IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 21, Issue 3 Ser. 1 (May. – June. 2024), PP 03-15
www.iosrjournals.org

Work-Related Musculoskeletal Disorders Among Indian Construction Workers And Multi-Disciplinary Solutions – A State Of The Art Review

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Abstract
Introduction: *The knowledge of evaluation method can save time and efforts of the ergonomist and researchers. This will help to select proper tool and techniques for the assessment of ergonomic risk.*
Objectives: *This paper aims to review 1) the previous work done for the development of different assessment methods emphasizing from oldest to newest/latest developed methods and 2) work done in the area of construction for assessment of ergonomic evaluation for construction worker and workplace.*
Methods*: To achieve this, internet materials since 1970 to 2020 searched to find the different methods used to assess physical exposure using Google search, Google Scholar, Research gate, Science Direct, Scopus and Academia etc. From 408 articles, 210 articles were chosen for screening of which 210 articles were thoroughly screened and 179 articles refer for the review which are related to the research work.*
Results: *Nearly 91 articles were found related to construction work and assessment of ergonomic risk. The first evaluation was performed on construction in 1993. There were various methods developed for the ergonomic risk evaluation. These method are 1) self-report method, 2a) simple observational method, 2b) advance observational method, 3) direct measurement methods (which includes IMU's, Biomechanical, Remote sensing method and vision based method) and 4) Computer modelling method (Software and Hardware based). In this paper, the all available methods tried to explore with emphasizing on the development of application of latest one and found that ample of researcher used direct measurement methods using all integrated sensor and devices.*
Conclusions*: From the study, it is revealed that though various methods are available for exposure evaluation, a single method cannot solve the problem with their limitations. It will be better to have knowledge of all the methods available so that proper method can be selected as per requirement. For construction workers evaluation self-reported, simple observational are best suited for primary investigation, for detailed investigation direct measurement methods can be implemented as per requirement and computational modelling methods can be used for modeling and analysis of variations.*
KeyWords: *Ergonomics, construction; work-related musculoskeletal disorders; multi-disciplinary solution*

Date of Submission: 24-04-2024 Date of Acceptance: 04-05-2024

I. Introduction

A work-related musculoskeletal disorder (WRMSD) is a distressing disorder of muscle, tendons, nerves, joints, cartilage and ligaments tissues which are exposed to ergonomics risk. Ergonomic risk includes working in awkward postures, improper working sites, forceful exertion, heavy lifting or lowering, repetitive work movement, static and dynamic working condition, extreme cold and heat, frequency of work, lack of recovery time, vibration, contact stress, improper tool design, improper working techniques, duration stress and carrying multiple jobs. Work-related musculoskeletal disorders never build up at a glance, but it developed over the time. From the literature it is evidence that there is a close relation between physical exposure and musculoskeletal health. This relationship is due to awkward posture, force, repetition of work, vibration, static Load, contact stress and extreme temperature, fatigue, and cumulative load of on workers body. The Biomechanical exposures, Psychosocial stresses and Individual risk factors are the main risk factors causes WRMSD due to Physical Exposure[1].

Again, from the definition of NIOSH "WRMSD are those diseases and injuries affecting the musculo-skeletal, peripheral nervous, and neurovascular systems that are caused or aggravated by occupational exposure to ergonomic hazards ….Ergonomic hazards relative to WRMSDs refer to physical stressors and workplace conditions that pose a risk of injury or illness to the musculoskeletal system of the worker. Ergonomic hazards include repetitive motions, forceful motions, vibration, temperature extremes (especially cold), and awkward posture caused by improper design of workstations, tools or equipment, and improper work methods."[2].

Every tasks has a risk, any type of risk or pain or disorders in the body is the early sign of WRMSD that can lead to serious injury or health problem. Pain or disorder for prolong period can reduce the quality of life. It is important to identify and categorized the risk will help to reduce exposure of risk[3].

cho et at., 2018 pointed out that 16% construction workers have WRMSD than other workers[4], Mgbemena et al., 2020 pointed out 41% construction workers have WRMSD in 2015-2016 and 40% of WRMSD for upper limb and 53% for lower back have been reported from 2009-2016 for MMH[1], Jebelli et al., 2018 pointed out that 68 % workers are suffering from excessive stress[5], Rahman et at., 2018 pointed out that 40% worker claimed for WRMSD claims for lower and upper back problem in Australia (2000-2013)[6], Yan et al., 2018 reported that 56% rebar workers suffering from low back problem in US7. Kim, In-Ju., 2017 reported that 25 % workers complaint about backache and 23% workers complaints for muscular pain in European Union countries whereas in US absenteeism is the biggest problem due to WRMSD[8]. Wang et al., 2015 reported that 33% of occupational injuries and illnesses accounting for WRMSD and absentees in US[9]. According to ILO, 35-40% fatalities occurs in construction work from the 10% of total work force[10].

Due to this, the loss of days in construction work is 34% in Great Britain[1] and 40% in US[11]. In India, every year nearly 48000 workers die due to work related accidents[11]. Out of these 48000 alone construction are contributes 24.2%[12]. Also the study of patel et al., 2016 revealed that as per census 2011, 53,45,5595 people were employed in 2012 in the construction sector all over India and 24.4 % construction workers dies due to occupational injuries and accidents which is more than UK, Singapore and Taiwan's fatality rate[13].

Ergonomics, on the other hand, meant for fitting the task to the individual and not the individual to the task means encouraging compatibility between human and work system. As per the definition of ergonomic given by Fernandez , J.E. "The design of the workplace, equipment, machine, tool, product, environment and system, taking into consideration the human's physical, physiological, biomechanical and psychological capabilities and optimizing the effectiveness and productivity of work systems while assuring the safety, health and wellbeing of the workers." , the objective of human factor and ergonomics is to give secure and productive workplace to the individual comfort. Also, the healing treatment of WRMSD is costlier hence it is necessary to take precautionary measures before it's too late[3,1].

The construction workers are under occupation risk whose main effect can observe on functional impairment, loss of productivity or permanent disability which is mainly because of biomechanical risk factors. Prevention can minimize the problem of exposure but it should be taken when it alarms[14]. This is only due to physical exposure and overexertion of the workers due to need of money. This now a day's causing problem of non availability of construction workers and labourers in India. The present data shows that the Indian workers are at the significant level of physical exposure of work-related musculoskeletal disorder in construction work they do. They are at the 50 percentage higher level than the other workers. An acquaintance of accurate physical exposure is essential for selection of proper assessment tool and for remedies of work-related musculoskeletal disorders. Assessment of WRMSD is crucial part of ergonomics and human factors to minimise WRMSD and improvement of health that can be achieved through proper knowledge of risk and techniques of solving it. Indian construction is basically depends upon the manual work. About more than 90 percent of construction work in India carried out manually in hazardous condition. In India, construction work is the only work which is carried out and jobs are available throughout the year in which skilled, semi-skilled or un-skilled workers' works. Construction work is a worker exhaustive and cannot depend on machine.

