INTEGRATING ERGONOMICS TOOLS IN PHYSICAL THERAPY FOR MUSCULOSKELETAL RISK ASSESSMENT AND REHABILITATION- A REVIEW

Sanjib Kumar Das*

Suman Mukhopadhyay*

Abstract

Background: Ergonomics or human factors engineering is a multidisciplinary science that synergizes man, machine and the working environment to optimize productivity and performance as well as to enhance and augment the safety, health and well-being of the worker. Ergonomics is concerned with the 'fit' between people and their technological tools and environments. It takes account of the user's capabilities and limitations in seeking to ensure that tasks, equipment, information and the environment suit each other.

Physiotherapy / Physical therapy, is a health care profession primarily concerned with the remediation of impairments and disabilities and the promotion of mobility, functional ability, quality of life and movement potential through examination, evaluation, diagnosis and physical intervention. It is believed that knowledge of ergonomics help the physical therapists play a greater role in numerous assessments and in different aspects of physical therapy care and rehabilitation.

Furthermore, rehabilitation ergonomics play a proactive role in the prevention of musculoskeletal injuries by utilizing ergonomic principles of worksite redesign, tool selection/modification, work method design, ergonomic education, fitness and early intervention. Rehabilitation ergonomists specialize in functional evaluation, improvement of functional work performance, education of the worker and redesign of work to reduce musculoskeletal stressors but they must analyze both the human who perform work activities and the setting in which they work. Rehabilitation Ergonomics is still in its early stages, while it gives immense innovative scope for physiotherapists/physical therapist to act as one.

Brief description of subject: Ergonomic tools are increasingly being found to be extremely useful for assessment / diagnosis as well as in treatment and prevention of work related musculoskeletal disorders, workplace risks and rehabilitation ergonomics.

* Ergonomics and Human Factors Engineering, National Institute of Industrial Engineering (NITIE), Mumbai, India 400 087

Physical exposure to risks for potential work- related musculoskeletal injuries is possible by using a variety of methods with subjective and objective approaches like questionnaires on health and wellbeing, physical, psychosocial and psychophysical risk factor perceptions, computer based evaluation tools, tools for work system and product design by simulation and biomechanical models, instruments for evaluating work environment, checklists for workplace evaluation, rehabilitation ergonomic components etc. The paper primarily addresses to integrate ergonomics and physiotherapy in assessment and rehabilitation.

Clinical implication:A strategy that considers both the ergonomics expert's view and the practitioner's needs for developing a practical exposure assessment tool is discussed that suggests ways in which physiotherapy treatment and rehabilitation can be geared to recovery of working capacity. Integrating ergonomics into rehabilitation efforts of all kinds holds significant promise for improving outcomes.

Keywords: Ergonomics, Human Factors Engineering, Rehabilitation, Physiotherapy, Musculoskeletal Disorder

1. Introduction of Ergonomics

The foundation of the science of ergonomics appears to have been laid within the context of the culture of Ancient Greece, as early as in the 5th century BC, who were believed to have used ergonomic principles in the design of their tools, jobs, and workplaces (Mukhopadhyay et. al.2012).

Ergonomics (or human factors engineering) is a multidisciplinary science concerned with the understanding of interactions among humans and other elements of a system and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Ergonomics draws on many disciplines in its study of humans and their environments, including anthropometry, biomechanics, mechanical engineering, industrial engineering, industrial design, information design, kinesiology, anatomy, physiology, pathology and psychology. The term *ergonomics* derives from Greek *Ἔργον*, meaning "work" and *Νόμος*, meaning "natural laws", coined by Wojciech Jastrzębowski in 1857(Mukhopadhyay et. al.2012).

The ergonomic tools aim to evaluate risk and consequences. Most of the tools attempt to quantify the physical load or psychosocial conditions. Several tools are oriented to quantifying outcomes such as pain or disability. A few tools consist of economic models that try to evaluate a potential change in terms of productivity, costs and financial benefits. There is no 'best' tool. The choice of tool depends therefore on what needs to be done. Thus, it can be said that, just because having a hammer in the hand doesn't mean the problem is a nail (Neumann, 2006).

