan meningkat kos ditempat kerja. WMSD ditempat kerja telah dikaji dengan meluas dan kajian umum menyatakan bahawa punca WMSD adalah berpunca daripada situasi persekitaran tempat kerja itu sendiri. Keadaan persekitaran kerja telah menyumbang kepada gangguan penyakit ini dan telah diburukkan dengan kondisi di tempat kerja atau faktor risiko di tempat kerja itu sendiri. Kesemua kecederaan yang disebutkan adalah berkaitan dengan bidang pekerjaan ergonomic. Dengan melaksanakan intervensi

ergonomic yang sesuai, kecederaan yang berkaitan dengan pekerjaan dan ketidakupayaan yang telah disebutkan dapat dicegah. Bidang kerja utama yang dijalankan di kilang ini berkait rapat dengan pengendalian mesin dan pengawalan di bilik kawalan. Oleh itu, bidang tenaga kerja ini mudah mengalami tekanan fizikal dan terdedah kepada kecederaan sekiranya intervensi ergonomic tidak dititik beratkan. Kajian terdahulu menyatakan bahawa tugas-tugas biasa yang dijalankan oleh pekerja industry elektrik sering melibatkan penggunaan alat manual dan kurang daripada 1% populasi pekerja mempunyai kekuatan untuk melaksanakan tugas secara manual seterusnya mengakibatkan penurunan produktiviti dan kecederaan kepada para pekerja. Menerusi keperluan yang disebutkan diatas, kajian ini dimulai dengan menilai pendedahan kepada risiko WMSD dan pengunaan asas cara kerja yang ergonomic di tempat kerja. Oleh itu, dengan memberi perhatian kepada masalah kesihatan dan keselamatan pekerja di stesen janakuasa, penggunaan satu bentuk pengurusan risiko perniagaan (BRM) telah membolehkan pertimbangan kesan risiko yang mungkin berlaku dapat dipertimbangkan dan mampu memberi kesan kepada utility elektrik. Diharapkan bahawa kajian ini dapat mengenal pasti intervensi ergonomic yang akan mengurangkan bil perubatan kakitangan, pampasan, dan kehilangan masa yang disebabkan oleh MSD.

Kata kunci: Pemandu; ergonomik; keselamatan dan kesihatan pekerja; janakuasa

INTRODUCTION

Electricity is a vital building block for any industrial and economic activities, especially to fast rising countries like China, India, as well as Malaysia, as high priority is given towards the country's industrialisation and commercial growth (Karanfil & Li 2015; Tang & Tan 2013). Realising its importance, it is widely accepted that electricity is considered as the driving force to realize the industrial, technical, and cultural potential of a nation. Electricity always has a significant role in the development process and the electricity supply industry and sectors utilizing power are necessary development blocks in growing the economy of a country (Enflo et al. 2009). However, this industry is continuously facing challenges in terms of blackouts, cost overruns, physical network losses, service quality, and environmental issues (Beard et al. 2010). As a result, the electricity supply industry is one of the least popular investment sectors characterised by increased risks and complexity, while being compounded with controversial issues such as unattractive business environment (Bacon & Besant-Jones 2001). The distinctive and substantial set of challenges facing this energy sector today will necessitate most utilities to revisit their business risk management (BRM) strategies.

Why is it very important for us to re-evaluate our BRM? The government aims to increase investment growth in the country is the driving force behind the electricity reform. Restructuring process initially involves only with the generation tier of the Malaysian electricity supply industry. However, talks at higher level are taking place to further restructure the electricity industry to create wholesale market and produce independent transmission and operation ownership.

Ever since industrial operations have been created that imply considerable risks for people, the environment and the business itself, there have been attempts to mitigate these risks in order to achieve safe operations with acceptable risk (Grote 2012). BRM have an instant bearing on the overall costs of a firm and thus to corporate profits generation. Of the various risks focused under BRM, occupational risk management is considered to be a catalyst in generating superior returns for all stakeholders. The occupational related injuries have increased considerably in Malaysia in recent years, in spite of the legal reforms beginning in 1994 with the establishment of Occupational Safety and Health Act (Act 514). These statistics has a significant human cost for Malaysian society, and leads to the loss of economic potential and productivity for the country besides taking into account of reduction in human capital, malfunction of equipment as well as contributing to a large number of working days are lost. In the context of a leading power utility, we could not afford to sustain any negative implications arising from employee's well-being related issues at workplace which might have everlasting scar on utility's corporate image. Knowing where employees are at risk can save them from health problems down the road, as well as business from legal penalties or high workers' compensations costs and premium (EPRI 2001). Therefore, it is imperative for the employer to invest in occupation safety and health which will surely increase its profitability, competitiveness as well as motivating the employees. This is a conceptual paper to study the appropriate ergonomics interventions to help minimize and prevent workplace injuries especially in a coal-fired power plant.