Further, the results of this study can be used to target specific hazardous tasks for ergonomic interventions and confirms the need to use a task-based exposure assessment strategy to properly assess ergonomic risk profiles for non structured jobs such as construction[15]. The Health and physiological aspect imbalance posture and postures are affected by different aspects like anatomy, age, physiology, pathology, occupation, recreational, environmental, social/cultural and temporary adopted postures[16].

Abundance of work has been carried out to assess the physical exposure and work-related musculoskeletal disorder in construction workers in different areas all over the world and found that the construction workers are suffering from WRMSD tremendously. In this review paper, the aim of the paper is to review 1) the previous work done for the development of different assessment methods emphasizing from oldest to newest/latest developed methods, 2) work done in the area of construction for assessment of ergonomic evaluation for construction worker and workplace.

II. **Methods**

Even since the data was available, articles were searched from the electronic database to identify the ergonomic risk assessment techniques and research carried out on postural evaluation of construction workers. The articles searched from 2020 and gone back up to 1970. The articles search was carried out on Google search, Google Scholar, Research gate, Science Direct, Scopus, Academia etc. The key words used for the search was "Postural Analysis", "Postural assessment methods", "Construction", "Work-related Musculoskeletal Disorders", "Ergonomic in Construction", "Postural assessment of construction workers", "Computer method for ergonomic", "Digital human model and postural evaluation in construction " "Observational" and "combination" etc.

Total 408 articles were found form 1974 to 2020 out of which 210 articles were selected for further screening which also includes some review articles also. From these articles different methods and technique identified those are used for the ergonomic risk assessment. From the review it is found that the development of assessment methods stared from 1974 till present, however research also reveals that it has been started early in the 1900 century. Total 210 articles were thoroughly screened from which articles related to development of evaluation methods and articles related construction and others are being separated. Total 91 articles found related to construction work and assessment of ergonomic risk on construction worker which are again thoroughly screened and found that the first assessment was done by Mattila et al., 1993 on construction worker in 1993 using Computerized OWAS[17].

III. Result

Construction work and related risk factors:

From the study, it is revealed that Indian construction workers are working under heavy risk; lift heavy load and work under heavy stress and unpleasant conditions lead to the development of work-related musculoskeletal disorder. The construction workers are not entirely skilled but gain knowledge and skills from on-site working and experience.

The workers are classified in three types

1) Unskilled workers: Unskilled worker are those who worked as a labour to the skilled workers. Basically they are called as "Coolie".
2) Semi-skilled workers: Semi-skilled workers are those who assist the skilled workers and some time work as a skilled worker for all occupations.
3) Skilled workers: Skilled workers are those who is trained in his work. They are Brick Mason/Brick layerer /Plasterer/ concreting, Rebar workers, Form workers, Electricians, Plumbers, Tilers, Painters, and Carpenters etc.

Risk Evaluation Techniques:

Over the years, many tools and techniques have developed for the assessment of ergonomic risk. These techniques have been developed for the detection of risk factors and reduction of risk, hazard and providing safeguard to the human beings.

From the literature, it is found that development of ergonomics assessment tools has been stared in 1970 century but other method like video recording was used early in the 1900 century. Formerly, different evaluation methods have been developed for the correct and reliable assessment of ergonomic risk factors. These methods are categorized in different communities like 1) self-report method, 2a) simple observational method, 2b) advance observational method, 3) direct measurement methods (which includes IMU's, Biomechanical, Remote sensing method and vision based method) and 4) Computer modelling method (Software and Hardware based)[9, 18, 19].

For the accurate risk assessment, correct method is required to be selected because ergonomic interference and suitable tool selection will provide greatest outcome to select the level of risk exposure to work-related musculoskeletal disorders.

The technique had been adapted in many areas like health and social activities, manufacturing industries, Automobile, dairy, textile, leather, metal, agriculture, livestock, fishing, forestry, transportation, inventory management system, administration, teaching, artistic, entertainment, sports, Wood, water supply and many more[20,21,22].

1) Self-Report Method:

A self-report method that was primarily developed for the assessment of WRMSD in a wide variety of ergonomics risk which includes diaries, interviews, questionnaires, self evaluation, check list, body map, etc.[18,23,24,25,26,27] The method can be used to collect data directly from the workers using diaries, face to face interviews, questionnaires and video recording. This method is use to collect physical as well as psychosocial aspect[18]. Formerly, many questionnaires also have been developed for the assessment of WRMSD in which NMQ[21] and rating scale like Borg scale[10,28,29] are the popular tool. The Nordic musculoskeletal Questionnaire does not differentiate symptoms of self report of work-related or non-work-related and need to be carried out cautiously since this is survey based technique[30]. Many development has been made with time in these methods[31, 32, 33, 34].

This method help to collect data regarding demographic variability, sign, symptoms and level of pain or discomfort, physical observation by visiting to site or workplace and allowing for video recording for future reference. The method is simple and easy for variety of work with minimum investment, but need to visit many place to collect large amount of data and difficult to rely on data because of variation in individuals experience and subjective in nature.

2) Simple Observational Method:

Observation method is a systematic observation of working postures at workplace with the help of assessment sheet. Several numbers of simple observational methods have been developed in last five decade and before. The observational methods were developed for the efficient recording of workplace exposure using experience observer and worksheet[18]. The different observational method provides different exposure factors i.e. some method provides exposure to body parts and some provides critical exposure like load/force, coupling, task duration, intensity, vibration, contact stress etc[27].

The simple observational methods are POSTUREGRAM, Posture Targetting, HAMA[23], CHECKLIST, Strain Index, OCRA, Manual Handling Guidance L23, FIOH Risk Factor Checklist, ACGIH TLVs, LUBA, Upper Limb Disorder Guidance HSG60, MAC[18], OWAS, RULA, NIOSH, PLIBEL, QEC, REBA[18,23], POSTURE ANALYSIS[35], FSS[36], PErforM[37], MAPO[38], HARM[39], HAT TOOL[40], KILA[41], ROSA[42], ERIN[43,44], EAWS[45], ALLA[46], KIM I, II, III[47,48], RAMP[49], WERA[50], SERA[51], PERA[52], AULA[53], EAWA[54], WRAP[55,56], ART, CTD, HAL, KC[57].

