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Review Article

Ergonomic Analysis Tools: A Review

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Abstract

Ergonomic analysis of industrial workstations is very essential for enhancing the productivity and reducing the musculoskeletal disorders. This paper presents the review on the studies carried out so far to analyse the various tools used for ergonomic analysis. Review shows that the many of the researchers are focussed on study of a single tool and its use in particular industry for analysing the problem. Some researchers focussed on comparison between two or more tools and determined the suitability of tools in particular field. Some researchers carried out the same study using various tools and discussed the strength and weakness of ergonomic analysis tool. While selecting a particular tool for ergonomic analysis it is necessary to know about the various options available and selecting one is quite difficult. This paper will make it easier to select an appropriate tool for particular ergonomic analysis.

Keywords: *Ergonomics, ergonomic analysis, industrial workstation, ergonomic tools, musculoskeletal disorder*

1. Introduction

Ergonomics is the science that pursues to fit the job to the person, rather than the person to the job. Ergonomics is achieved by evaluation and design of the workstation and by achieving a golden mean between task, operator and working area. In industries there is a continuous change regarding new employee, new adjustments, new processes etc. So every time new ergonomic solutions are required as per the situation.

In industries usually workers work in shifts. The same machine, same workstation is going to be used by various workers, in different shifts. So naturally the variation will be there in each case. In order to ergonomically fit the workstation for maximum operators at various conditions, it is necessary to make ergonomic evaluation of the workstation. For ergonomic analysis there are various tools available. But it is necessary to select the proper tool for analysis.

To select the ergonomic analysis tool, parameters like analyst capability, task being analysed, and characteristic of tool themselves, data for analysis and its use are to be considered. The main factors considered are analyst characteristic, task attributes, tool capabilities and data application. The analyst characteristics generally considered are knowledge of ergonomics, ability to maintain application skills, frequency of tool use, role in decision making regarding interventions, time available to conduct analysis etc. The task attributes to be considered will include the parameters like existing job verses task being designed, body region affected, work activity level, ergonomic risk factor involved, task variability and frequency, Worker control of workspace, movements, and pace. Tool Capabilities and limitations will include the research underlying tool development, body parts and physiological functions analysed, risk factors analysed, sensitivity, repeatability, computerization, cost etc. Data application factors considered are quantification of risk, acceptability of subjective data, research vs. general impression, credibility requirements, simulation and use to assess hypothetical solutions etc.

The common ergonomic analysis tools are:

a. NIOSH RLE (Revised Lifting Equation)
b. RULA (Rapid Upper Limb Analysis)
c. REBA (Rapid Entire Body Assessment)
d. Strain Index
e. Jack
f. OWAS
g. Push pull analysis
h. Plibel
i. Anybody
j. Humosis
k. Washington State Proposed OSHA Standard Appendix B
l. GM-UAW Risk Factor Checklist
m. Humantech BRIEF Survey
n. Auburn Engineers ERGO Job Analyzer
o. Snook & Ciriello Tables (aka. Liberty Mutual Tables or simply Snook Tables)

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p. ACGIH Hand/Arm (Segmental) Vibration TLV's
q. HAL (Hand Activity Level)
r. Univ. of Michigan's 3DSSPP (3-Dimensional Static Strength Prediction Program)
s. Garg Model (Metabolic Energy Expenditure Prediction Program)
t. LMM (Lumbar Motion Monitor System)

2. Literature Review

While doing study of various ergonomic analysis methods it is necessary to have overlooked over the previous study, tools and their comparison etc. In different sectors different tools of ergonomic analysis are used. Some tools are specially designed to solve the problems in concerned field. Some researchers have carried out a same analysis with different tools in order to compare between tools and their concerned results. There are various aspects through which we can compare the tools. To decide a particular tool for solving a problem is somewhat a matter of expertness because to complete this it is necessary to consider lot of parameters like specific setting, accuracy needed, field of analysis ,data required, complexity, costs, and ease of use etc. This paper will help to understand the capabilities of a particular tool, comparison between various ergonomic analysis tools and their use in various sectors

Silvia A. Pascual *et al*. (2008), showed that most of the certified ergonomists used the Snook/Mital tables, the National Institute of Occupational Safety and Health (NIOSH) equation and rapid upper limb assessment (RULA)/rapid entire body assessment (REBA).Various ergonomics analysis tools are available for assessing exposure to risks associated with WMSDs. Analyses can be qualitative, semiquantitative or quantitative. Qualitative analysis tools gather basic observational data about a job. These analysis tools generally require the least amount of effort from the analyst. Job analysis checklists are an example. Simple ergonomics analyses assess whether a risk factor is present. Semiquantitative analysis tools include both judgment data and simple quantitative data, e.g., Snook tables, the American Conference of Governmental Industrial Hygienists (ACGIH),hand activity level (HAL),threshold limit value (TLV) [and the Washington Industrial Safety and Health Act (WISHA) ,hand–arm vibration analysis. These analysis tools require more effort from the analyst as well as knowledge of ergonomics. Quantitative analysis tools include the National Institute of Occupational Safety and Health (NIOSH) lifting equation, the Moore-Garg strain index and biomechanical analyses.