ERGONOMIC RELATED IN MALAYSIA

According to Social Security Organization Malaysia (SOCSO), it was found that the accident cases reported by the electrical, gas and steam industry are increasing year by year. The percentage of accident cases reported are nearly doubled in 6 years' duration as shown in Figure 1.

FIGURE 1. Accident cases reported by SOCSO from 2009-2014 among electrical, gas and steam industry

Furthermore, the number of accident cases reported due to MSD are also increasing since 2009 till 2014 where the percentage of MSD cases reported in 2014 are nearly four times more than reported cases in 2009 as shown in Figure 2.

FIGURE 2. MSD cases reported by SOCSO from 2009-2014

One of the core business divisions of Tenaga Nasional Berhad (TNB), the Generation Division is entrusted to develop, operate, and maintain TNB's portfolio of power generating units. The Generation Division has thermal generation assets and major hydro-generation schemes in Peninsular Malaysia and one IPP operating in Pakistan. Work at fossil-fuelled power plant is physically strenuous and could expose workers to Work-related Musculoskeletal Disorder (WMSD) such as Carpal Tunnel Syndrome (CTS), low-back pain (LBP), or shoulder tendonitis. WMSDs are considered as a leading factor in disabilities and absenteeism, reduced production, and increased costs (Motamedzade et al. 2013). WMSDs in the workplace were extensively investigated and the work conducted by the employee itself is a major cause of MSDs (Robone et al. 2010; Govindu & Babski-Reeves 2014). Musculoskeletal disorder refers to health conditions that involve the locomotor apparatus, i.e., muscles, tendons, the skeleton, cartilage, the vascular system, ligaments and nerves, with back pain/injuries, and work-related upper limb disorders as the main groups (Sole et al. 2013). Work environment contributed to these types of disorders and are made worse by the working conditions or workplace risk factors. All those mentioned common occupational disorders are related with the ergonomic field of study. Ergonomics is the study of human factors relationship between workers and their environment. By implementing appropriate ergonomic interventions, the above-mentioned work-related injuries and resulting disability is potentially preventable.

The major workforce in these plants are either associated with handling of machineries or serving as control room operators. Hence, this category of manpower is subjected to physical stress and workplace injuries if there is no form of ergonomic interventions. Previous studies have shown that common tasks performed by workers in the electric power industry often involve the use of a manual tool and revealed that less than 1% of the general population has sufficient strength to manually perform the task resulting in decreased productivity and worker injury (Seeley & Marklin 2003). Introduction of appropriate ergonomic interventions that are effective in reducing both the incidence of initial work-related musculoskeletal disorders, reducing disability and costs associated with them is imperative to prevent work-related injuries and disabilities amongst workers in power plants. Departing from the aforementioned need, this study embarks to assess exposure to risk factors for WMSDs and to provide a basis for ergonomic intervention at the workplace. Subsequently, the output from this study will be utilized to evaluate the effectiveness of any interventions made whilst proposing customized behaviour-based safety program for power plant workers. Therefore, by focusing on health and safety matter of workers at our power plants, we are actually applying a form of business risk management (BRM) to consider possible impacts of related foreseeable significant risks on TNB's performance.

THE CASE STUDY OF LOCAL COAL-FIRED POWER PLANT

From the ergonomic standpoint, if we look closer at the case of selected coal-fired power plant in Peninsular Malaysia, there are currently two main control room that operates and monitors all four units of the power plant. It takes 15 operators per shift to control and monitor the processes in the plant from the control room which is operated 24 hours a day and 365 days a year. There are three shifts in a day and the operator needs to be in the control room for a total of eight hours where they are not allowed to be further than 20 meters away from their workstation. These long exposure of sitting at the workstation could further lead to common occupational injuries which in turn will affect their working performance, operational downtime due to discussion of injury, medical costs, lost time, and employee replacement and training

overtime for substitutes or additional manpower (Choi & Woletz 2010; Bohlin 2005).

