A Review on Ergonomic Evaluation of Industrial Tasks in Indian Manufacturing Industries

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Abstract: This paper focuses on the various techniques used for the ergonomic evaluation of industrial tasks in manufacturing industries. Work related musculoskeletal disorders (MSDs), low back injuries and incorrect/bad body postures are the most common problem occurring in the industries. The injuries if are not properly taken care off will results in higher medical compensation. So to avoid this, the objective of current paper is to discuss the various measurement techniques that can be used for the ergonomics evaluations of different task in Indian industries.

Keywords: Ergonomic Evaluation of Industrial tasks, Postural analysis, NIOSH, RULA & REBA

1. Introduction

Ergonomic (or human factors) is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system. This is achieved by applying theoretical principles, data and methods to design in order to optimize human well being and thus improving overall system performance. Ergonomists, contribute to the planning, design and evaluation of tasks, jobs and products in industries. These also include environments and systems in order to make them compatible with the needs, abilities and limitations of peoples.

The term Ergonomics derived from Greek ergo (work) and nomos (laws) to denote the science of work, ergonomics is a systems-oriented discipline, which now applies to all aspects of human activity. Physical ergonomics is concerned with human anatomy, and some of the anthropometric, physiological and bio mechanical characteristics as they relate to physical activity.
Cognitive ergonomics is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. This includes mental workload, decision-making, skilled performance, human-computer interaction, human reliability, work stress and training as these may relate to human-system design.

Organizational ergonomics is concerned with the optimization of socio-technical systems. This includes organizational structures, policies, and their processes. Others relevant things includes communication, crew resource management, work design, work systems, design of working times, teamwork, participatory design, community ergonomics, cooperative work, new work programs, virtual organizations and quality management. According to Grzybowski et al. (1997-1999) for evaluating complex work systems four main factors are considered [1]. These include Physical working environment factors, Physical strain factors, Psychological strain factors and Technological and organizational factors.

Ergonomics has spread in various sectors, including academics, defence, agriculture, design, industry and so on. A variety of Ergonomic evaluation tools have been applied universally in various sectors of different industries. But still there is a little awareness about these tools and their uses amongst Indian industries. Thus a lot of research is required with context to Indian industries, so that injuries can be avoided.

2. Fatigue and its Measurement Techniques

Fatigue is two types namely mental and physical which are explained in following subsequent sections.

2.1 Mental Fatigue

Mental Fatigue is the tiredness occurred due to the longer shifts and excess work without proper sleep and rest [2]. The sleeplessness is the main cause of tiredness. For humans eight hours sleep per night is the requirement for work efficiently. Most of the industrial accidents amongst workers happen due to tiredness caused by fatigue [3].

2.2 Measurement of Mental Fatigue

2.2.1 Electroencephalograph (EEG)

Electroencephalograph (EEG) is a method for measuring and recording brain signal with the help of electrodes placed on the scalp. An electroencephalograph (EEG) is the recorded electrical activity generated by the brain. In general, EEG is obtained using electrodes placed on the scalp with a conductive gel. In the brain, there are millions of neurons, each of which generates small electric voltage fields. The aggregate of these electric voltage fields create an electrical reading which electrodes on the scalp are able detect and record. Therefore, EEG is the superposition of many simpler signals.

3. Physical Fatigue

It is the temporary inability of a muscle to perform optimum work. During physical activity, muscle fatigue is gradual and depends upon an individual's physical fitness, and also upon the other factors such as sleep deprivation and overall health of the individual. It can be regained with the help of rest. Physical fatigue can be caused by a lack of energy in the muscle.

3.1 Measurement of Physical Fatigue

3.1.1 Oxygen O_2

The name is derived from V - volume, O_2 - oxygen, max - maximum. VO_2 max (also maximal oxygen consumption, maximal oxygen uptake, peak oxygen uptake or maximal aerobic capacity) is the maximum capacity of an individual's body to transport and use oxygen during incremental exercise, or labour work which reflects the physical fitness of the individual. Spirometer and gas analyzer is used for measuring oxygen consumption. (Source: http://en.wikipedia.org/wiki/VO2_max)