According to Lamkull *et al*. (2009), Digital Human Modelling System offers a set of analysis tools that can be divided in quantitative evaluation tools and semi-quantitative tools. Quantitative tools are used to evaluate working postures and physical workloads. These tools require as input the digital human models postures (representing an operator performing the task being analysed with some other information (i.e. age, health conditions, etc.) and they give as output quantitative results. These quantitative results can be related to several task characterization aspects, such as postural risk, spine compression forces, cycle time or energy expenditure, weight lifting limits, etc. Semi quantitative tools are used to visualize or analyse the digital human model interactions with the working environment and are usually integrated within 3D-CAD packages. Examples of semi-quantitative tools are field of vision, reach envelopes, and accessibility and clearance analysis.

G. C. David (2005) has worked on Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders. He has explained different ergonomic analysis methods with their main features and functions. He has made a comparison between different methods showing their abilities regarding Posture Load ,force, Movement, frequency, Duration Recovery Vibration etc.

The various ergonomic analysis methods and their features are as follow.

a. RULA

Lynn McAtamney and E Nigel Corlett developed the RULA method. It was first described in a 1993 issue of the journal Applied Ergonomics. RULA (rapid upper limb assessment) is a survey method developed for use in ergonomics investigations of workplaces where work-related upper limb disorders are reported. This tool requires no special equipment in providing a quick assessment of the postures of the neck, trunk and upper limbs along with muscle function and the external loads experienced by the body. A coding system is used to generate an action list which indicates the level of intervention required to reduce the risks of injury due to physical loading on the operator. It is of particular assistance in fulfilling the assessment requirements of both the European Community Directive (90/270/EEC) on the minimum safety and health requirements for work with display screen equipment and the UK Guidelines on the prevention of work-related upper limb disorders.

Chowdury M. L. Rahman (2014) stated that this ergonomic technique evaluates individuals' exposures to work postures, forces and muscle activities that have been shown to contribute to repetitive strain injuries (RSIs). Use of this ergonomic evaluation approach results in a risk score between one and seven, where higher scores signify greater levels of apparent risk. A low RULA score does not guarantee that the workplace is free of ergonomic hazards, and a high score does not assure that a severe problem exists. It was developed to detect work postures or risk factors that deserve further attention

Takala E-P *et al*. (2010) stated that, in the RULA method, positions of individual body segments are observed and scored, with scores increasing in line with growing deviation from the neutral posture. Summary scores are first calculated separately for both upper and lower arms and wrists and trunk, neck and legs, and then transformed to a general postural grand score. Additional weights are given to the postures according to forces/loads handled and the occurrence of static/repetitive muscular activity. These scores are then compared to tables stating risk on four levels and the actions needed (ranging from acceptable to immediate investigation and change needed).

b. REBA

A need was perceived within the spectrum of postural analysis tools, specifically with sensitivity to the type of unpredictable working postures found in health care and other service industries. This lead to the development of the postural analysis tool which is Rapid Entire Body Assessment, REBA. Sue Hignett *et al*. (2000) states that the development of REBA aimed to:
_ Develop a postural analysis system sensitive to musculoskeletal risks in a variety of tasks.
_ Divide the body into segments to be coded individually, with reference to movement planes.
_ Provide a scoring system for muscle activity caused by static, dynamic, rapid changing or unstable postures.
_ Reflect that coupling is important in the handling of loads but may not always be via the hands.
_ Give an action level with an indication of urgency.
_ Require minimal equipment - pen and paper method.

Takala E-P *et al*. (2010) states that REBA was designed as a quick and easy observational postural analysis tool for whole-body activities in healthcare and other service industries. The basic idea of REBA is similar to that of the rapid upper-limb assessment (RULA) method: positions of individual body segments are observed and postural scores increase when postures deviate from the neutral position. Group A includes trunk, neck, and legs, while group B includes upper and lower arms and wrists. These groups are combined into one of 144 possible posture combinations that are transformed to a general postural score (grand score).

c. Strain –Index

Takala E-P *et al*. (2010) stated that the strain index is a semi-quantitative job analysis method yielding a numerical score, which is intended to correlate with the risk of developing distal upper-extremity disorders. According to the index six task variables describing hand exertions must be observed and scored on five levels. The six variables include: (i) intensity of exertion, (ii) duration of exertion, (iii) exertions per minute, (iv) hand–wrist posture, (v) speed of work, and (vi) duration of work per day. Each score is then weighted based on physiological (endurance, fatigue, recovery), biomechanical (internal forces, nonlinear relationship between strain and intensity of effort), and epidemiological principles.

d. Jack

Peter Blanchonette *et al*. (2010) stated that the Jack human modelling tool (originally called Tempus) was developed at the Centre for Human Modelling and Simulation at the University of Pennsylvania in the mid-1980s by a team led by Dr Norman Badler . The main impetus for the development of Jack was to support the design and development of workspaces, with the emphasis on optimising the human machine interface. Funding for the development of Jack came from a number of sources, including significant support from NASA and the US Army.

