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Design and Analysis of Physical Strength in Ergonomics- A Review

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ABSTRACT

The purpose of the present study was to determine if a relationship between what individuals chose as an acceptable workload and muscle effort existed. Additionally, physical capability limits for direct current right-angle power tool operation were established. A psychophysical methodology was utilized to examine 40 non-skilled female participants while performing a right-angle power tool fastening task on a simulated joint. A combination of two between subject variables were examined: joint orientation (horizontal and vertical planes) and joint hardness (hard and soft joints). Participants were evenly distributed into one of the four joint orientation hardness groups via a minimization technique that reduced between group mean characteristics (i.e., height, weight, age, grip strength). Within each of these four groups, a combination of three fastening strategies (Automatic Tightening Control, Quick Step, and Turbo Tight) and three fastening frequencies (1/min, 3/min, and 5/min) were performed by each participant. The chosen target torque, forces experienced in all three orthogonal axes, and surface electromyography were gathered throughout the data collection. Separate mixed-design repeated analyses of variance were used to assess each of the dependent measures, with Tukey's post hoc test comparisons as relevant ($p<0.05$). Fastening strategy and frequency influenced the target torque and forces participants chose as an acceptable workload, which was also supported by the surface electromyography data. Participants chose significantly higher target torques with the Turbo Tight strategy, which was associated with lower peak force and force impulse in comparison to the other two strategies. Participants chose to accept lower target torques and forces as fastening frequency increased. Physical capability limits were calculated to accommodate 75% of the female working population, which will help reduce the risk of injury associated with right-angle power tool use in the automotive sector and elsewhere.

Key words: Ergonomics evaluation in physical strength, Case studies, Designing of model, Parameters.

INTRODUCTION

We have pleasure in introducing our new project "Design and Analysis of Strength in Ergonomics", Humankind's interest in measurement of human physical strength probably dates to the first humans. At that time, life was truly a struggle in which the fittest survived. To a great extent, fittest meant strongest. Interestingly, current interest in human physical strength in the workplace stems from 1970–1980s vintage research demonstrating that persons with adequate physical strength are less likely to be injured on physically demanding jobs. Survival in many modern workplaces may still be a case of survival of the strongest. There is, however, a flip side to this issue — that person with limited strength is more likely to be injured on "hard" jobs. To address this problem, we can apply what we know about physical strength to job design. "Hard" jobs can be redesigned to be within the physical strength capability of most people. Since physical strength is important to these jobs, we must find ways to quantify it through testing.

LITERATURE REVIEW

Ergonomics deals with the exploration of human physical and mental capabilities during working and adjusting the working load. By using ergonomic arrangement of the workplace it is possible to adapt work to a human's physical and mental characteristics and to reduce or prevent adverse effects on health (Polaner et al., 2010; And relieve et al., 2012). Correct designing of the workplace also includes human habits to ensure humans' work as productively effectively, and safely as possible. The two most important factors that influence stress at work can be divided into: Working environments with working conditions such as noise, heat, humidity, illumination, air velocity and Body postures; numerous studies confirmed the relationship between the risks for developing musculoskeletal disorders (MDS) and awkward postures.

The number of existing ergonomics methods for assessing body postures is many and they vary in the area of the body they assess (Roman-Liu, 2014). Some methods assess the load on selected body part independently of each other and other methods provide a total assessment. Some methods focus on different work tasks such as repetitive and non-repetitive tasks and there are methods that evaluate static load e.g., load sustaining the same posture for a long time. Manual handling is another type of tasks that should be especially consider. Beside manual evaluation tools which are time consuming there exist also several computers aided tools that shorten evaluation time and usually offer several methods for body evaluation.

Physical Strength – MSD – Ergonomics Evaluation

Physical ergonomics deals with the physical load on the human body when performing activities like work, sports, jobs at home or dealing with products. With regard to the exposure to physical loads and its potential effects on the human body, the presented framework is helpful.