3.1.2 Heart Rate

Heart rate (HR) refers to the speed of the heartbeat, specifically the number of heartbeats per unit of time. The heart rate is typically expressed as beats per minute (bpm). The heart rate can vary according to the body's physiological needs, including the need to absorb oxygen and excrete carbon dioxide. The normal heart rate ranges from 60-100 bpm. Heart rate is measured by finding the pulse of the heart. Heart rate is measured with the help of stethoscope. This is a long, thin plastic tube that has a small disc on one end and earpieces on the other end. The disc and tube of the stethoscope amplify small sounds, such as heartbeats. Modern techniques of measuring heart rate includes heart rate monitors, usually comprises a polar chest strap transmitter and a polar wrist watch receiver. (Source: http://en.wikipedia.org/wiki/Heart_rate)

3.1.3 Electrocardiogram (ECG)

This instrument is used for measuring electrical activity of the heart. The electrical activity is related to the impulses that travel through the heart. It provides information about the heart rate, rhythm, and morphology. ECG is recorded by attaching a set of electrodes on the body surface such as chest, neck, arms, and legs [4].

3.1.4 Blood Pressure

Blood pressure is the pressure exerted by circulating blood upon the walls of blood vessels, and is one of the principal vital signs. During each heartbeat, blood pressure varies between a maximum systolic and a minimum diastolic pressure. The blood pressure in the circulation is principally due to the pumping action of the heart. Blood pressure is recorded as two numbers, such as 120/80. The larger number indicates the pressure in the arteries as the heart pumps out blood during each beat. This is called the systolic blood pressure. The lower number indicates the pressure as the heart relaxes before the next beat. This is called the diastolic blood pressure. Blood pressure is most commonly measured by a sphygmomanometer [5].

4. Postural Analysis and its Measurement Techniques

It is the most important tool for finding the injuries of the workers in industrial environment. In this the posture of the workers is studied and corrected if found wrong.

4.1 Methods Used For Postural Analysis

4.1.1 RULA (Rapid Upper Limb Assessment)

Rapid Upper Limb Assessment (RULA) is used for ergonomic investigations of workplaces where work related injuries are reported. RULA is a simple diagnostic tool that allows surveying various tasks involving the upper limbs at workplace with focuses on use of arms, wrists, position of the head and the posture of the upper body. McAtamney and Corlett (1993) introduce RULA, or Rapid Upper Limb Assessment [6]. It is developed to observe the operators who suffered upper limb disorders due to the musculoskeletal loading. The RULA is used without need for advanced and expensive equipment that's why it is one of the most popular ergonomic investigation tools in industry. It proved a tool which is reliable for use by those whose job it is to undertake workplace investigations.

4.1.1.1 Procedure of RULA

RULA (Rapid Upper Limb Assessment) ergonomic assessment tool considers biomechanical and postural load requirements of job tasks/on the neck, trunk and upper eternities. In this tool a single page worksheet is used to evaluate required body posture, force and repetition. The evaluated scores are entered for each body segment in for arm, wrist, neck and trunk.
Score that represents the level of MSD risk is listed below:

Table 1: RULA Score Table

SCORE	*LEVEL OF MSD RISK*
1-2	1-2 Negligible risk, no action required
3-4	Low risk, change may be needed
5-6	Medium risk, further investigation change soon
6+	Very high risk, implement change now.
Source: www.ergo-plus.com	

RULA is quick method, so multiple positions & tasks within the work cycle can usually be evaluated without much time & effort. But only the right or left side is assessed at a time.

4.1.2. REBA (Rapid Entire Body Assessment)

The RULA and REBA both are similar tools for evaluate the musculoskeletal disorders. REBA is an ergonomic assessment tool uses an orderly process to evaluate whole body postural MSD and risk associated with workplaces. Hignett and McAtamney (2000) introduce REBA and stated that it is used to investigate posture for risk of work related musculoskeletal disorders (WRMSDs) [7]. REBA is a better tool for whole body parts (wrist, upper arm, lower arm, neck, trunk and legs,) REBA is user friendly and useful for manual task risk assessment. But here some drawback of REBA is: REBA does not give the combine assessment of biomechanical risk factors.