A central control room's (CCR) purpose is as a production control, and serves as a central space where a large physical facility or physically dispersed service can be monitored and controlled where it came into general use in factories during the 1920s (Bennett 1993). One of the most prevalent health problems caused by work in the modern job market that usually attacks industrial worker is work-related musculoskeletal disorder (WMSDs) (Ramos et al. 2017). A large range of workplace, individual, and psychosocial risk factors are associated with the development of WMSDs. Individual risk factors include age, gender, education level, anthropometry, muscle strength, and physical fitness (Wu et al. 2012). Work-related physical factors include the physical demands imposed by performing the task, such as awkward posture during work, bending, static sedentary posture, and task demands while work-related psychosocial factors such as work or time spent working to meet deadlines can also contribute to WMSDs (Wu et al. 2012). Although sitting requires less muscular effort than standing, it still causes physical fatigue because it holds parts of human body steady for long period of time. Prolong of sitting in the same posture may reduce circulation of blood to muscles, bones, tendons, and ligaments which will lead to stiffness and pain (Mustafa et al. 2009).

CCR operator at the plant had put on a request to their management on purchasing a heavy-duty base chair with 3D armrest, backrest recline function, headrest, and lumbar support. They claim that the current chair that they are using is uncomfortable for them to sit on and causes some back pain among the operators. An observation had been done on the CCR at the plant and it is found that there are various different types and designs of chairs being used by the operators there. Inappropriate design of chair will cause discomfort to the workers to do their job and this becomes worst for those who are working in night shift. We must realize that most original console standards were set back in the 1960s and have since been revised to accommodate both new technologies and new understandings of how our head, neck, and eyes operate. Latest ergonomic studies of people sitting in a relaxed position show that our heads tilt forward approximately 8 to 15 degrees at a viewing angle of minus 30 to 35 degrees (Lee et al. 2015).

Carpal Tunnel Syndrome (CTS) is a condition affecting the hand and wrist. People with CTS experience difficulty in performing tasks such as unscrewing bottle tops, fastening buttons, or turning keys. The National Institute of Neurological Disorders and Stroke (USA) indicate that CTS is often the result of a combination of factors that increase pressure on the median nerve and tendons in the carpal tunnel, rather than a problem with the nerve itself. CTS has been associated with certain tasks including, repetitive hand motions, awkward hand positions, strong gripping, mechanical stress on the palm and vibration Typical symptoms of CTS are tingling of the thumb, and of the index, middle, and ring fingers, and night pain. CTS has been associated with certain tasks including repetitive hand motions, awkward hand positions, strong gripping and many more. Repetitive manual work tasks requiring a forceful grip and use of vibrating tools can damage the median nerve in the arm, which later leads to CTS (Hussain & Winterton 2016; Stein at al. 2015). There had been one CTS incident that occurred on 2014 to one of the administrative employees. The worker had been diagnosed and found to be infected by De Quervain's Disease which relates to CTS. The worker had to undergo a minor operation on her left thumb. Furthermore, recently in the year 2016, there were complaints received from another admin worker of having the same symptoms (numbness).

In Malaysia, problems and awareness in ergonomics are still low and people tend to ignore the problems. It is essential to open up the knowledge on ergonomics to the workers for better and effective work in the future. Based on random interview conducted at the plant, workers didn't realize that some of the symptoms they had and experienced are related to occupational injuries that might be due to the lack of ergonomics awareness among them. They claimed that the discomfort felt such as back pain, pain on neck and discomfort in sitting are just normal pain which will disappear after a while. Due to this purpose, a customized Behaviour Based Safety Module might need to be introduced to educate the workers about the ergonomic risk factors and how to reduce and further eliminating these problems.

OBSERVATIONS AND DISCUSSIONS

A preliminary observation study has been conducted at a selected coal-fired power plant with the main intention to ascertain and verify the basis or need to conduct further research on the ergonomics concern. The safety official of this power plant has raised the concern on the well-being of employees with regards to ergonomic related matters. The preliminary observations cover the Control Room (Central Electrical Building), Control Room (Central Control Room), and Administration Department to have a visual on the current workstation design and worker's behavior. At control room, most of the staff work for eight hours a day. They tend to sit continuously on their chair during working hours. Seven types of chair (Figure 3-9), namely CT1-CT7 are currently being used in the control room. The posture of how the staff sit during working hours has been observed as well.