The simple observational methods are economical and can be used for wide range of static and repetitive risk assessment. These categorical methods do not disturb the workers. This method's scoring system is hypothetical in nature and the Different aspect is weighted and connection between the factors is to be measured. More than one method can be used for the group of exposure that can be allowable risk boundary.

3) Advance Observational (Computer Based) Method:

Advance observational method includes video-based observational method that are developed for the evaluation of dynamic, static, non-repetitive, force, velocity, prolong observation and high frequency postural instants[9,18,19,27]. The Advance Observation Methods includes methods like ROTA, TRAC, HARBO, PEO, Video analysis for different purpose[18,23], COWAS[58], WOPALAS[59], PATH[60], CUBE MODEL[61], SIMI MOTION[62], SNOOK TABLE[63], VIDAR[64], NERPA[65], CERA[66], ERGAN (ARBAN)[67], AUVAfit[68] and VIRA[23].

These methods record the data using video and computer and analysed using customized software subsequently. For analysis of the working postures the worker's postural instances have been video recorded in real time and all measurements like distance of movements, angular changes, velocity and acceleration are measured and noted down. This method includes biomechanical models and use anthropometric, postural and hand load data for calculation of inter-segmental moment and force for analysis. The advance observational method requires high technical support and system having considerably high cost. The process of this method is time consuming and not suitable for practical scenario[9,18,19].

4) Direct Measurement Methods (Integrated With Sensor, Inertial Measurement Units (Imu's), Biomechanical, Remote Sensing And Vision Based Method):

All the direct measurement methods are sensor based. Accelerometer, gyroscope, magnetometer, electromyography (EMG), optical markers, goniometer, inclinometers, optical scanners and sonic sensors are electronic devices use to measure and report body's specific force, angular rate and unsafe posture at work place since long time. Accelerometer measures the physical accelerations of the object in translational movements like sway, surge and heave. Gyroscope measures the orientations of the object which consists of row, yaw and pitch. Magnetometer measures the directions of the magnetic field. It measures static angular displacement with respect to g-line, linear accelerations and angular velocities of an object in orthogonal directions. Electromyography (EMG) measures muscle tension and fatigue. It reveals nerve dysfunction, muscle dysfunction or problems with nerve-to-muscle signal transmission. Goniometer measures angular displacement. Inclinometers measures angles of slope, elevation, or depression of an object with respect to gravity's direction. An Optical scanner scan and digitally convert images, codes, text or objects as two-dimensional (2D) digital files and sends them to computers and sonic sensors measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal[9,18].

When the devices like accelerometer, gyroscope and magnetometer are integrated, the newly designed device is known as Inertial Measurement Units (IMU). The IMU is robust, low cost and provide data with high quality. These IMUs is a self-contained system which measures linear and angular movements which is a triad of gyroscopes and accelerometers. The IMUs are generally called as rate-integrating gyroscopes and accelerometers that are sensor based. Recently, many scientist and researchers are using Inertial Measurement units and developing new advance devices for measuring physical exposure of human body. These are light weight sensors and can directly attach to the human body for recording different parameters generally 3D joints motion and body segments. Different direct measurement devices are available commercially.

Biomechanical on the other hand is use to estimate joint load responsible for WRMSD. The joint load is force or moment that has been applied on a weight-bearing or load-bearing joint while doing any task. Biomechanical are used to evaluate human resources movements of tissues and estimate joint load on body. According to the biomechanical model, higher the load, more the risk. The biomechanical model can be used for post-analysis and human movement analysis; therefore, currently this technique is used for the post processing of data of human motion collected through direct measurement. However, this method requires more money and time to collect large amount of individual and motion data at the same time possibility of variation and error in data[9]. Remote sensing technique is a sensor based biomechanical analysis method that requires range, image or video sensors to record and capture human motions. In this technique, sensors do not fixed on the human body, hence the human being to be evaluated will be visible to the expert for real time assessment[9].

Vision based technique is also a sensor based method with uses depth sensors and multiple video camera's for 3D reconstruction of human motions. This technique is specifically used for extraction of skeleton and tracking of motion of object. The motion data like rotation angles, joint angles, position vectors and movement direction etc are used for evaluation. Microsoft Kinect, stereo camera and wearable sensor systems, Joint angle measurement system, real-time location system, physiological status monitor sensor are use for evaluation of risk using vision based techniques[9].

Direct measurement method includes methods like BODY POSTURE SCANNING SYSTEM[69], CYBERGLOVE, EMG, LMM[18,23], FORCE MEASUREMENT[70,71], GONIOMETER[72], Inclinometer, Accelerometer, sonic system, electromagnetic system[23] and IMU[9].

Direct measurement system requires sophisticated instruments that provide detailed information about the worker however cost of the equipment is high, requires high storage device and time consuming but provides high accuracy with simple post-processing. The system is not suitable for onsite measurement of risk exposure as bodily attached sensors change the behavior and performance of the workers[9].

5) Computer Modeling Techniques Using Dhm:

Computer modeling techniques is popular and widely used method for the evaluation of ergonomic risk. An evaluation of working postures for risk factors are carried out by developing Digital Human Model (DHM) by using computer software, computation algorithms for configuring and driving mannequin and thereby simulating and analyzing. Computer modeling technique found an effective tool in the area of development of assessment of ergonomics risk method since it does not obstruct the work at workplace and different analysis can be carried out[1,73].

This is an upcoming technique which uses the principal of redesigning of product and workplace as per human comfort and safety to evaluate risk which was developed early in the 1960 after CAD which was design for aerospace and automobile industries. Subsequently various computer modeling ergonomic risk evaluation tools was invented and developed to create Digital Human Model (DHM), called as computer manikin. The computer modelling ergonomic risk evaluation software found worthy and most efficient which permit real-time modeling, simulation and evaluation of object and workplace. The computer modeling methods that are used to create manikin are MannequinPro, Jack (Tempus), Ramsis, Safework, Sammie, Delmia (CATIA) are the modern DHM based ergonomic tools whereas Anybody, 3DSSPP, Tecnomatic, SantosHuman, HumoSim, HandiMan, Hadrian, Santos and Ergonaut etc are the tools and software used for virtual environmental evaluation[1,73].