4.1.2.1 Procedure of REBA

REBA (Rapid Entire Body Assessment) ergonomics assessment tools uses to evaluate whole body postural MSD. Here also a single page worksheet is used to evaluate selected body posture, forceful excretion, type of movement or action, repetition and coupling. The evaluator will assign a score for different body region: Wrist, Forearms, Elbows, Shoulders, Neck, Trunk, Back, Legs and Knees. After data collected and scored. Then tables are used to compile risk factor variables.
The level of MSD risk represents with the help of score:

Table 2: REBA Score Table

SCORE	*LEVEL OF MSD RISK*
1	Negligible risk, no action required
2-3	Low risk, change may be needed
4-7	Medium risk, further investigation change Soon
8-10	High risk, investigate and implement change
11+	Very high risk, implement change now.
Source: www.ergo-plus.com	

Application of REBA: REBA can be used when an ergonomic workplace assessment identifies that further postural analysis is required and:

- The whole body is being used.
- Posture is static, dynamic, rapidly changing, or unstable.
- Animate or inanimate loads are being handled either frequently or infrequently.
- Modifications to the workplace, equipment, training, or Risk-taking behaviour of the worker are being monitored Pre/post changes.

5. Digital Human Modelling (DHM) Used For Postural Analysis

Digital human modelling (DHM) is an emerging tool allow assistance in design, manufacturing and ergonomic evaluation. Different DHM models are developed with different capabilities still there are common analysis that can be done by using DHM technologies. Some common listed capabilities and functions:

- The ability to move the manikins in predefined motions
- The ability to create customizable 3D manikins
- Reach analysis
- Posture analysis
- Push/Pull analysis
- Carrying analysis
- RULA based motion (Rapid Upper Limb Analysis)

6. Methods for Finding Safe Load Limits for Manual Material Handling Tasks

6.1. The NIOSH Equation

The National Institute of Occupational and Safety Health (NIOSH) constitute a team of experts in 1985 to review literature on lifting including the NIOSH Work Practices Guide of 1981. This revised edition became the 1991 lifting equation which reflected new findings and provide methods for evaluating asymmetrical lifting tasks, objects with less than optimal hand container couplings and offers new procedures for evaluating a large range of work durations and lifting frequencies than the 1981 equation. The 1991 lifting equation is more accurate given by NIOSH is more likely to protect most workers than the 1981 equation [8].

The reasons are that:

1. The 1991 equation is applicable to a wider variety of lifting jobs because of the addition of the asymmetric and coupling multipliers.
2. The recommended weight limits computed are generally lower than the Maximum Acceptable Weight Limits reported [9]. However, some authors Waters et al. (1993) reported that the NIOSH Committee noted that due to uncertainties in the existing scientific studies and theoretical models, further research was needed to assess the magnitude of risk for lifting related low back pain and its association with the lifting index [10]. Recommended Weight Limit: (Calculated from NIOSH, 1991)

$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM$ (1)
LC = Load Constant of 23 kg (51 lbs) and where each multiplier can assume a value between 0 and 1.
HM = Horizontal Multiplier: H is the horizontal location (distance) of the hands from the midpoint between the ankles at the start and end point of the lift.
VM = Vertical Multiplier: V is the vertical location (height) of the hands above the floor at the start of and end of the lifting point.
DM = Distance Multiplier: D is the vertical travel distance from the start to the end point of the lift.
AM = Asymmetry Multiplier: A is the angle of asymmetry, i.e. – the angular displacement of the load from the medial, which forces the operator to twist the body. It is measured at the start and end point of the lift, projected onto the floor.
FM = Frequency Multiplier: F is the frequency rate of lifting, expressed in lifts per minutes. It depends on the duration of the lifting task.
CM = Coupling Multiplier: C indicates the quality of coupling between hand and load.

7. Environmental Measurement Techniques

It includes noise, vibration and illumination.

7.1 Sound

Noise is measured in decibels dB (A). Audible noise greater than 85 dBA or greater is hazardous. Some preventative strategies to consider in countering the effects of noise include avoidance of noise generation, impedance of sound transmission and using adequate protective hearing devices such as sound-isolating helmets, caps or plugs.

Guidelines to follow for sound which includes:

- Keep the noise level below 85 decibel.
- Rooms should not be too quiet.
- Limit the annoyance.
- Use quiet machines.
- Use the ceiling to absorb noise.
- Separate noisy work from quiet work.

OSHA (1981 & 1983) gave the sound level with exposure time explain below:

The human can bear 95 dBA level of sound for 3.5 hr, 105 dBA level of sound for 0.5 hr and 85 dBA level of sound for 4 hr. A sound level meter or sound meter is an instrument that is used for measuring sound pressure level.

7.2 Vibration

Barbara et al. (2009) evaluated that three important design factors need to be considered for vibrations are explained below [11].