Purposes of Strength Measurement in Ergonomics

People may want to collect human strength data for a number of reasons. One common reason is to build an anthropometric database of population strength data that can be used to create design data for products, tasks, equipment so forth, as well as for basic research into the strength phenomenon. This publication focuses on two common uses of physical strength assessment in worker selection and placement and job design.

MSD (Muscular Skeleton Disorder)

Ergonomics point of view, manual material handling is a high-risk activity that could cause spinal injuries. From physiology perspective, manual material handling requires high amount of energy and strength. Hence, all activities, if carried out inaccurately, could cause inflammation at the nerves and muscles. MMH activities that require high physical demands, continuous bending, crouching and hip twisting could disturb the musculoskeletal system. The main source of this problem is enduring static loads frequently for long duration, which causes tensions or disruptions on the joints, ligaments and tendons. These are known as Musculoskeletal Disorders.

Musculoskeletal disorders or MSDs are cumulative and chronic injuries of the soft tissue-muscles, tendons, ligaments, nerves, joints, and blood vessels. The body has limits and can fail or wear out when abused or misused. MSDs are defined as injuries to muscles, tendons, ligaments, joints, nerves and discs that are caused or aggravated by our actions and/or environment that does not follow safe and healthy work practices. A well-known MSD is carpal tunnel syndrome which occurs when the nerve, which runs from the forearm into the palm of the hand, becomes pressed or squeezed at the wrist. The carpal tunnel - a narrow, rigid passageway of ligament and bones at the base of the hand - houses the 5 median nerve and tendons. Sometimes, thickening from irritated tendons or other swelling narrows the tunnel and causes the median nerve to be compressed resulting in pain, weakness, loss of grip or numbness in the hand and wrist, radiating up the arm.

Single or individual MMH task are lift, lower, push, pull, carry and hold. Any MMH operation or job is composed of these elemental tasks. A combined MMH task is composed of a combination of tasks involving lifting, lowering, pushing, pulling or carrying. 'Combined MMH' (Taboon & Dutta, 1989; Straker et. al., 1997; Li et. al., 2009) or multiple-component MMH task is combination of MMH tasks in sequence. Based on literature a number of different types of CMMH have been identified. Waters et. al. (2007) defined 'multi-task lifting' jobs as jobs in which there are significant differences in lifting tasks that are done concurrently, such as a palletizing job, were the vertical height can vary from lift to lift. This definition can be extended to other basic tasks and can be termed 'Multi-task MMH' job where there is within task variability of critical parameters. For example, carry distance may vary when a worker moves concrete slurry on head during a roof concrete laying process over a period of 1-2 hours. Waters et. al. (2007) termed sequential lifting jobs where workers rotate between job elements in sequence. There are ample situations where team MMH is relevant. For example, loading a log from ground to floor of truck is a team lift task. An example of multi-person MMH task is loading of boxes into truck by 4 material handlers, two handlers lifting from floor height to hip height into the hands of two handlers standing on truck in stooped posture, and those two handlers then placing in appropriate location in truck. Dempsey (1999) used the term 'Multiple task MMH' job as job comprising of different types of MMH tasks over task duration. Mittal & Ramakrishnan (1999) used 'Complex manual materials handling' task to designate a combination of different types of MMH tasks where non-basic task types like turning and sliding are also involved.

There is ample evidence from literature to point to the usage of different terms in MMH that cater to the need of describing the situation or scenario of that manual exertion. The MMH terms are used interchangeably and with lot of overlap. The usage of term 'multi-task' and 'multiple task' MMH creates ambiguity in their usage. Combined MMH task describes a material handling where material is moved from origin to a prescribed destination. 'Multiple component MMH' task or 'Multiple task MMH' equally means the same. 'Multiple task MMH' job considers time aspect of exposure dimension i.e., frequency and duration. In principle 'sequential lifting' can be extended to mean 'Sequential carrying' or 'sequential pushing/pulling' where carry distance and sequence of those can be varied. Such interchangeable use of terms can be stream lined if a commonality of ergonomic parameters can be highlighted, and used further for better classification.