Every tool has a blind spot i.e. there are often intangible effects from the changed projects. Hence, it is helpful to try and capture these with more qualitative approaches especially by interviewing the people involved. This can provide insight into the effects and process of change that might not be clear from a particular tool. A good tool makes a big difference, but how the tool is used is also critical. It's the skill of the carpenter not just the sharpness of the saw that counts. With the time, new tools are being continuously developed and old tools are becoming obsolete and unavailable (Neumann, 2006).

1.1 Rehabilitation Ergonomics

Rehabilitation Ergonomics is the practice of applying scientific and functional principles to provide a match of work and worker that prevents injury or assists in the return to work process. They must analyze both the humans who perform work activities and the setting in which they work. Rehabilitation ergonomists specialize in functional evaluation, improvement of functional work performance, education of the worker and redesign of work to reduce musculoskeletal stressors (Marras, and Karwowski, 2006).

Rehabilitation ergonomists specialize in the prevention of musculoskeletal injuries by utilizing ergonomic principles of worksite redesign, tool selection/modification, work method design, ergonomic education, fitness and early intervention. They perform as part of a larger prevention team often including engineer ergonomists, safety departments, production managers and other medical professional involved in prevention. Ergonomic training and education are a foundation for the prevention practice of the rehabilitation ergonomist (Marras and Karwowski, 2006).

1.2 Ergonomics and Physiotherapy

Physiotherapy / Physical therapy is a healthcare profession that works with people to identify and maximize their ability to move and function. This means that physiotherapy plays a key role in enabling people to improve their health, wellbeing and quality of life. Physiotherapist practice however, occurs across a wide spectrum of health care and as a profession requires solving complex and poorly defined practice problems (Edwards's et. al. 2004). Thus it is believed that with ergonomic understanding it will play a greater role in numerous assessments and in different aspects of physical therapy care.

2. Inventory of Tools for Ergonomic Evaluation- Brief Review

The Ergonomics Tools reviewed here is intended to assist practitioners in identifying potentially useful methods for evaluating working environment in their professional work (or perhaps evaluating their own working environment). The emphasis here is on tools that can be used to evaluate a workplace or a potential design for a workplace, often in some kind of quantitative way.

2.1 Questionnaires on Health & Wellbeing

The tools in this category all focus in the effect work has on the individual. This might include health outcomes, pain surveys, stress. The distinction between these and the psychosocial tools is the change from the experience of the workplace to the effects that workplace has on the individual.

2.1A. Pain, Disability & Symptom surveys

i. NIOSH survey – a musculoskeletal survey by the US NIOSH (Stanton et al., 2004).

ii.'Nordic' symptom questionnaire – A 'standardized' questionnaire that allows description of pain and disability for various body parts (Kuorinka et al., 1987). The tool has since been broadly adapted and applied in research.

iii. SF-36, SF-12 – questionnaires (36 items & a less detailed 12 item version) on general health including physical and mental health (Ware et al. 2000).

iv. Tools for Modified Work - A process and checklist set supporting efforts of returning injured workers to the workplace with a focus on communications between the workplace and the care-giver.
From the Quebec department of Public Health.

2.1B. Fatigue, Motivation, Satisfaction

i. ORS – Organizational Role Stress Scale (Pareek, 1983)

ii. Job Satisfaction tool (Spector, 1997). One example found is a three question item in (Pousette and Hanse, 2002)

2.2Questionnaires on Risk Factor Perceptions

These tools are intended to be used to survey groups of workers on their perception of physical and psychosocial work environment. It is common for these tools to have several questions on a particular factor that are then combined to generate a single index for that factor.