- Whole-body vibration (WBV) - where the vibration is transmitted to the body as a whole by its supporting surface (i.e. seat or floor);
- Segmental - where the vibration is transmitted to a specific segment of the body such as the hand/arm or foot/leg.
- Vibration arises from various mechanical sources with which humans have physical contact. Vibration energy can be passed on to operators from vehicles on rough roads; vibrating tools; vibrating machinery; or vibrating work platforms and may give rise to adverse health effects.

7.2.1 Effective Management of Whole-Body Vibration (WBV)

Like other hazards at work vibration needs to be identified as a problem and controlled. The approach most usually taken is one of risk management.

- Risk Management involves:
- Identifying vibration hazards that might exist
- Assessing these to decide if they constitute a risk to health and safety of employees
- Controlling those factors that do pose a risk
- Monitoring and evaluating controls/solutions Controls or Solutions are usually a combination of measures that reduce the risks to an acceptable level.

Vibration is measured by Digital Vibration Meters, Analog Vibration Meters, Transmitters and Monitors.

7.3 Illumination

Illumination as regards three important design factors need to be considered these are:

- Illumination- the amount of the lighting falling on a surface.
- Luminance- the amount of light reflected or emitted from a surface.
- Luminous contrast ratio- the difference between the luminance values of the adjacent areas, assuming that there is a defined boundary between them. Kaufman and Christensen (1984) gave some of the guidelines to be followed are -
- Select a light intensity of 10-200 lux for orientation tasks.
- Select a light intensity of 200-800 lux for normal activities.
- Select a light intensity of 800-3000 lux for special applications.

Illuminance is measured by a luxmeter, which is a handy instrument with a sensor. The measured illuminance is directly displayed in lux (lx).

8. Literature Review

Tan (1996) studied the analyses of tasks carried out in an electronics factory [12]. The ergonomic and biomechanical hazards of problem work tasks are identified. Each task were analysed systematically in order to evaluate the workers exposures to the risk factors of force, posture pressure and repetition. Finally the recommendations were made to reduce the risks and hazards. The methodology included objective measures and detailed analysis by going through training manuals, job description and production records. Yeow and Sen (2003) studied an ergonomic study that was conducted to improve the workstations for electrical tests in a printed circuit assembly (PCA) factory [13]. Subjective assessment and direct observation methods were used on the operators to discover the problems in their workstations. Ergonomic interventions were implemented for corrective action. Yeow and Sen (2003) aimed at reducing the occupational health and safety problems faced by the manual component insertion operators [14]. Subjective, objective assessments and direct observations were made in the printed circuit assembly factory. Simple and low-cost ergonomic interventions were implemented. These included repairing chairs, reducing high workloads, assigning operators to a maximum of 2 workstations, confining machines that emitted bad smell and higher noises and providing finger work aids. Yeow and Sen (2004) studied an ergonomics improvement that was conducted on the visual inspection process of a printed circuit assembly (PCA) factory [15]. Three problems identified were operator's eye problems, insufficient time for inspection and ineffective visual inspection. Ergonomics interventions were made to rectify the problems. A visual inspection sequence was introduced to rectify it. Abdullah et al. (2009) studied to identify and quantify ergonomics working postures that contributed to the serious development of musculoskeletal injuries and thus investigated possible contributory their related causes [16]. Rapid Entire Body Assessment (REBA) methods were used to estimate the final score of working posture. Immediate corrective actions were to improve the current work procedures and workstations' designs. Thus the high risks of injury to the operators were overcome. Wong and Richardson (2010) examined two manufacturing lines producing semiconductors using different technology concepts, namely Conventional Line (CL) and Lean Production Line (LPL) [17]. Both lines manufacturing the same products were compared using various factors, including working conditions, task risks and dangers of the job, and physical body stress. The improved ergonomics factors resulted in better working conditions and thus increased job satisfaction. Grzybowski (2001) discussed new trends in developing and implementing methods of workplace analysis [18]. A sample method for the workplace ergonomics evaluation was developed. The method gives response to the industrial sector's demand and can be used as tool supporting occupational risk assessment. The authors also present opportunities and benefits of applying the method in occupational safety management systems. Mirka et al. (2002) studied to develop and evaluate engineering controls for the reduction of low back injury risk in workers in the furniture manufacturing industry [19]. An analysis of injury/illness records and survey data identified upholsterers and workers in the machine room as two occupations within the industry at elevated risk for low back injury. This research shows the impact of engineering controls for the furniture manufacturing industry on the risk factors for work-related low back injuries. Neumann et al. (2002) evaluated the impact of partial automation strategies on productivity and ergonomics [20]. This research concluded that strategic decisions made by designers and managers early in the production system design phase have considerable impact on ergonomic conditions in the resulting system. Automation of transport and assembly both lead to increased productivity. But elements related to the automatic line system also increases mechanical loads on operators and hence increased the risk for work-related disorders. Keyserling et al. (1992) developed a one-page checklist for determining the presence of ergonomic risk factors associated with awkward postures of the lower extremities, trunk and neck [21]. Workers were observed using awkward postures for most of the jobs in the survey. The checklist was found to be an effective rapid-screening instrument for identifying cyclical jobs that expose workers to potentially harmful postures. Keyserling et al. (2010) studied inter-worker variability in lower body posture and work activity during highly-structured assembly line work [22]. Data were collected from 79 unique assembly line workstations in an engine manufacturing plant. Lower body posture/movement was determined and used to estimate the percentage of time the workers spent in various postures and activities. Vignais N et al. (2013) studied a system that permits a real-time ergonomic assessment of manual tasks in an industrial environment [23]. A biomechanical model of the upper body has been developed by using inertial sensors placed at different locations on the upper body. Based on this model, a computerized RULA ergonomic assessment was implemented to permit a global risk assessment of musculoskeletal disorders in real-time. Chang et al. (2007) proposed a method of conducting workplace evaluations in the digital environment for the prevention of work-related musculoskeletal disorders and apply a digital human modelling system to the workplace virtual dynamic simulation [24]. The captured workplace motion data was used for ergonomics evaluation which includes biomechanics and posture analysis. Sarder et al. (2006) studied an export garment manufacturing plant in South East Asia to evaluate the working conditions of the plant from an ergonomics/human factors perspective [25]. The investigation includes a questionnaire survey and various observations and measurements done in the workplace. Various possible solutions were given on the basis of results outcome. Fellows and Freivalds (1991) studied an ergonomics evaluation of a foam rubber grip for tool handles [26]. The outcome of result was to use proper grips in tools to avoid discomfort and reductions of work efficiency. Mittal and Sharma (2013) studied an ergonomic risk controls in construction industry [27]. A basic introduction of ergonomic in construction industry and risk controls in relation to minimize the ergonomics risk factors was given.