Nicole Ronald *et al*. (2006) states that JACK is based on the BDI architecture and was purpose built for simulations, in particular defence simulations. The aim of the package was to develop a stable, lightweight and practical agent-based programming language that would not be superseded quickly and would facilitate further research. It is based on Java with a few syntactic extensions, and when compiled compiles to Java code . Java was chosen due to its widespread availability and acceptance. As the JACK files are compiled into Java before execution, normal Java statements can be embedded in JACK files.

e. Push-pull analysis

Norhidayah Hashim *et al*. (2014) has worked on push pull analysis in aerospace industries. An ergonomic design and analysis tool of computer-aided three-dimensional interactive application version 5 release 19 (CATIA V5R19) software were used to analyse the pushing and pulling activity associated with awkward posture of the workers. Besides that, the comfort level of working posture also measured using this tool. By using ergonomics analysis tool from CATIA V5R19, the pushing and pulling activity can be analysed. The analysis is used to analyse the maximum acceptable and sustainability force when workers push or pull each mould. Push-pull analysis is carried out to assess the awkward postures which occur during the push-pull activities in various sectors. Such activities are observed in aeroplane industries. The objective of analysis is to measure the maximum acceptable initial force and sustained force for push-pull activity while workers perform their tasks. It can also predicted which activity can endure longer between push or pull activity.

f. OWAS (Ovako Working Posture Analysis System)

Dohyung Kee *et al*. (2007) has made a study on OWAS. He stated that OWAS technique (Ovako Working Posture Analysing System) was developed by a Fininish steel company of Ovako Oy . The method is based on ratings of working postures taken in several divisions of one steel factory performed by 32 experienced steel workers and international postures found in health care and other service industries. The posture classification system, which includes the upper arms, lower arms, wrist, trunk, neck, and legs, is based on body part diagrams. The method reflects the extent of external load/forces exerted, muscle activity caused by static, dynamic, rapid changing or unstable postures, and the coupling effect.

Kumkum Pandey *et al*. (2012) stated that OWAS method allows estimating the degree of a worker's static load at workstation by analysing his posture. It is an analytical method which enables the improvement of ergonomic conditions at a workstation. It takes into consideration various positions of the back, shoulders and legs. It also includes the weight lifted by a worker. Each body position is encoded and categorized in four risk groups of static injuries. The method also requires the analysis of force exerted during work as well as the time of force influence in a defined position. Each of these factors has an attributed code value. On the basis of identified evaluation factors of the back, arms, legs position, and load one must determine position code. Each posture is defined by a four digit code. Sometimes there can be additional fifth element of the code which determines the head and neck position. Identifying four-digit body position code with OWAS method allows determining risk class of every workstation. According to OWAS method and basing on the body position code there are classes which reflect static load risk degree. Class 1 identifies body position as regular and natural; the load is optimal or acceptable. There is no need then to introduce changes to a workstation. Class 2 encompasses potentially hazardous postures which may have negative effects. Static load is practically acceptable which indicates future assumption of certain means in order to improve working conditions as well as to change methods and manners of performing the job. Class 3 points out a clearly hazardous influence of body posture, while static load is fairly large. Actions must be taken promptly which should improve working conditions and methods.

Nilgun Figlal *et al*. (2014) stated that OWAS is one of the methods for analysing working postures and can be applied to very diverse areas successfully. I-OWAS begins with separating the video film into frames, producing OWAS codes belonging to working posture in each frame, and then classifying the images according to risk categories. Despite OWAS being a successful method for analysing working postures, it requires an expert analysis. Also the manual analysing process is so laborious and time consuming. I-OWAS provide the computer support for the manual coding stage and eliminates the need for an expert analyst; hence, the method can be widely used in industry.

g. Anybody

John Rasmussen *et al*. (2003) stated the history of origin of Anybody. In the late nineties, a group at the Institute of Mechanical Engineering at Aalborg University was studying the design of bicycle frames for optimum performance. It transpired over a period of time that the problem is ill posed unless the model includes the rider. In other words, the bicycle and the rider form one machine, and one part cannot be optimized in the absence of the other. Inspired by the bicycle design problem, a group comprising experts within multibody dynamics, biomechanics, physiology, design optimization, mathematics, and software engineering was established. The group developed three major versions of a software system for modelling the human musculoskeletal system:

a. A hard-coded, procedure-oriented prototype distinctly developed for optimization of bicycles. This prototype demonstrated the feasibility of the basic numerical methods. b. An object-oriented prototype capable of handling different models by means of object definitions, albeit still hard-coded into the software. This version was used for optimization of a handsaw and a tricycle for paraplegics. c. A version capable of handling object-oriented models in a specially developed model description language. In this version, users can develop their own models, and models can be combined and easily exchanged between users. The system was named AnyBody to reflect its ability to model any body the user desires.