With development of computer modeling method, recognition of ergonomics risk and evaluation become easy, fact and eliminates the physical intervention of human being for real testing due to integration of simulation. This allows ergonomist and researchers to change the posture, design, working environment and improvisation virtually for analysis thereby saving cost, time and man-hour's losses. As the analysis carried out by virtual simulation hence no destruction, injury and damage to the real work scenario, workplace as well as human being. Detailed review on computer modeling techniques are presented by Mabemena et al., 2020 and Raghunathan at el., 2016[73]. The methods has been adopted initially by different authors for various analysis using computer modeling technique specially using CATIA[65,74,75,76,77,78,79].

Construction risk factors and Researches:

As per the Jaffar et al., 2011, ergonomic risk factor is categorized as 1) Biomechanical exposure 2) Psychosocial and 3) Individual risk factors. The level of exposure normally assessed with respect to work intensity (or magnitude) and Contact stress (Pressure Points) on body parts. The above mentioned three factors are causing work-related musculoskeletal disorders (WRMSD) in human being. Among these three factors, Biomechanical exposure is most common factor for work related musculoskeletal disorders among the workers or combination of all[80].

With the development of assessment methods, work-related musculoskeletal disorders (WRMSD) assessment has been started in the construction work also. All types of methods being used for the assessment of work-related musculoskeletal disorder amongst the construction workers.

The feasibility of the direct measurement method is not limited and it has been applied to other areas also, in 2013, Vignais et al., 2013 have developed an innovative system for real-time ergonomic assessment in industrial manufacturing. In this system the evaluation was done by referring the scoring sheet of RULA and joint angles and orientations were calculated by using IMU units. The IMU units was places at upper arm, forearm, head, trunk and pelvic. The upper body of the worker is interpreted in biomechanical model with 20 degrees of freedom and goniometer synchronizes the networking of IMU units. The result showed that the IMU has advantages on the movement freedom and in-field application. In this system authors found that there is a magnetic disturbance from the IMU units while evaluation[82].

In 2014, Li at el., 2014 has presented a Smart Safety Helmet (SSH) to detect the risk of ergonomics of the workers in the industries. The Smart Safety Helmet has consisted of IMU units and EEG sensors. The IMU units were deployed to measure the head gestures of the users and EEG sensors were deployed to determine the brain activities or the mind state of the users. The overall system was controlled by the artificial intelligence module. This interpreted and evaluated the risk factors of the workers as per the raw data received from the sensors. The risk factors considered were the probability of occurrence, the severity of mishap, and exposure. The results showed that SSH was able to identify the relationship between the motions of head and the mind state of the workers. The disadvantage of this device was that it unable to provide the information on the body movement and posture[83].

Chen et al., 2014 proposed a coupled system that incorporated the Kinect and IMU unit which cover up each other's limitations and provides a more flawless system. The system was designed to detect the manual lifting hazards at construction industries. Kinect was used to synchronize the motion of the workers to the skeletal tracking system with its 3D-mapping function and also evaluate height and body shape. In this system, Kinect drawbacks were overcome by IMUs which was allowed to work independently and collect motion data in low light condition. The result showed that the overall performance of the system had improved using joint utilization of Kinect and IMUs for posture measurement[84].

Pepploloni et al., 2014 in 2014 had developed an upper limb wearable device for assessment and measurement of force exerted by the muscle and the postures of the upper limb. For this authors used Inertial Measurement Units (IMU) and Electromyography (EMG) sensors. IMU was used to measure the motion and posture of the subject and EMG was used to assess the force exerted by the muscle. The authors proposed a novel wired system for assessing the muscular effort and posture of the upper limb for ULWMSD assessment. In this study, authors considered upper limb as a kinematic chain and incorporated 3 DoF for shoulder, 2 DoF for elbow and 2 DoF for wrist and EMG had observed the forearm flexor muscles. The recorded result of the each sensors showed the corelation between these two i.e. force exerted by the muscle and postures of the upper limb. The result showed that both devices measured the ULMSD risk but only limited parts of upper limb[85].

Schall et al., 2015 in 2015 compare the IMU with LMM for direclty measuring thoracolumbar trunk motion with aim to 1) compare estimates of thoracolumbar trunk motion obtained with a commercially available IMU system with estimates of thoracolumbar trunk motion obtained with a field-capable reference system, the LMM, and 2) explore the effect of alternative sensor configurations and processing methods on the agreement between LMM and IMU based estimates of trunk motion during a simulated Manual Material Handling task with both systems. The ACUPATH™ Industrial Lumbar Motion Monitor™ (Biomec Inc., Cleveland, OH) and the I2M Motion Tracking System (series SXT IMUs, Nexgen Ergonomics, Inc., Pointe Claire, Quebec) were used to measure angular displacements of the thoracolumbar region of the trunk in the position of flexion and extension, lateral bending and axial rotation. A custom LabVIEW program was used to control the simulation of MMH task which was developed in MATLAB (r2013b, The MathWorks, Inc., Natick, MA). The Statistical analysis was carried out using angular displacement waveform obtained from the LMM and a custom MATLAB program which identified the maximum peak value of different postures and corresponding four second before and after each peak. Result showed that IMU system is useful for the estimation of trunk angular displacement form the LMM, the only thing is that the multiple IMU using fusion algorithms should be preferred rather than single IMU for better result. The present system cannot be used for complex joints and dynamic working conditions[86].

Yan et al., 2017 in 2017 have developed real time motion warning personal protective equipment (PPE) which permit workers for self awareness and self management from ergonomics hazards prevention using wearable inertial measurement units (WIMUs). The authors proposed a wearable IMU-based real-time motion warning system to raise the awareness of the construction workers to prevent musculoskeletal disorders of lower back and neck. In this system, a smartphone application has been used for automatically detecting and warning of discomfort posture to the workers. This smartphone application provided with real-time data process algorithm and warning thresholds algorithm for automatic risk assessment and warning. The real time data process algorithm collected and processed the raw posture data. The warning threshold algorithm send a warning signal to the worker if the analysed data cross the threshold limit. The system was tested and validate in the laboratory and field and worked well with the construction workers but operates for a short time. This device gave substitute to construction workers to prevent WMSD due to physical exposure[87].

Planard et al., 2017 has carried out their work to evaluate and validate the assessment method using kinect data in a real workplace conditions. Authors proposed and evaluate a RULA method in real work using occlusion-resistant Kinect skeleton data correction which s marker and calibration free. The new method calculates RULA scores at 30 Hz using Kinect skeleton data and assesses relevance in ergonomic analysis. The result of the Kinect data presented more accurate RULA scores. The developed method assesses WRMSD of dynamic nature with 30 Hz continuous information which assess offline in real time[89].