9. Conclusions

From the research reported by different researchers it can be concluded although different ergonomics evaluation techniques were used in different manufacturing industries but still there is lack of ergonomic awareness in Indian industries. This can help in achieving safer and productive workplace for workers. Thus results in reducing the workplace injuries and compensation cost.

References

[1] Grzybowski W., Pacholski L., Jasiak A., Andrzejczak K., Dahlke G., & Gorny A., (1997–1999) "A method of ergonomic workplace evaluations in industrial companies", (Research paper No. 1 H02D 033 12). Poznan, Poland: Poznan University of Technology.
[2] Caldwell J., and Caldwell J., (2003) Fatigue in Aviation. Burlington, VT: Ashgate.
[3] Flin, R., O'Connor, P. & Crichton, M. (2008) "Safety at the Sharp End: A Guide to Non-Technical Skills" Farnham: Ashgate.
[4] Wang Y., Agrafioti F., Hatzinakos D., and Plataniotis N. K., (2008) Hindawi Publishing Corporation EURASIP Journal on Advances in Signal Processing Volume 2008, Article ID 148658, 11 pages doi:10.1155/2008/148658
[5] Caro., Colin G., (1978). "The Mechanics of the Circulation" Oxford [Oxfordshire]: Oxford University Press. ISBN 0 - 19 – 263323 - 6.
[6] McAtamney L., and E Nigel Corlett E. N., (1993) "RULA: a survey method for the investigation of world-related upper limb disorders", Applied Ergonomics, Vol. 24(2) pp. 91-99.
[7] Hignett S., and McAtamney L., (2000) "Rapid Entire Body Assessment (REBA)", Applied Ergonomics, Vol. 31 (2) pp. 201-205.