Musculoskeletal disorders (MSDs) are a major cause of work-related disability and lost-time illnesses for many occupational groups. This study determined the prevalence of musculoskeletal symptoms among young construction workers. A symptom and job factors survey were self-administered to 996 construction apprentices. Prevalence was determined by the percent of positive responses to musculoskeletal symptom questions. Odds ratios and 95 percent confidence intervals were the measures of association between prevalent musculoskeletal symptoms and demographic, leisure, and job factors and were determined by logistic regression. The low back was the site most commonly reported for job-related musculoskeletal symptoms (4.54%), which was also the most common reason for seeking care from a physician (16.8%) and missing work (7.3%). Number of years worked in the construction trade was significantly associated with knee (p-trend = 0.0009) and wrist/hand (p-trend < 0.04) MSD symptoms and was suggestive of an association with low back pain (p-trend = 0.05). "Working in the same position for long periods" was the job factor identified as most problematic, with 49.7 percent of all construction apprentices rating it as a moderate/major problem contributing to musculoskeletal symptoms. Musculoskeletal symptoms are a significant problem among young construction workers at the beginning of their careers. Prevention strategies are needed early in the apprentice training program to reduce the potential disability associated with work-related musculoskeletal symptom disorders.

Psychosocial factors

WRMSDs do not only result in the physical stressors. However, a set of multiple factors determine the formation. Psychosocial risk factors such as stressful job, social pressure at work, and job dissatisfaction are such factors which contribute to the formation of WRMSDs. When an injury occurs, psychosocial factors, such as incongruous pain and depression, are the main reasons for the development of a disability and transition from acute to chronic pain. These include monotonous work, time pressure, a high workload, unorganized work-rest schedules, complexity of tasks, career concerns, lack of peer support, a poor relationship between workers and their supervisors, and poor organizational characteristics (climate, culture, and communications). The way to structure and manage the work processes are called as organization of work and it deals with the following subjects: Work scheduling (work-rest schedules, work hours, and shift work). Job design (task complexity, required effort and skill, and the degree of control of work). Interpersonal facets of work (relationships with colleagues, subordinates, and supervisors). Concerns regarding career (job security and opportunities to grow). Style of management (teamwork and participatory management). Characteristics of the organization (culture, communication, and climate). Many of the above components are called as "psychosocial factors," and they are known as risk factors for psychological strain and job stress. Stress is a conceived emotional and physical reaction of the human body to events or circumstances which cause excitement, danger, confusion, irritation, or frightening. Particularly, it is a transition from someone's normal behavior according to a cause that results in tear and wear on the body’s mental or physical resources. There are internal or external stimuli that cause stress. The internal stimuli are those stressors that involve self-expectations, impersonal barriers, and conflicting desires. Apparently, internal stimuli depend on personal aspects. However, external stimuli include situations where expectations, time limit, lack of resources, and lack of vision and goals present

Stressors may be physiological, psychological, social, environmental, developmental, spiritual, or cultural and represent unmet needs. Stress causes changes in the human body that are usually centered on the nervous system and endocrine system. Therefore, the human body’s internal environment is constantly changing, and the body’s adaptive mechanisms continually function to adjustments in heart rate, respiratory rate, blood pressure, temperature, fluid and electrolyte balances, hormone secretions, and level of consciousness. Intensive and extensive stress results in disorders in the musculoskeletal system. Emotions like anger, frustration, irritation, confusion, tension, and nervousness cause the stress. It is not only the experience and frequency of such feelings but also the repedition of the activities and motions that induce injuries or musculoskeletal disorders. In considering human emotions and feelings and applying the results of the research to their impact on the musculoskeletal system, it is probably platitudinous to make a statement that the greater the knowledge and understanding of the human being, the better the result obtained. In order to identify and understand the effect of the emotions on the musculoskeletal system, important risk factors for musculoskeletal disorders should be recognized.

Psychological risk factors

Moreover, together with the above conditions, some other work aspects contribute to both physical and psychological stress as well. The human body in fact is limited in kinematic motions as it is a mechanism formed by biological characteristics. Beyond this, it also includes a brain which thinks, reasons, and feels. Thus, feelings such as joy, pain, anger, sadness, depression, frustration, outrage, boredom, fear, jealousy, hate, love, and (even) schizophrenia are experienced by human beings. When exposed to stress, human beings show responses such as fear, frustration, anger, fatigue, tension, depression, anxiety, helplessness, confusion, and lack of vigor.