AnyBody Modelling System, is a unique tool for analysis of the musculoskeletal system of humans or animals. It compute muscle forces, joint reactions, metabolism, mechanical work, efficiency, etc. for given movements. Any property of the AnyBody model is parametric, and the system can be used for optimization. This means that AnyBody can determine movement patterns, working positions, anthropometric data, boundary conditions etc. This technique is called as inverse-inverse dynamics. It uses an inverse dynamics optimization technique to solve the muscle recruitment problem and reverses this by means of other optimization techniques so that forward dynamics problems can also be treated. It is object-oriented and developed in C++. It runs on the MS Windows platform. A cross-platform version of the system is being considered. Graphics display is based on OpenGL. It handles very large models on small computers. It is entirely feasible to analyze a model with several hundreds of muscles on an ordinary PC. Models are developed in the body modelling language AnyScript.

h. Plibel

Kristina Kemmlert (1995) has first time gave the introduction of PLIBEL-A method assigned for the identification of ergonomic hazards. A checklist is presented for the identification of ergonomic hazards, with relevance to different body regions. Literature on the association between certain work characteristics and occupational musculoskeletal disorders was studied, and relevant items were chosen for the checklist. The method was tested for validity through workplace observations performed with the checklist and a well-documented method (AET). The agreement between matching items was considerable. The inter-observer reliability yielded kappa values expressing a fair to moderate agreement. The applicability of the method is demonstrated through references to studies where it has been used.

BELLIAPPA C.C. *et al*. (2014) has carried out a study of ergonomic analysis tools for the assessment in garment industry. He states PLIBEL is a simple checklist screening tool intended to highlight musculoskeletal risks in connection with workplace investigations. Time aspects as well as environmental and organizational considerations also have to be considered as modifying factors. A workplace assessment using PLIBEL starts with an introductory interview with the employee and with a preliminary observation. The assessments focus on representative parts of the job, the tasks that are conducted for most of the working hours, and tasks that the worker and/or the observer look upon as particularly stressful to the musculoskeletal system. Unusual or personal ways of doing a task are also recorded. When an ergonomic hazard is observed, the numbered area on the form is checked or a short note is made. In the concluding report, where the answers are arranged in order of importance, quotations from the list of ergonomic hazards can be used. Modifying factors duration and quantities of environmental or organizational factors are then taken into consideration. Usually PLIBEL is used to identify musculoskeletal injury risk factors for a specific body region, and only questions relevant to that body region need be answered. It observes a part, or the whole, of the body and summarizes the actual identification of ergonomic hazards in a few sentences. It is simple and is designed for primary checking. For labor inspectors and others observing many tasks every day, it is certainly enough to be equipped and well acquainted with the checklist. PLIBEL method is a general assessment method and is not intended for any specific occupations or tasks.

Takala E-P *et al*. (2010) stated that PLIBEL is a simple checklist, intended as a rapid screening tool of major ergonomic risks which may have injurious effects on the musculoskeletal system. Time aspects and environmental and organizational factors are also included as hazard modifiers.

i. NIOSH Survey

BELLIAPPA C.C. *et al*. (2014) stated that NIOSH Survey is a self-report method allows the ergonomist to easily assess measures of musculoskeletal discomfort in numerous body regions, such as the intensity, frequency, and duration of discomfort. Two different display formats have been used for identifying body parts in the NIOSH studies. For nearly one half of the studies partial-body diagrams provided multiple views of designated regions of interest. Each of these targeted regions was accompanied in the survey with a series of questions and rating scales for assessing multiple facets of discomfort at that location. In most of the remaining studies only a single attribute of discomfort (usually intensity) was rated. The survey begins with a single question that screens for the presence of one or more of six symptoms (pain, aching, stiffness, burning, numbness, or tingling) in each body region. An affirmative response is then followed by a rating of this problem using as many as three severity measures (duration, frequency, and intensity). Research has shown the NIOSH survey to be sensitive to a wide range of physical stressors across many occupations, and to have prognostic value for more objective measures of musculoskeletal disorders. Widely used in health and safety practices, anthropometric surveys.