2.2A. Physical Risk Factors

i. DMQ – The 'Dutch Musculoskeletal Questionnaire' from TNO (Hildebrandt et al., 2001; Stanton et al., 2004).
ii. Nordic Safety Questionnaire – A questionnaire tool from Scandinavian researchers with a Safety-culture focus (Kines et al., 2011).

iii. RFQ - Risk Factor Questionnaire a 25 item questionnaire with a focus on risk factors for low back pain (Halpern et al., 2001).

2.2B. Psychosocial and Psychophysical

i. Job Content Instrument – perhaps the best-known psychosocial questionnaire. Based on the 'Demand-Control' model by Karasek and later extended to include a 'Support' dimension (Karasek et al., 1998).

ii. QPS Nordic & QPS34+ – A 123 question (34 question short form) instrument on stressors in the working environment.

2.3 Computer Based Evaluation Tools

This list focuses on tools explicitly oriented to computer use. However many of the 'Checklist' observational tools have also be implemented onto a computer or handheld PDA type device. Computer implementation can speed use and improve usability.

ii. ErgoIntelligence and Ergomaster – Software tools implementing a number of different checklist tools.

iv. ERGOMIX – a method for integrating images of real operators with CAD drawings to evaluate workstation layout (de Looze et al., 2003).

v. ERGOWATCH – A computerized ergonomics 'toolbox' including the Watbak biomechanical model, NIOSH equation, Snook Tables, and a job demands / worker capabilities analysis tool. From the University of Waterloo (www.uwaterloo.ca).

vi. FIT – Flexible Interface Technology is a Personal Digital Assistant (PDA) based tool for the observation of work tasks (Held et. al.1999).

vii. HARBO – A simple computer aided observation method for recording work postures (Wiktorin et al., 1995).

ix. MVTA – Multimedia Video Task Analysis tool for analyzing video sequences in terms of postures and task performance. Developed at the University of Wisconson-Maddison.

x. NIOSH lifting equation – A well known tool for calculating maximal permissible lifting loads (Waters et al. 1993) and (Waters and Putz-Anderson, 1999). This tool is often implemented in other software packages like Ergowatch.

xi. The Observer XT – An advanced video analysis tool suitable for task analysis and usability evaluation, allows PDA based assessment or integration of biophysical signals like force, EMG etc.

xii. PEO – Portable Ergonomics Observation method for computer supported field observation, developed in Sweden (Fransson-Hall et al. 1995).

xiii. Posture Program – A relatively simple video based approach, allowing quantification of trunk and arm postures and velocities during work (Neumann et al., 2001).

xiv. VIDAR/PSIDAR – A video based system allowing employees to rate both physical (VIDAR) and psychosocial (PSIDAR) working environment at chosen points in time from the video (Kadefors and Forsman, 2000).

2.4 Tools for Work System and Product Design

Tools in this category are useful in the evaluation of workplaces in the design stage. These tools can also often be used to evaluate existing designs.

2.4A. Complex Human Simulation Models

"Complex" computer models include higher-end products designed to allow 3D modelling of humans in a 3D environment such as CAD. A complete discussion of the capabilities and utility of these tools for practitioners and researchers has been executed by Sundin (Sundin et al. 2004).These tools often contain various ergonomics assessment approaches such as reach and fit checking, NIOSH equation, modified checklist approaches and biomechanical models to determine physical loading and exposure to risk factors.

e.g.: Jack, Ramsis, SAFEWORK, ENVISION/ERGO, eMHuman, ERGOMan, ManneQuinPRO.

2.4B. Simpler Computerised Human Biomechanical Models

These models may be two or three dimensional and may even consider repeated or cumulative loading as part of the assessment. These are good tools both in design stages and also to quantify loading of existing systems to help identify areas for improvement and quantify the extent of load reduction in a particular situation (Neumann, 2006).

i. 3D SSPP - The University of Michigan's famous 3D Static Strength Prediction Program allows fast determination of 3D loads for specific work actions.

ii. 4D WATBAK – A simple model from the University of Waterloo that allows modeling of single work activities as well as calculating cumulative load over a full shift. It have been risk calibrated in epidemiological research (Neumann et al., 1999).

iii. BakPak - University of Windsor model - predicts spinal loads based on reach location inputs.