Hiroyuki et al., 2018 has developed and used novel lightweight lumbar-motion measurement device (LMMD) with stretchable strain sensors to measure the risk of lower back. This device help to diagnose lower back pain by mounting this device on the lower back of the workers. It is a lightweight, low elasticity, high durability, good repeatability and stretchable strain sensors which form parallel sensor mechanism which are capable of measuring rotation angles of lumbar motion in tree-axis direction with six sensors. The result of this device revealed that this prototype device effectively measures the lumbar-motion over the time without disturbing work task. The accuracy is slightly lower hence authors are planning to improve device by changing the shape to arc-shaped so that it can fix properly on waist of the user[90].

Shahvarpur et al., 2018 has studied the effect of wearing a lumbar belt for biomechanical and psychological assessment to flexion, extension motion and manual material handling. Authors studied the effect of wearing lumbar belt (LB) for extensible and non-extensible belt on segmental trunk range of motion (ROM) and compare coordination in trunk maximum forward bending (flexion) and maximum backward bending (extension) and manual material handling. Healthy and low back pain participants were tested with pain intensity, pain fear and catastrophizing during activities. In both cases, authors found that two Lumbar belt reduced the lumbar range of motion and also reduced pain, pain fear and catastorophizing in workers with low back pain and helps to maintains their activities. It also helps to reduce disability prevention (gradual exposure to physical risk) and maintaining regular activities. This LB device may works as a protection against various injuries and reduce pain intensity during work[91].

Chen et al., 2018 has proposed an automatic system to identify and visualized work-related musculoskeletal disorders risk factors by using wearable and connected gait analytics system (WCGAS) and Kinect skeletal models. The authors developed this system of identify the risk factors like overexertion, awkward postures, excessive repetition and their combination. The postures, force exertions and repetitions of work has been recorded by planter pressure using insole shaped wearable device with the help of WCGAS and recognized with sequential minimal optimization (SMO) and long short term memory (LSTM) algorithms as well as work-related musculoskeletal disorders risk factors has been recognized with the help of Kinect skeleton models. The algorithms was applied for quasi-static postures and force exertions like lifting, carrying, bending, pulling and pushing with variable loads. An algorithms CNN and LSTM applied for sequential and repetition postures identification. The result shows that the use of WCGAS and kinect skeleton models can be useful to identify and visualize risk factors of WMSD using SMO, CNN and LSTM algorithms[92].

Fang et al., 2017 has designed an accelerometer-based fall warning detection system by using hierarchical threshold based algorithms for tiling operations in construction using smart phone. The four accelerometers have been connected to chest, waist, arms and hands of tiler's while working on scaffold in normal, drunken and drowsiness conditions. Once the system senses the fall warning of lose of balance or sudden swaying, it informs the workers about susceptibility. The authors used SVM, VA and Hierarchical based algorithms with different practice of accelerometers explore. The result shows that detection of fall warning is significantly simple than avoiding false warnings. The authors also pointed out that accuracy is more critical sign than detection rate for recognizing the fall waning[93].

Akanmu et al., states that whenever construction workers exposes to work-related musculoskeletal disorder risk or injury, they are being reassigned to other simple work on construction sites. The authors has proposed an ergonomic analysis framework to measure the risk factors on body parts while doing construction work for reassignment of work to the labourers that enforce minimum strain on the defecting body parts. The authors used the inertia 3D suit motion capture suit which incorporated 3D miniature inertial motion unit (IMU) and equipped with on-board signal processor and data fusion algorithms and capture full human body motion. For demonstration, author's perform laboratory experiment on workers having knee problem carrying lifting of stacking wooden boards, plumbing work and electrical work to evaluate motions, postures, body parts and joints and environmental condition and found the data will be optimized and feasible to predict the works of construction with minimal effect on affected body parts[94].

The practical approach of the direct measurement system is comparatively complex and requires computational with 3D biomechanical model in analysis and practical scenario; hence some software based methods have been developed and applied for the risk assessment in the past recent years. Recently, research works are executing on automation and optimization of observational and other risk assessment techniques using IMU's, different computer programming and hardware- software interfaces techniques, machine learning, metaheuristics, CNN and Multi-objective optimization[95,96,97,98,99].

COMPUTER MODELING TECHNIQUES using DHM use for designing and evaluation of ergonomic risk. The method has not been applied in the field of risk assessment of construction work and workplace nevertheless it has wide application. Only Das et al., 2016 has used CATIA for presenting conceptual trowel for plastering work and material handling device with adjustable height to hold iron-pan[100].

Role of ergonomics in construction:

According to Kim, In-Ju (2017), construction work is manual physical demanding and workers dependent work which requires working in awkward postures, manual lifting and handling of heavy and irregular-sized loaded materials, repeated twisting and bending of the body, work over the shoulder height, work below the knee, work in static position for prolong, climbing and descending, pushing and pulling of loaded materials etc which are the primary reasons for WRMSD in the construction and not possible to avoid. Due to these reasons the workers are exposing to work-related injuries. Construction work is more hazardous than other work accounted for 34% of nonfatal injuries and more than 50% workers suffering from WRMSD however there exist sophisticated tools and equipments[167]. Human factors and ergonomics are meant for avoiding occupational injuries and fatalities on workplace. Kim, In-Ju (2017) has presented role of ergonomics in construction industry and proposed some remedies to reduce or prevent WRMSD at construction site[101].

Different evaluation methods will help to assess the working postures and other related risk of construction workers. Self-reported methods can help to collect personal data as well as work related problems faced by the construction workers by interviewing, observing and pain in different body parts with the help of NMQ.

Assessment can be carried out using simple observation methods using different evaluation worksheets developed by different authors and researchers. A simple observation methods like REBA, RULA, NERPA, OWAS, NIOSH, OCRA, QEC, SI, WERA and ERIN. These methods are able to evaluate body part. Some methods are able to evaluate whole body parts or upper body with load on muscle for static and dynamic working posture, load on body parts and coupling facility like REBA, RULA and NERPA. OWAS method was also developed for construction worker evaluation which evaluates back, upper limbs and legs with force to be handled. NIOSH known as NIOSH lifting equation is used for manual lifting which is developed for calculating maximum weight to be lifted to avoid lower back pain or disorders. OCRA is an observation method for exposure of occupational repetitive movements of the upper limbs. The method is the ratio of actual Technical Action (ATA) and Reference Technical Actions (RTA). where ATA is the number of various task carried out in different task in a shift and value of RTA may be obtained by following formula $RTA = \sum_{i=1}^{n} CFxF_f xF_p xF_a xDFxF_r$ by considering frequency (CF), repetitive movements (DF), force (F_f), posture (F_p), recovery time (F_r), additional factors (F_a), vibration and compression of tissue. The "n" represent number of repetitive movements per shift.