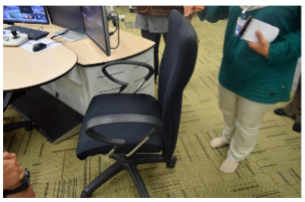

FIGURE 3. CT1

FIGURE 4. CT2

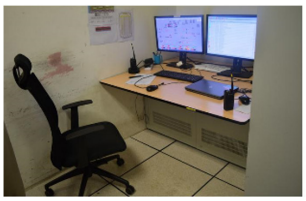

FIGURE 5. CT3

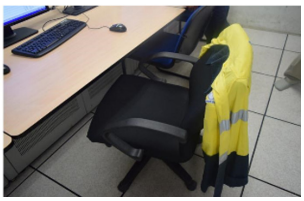

FIGURE 6. CT4

FIGURE 7. CT5

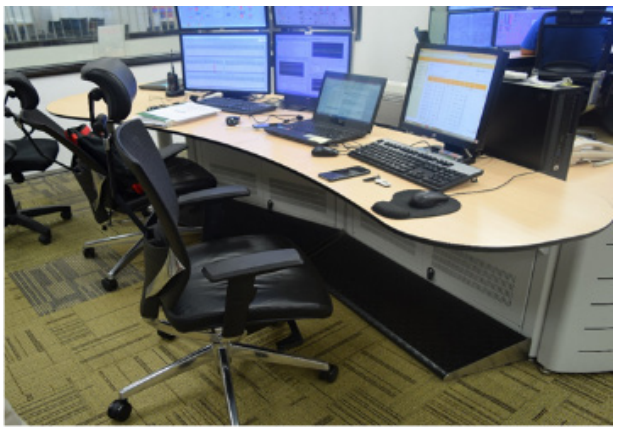

FIGURE 8. CT6

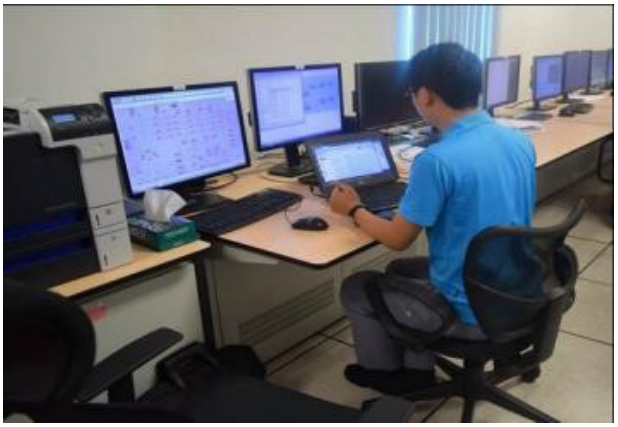

FIGURE 9. CT7

CT1-CT7 seems to provide different levels of comfort to the operators. However, from the observation, this could be attributed to either erroneous designer conception about operator's requirements or erroneous operator's conception about functional environment with regards to operational safety. Figure 10 shows the common posture in a control room. It is evident that prolonged seated position could cause discomfort in musculoskeletal system. Such discomfort could be attributed to unchanging seating positions and lack of movement. Posture adjustments such as adjusting seating position, alternating sit-stand positions, and taking breaks at certain intervals throughout the day might help in reducing the aforementioned discomfort. Figure 11 indicates repetitive hand motion which could be related to contribute to work-related musculoskeletal disorders. Operators were found to be exposed to repeated forceful finger and wrist flexion and extension which are considered as aggravating factors for CTS. Therefore, it is imperative to place the hand in neutral position while working with the control panels, which could be achieved by adjusting the seating position, or proper positioning of the mouse.

FIGURE 10. Common postures in the control room

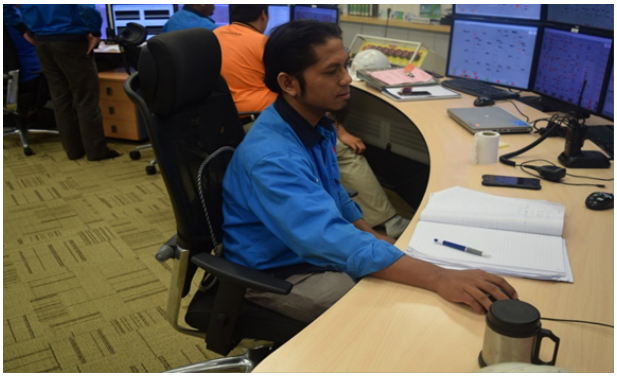

FIGURE 11. Possibility of facing CTS if no proper ergonomic interventions

THE NEED FOR EXTENDED INVESTIGATION

The preliminary observation has provided the basis to conduct a detailed experimental investigation on the different postures and motions that are performed by workers in order to find the ergonomics risk occurrence while performing their job.