j. Muscle Fatigue Assessment: Functional Job Analysis Technique

BELLIAPPA C.C. *et al*. (2014) stated that this muscle fatigue assessment method (MFA), also known as the functional job evaluation technique, was developed by Rodgers and Williams (1987) to characterize the discomfort described by workers on automobile assembly lines and fabrication tasks. The MFA method can define which jobs might be appropriate for people to work on for a short term during initial return-to-work after an injury or illness. By rating all body parts on a task, those tasks that might exacerbate a muscle or joint problem can be separated from those tasks that should be acceptable for the injury or illness of concern during a short term rehabilitation period. This reduces the need for general work restrictions and minimizes the chance of re injury. MFA identifies fatigue-producing patterns of work and shows how to improve them and prioritizes these improvements. MFA is less effective if done by one analyst rather than a team of people on the production floor. It is very sensitive but not very specific in detecting the potential MSD (musculoskeletal disorder) risks.

k.RAMSIS

Peter Blanchonette *et al*. (2010) stated that the realistic anthropological mathematical system for interior comfort simulation (RAMSIS) model was developed in the late 1980s. It was developed as a co-operative arrangement between German automobile manufactures, Tecmath and the Technical University of Munich, Germany.

l. The HUMOSIM ergonomics framework

The HUMOSIM ergonomics framework is a modular system of algorithms that function together to produce realistic human motion in a wide variety of task scenarios. Matthew P. Reed has worked on this at the Human Motion Simulation laboratory at the University of Michigan was founded in 1998 with the goal of improving motion simulation in digital human models. HUMOSIM framework has been guided by a set of Principles such as modularity, algorithmic, behaviour based, coordination, robustness, integrated analysis etc. In HUMOSIM the background on selected modules include Head motion, Hand trajectory, Upper-Extremity Inverse Kinematics , Torso Motions, Lower-Extremity Motions, Reach and Object Transfer Effort and Difficulty , Biomechanical Analysis, Dynamic Environments etc. The HUMOSIM ergonomics framework encompasses many individual innovations in motion simulation algorithms, but the primary innovation is in the development of a comprehensive system for motion simulation and ergonomic analysis that is specifically designed to be independent of any particular human modelling system. Nonetheless, the current diversity of research in human motion simulation will benefit the framework, because the modular structure allows the components to be continuously improved as better algorithms or more validation data become available.

3. Relative comparison of tools

Nopparat Manavakun *et al*. (2004) has made a comparison between the OWAS and REBA observational techniques for assessing postural loads in tree felling and processing. He revealed that postural load by REBA was generally higher than by OWAS. In his study only about 22.6 % of 248 postures were classified at the action category 3 or 4 by OWAS, about 72.6 % of the postures were classified into action level 3 or 4 by REBA. Its study implied that OWAS underestimated posture-related risk compared to REBA.

Silvia A. Pascual *et al* (2008) showed that the certified ergonomists' ratings of how easy it was to use the ergonomics analysis tools on a regular basis. The scale ranged from 1 to 5 with 1 representing an easy ergonomics analysis tool that anyone could use and 5 representing an ergonomics analysis tool that could only be used by expert ergonomists. The results show that the certified ergonomists surveyed felt that the biomechanical models, ACGIH HAL TLV and anthropometric tables were the most difficult to use (4—difficult, need an ergonomics background). The WISHA caution zone checklist and risk assessment checklists were rated 2 (fairly easy, can be used by anyone with limited ergonomics knowledge). The ergonomists felt that these were the easiest tools to use.

Dohyung Kee *et al*. (2007) stated that OWAS and Reba divide leg postures into relatively more classes of seven or four where Rula with only two classes of leg posture. The results from his study showed that regardless of industry, task type, and body balance, OWAS and REBA underestimated posture-related risk compared to RULA. The inter-technique reliability for postural loads between OWAS and RULA was much lower than that between RULA and REBA, and OWAS and REBA for study.

Patrik Polasek stated that in case of Carry (Manual Handling Limit) analysis the one made in Delmia was more accurate, because concrete height of manipulation was deducted from the digital human model. On the other hand Lift-Lower (NIOSH) analysis was more accurate in Tecnomatix Jack where the aspect of recovery time and detailed object grip settings could be incorporated in the calculation. In case of Carry (Manual Handling Limit) analysis in Delmia the height of carrying is deducted from actual height of digital human model hands, in case of Tecmonatix Jack the height is stated by the user that inputs the right data. Delmia also uses interpolation for calculating the result values, Tecnomatix gives us only the border values.

Troy Jones *et al*. (2010) has assessed five ergonomic risk assessment tools (rapid upper limb assessment [RULA], rapid entire body assessment [REBA], American conference of governmental industrial hygienist's threshold limit value for mono-task hand work [ACGIH TLV], strain index [SI], and concise exposure index [OCRA]) for output in four sawmill job. The study has demonstrated the limited agreement between published ergonomic risk assessment methods used to assess four at risk sawmill jobs. Considerable variation in the ability to identify at risk jobs as at risk was identified between methods. Variation in agreement present when the jobs were considered individually indicates the appropriateness of the methods may be affected by the exposure profile of the job. Of the methods examined, the RULA and SI were best (correct classification rates of 99 and 97% respectively). The quantitative ACGIH-TLV for monotask hand work and Borg scale were worst (misclassification rates of 86 and 28% respectively).