QEC is a technique consists of a questionnaire and a scoring sheet. In this technique both expert and workers are allow to fill the QEC assessment form. The form consist of body parts for observer and other parameters like weight, duration, force exerted, visual demand, driving of vehicle, vibration tools used and personal attitude. SI technique find out physical risk exposure associated with upper limbs basically hands and wrist. This technique evaluates six parameters that cause work-related musculoskeletal disorders and its magnitude. These six parameters are 1) Intensity of Exertion 2) Duration of Exertion 3) Efforts per Minute 4) Hand/Wrist posture 5) Speed of Work and 6) Duration of Task per day. Each parameter consists of five different variable criteria for exposure and can be obtained from the time-motion study. This old SI has been revised now[169]. The WERA evaluate body parts like shoulder, wrist, back, neck and legs with force, vibrations, contact stress and task duration. This method was specifically developed for construction work evaluation. ERIN method is basically focused on factors like workplace and worker assessment. The worksheet of ERIN has been designed using available ergonomic tools like RULA, REBA, SI, QEC, OCRA and OWAS. This method measure posture, frequency of movement of the trunk, shoulder/arm, hand/wrist and neck that results from speed of work, task duration, intensity of effort and self assessment.

Other methods like Snook Table can be used for manual material handling which includes lifting, lowering, pushing, pulling, carrying and walking.

Advance observational methods and direct measurement methods are difficult to apply in construction work evaluation process due to high cost, required high technical knowledge and support, on body sensors disturb workers. The process is complicated and time consuming and also not suitable for Indian scenario especially for individual house construction work. On the contrary, computer modelling method can easily be used for the assessment of risk factors as well as for simulation purpose and development of models for construction equipment, tools and accessories. This can be evaluated with the help of different modules available in the computer modeling software's and simulation with hampering or damaging real life world.

According to review of Kim, In-Ju (2017), there is an obvious confirmation of an involvement of physical risk factor and WRMSD in construction work[101]. To prevent WRMSD at construction work, construction contractors, workers and unions should come together to solve this problem. At the same time, attitude and awareness of these people can bring changes in construction work to reduce WRMSD.

IV. **Discussion**

WRMSD is a stressful disorder of muscle, tendons, nerves, joints, cartilage and ligaments tissues arises when extremely exposed to the ergonomics risk like working in standing or sitting position for long period, pace (repetitive) of work, working in flexion position for prolong at lumbar, awkward position, working above shoulder or in the reaching position, improper workplace, working prolong in squatting/stooping/kneeling position etc and developed with time. This is the rationale of development of ergonomic risk assessment tools and its execution of ergonomic. The important of Ergonomics in any industry is for that it save money, improves productivity by reducing mistake, improve quality of product as well as life of workers, safety and hazard free workplace, expertise of workers etc. In the recent year, development and implementation of ergonomic risk assessment tools for measuring risk exposure for WRMSD has been increase tremendously as discussed in section 3.

Since the 1900 and specifically since 1970, a range of methods have been developing for the evaluation and measurement of exposure rate of physical risk factor that leads to the development of WRMSD. As discussed in section 3, self-reported method, simple observational method, advance observational (COMPUTER BASED) method, direct measurement method, computer modeling (software and hardware based) methods have been developed and implementing in different area.

Since 2011, various ergonomic assessment methods were reveals from this review. Workplace Ergonomic Risk Assessment (WERA)[50] and Agricultural Upper -Limb Assessment (AULA)[53] in 2011, Rapid Office Strain Assessment (ROSA)[42] and Working posture risk assessment tool (WRAP 1.0)[55,56] in 2012, Evaluation Del Riesgo Individual/Individual Risk Assessment (ERIN)[43], Novel Ergonomic Postural Assessment Method (NERPA)[65] and European Assembly Worksheet (EAWS) in 2013[45], Push-Pull Analysis using CATIA V5R19[74] and Fatigue Assessment Scale for Construction Workers (FASCW)[81] in 2014, in 2015 Image Processing-Aided Working Posture Analysis (I-OWAS)[102], Revised Job Strain Index (JSI)[103], A Computer-Based Expert System (SONEX)[2], Simple Ergonomics Risk Assessment (SERA)[51] in 2016, PRASAD (Predictive Risk Assessment for Safe Assembly Design)[104] and Postural Ergonomic Risk Assessment (PERA)[52] in 2017, in 2018 Allgemeine Unfallversicherungsanstalt - the Austrian Workers' Compensation Board (AUVA fit)[68] and Composite Office Ergonomic Risk Assessment (CERA)[66] . From 2011, many research and evaluation work has been carried out using direct measurement methods specially Inertial Measurement Units (IMU), kinect and ANN, KNN, optimization techniques, biomechanical models etc. Various authors and researchers also review methods of risk assessment in last three decades and presented their view. Following is review about ergonomic risk assessment methods and their application, advantages, disadvantages and limitation.

Pinzke, S. (1997) in 1997 conducted review study for available observational methods developed for evaluation of posture. Author carried out his review for applicability of evaluation methods for agricultural working stances. Author found three categories of evaluation method i.e. direct measurement, observational and self-report methods and described them in details. Author provide detailed description of method review in the paper whether method (OWAS, WOPALAS, TRAM, ARBAN, RULA, Keyserling, PWSI, VIRA, PEO, HAMA, TRAC, Observer, Graf, Stetson, Cube model, Forman, AET, EWA and PLIBEL) is manual, computer, direct, video, task sample, time sample and real time. Also author highlighted body parts, other component, application and suitability for agriculture and suggest improvements in observational methods[27].

Guangyan et al., (1999) in 1999 presented review paper on posture-based method for the assessment of physical exposure to WRMSD. In 1999, authors presented this paper reviewing self-report method, observation method based on pen and paper, video tape and computer analysis method and direct measurement methods and brought attention to its application, benefits and limitation. In this review authors found that all the reviewed methods are reflected the principles of methods developed in 1970 centuries and need further development for precision investigations[23].

David G.C. (2005), concluded that selection of method is depends upon the objective, nature of investigation and relevance to the area. Author also highlighted the features, functions and exposure factors assess by the different methods and recommended observational methods. Author have categorized methods into three categories as 1) self report 2) observational (simple and advance) and 3) direct measurement[18].