2.4C. Design Checklists and other Design Tools

This includes 'paper' checklists or working concepts which may even be implemented in a computer system that can support the evaluation and application of ergonomics factors in process design. These tools tend to operate at different stages of the design process but share a common strength in that they have potential to connect to existing engineering tools and processes.

i. ERGONOVA – Ergonomics addition to the classic 'value stream mapping' tool for production system improvement (Jarebrant et al., 2004).

ii. ErgoSAM - An ergonomic add-on for the Swedish SAM method for standard time allocations (which is a common job planning tool, an MTM system). Provides red-yellow-green determination based on the engineer's determination of task requirements (Laring et al., 2005).

iii. FMEA tools – Failure Mode Effect Analysis; a common risk analysis tool that has been adapted to include ergonomics aspects in product and production process development (Munck-Ulfsfalt, 2004).

2.4D. Flow Simulation Tools

A number of different flow simulation tools exist which can be used to assess human factors in terms of time utilized for different activities in the system and can also be used to test how the system performs under different work organization strategies. Flow simulation can also be used in combination with human-biomechanical simulation or other tools to predict loading with different configurations (Neumann, 2006).

e.g.: Simul8, Delmia, Technomatix, microSAINT.

2.4E. Tools for Product Design

A couple of literatures do exist in this area mentioning about few tools oriented to the determination of ergonomics issues in the design of the product.

i. Quality Function Deployment – an adaptation of a well known design tool to integrate human factors considerations into early design stages and provides an example of deboning knife design (Marsot, 2005). The method, based on the 'house of quality' approach supports balanced consideration of varying requirements based on their priority and the extent the criteria is fulfilled by a given design option.

ii. Kansei Engineering – More an approach than a tool this method focuses on designing products according to the user's feelings and impressions (Nagamachi, 2002).

2.5 Instruments for Evaluating Work Environment

These tools actually are oriented towards the evaluation of individuals while at work. This includes simple tools and sophisticated measuring equipment.

i. Tape measure – a classic but useful tool for reach and fit measures.

ii. Stopwatch – time remains an important aspect of biomechanical exposures

iii. Force gauge – another classic tool; fish-hook type scales are cheapest but a push pull gauge can be more versatile for measuring forces other than lifting.

iv. Counter – A handheld counting tool that is helpful when counting repetition rates or parts for estimating total loading.

v. Data Loggers – Advanced data collection system for measuring EMG or posture while working (Hansson et al., 2003).

vi. Lumbar Motion Monitor – A device for tracking back postures in 3dimensions at work, development headed by Marras at Ohio State (Stanton et al., 2004).

vii. SEIP – (Synchronised Exposure and Image Presentation); a tool allowing the presentation of video recordings and synchronised load/force/EMG measurements on a computer screen (Forsman et al., 1999).

viii. Vibration and Sound meters.

2.6 Checklists for Workplace Evaluation

Many checklist type tools exist both as paper forms and sometimes implemented into computer programs. This list highlights a number of examples that are either well-known or provide potentially useful opportunities for practitioners. It is quite common for ergonomic practitioners to adopt a checklist for their own needs.

i. PLIBEL - Checklist, mostly of physical risk factors, (Kemmlert, 1995).

ii.RULA – Rapid Upper Limb Assessment tool provides a ‘score’ for upper limb demands by McAtamney and Corlett, 1993.

iii.REBA – Rapid Entire Body Assessment tool, similar to RULA but with a whole body focus (Hignett and McAtamney, 2000).

iv.The Strain Index – Combines time, repetition, load, and posture into a single index focused on hand/wrist load (Steven Moore and Garg,1995).

v. QEC – The ‘Quick Exposure Checklist’ for assessing risk factors for work-related musculoskeletal disorders (Li and Buckle, 1998).