Fernanda Diniz de Sa *et al*. (2006) evaluated posture stress in Odontology students by means of RULA and REBA methods. The research instruments had been two software's of evaluation of work positions. The work situation used for this comparison was an odontological assistance service, developed by students of the Odontology course, at Federal University of Paraiba. The RULA method has presented a better sensibility to detect fast and urgent action levels, knowing that during the analysis, using both methods, the RULA one has detected a bigger proportion of postures in these categories than the proportion detected by the REBA method . It is explained by the fact that the in the dentists work, during a bigger part of the time, using the top superior part of the body, exactly the evaluation focus of the method RULA.

Takala E-P *et al*. (2010) found from his study that, OWAS results were clearly different from those obtained by the NIOSH lifting equation probably due to the different basic approaches of these two methods.

Dhananjay Singh Bisht *et al*. (2013) studied on ergonomic assessment methods for the evaluation of hand held industrial products. The paper presents a sound discussion on various techniques / tools adopted by the researchers for the design/redesign of hand held industrial products, which increases performance, as well as comfort in arms, shoulder and different arm regions.

Pamela McCauley Bush *et al*. (2012) has worked on a comparison of software tools for occupational biomechanics and ergonomic research. The purpose of his study was to evaluate and compare commercially available software tools in ergonomics and biomechanics research. The project provides a survey of selected biomechanical software tools and also gives a detailed analysis of two specialized packages, 3DSSPP and JACK as well as examples of applications where one or the other may be better suited. He found that the results of the two software packages can produce different results that sometimes lead to conflicting conclusions about the safety of a given task. Differences in results may be a factor of the higher degree of freedom of joint movement that is possible by manually manipulating of the postures in 3DSSPP, which may allow the manikin to pose in a sometimes unnatural and improbable manner. JACK seems to do a better job of only allowing realistic human contortions. Despite the biomechanical conflicts, the two software packages did produce relatively similar results in the ergonomic assessment of risk associated with each task. Evaluating the software's assessment of tasks, based on the overall risk score, the researchers find that the packages are relatively consistent.

N. A. Ansari *et al*. (2014) has carried out evaluation of work Posture by RULA and REBA. The results found that workers are under moderate to high risk of musculoskeletal disorders. The RULA method determined that the majority of the workers were under high risk levels and required immediate change. The REBA method determined that some of the workers were under lower levels and majority at high risk levels. Evaluation using postural analysis by RULA and REBA indicates that the workers are working above the secure limit. The major percentage of the workers having awkward postures.

Tarwinder Singh *et al*. (2014) has made a study on Ergonomic Evaluation of Industrial Tasks in Indian Electronics Industries. He carried out RULA and REBA analysis. Results showed that activities found in electronic industries may result in high risks and potential injuries to the workers.

Gurunath V. Shinde *et al*. (2012) has studied on acomputer based novel approach of ergonomic study and analysis of workstation in a manual process. This study of ergonomics includes application of various kinds of IE tools like fishbone diagram, time study, motion study, SIMO chart, WHY-WHY sheet etc.

P. Wintachai *et al*. (2012) has carried out the comparison of ergonomics postures assessment methods in rubber sheet production. According to the results from RULA and REBA methods, it was found that the postures assessed using these methods display a high level of risk and required immediate correction or work adjustment. For the OWAS method, the result indicated that the working postures during the formic acid and rubber latex mixing process create a high risk. The RULA, REBA and OWAS assessment result showed that many working postures in the study are at risk.

Phillip Drinkaus *et al*. (2003) has made comparison of risk assessment outputs from RULA and Strain Index in automotive assembly plants. The outcomes of each tool were compared for each task. This study compared only the ergonomic risk outputs from each tool; it does not pursue the question which tool best predicts injury.

Jennie J Window (2006) has worked on validity of using quick ergonomics assessment tools in the prediction of developing workplace musculoskeletal disorders. The purpose of this study is to test the validity of quick ergonomics assessment tools by comparing the results of the posture risk analysis obtained from the Rapid Entire Body Assessment (REBA) and Manual Task Risk Assessment Tool (ManTRA) with historical injury data from an employer and industry data collected by WorkCover South Australia.