Costa et al., (2009), in their review classified and arranged WRMSD as per body parts, type of risk (Biomechanical, psychosocial and individual) and level of exposure (strong, reasonable and insufficient). From the review, authors reveals that awkward postures, heavy lifting and repetition of work and high physical/psychosocial works, high BMI, addiction to smoke are the most common and less rational data shows correlation for the growth of WRMSD[105].

Takala et al., (2010), carried out review for the methods used for the assessment of biomechanical exposures and found 30 methods out of which 19 methods were compared with other methods. In this paper, authors presented general methods(like OWAS, AET, Posture Targeting, ERGAN, TRAC, PEO, HARBO, PLIBEL, PATH, QEC, REBA, Washington State ergonomic checklists, VIDAR, LUBA, Chung's postural workload evaluation), methods use for upper limb assessment (includes HSE for upper limb, Steson's checklist, RULA, Keyserling's cumulative trauma checklist, strain index, OCRA, ACGIH HAL, Washington state ergonomic checklists and Ketola's upper-limb expert tool along with methods used for material handling (NIOSH lifting equation, Arbouw, New Zealand code for material handling, MAC, Washington state ergonomic checklists, ManTRA, ACGIH lifting TLV and back exposure sampling tool). Authors provide target exposure and dimensions, metrics, Observation strategy and recording mode of these methods. Authors' reveals that many studies had carried out similar studies and not a single method found best. Authors suggested that ergonomist or researcher should define need to decide appropriate method[106].

Wang et al., (2015), has review the current available methods for WRMSD risk evaluation for the construction work and state there advantages, limitations, applicability, efficiency, cost, and labor requirements. The authors review paper shows that the methods are grouped into self-report, observational, direct measurement, remote sensing, biomechanical and vision based assessment methods and emphasize on wearable-sensor and vision-based methods in the construction work assessment. In this review author reveals that single method is not enough for effective evaluation. It should be better to use multiple methods as per the requirement of study, severity and situation. Authors, also reveals that direct measurement methods are not relevant for the risk assessment in all circumstances (like at field work and dynamic type of work), where wearable sensor disturb the work and minimize speed, hence use of multiple method can solve the problem[9].

Raghunathan et al., (2016) presented this review paper to ascertain expansion in the method of computer aided ergonomic design and application of DHM. Author reviewed 1) ergonomic interventions and ergonomic design, 2) ergonomic analysis and tools and 3) Digital human model (DHM) and Virtual ergonomics. Review reveals that in virtual ergonomics, development of DHM with virtual reality and virtual manufacturing is gaining more popularity and has more scope in incorporating computer for product and work system design. HFE and DHM should incorporate for which authors has attempted to incorporate human and machine for human compatibility. Authors suggested that product life cycle software designs, work-system design and design academician should integrate for the well-being of humans[73].

Sukadarin et al., (2016) presented simple observational method based on pen and paper. In this review paper, authors review six methods i.e. WERA, QEC, REBA, OWAS, PATH and PLIBEL. Authors presented and highlighted work activity, risk levels and joint angle and ranges of motion of joints of all body part (like upper arms, lower arms, shoulders, elbows, wrists, neck, trunk and legs) are categorized in 5 - 10 risk levels used in these methods and its adverse effect on body. Authors revealed that these methods have some potential to assess risk but have some limitations also[103, 108].

Kolgiri et al., 2016 has carried out review for ERF related to power loom industry and found that working in awkward posture, vibration, force, repetition, less recovery time, hot and cold temperature, static posture, contact stress are responsible for damage. Proper design of work place, production line balancing, healthy working condition, work system, safety, can reduce fatigue. Stress and strain, capacity, efficiency, work simplification, quality product etc can minimize the problem of ergonomic risk. Authors also discuss in details about ERF that are Awkward Posture, Force, Repetition, Vibration, Static Loading, Contact Stress, Extreme Temperature and Sound as well as summarized some risk factors with examples[3].

Kale et al., (2016) in their review presented that the researchers have studied on single tool, some compare tools, some used different methods on same area and conclude that selecting single tool for ergonomic analysis is intricate in nature. Authors discuss comparison, major studied area and application of the methods in industries. According to the review of the authors while selecting particular tool for particular evaluation, it is necessary to define specific setting, accuracy needed, field of analysis, data required, complexity, costs, and ease of use and the other factor that can give best solution[109].

Tee et al., (2017) highlighted some observational and direct measurement method. In this review paper, authors compare previous works done by the different researchers. Compares their assessment methods and devices, field, parameters, postures, materials, cost, reliability and accuracy of survey based observational methods and direct measurement method specially REBA, RULA, IMU and Kinect. Authors found that all methods have their own application area however, IMU based methods shows promising results as compare to the others. Authors also focus on the fact that workers should be aware of risk factors that can minimize the risk and injuries at workplace[110].

Grooten et al., 2018 have explore three the main indicating factor of ergonomic exposure that are intensity, frequency and duration with when come in contact with body parts or risk factor causes WRMSD. Authors specifically explain some observational method (ALLA, ART, CTD risk index, HAL, HARM, KC, KIM-I/II, KIM-III, LUBA, OCRA, OWAS, PATH, PLIBEL, QEC, RAMP, REBA, RULA, SI, WERA) and main indicating factor which lead to the development of WRMSD. According to the authors, all methods assess intensity of posture but not biomechanical (frequency and duration) which can be measured by SI, HAMR, KIM-I-II, KIM-III, RAMP and WERA. Among these WERA method measured biomechanical risk of whole body parts. Authors found that no single method can assess all types of risk assessment however it is pre-eminent to acquire knowledge of all the available methods and apply best method as per requirement[57].

Badhe et al., 2018 presented this paper on postural assessment. Authors focus on three approaches i.e. sensor-based approach, manual goniometric approaches, digital photography and photogrammetric approaches as well as describe posture assessment, importance of posture assessment and its application. Authors also described assessment methods and their limitations like visual observational method, X-ray examination, flexible ruler, radiologic data, scanner with laser/ video camera/triangular sensors, photography and filming and software. Authors found different limitations for all these methods like in visual observation; it only provides details and detects deviations. In X-ray, subject exposes to radiation, whereas flexible rule found to be low cost non-invasive tool compare to x-ray followed the scanner and photography limited to analytical deviations. Software on the other hand provides 2D image with 3-6 cameras and convert them in to 3D analysis but it is costly, complex and calibration required every time[16].