[8] Liles D.H., and Mahajan P., (1985) "Using NIOSH lifting guide decreases risks of back injuries", Occupational Health and Safety, pp. 57-60.
[9] Snook S.H., and Ciriello V.M., 1991, "The design of manual handling tasks: revised tables of maximum acceptable weights and forces", Ergonomics, Vol. 34, pp. 1197-1213.
[10] Waters T.R., Putz-Anderson V., Garg A., and Fine L.J., (1993)"Revised NIOSH equation for the design and evaluation of manual lifting tasks" Ergonomics, Vol. 36, pp. 749-776.
[11] A Handbook on Whole-Body Vibration Exposure In Mining (2009) Barbara Mcphee, Gary Foster, Airdrie Long pp. 6-10.
[12] Tan G.L., (1996) "Ergonomic task analysis in electronics industries: some case studies", J Hum Ergol (Tokyo), Vol. 25(1), pp. 49-62.
[13] Yeow P.H.P., and Sen R.N., (2003) "Quality, productivity, occupational health and safety and cost effectiveness of ergonomic improvements in the test workstations of an electronic factory", International Journal of Industrial Ergonomics, Vol. 32, pp. 147–163.
[14] Sen R.N., and Yeow H.P., (2003) "Ergonomic study on the manual component insertion lines for occupational health and safety improvements," International journal of occupational safety and ergonomics (JOSE), Vol. 9, (1), pp. 57-74.
[15] Yeow P.H.P., and Sen R.N., (2004) "Ergonomics Improvements of the Visual Inspection Process in a Printed Circuit Assembly Factory", International Journal of Occupational Safety and Ergonomics (JOSE), Vol. 10 (4), pp. 369-385.
[16] Abdullah A.S., and Rahman M. N. A., (2009) "Ergonomic assessment of working postures in semiconductor manufacturing processes," National Symposium on Advancements in Ergonomics and Safety (ERGOSYM2009), pp. 111-114.
[17] Wong S. B., and Richardson S., (2010) "Assessment of working conditions in two different semiconductor manufacturing lines: Effective ergonomics interventions", Human Factors and Ergonomics in Manufacturing & Service Industries, Vol. 20 (5), pp. 391-407.
[18] Grzybowski W., (2001) "A Method of Ergonomic Workplace Evaluation for Assessing Occupational Risks at Workplaces," International Journal Of Occupational Safety And Ergonomics 2001, Vol. 7, (2), pp. 223–237.
[19] Mirka G.A., Smith C., Shivers C., and Taylor J., (2002) "Ergonomic interventions for the furniture manufacturing industry. Part I - lift assist devices", International Journal of Industrial Ergonomics, Vol. 29 pp. 263–273.
[20] Neumann W. P., Kihlberg S., Medbo P., Mathiassen S. E. and Winkel J., (2002) "Evaluating the ergonomic and productivity impacts of partial automation strategies in the electronics industry", int. j. prod.res, Vol. 40, pp. 16, 4059-4075.
[21] Keyserling W.M., Brouwer M., and Silverstein B. A., (1992) "A checklist for evaluating ergonomic risk factors resulting from awkward postures of the legs, trunk and neck ", International Journal of Industrial Ergonomics, Vol. 9(4), pp. 283-301.
[22] Keyserling W. M., Wiggermann N., Werner R.A., and Gell N., (2010) "Inter-worker variability in lower body postures during assembly line work: implications for exposure assessment," J Occup Environ Hyg, Vol .7(5), pp. 261-71.
[23] Vignais N., Miezal M., Bleser G., Mura K., Gorecky D., and Marin F., (2013) "Innovative system for real-time ergonomic feedback in industrial manufacturing", Applied Ergonomics, Vol. 44(4), pp. 566–574.
[24] Chang S.W., and Wang M. J., (2007) "Digital human modeling and workplace evaluation: Using an automobile assembly task as an example", Human Factors and Ergonomics in Manufacturing & Service Industries, Vol. 17(5), pp. 445-455.
[25] Sarder M.D. B., Imrhan S. N., and Mandahawi N., (2006) "Ergonomic Workplace Evaluation of an Asian Garment-Factory", J. Human Ergol., Vol. 35 pp. 45-51.
[26] Fellows G.L. and Freivalds A. (1991) " Ergonomics evaluation of a foam rubber grip for tool handles," Applied Ergonomics , Vol. 22(4), pp. 225-230.
[27] Mittal A. and Sharma H.K., (2013) "Ergonomic Risk Controls in Construction Industry," International Journal of Emerging Research in Management &Technology ISSN: 2278-9359, Vol. 2, (8), pp. 28-33.

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