4. Statistical analysis of the papers

Table 1: Studies carried out for specific ergonomic evaluation tool

Sr.No.	Tool studied	Major Study	Reference
01	RULA	A survey method for the investigation of world-related upper limb disorders.	Lynn McAtamney and E Nigel Corlett, [1993]
02	REBA	Introduction to the method	Sue Hignett *et al.* [1999]
03	PLIBEL	Method assigned for identification of ergonomic hazards	Kristina Kemmlert [1995]
04	THERMOGRAPHY	Ergonomic analysis of a work station in the foundry industry	Marcelo Gonçalves Trentin *et al.* [2012]
05	HUMOSIM	Digital human simulation for ergonomic analysis	Matthew P. Reed *et al.* [2006]
06	I-OWAS	Image processing-aided working posture analysis	Nilgun Fıglal *et al.* [2015]
07	STRAIN – INDEX	Semi-quantitative job analysis method	Takala E-P *et al.* [2010]
08	JACK	Design and development of workspaces for optimising the human machine interface	Peter Blanchonette *et al.* [2010]
09	ANYBODY	Analysis of the musculoskeletal system of humans	John Rasmussen *et al.* [2003]
10	NIOSH SURVEY	Method that allows the ergonomist to easily assess measures of musculoskeletal discomfort in numerous body regions	BELLIAPPA C.C. *et al.* [2014]

Following is the analysis of use of tools in a particular industry occurred in the review.

Table 2 Use of ergonomic analysis tools in various applications

Sr.No.	Tools Used	Industry/Organization	References
01	RULA	A. Agricultural (Maize Sheller) B. Automobile (Truck Drivers) C. Stamping Industry	R. T. Vyavahare *et al.* (2015) M. Massaccesi *et al.* (2003) Seri Rahayu K
02	REBA	A. Forging Industry B. Wire-tying hand tools.	Surinder Singh *et al.*(2013) Kai Way Li (2003)
03	PLIBEL	A. Garment Industry	Belliappa C.C. *et al.* (2014)
04	THERMOGRAPHY	A. Metal casting	Marcelo Gonçalves

		B.Manual moulding and finishing.	Trentin *et al.* (2012) Guimaraes (1998)
05	HUMOSI M	A. Motion simulation in digital human models	Matthew P. Reed [1998]
06	OWAS	A. Steel ,iron industry B. Construction site C. Brick manufacturing	Dohyung Kee *et al.* (2007) Tzu-Hsien Lee *et al.* (2014) Kumkum Pandey *et al.* (2012)
07	JACK	A. Defence Simulation	Nicole Ronald *et al.* (2006)
08	NIOSH SURVEY	A. Health and safety practices	Belliappa C.C. *et al.* (2014)

5. Preferences of tools

Dohyung Kee *et al*. (2007) stated that each technique has its own strengths and weaknesses depending upon the industries or assumptions made. He states that OWAS originally developed in the steel industry, OWAS was known to be suitable for manual materials handling tasks with high biomechanical lowback loading frequently performed in the iron and steel industry. But according to study he made he found that compared to RULA, OWAS failed to correctly identify high biomechanical low-back loading.

Tzu-Hsien Lee *et al*. (2014) has worked on an analysis of a construction site by using OWAS method. M. Rabiul Ahasan *et al*. (1996) has also used the OWAS method to analyse the Small industry workers involved in manual handling operations. M. Arip Wahyudi *et al*. (2015) also used OWAS method for Work Posture Analysis of Manual Material Handling. Kumkum Pandey *et al*. (2012) also used the OWAS for the analysis of awkward posture in a brick manufacturing industry. The OWAS method for postural data analysis proved to be a very useful way to reduce postural load of dynamic brick making tasks, and allowed for efficient application of the original OWAS method. The OWAS method is used to solve the problems in the field of steel industry, agricultural, fishing industry, Chemical plants, ship maintenance etc.

Sue Hignett *et al*. (2000) stated that Ovako Working posture Analysis System has a wide range of use but the results can be low in detail. In contrast NIOSH requires detailed information about specific parameters of the posture, to give high sensitivity with respect to the defined indices, but has a limited application in health care in particular with respect to animate load handling.

Matthew P. Reed has made a study on critical features in human motion simulation for ergonomic analysis. He states that each DHM software packages has different ranges of motion and the definitions of joint Range Of Motions are inherently tied to the joint-angle definitions each model uses. The intuitive perception of realistic joint motion is apparently keyed not to the average joint ROM typically implemented in DHM, but rather to extreme values, beyond which a posture is seen as unrealistic. This creates a situation in which the default figures in DHM packages typically cannot achieve the range of postures that most individuals can.

Francesco Longo *et al*. (2011) stated that DHMS based approach for workstation design has been used also in some minor sectors, where usually research activities on this specific topic are very limited. Zhang *et al* (2010) present an approach for the workplace redesign on board fishing vessels in order to increase safety for fishermen. First, the equipment and procedures for catching, handling, and storing fish are studied so that risks can be identified and assessed. Then the work postures are simulated using the ergonomic digital human modeling system ManneQuin Pro (by NextGen Ergonomics, a PC-based, 3D human modeling software package).