Authors observed postural variation in all aged group people and all the described methods are under development stage. Authors also faced problem with availability and high price of the software's. Corel Draw/ AutoCAD/ Photoshop require calibration and no method found that can assess whole body. Also, authors found that nearly all methods are under development stage hence no strong evidence has been found that can enlighten the procedure for assessment of photographic postural evaluation.

Mgbemena et al., (2020) has emphasized on computer modeling method. Although work for manufacturing shop floor, authors highlighted use of ergonomic modeling and evaluation tools (software) and hardware technology. Author reveals that computer modeling method is effective technique for numerous application of risk assessment and can be used by computer software for different application area. Construction work is a physical demanding work and cannot be substituted by machineries[1]. OWAS[18] and WERA[50] methods are particularly developed for the analysis of construction work assessment.

As per the review of this study and Wang et al (2015)[9], in the construction area numerous research work is being carried out using direct measurement methods (integrated with sensor, inertial measurement units (IMU), biomechanical, remote sensing and vision based) for different assessment of construction occupations and same found in the present review study (section 3). This study reveals various research works carried out in the field of construction work for the evaluation of ergonomic risk. In the last 10 years the direct measurement methods has been used in construction work includes IMU, kinect, biomechanical, ANN, KNN, optimization, computer modeling method using DHM and hardware/software application includes, lifting and lowering risk exposure evaluation using 3D sensing and IMU[84], real time motion warning PPE using WIMU[87], truck posture assessment using SPMWS and MPMWS[111], awkward posture identification using machine learning algorithms and canonical polyadic decomposition system, SVM and IMU[112], stress assessment using EEG[5], detection and classification of awkward posture using wearable insole using simulation with ANN, DT, KNN, SVM[11], evaluation of motion and postures while lifting using robotic wearable exoskeleton with IMU and CANE[4], fall warning detection system for tilling work using hierarchical threshold based algorithms with SVM, VA[93], reassignment of work for minimum strain on body using 3D motion capture suit, onboard signal processor, data fusion algorithms and IMU[94], muscle force for pushing and pulling using smart phone, work simulator and ANN[137].

From this review, the paper identified that since the last 5 decades or before, various ergonomics risk assessment methods have been developed and implemented in many areas however every method has their own pro and con.

Self-report method is easy, economical and applicable in all application. The primary data like personal information and personal experience about work or pain or discomfort can be recorded from large number participants. The reliability of this method is little doubtful for reliability as the gathered information is vary from individual to individual as the same time data collection is robust as it need to visit different location[9,18].

Simple observational method or pen and paper based observational method is simple, inexpensive; mostly posture based and use in many applications. This method never disturbs workers and carried out at compact workplace. The method consisted in simple observational method are able to evaluate body postures with other factors but not all which are to be evaluated at the same time inaccurate. These methods are also do not consider load/force, repetition and duration of movement, vibration, as well as psychosocial and individual factors, and also the interaction/combination of these factors and not fit for evaluation of dynamic work postures (i.e. assess only static or movement of simple repetitive motion)[23]. Another drawback of this method is that, this method may be subject to intra and inter observer variability[18].

Advance observational method is based on video-based observational method in which the dynamic working postures are recorded using videotape and analyzed thereafter. This method record real time postures and can be recorded by observer or any other person. The video recording are then analysed using trained analyst (generally ergonomist) using scoring sheet and apply to analyse kinetic chain of articulated links of human body, joint segments, distance of movements, angular changes, velocities, accelerations, force and moments using anthropometric, postural and hand load information. The method is expensive, time consuming and required specialized trained person for analysis at the same time continuous assessment is not possible[18,57].

Direct Measurement Methods integrated with sensor, inertial measurement units (IMU's), biomechanical, remote sensing and vision based method) is now a days has got popularity and application in the field of ergonomic risk evaluation. In this method, sensors are directly tied to the workers body for exposure assessment and give high accuracy data on a exposure variable range in large quantity. The real drawback of this method is that it requires high cost sensors, high capacity storage device, sophisticated and high cost equipments and; more time for execution and analysis. Also, tied sensor to the body result in discomfort to the worker, change workers behavior and reduce performance and efficiency. The method is basically applicable for laboratory evaluation and not for field[9,18].

Computer Modeling Techniques using DHM is popular with wide variety of application in the area of assessment of ergonomic risk which is fast, easy and without physical intervention. Still, the method has some limitation like it does not evaluate time factor, required high cost and infrastructure, required more competent in mathematical modelling and programming, required high technical support. With these limitations; method shows promising result in the field of ergonomic risk evaluation[1,73].

Another method which is showing significant result and improvement in the field of ergonomic risk evaluation is "Ansys" developed early in the 1970 century. "Ansys" mechanical final element analysis (FEA) software is engineering simulation software which is use to simulate computer models of structure, electronics or machine components to evaluate strength, toughness, elasticity, temperature distribution, electromagnetism and fluid flow over the time[113,114,115].

Construction work is a hard, dynamic and physical demanding work in which workers always perform work in awkward postures and techniques, prolong standing and sitting, prolong forward bending, repetitive nature of work, forceful working condition for manual material handling and for other work, works with lifting and lowering, work for long period, vibration, contact stress, working pressure (completion of work within time), lack of rest period, knowledge and awareness, work in adverse environmental conditions, carry out multitasking work, physically and financially weak, lack of nutrition etc.

From the review of the research work carried out in the area of construction, all work shows that all occupational task of the construction work

Multiple methods are available for the evaluation of physical exposure; still instead of using single method integration of multiple methods can give better output to the ergonomist and researchers. Also, computer modelling method shows promising result for design, development and analysis of real risk evaluation in the virtual scenario.

V. Conclusion

In this paper, almost all up to date methods have been presented from the start of the development of risk assessment methods and review almost all the research work done in the field of construction. Early precaution of the ergonomic risk not only detect but also minimize the development work-related musculoskeletal disorder improving man hours and reducing expenditure on injuries and fatalities. From the review, it is revealed that, even though methods are developed over the years, every method has their own advantages, disadvantages and limitation. Not every method is applicable everywhere hence basic knowledge is required for selecting proper method. Also, method should be selected as per prerequisite of study, work and workplace.

As the construction work is robust and dynamic work; in India, it is influenced by the locally available tools and equipments. The construction worker has to work in irregular, complex, uneven and confined places where work with wearable sensor or other types of direct measurement devices is not possible. For construction workers evaluation self-reported, simple observational are best suited for primary investigation, for detailed investigation direct measurement methods can be implemented as per requirement and computational modelling methods can be used for modeling and analysis of variations. Hence construction work needs multiple solution methods for evaluation of ergonomic risk.

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