SAMPLE

The study is to be conducted at TNB owned thermal and hydroelectric power plants. Target respondents would be CCR operators, workers at main plant, and administration staff.

INSTRUMENTS

Respondents will be asked to answer two sections question which are question about respondents' demography, ergonomics awareness, and question about safety climate, respectively. For questions that are related to ergonomics awareness and safety culture, the respondents will be asked to answer each question using a five-point Likert-scale ranging from '1: Strongly agree' to '5: Strongly disagree'. Seven factors in the safety climate questionnaire have been used to measure safety culture: safety management system and procedure, management commitment, safety attitudes, workmate's influences, employee's involvement, safety knowledge, and safety behaviour. The collected results will then be analysed using a statistical analysis software.

Next, data are collected from the on-body sensor network and the upper body biomechanical model. Data on joint angles and segment orientations of the respondents while performing their task are captured for postural assessment analysis. These two parameters will be derived using a mobile processing unit and an on-body sensor network. Seven wireless Colibri IMUs are used in this system where each lightweight sensor (48g, 56 x 42 x 19 mm) contains a tri-axial accelerometer, a tri-axial gyroscope and a tri-axial magneto inductive magnetic sensor. Samples from the sensors are captured at 100 Hz. The IMUs will be placed on the operator's body as follows: one IMU for each upper arm and each forearm, one IMU for the head which is placed on the STHMD, one IMU for the trunk which is placed on the chest, and one IMU for the pelvis. This last IMU is needed to define the trunk movement with respect to the pelvis. Bi-axial SG65 goniometers will be added to the on-body sensor network and synchronized with the IMUs to record wrist angles (flexion/extension, radial/ulnar deviation).

The biomechanical model of worker's upper body comprised of 10 rigid segments (head, hands, trunk, clavicles, upper arms, and forearms) connected by anatomically motivated restricted articulations (pelvis, sternoclavicular joints, neck joint, shoulders, elbows, and wrists). This biomechanical model provides 20 degrees of freedom (DoF), three for the neck joints, three for the pelvis, three for each shoulder (composed of acromioclavicular and glen humeral joints), two for each elbow and two for each wrist.

Lastly, RULA ergonomic tool is utilized to compute a global risk score that estimates the exposure to upper limb MSDs. This global score for a current posture (also known as final score) ranges from one (being most comfortable) to seven (being most uncomfortable). This score is based evaluation on posture, muscle use and weight of loads, duration of task, and repetitiveness. Originally, based on a discrete observation of postures, the RULA tool has been implemented into the biomechanical model so that real time score of risk exposure to MSDs can be computed. To meet this aim, the described biomechanical model provides joint angles needed to locate the positions of head (also known as 'neck' in the RULA sheet), trunk, upper arm, forearm, and hand (known as 'wrist' in the RULA sheet). These angles provide a score computation for each articulation, also called local score and these local scores will be accumulated for the final global score. Furthermore, data collected from the analysis will then be used to identify the ergonomics factors and issues. These ergonomics factors and issues will then be eliminated or reduced by redesigning the most suitable postural analysis among the workers where the analysis would help the workstation designers and engineers of a control room to design the workstation of a control room that would fit the operators while they are performing their tasks.

EXPECTED RESEARCH OUTCOME

It is envisaged that the extended investigation on this subject matter will assist in refining and reviewing current working environment, rotational job deployment, working hours, and types of job assigned at main plant, HR Office, and CCR at all TNB owned power plants. It is intended to gather current posture and BMI's data based on each worker stationed inside main plant and CCR. Data will be collected for all staff by shift. Furthermore, based on the collected information, appropriate ergonomics interventions will be proposed. To assist in educating the workforce, Ergonomics Concern Edge (ECE) will be disseminated through facts and figures in particular formats and languages for distribution through print, booklet, and website. Finally, customized Behaviour Based Safety (BBS) programs will be designed for providing awareness to staff pertaining to ergonomics at all TNB owned power plants.

CONCLUSION

This preliminary investigation is part of a comprehensive study to assess the exposure of power plant workforce towards work-related musculoskeletal disorders. It is evident that design of control room and posture adjustments of the operators are important to reduce the effect of musculoskeletal discomfort. However, an in-depth study is required to further assess the appropriate ergonomics interventions which will reduce staff medical bills, compensation, and lost time injury from MSDs. Furthermore, it is foreseen by designing a job to allow for good posture, less exertion, fewer motions, and better heights and reaches, the workstation becomes more efficient which in turn will increase the productivity at the power plant. Therefore, the overarching aim of this study is to assist electricity utility to reduce both employee turnover and absenteeism due to MSDs, further improve morale and increase employee involvement. This is in line with the Government's aspiration in promoting a safe, secure and comfortable society whilst maintaining and promoting people's health.