Common types of occupational MSDs

Tendonitis: it is the most common hand problem, which happens when the tendons connecting the fingers to muscles in the forearms get inflamed. Tendons help attach muscle to bone to allow movement of a joint.

Tenosynovitis: this is another common ailment, where the synovial sheaths (sacks filled with fluid) swell which surround and protect the tendons. Carpal tunnel syndrome (CTS) is the condition which is a result of this swelling. The carpal tunnel is a small opening close to the bottom of the hand which accommodates the tendons and the median nerve that provides sensation to the hand. In the case of swelling of the synovial sheaths, the carpal tunnel cramps and puts pressure on the nerve. There are several syndromes of the CTS, but the most frequent ones are numbness, tingling, or a burning sensation in the palms, fingers, and wrists. These conditions can lead to strength and sensation loss in the hands in time.

Nerve compression: throughout the body, there are several nerves that transmit signals from the body parts to the brain. These often move in the spine through small tunnels available between the vertebrae. There are many conditions which cause the nerves to become compressed, pinched, or squeezed, which can result in weakness, numbness, severe pain, and loss of coordination. The condition in which the sciatic nerve in the spine becomes compressed is known as sciatica. The symptoms of this condition appear in the back of the leg and at the side of the foot.

Raynaud’s syndrome/disease: this is a loss of blood circulation, which results in whitening and numbness of the finders. It is sometimes called “white finger,” “wax finger,” or “dead finger”.

Reflex sympathetic dystrophy: this is a rare, incurable condition characterized by fry, swollen hands and loss of muscle control. It is consistently painful.

Ganglion cyst: this disorder arises when a swelling or lump in the wrist resulting from jelly-like substance leaks from a joint or tendon sheath.

Cervical radiculopathy: this is the condition of an injury due to the extending out of those nerves that provide sensation and trigger movement from cervical vertebrae which result in weakness, numbness, or pain in the hand, wrist, arm, or shoulder.

Lateral epicondylitis: this is a condition when the outer part of the elbow becomes painful and tender, usually as a result of a specific strain, overuse, or a direct bang.

Rheumatoid arthritis: this is a disabling autoimmune disease which is progressive and happens in a long term. It causes pain, swelling, and inflamemotion in and around the joints and other body organs. Hands and feet are affected mainly, but it can be seen in any joint as well. It usually occurs at the same joints on both sides of the body.

To achieve the main goals of the organization, the perfect aspect of safety and health and work systems should be established in order to implement the organization's goal to cause all the employees and organizations to be safe at work. The uniqueness of the work system and management in the manufacturing sector requires accuracy and details on ergonomic aspects and occupational health and safety to perform all the activities involved. This is because the abandonment of the aspects of occupational health and safety will have a negative impact on the employees and organizations for a long period of time. Moreover, irresponsibility on the aspect of occupational safety and health can affect employees and organizations and outsiders that are involved with the organization's activities. According to Hagg' (2000) and Bridger (2003), the ergonomic environment of workstation literally giving an impact on human resources either psychologically or physiologically.