Deogratis Kibira *et al*. (2002) have worked on virtual reality simulation of a mechanical assembly production line. In this the simulation model was constructed using three software applications. A CAD package was used for modelling the geometry of components. The two simulation tools were used to model individual station operations and the overall flow of the line. The synergistic effect of different software applications provided a platform upon which the simulation model of the manufacturing system was built. The applications that were used were QUESTR, for discrete event modelling, IGRIPR and the ERGO Option for script development and animation of work cell operations, AutoCADR, a computer-aided design application for object modelling.

Marcelo Gonçalves Trentin *et al*. (2012) stated that thermography has been increasingly used in various areas of knowledge. Equipment, components and systems are still the main focus of this technique. Currently items of thermographic equipment have become more accessible thus enabling new applications. His paper explores thermography as a means to make an ergonomic evaluation of a job in metal casting, an area that involves activities that are energy sapping wearisome and uncomfortable for workers. Use was made of the method of macro-ergonomic analysis of work proposed by l, in a medium sized industry, in the sectors of manual moulding and finishing.

R. T. Vyavahare *et al*. (2015) has made ergonomic Evaluation of Maize Sheller cum Dehusker by using the RULA analysis. M. Massaccesi *et al*. (2003) has made RULA analysis of work-related disorders in truck drivers. In this first RULA study of the working posture of professional truck drivers, the method proved to be a suitable tool for the rapid evaluation of the loading of neck and trunk. Seri Rahayu K *et al*. has worked on design and analysis ergonomics workstation in stamping industry. The productivity of the company before and after improvement is calculated using mathematical equations. After redesign the workstation, the RULA scores of the worker's working postures improved. Nilufer Ozturk *et al* (2011) has carried out RULA analysis of ergonomic risk factors among female sewing machine operators in Turkey. Er. Surinder Singh *et al*.(2013) has a Proposed REBA on Small Scale Forging Industry. The results show that the operators are working in an inadequate working environment with awkward postures the results are supported by the subjective assessment of discomfort. Kai Way Li (2003) has worked on Ergonomic evaluation of a fixture used for power driven wire-tying hand tools.

Imtiyaz Shaikh *et al*. (2004) have worked on the participatory ergonomics using VR integrated with analysis tools. He states that Jack provides a Motion Capture Toolkit to configure and use virtual reality (VR) devices. It was observed that loading of the entire virtual environment in Jack slows down the application significantly. A feeling of immersion is attained only when the entire surrounding environment is loaded, including the work station, parts involved, tools used, bins, fixtures and other objects in the environment. Therefore, the real-time immersive VR evaluation performance of Jack was deemed to be inadequate by itself. Jack's main functionality of ergonomic analysis tools can be better utilized with another application whose main functionality is to provide the capability for immersed visualization. Thus, the two applications, VADE and Jack, can be used concurrently to leverage the functionality strengths of each, without inducing significant overhead in either application.

Nicole Ronald *et al*. (2006) stated that JACK has been used for several applications, mainly within defence, however it has a strong reputation worldwide both in research and industry. The intended users of JACK are people with knowledge of agent-based applications, concurrent object-oriented programming and software engineering.

Min K. Chung *et al*. (1999) have carried out Evaluation of lifting tasks frequently performed during fire brick manufacturing processes using NIOSH lifting equations. The results suggest that the tasks should be redesigned ergonomically to eliminate the risk factors that may cause low back injuries.

Patrik Polasek *et al*. (2014) have studied on two simulation tools Delmia and Technomatrics Jack. From the survey he carried out, he found that Ramsis is mostly suitable for designing an interior of cars. He stated that the core part of both Delmia and Tecnomatrics Jack software is material handling and work position evaluation. Peter Blanchonette *et al*. (2010) states that the RAMSIS is used extensively in the automotive industry for the design of vehicle interiors and exteriors, by companies such as Audi, Volkswagen, Daewoo, Ford, Honda, Mazda and Renault. In the Australian automotive industry, Ford Australia has used RAMSIS for a number of years, the tool being extensively used during the development of the BA Falcon. He also states that Jack is used across a broad range of industries by companies and organisations such as John Deere, BAe Systems, NASA and the US Army.

Conclusion

This paper reviews a various ergonomic analysis tools and their comparison with each other. All tools have their own parameters for analysis. Though all are carrying ergonomic analysis, it may might impossible to carry out a same analysis in all tools due to their uniqueness. Through the study carried out, it is observed that differentiation of tools on the basis of their advantages is quite tough. It is difficult to make a comparison between all the tools and determining the one because no single tool have a clear advantage over any other. So while selecting a particular ergonomic analysis tools, it is necessary to define all parameter like specific setting, accuracy needed, field of analysis ,data required, complexity, costs, and ease of use etc. Tools used in industry, medical field and for general purpose are usually require a certain anthropometric data and according to that RULA, REBA, OWAS, PUSH-PULL analysis are carried out. Certain tools like PUSH-PULL analysis are mainly used for push pull activity in aerospace industries. So while selecting an ergonomic analysis tool for solving a problem, it is necessary to go through all the parameters to have an optimum solution.

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