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DECLARATION OF COMPETING INTEREST

None

REFERENCES

Bacon, R.W. & Besant-Jones, J. 2001. Global electric power reform, privatization and liberalization of the electric power industry in developing countries. *Annual Reviews Energy and the Environment* 26: 331-359.

Beard, L.M., Cardell, J.B., Dobson, I., Galvan, F., Hawkins, D., Jewell, W. & Tylavsky, D.J. 2010. Key technical challenges for the electric power industry and climate change. *Energy Conversion* 25(2): 465-473.

Bennett, S. 1993. A History of Control Engineering 1930-1955. London: Peter Peregrinus Ltd.

Bohlin, F. 2005. Literature survey on costs and benefits from a better work environment. Scientific reviews of ergonomic situation in mechanized forest operations 131-148.

Choi, S.D. & Woletz, T. 2010. Do stretching programs prevent work-related musculoskeletal disorders. *Journal of Safety, Health and Environmental Research* 6(3): 1-19.

Electric Power Research Institute. 2001. Final report for ergonomics handbook for the electric power industry: Overhead distribution line workers' interventions. EPRI Report Number 1005199.

Enflo, K., Kander, A. & Schön, L. 2009. Electrification and energy productivity. *Ecological Economics* 68(11): 2808–2817.

Govindu, N.K. & Babski-Reeves, K. 2014. Effects of personal, psychosocial and occupational factors on low back pain severit severity in workers. *International Journal of Industrial Ergonomics* 44 (2): 335-341.

Grote, G. 2012. Safety management in different high-risk domains: All the same? *Safety Science* 50(10): 1983-1992.

Hussain, A. & Winterton, R.I. 2016. Peripheral nerve entrapment syndromes of the upper limb. *Surgery (Oxford)* 34(3): 134-138.

Karanfil, F. & Li, Y. 2015. Electricity consumption and economic growth: Exploring panel-specific differences. *Energy Policy* 82: 264-277.

Lee, H.S., Chung, H.K. & Park, S.W. 2015. Correlation between trunk posture and neck reposition sense among subjects with forward head neck postures. *BioMed Research International* 1-7.

Motamedzade, M., Faghih, M.A., Golmohammadi, R., Faradmal, J. & Mohammadi, H. 2013. Effects of physical and personal risk factors on sick leave due to musculoskeletal disorders. *Int J Occup Saf Ergon* 19(4): 512-521.

Mustafa, S.A., Kamaruddin, S., Othman, Z. & Mokhtar, M. 2009. Ergonomics awareness and identifying frequently used ergonomics programs in manufacturing industries using quality function deployment. *Am. J. Sci. Res* 3: 51-66.

Ramos, D.G., Arezes, P.M. & Afonso, P. 2017. Analysis of the return on preventive measures in musculoskeletal disorders through the benefit–cost ratio: A case study in a hospital. *International Journal of Industrial Ergonomics* 60: 14-25.

Robone, S., Jones, A.M. & Rice, N. 2010. Contractual conditions, working conditions and their impact on health and well-being. *The European Journal of Health Economics* 12(5): 429-444.

Seeley, P.A. & Marklin, R.W. 2003. Business case for implementing two ergonomic interventions at an electric power utility. *Applied Ergonomics* 34(5): 429-439.

Solé, M., Diaz-Serrano, L. & Rodríguez, M. 2013. Disparities in work, risk and health between immigrants and native-born Spaniards. *Social Science & Medicine* 76: 179-187.

Stein, K.M., Borg-Stein, J. & Ramey, L.N. 2015. Upper limb issues in pregnancy and postpartum: Carpal Tunnel Syndrome and DeQuervain's Tenosynovitis. *Musculoskeletal Health in Pregnancy and Postpartum* 159-169.

Tang, C.F. & Tan, E.C. 2013. Exploring the nexus of electricity consumption, economic growth, energy prices and technology innovation in Malaysia. *Applied Energy* 104: 297-305.

Wu, S., He, L., Li, J., Wang, J. & Wang, S. 2012. Visual display terminal use increases the prevalence and risk of work-related musculoskeletal disorders among Chinese office workers: A cross-sectional study. *Journal of Occupational Health* 54(1): 34-43.