Ergonomics is about designing or planning work tasks in such a way as to improve human health, comfort and performance. Ergonomics in practice involves a study of work activities and the work environment in order to understand how people carry out the work activities. Human performance is affected by: Physical ergonomics: the physical requirements of an activity Cognitive ergonomics: the way information in relation to the task is presented to the person Organizational ergonomics: how work is organized, for example shift patterns This guide relates to physical ergonomics and is designed to help employers to manage ergonomic risks that affect the musculoskeletal system. The musculoskeletal system is a combination of the muscular and skeletal systems, which work together to allow the body to move and perform activities. It consists of muscles, tendons, ligaments, nerves, blood vessels and supporting tissues. Evidence-based information is used to study a work activity in order to assess both human comfort and physical capability to complete the task. Having studied the activity, opportunities to redesign or change the task to allow the person to carry it out without detriment to their musculoskeletal health should be considered. Musculoskeletal disorders (MSDs) are injuries or disorders that affect any part of the musculoskeletal system. MSDs are associated with ergonomic risk factors such as excessive force, awkward posture and repetition. Symptoms of MSDs can include aches and pains, swelling, numbness and weakness. It is useful to look at an example of ergonomics in practice. and 1a show a work activity that involves a person manually lifting a metal part (a billet) into a CNC machine for drilling. The ergonomic risk factors include the heavy weight of the billet (up to 130kg) and the awkward twisting posture involved in the manual transfer of the metal part into the machine, which results in the load having to be manipulated at a distance from the trunk. It is clear that carrying out this task exposes the worker to physical stress due to these ergonomic risk factors.

To minimize psychosocial biases towards manufacturing assembly, participants without prior experience with using DC RAPT in automotive assembly were recruited for the present study. At first glance this may appear as a limitation, however, research by Potvin et al. (2000) demonstrated that skill differences between experienced and unexperienced individuals can be significantly reduced through an adequate training protocol, as was done in the current study. Participants in the present study completed a minimum of 6.75 hours of training (45 minutes per experimental condition) prior to proceeding to the testing sessions. This was done to familiarize participants with the fastening task with the aim of producing reliable assessments of the task at hand. Based on the low within-subject COV observed in the chosen target torque, RAPT-HFT, and sEMG data the training protocol achieved what it was designed to do.

This paper has presented a review of the different types of methods and devices used in ergonomics assessment but it is not only limited to the approaches as stated in this paper. The strength and weakness of the methods and devices are highlighted in this paper which will be useful as a reference for future works. For ergonomics assessment methods, RULA and REBA are evaluated and compared by referring the parameters, professions and postures of the case of studies from different researchers. Both survey-based methods show their importance to assess the risk of ergonomics of the workers at their working environment with the condition on applying them relative to the professions and postures. For ergonomics assessment devices, IMU and Kinect on different applications are compared to determine their performance, reliability and features. According to the findings, IMU based devices show more promising result while Kinect based devices still have room for improvement in the future works. In conclusion, it is vital for the workers to realize the importance of the ergonomics to assess potential ergonomics risk factors existed around their work place. The raise of awareness of the workers towards these matters may save their life from any hazardous activities or places.

CONCLUSION

In spite of advances in measurement techniques and an explosive increase in the volume of research, our understanding of human strength remains in its introductory stages. It is clear that muscle strength is a highly complex and variable function that depends on a large number of factors. It is not surprising, therefore, that large differences in strength exist not only between individuals, but even within the same individual tested repeatedly on a given piece of equipment. The issue is compounded by the fact that correlations of strength among different muscle groups in the same individual are generally low, and tests of isometric strength do not necessarily reflect the strength an individual might exhibit in a dynamic test. As a result of these and other influences, great care needs to be exercised in designing, evaluating, reporting, and interpreting muscular strength assessments. Traditionally, tests of muscular strength were in the domain of the orthopedist, physical therapist, and exercise physiologist. Such tests are also an important tool for the ergonomist, however, because of the high strength demands on workers in manual materials-handling tasks. In some cases, task demands may approach or even exceed the strength that an individual is voluntarily willing to exert in a test of strength. In such cases, evidence suggests that the likelihood of injury is significantly greater than when the task demands lie well within an individual’s strength capacity. Because the relationship among strength capabilities, job demands, and musculoskeletal injury has been established, it is apparent that tests of muscular strength may benefit the ergonomist both in designing jobs and in ensuring that individuals have sufficient strength to safely perform physically demanding jobs. Several strength assessment techniques have been employed for these purposes, each possessing unique characteristics and applicability to job design and worker selection procedures. Our main purpose has been to elucidate these strengths and weaknesses, so that tests of strength may be properly applied in designing jobs and selecting workers. One of the crucial points we have emphasized is that any test of strength used in job design or worker selection must be directly related to the demands the job.

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