vi. OCRA – A ‘concise’, checklist based, index for assessing risk due to repetitive movements (Occhipinti, 1998).

vii. OWAS – The Ovako Working Posture Analysis System for rapid assessment of postural loads at work (Wilson and Corlett, 2010).

viii. WEST – (Work Environment Survey Tool) provides both traditional ergonomic and occupational hygiene analysis possibilities (Neumann, 2006).

ix. Ergonomithermometer – A Swedish language tool using a 'thermometer' metaphor to help assess risk levels.

x. Keyserling checklist – A classic, simple, risk factor checklist easily adapted tousers needs (Keyserling et al. 1991).

xi. MAC – The Manual Handling assessment Chart, like the NIOSH equation this allows easy assessment of MMH tasks.

xii. ManTRA – A checklist from the University of Queensland.

xiii. NIOSH equation – An approach to calculating a 'maximum' permissible load for different lifting circumstances (Waters et al. 1993) and (Waters and Putz-Anderson, 1999).

xiv. Psychophysical ratings – A rating made by someone of their own experience ('psycho') of loading ('physical'). A versatile approach pioneered by Borg and broadly applied in various contexts (Borg, 1998).

3. Physical Methods of Assessment for work related Musculoskeletal risks

The physical methods are crucially used by ergonomist to obtain essential surveillance data for the management of injury risks in the workforce. It is generally accepted that many musculoskeletal injuries begin with the worker experiencing discomfort. If ignored, the risk factors responsible for the discomfort eventually will lead to an increase in the severity of symptoms and will be experienced as aches and pains. If left unchecked, the aches and pains that signal some cumulative trauma eventually may result in an actual musculoskeletal injury such as tendonitis, tenosynovitis or serious nerve compression injury like carpal tunnel syndrome. Discomfort will also adversely affect work performance either by decreasing the quantity and quality of work through increased error rates or both.

Various methods are now available for assessing exposure to the risks associated with work-related musculoskeletal disorders, or identifying potentially hazardous jobs or risk factors within a job. The aim of this paper is to give an overview of existing techniques, which can be used by physiotherapist for clinical assessment of physical work load and associated exposure to work-related musculoskeletal risks.

3.1 NMQ (Nordic Musculoskeletal Questionnaire) is used to find the prevalence of work related musculoskeletal disorders in different anatomical regions such as neck, shoulders, upper back, lower back, knees, elbow, wrists/hands, buttocks, ankles. Respondents are asked if they have had any musculoskeletal trouble in the last 12 months and last 7 days which have prevented normal activity. Additional questions elicit any accidents affecting each area, functional impact at home and work (change of job or duties), duration of the problem, assessment by health professional and musculoskeletal problems in the last 7 days (Kuorinka et. al. 1987). The NMQ is used as a questionnaire or as a structured interview (Crawford, 2007). NMQ can be widely used by therapists as a screening tool for work related musculoskeletal disorders.

3.2 PLIBEL (method for the identification of musculoskeletal stress factors that may have injurious effects) is a screening tool designed to identify ergonomic hazards in the workplace, via the use of a checklist (Kemmlert and Kilbom, 1987). The checklist consists of questions regarding work posture, movements, workplace or tool design. These are answered in accordance with the body regions concerned, including neck /shoulders and upper part of back, elbows /forearms and hands, feet /knees and hips, and low back. The tool is useful for identifying risk factors for musculoskeletal injuries of a specific body region, and has been applied in several studies (Vink, 1991and Jakobsson, 2003). PLIBEL results can serve as the basis for discussion on improvements to job design and prevention of work related musculoskeletal disorders by the therapists.

3.3 QEC system (Quick Exposure Check for work-related musculoskeletal risks) has been developed by Li and Buckle, 1998. The method includes the assessment of the back, shoulder /upper arm, wrist /hand and neck, with respect to their postures and repetitive movement. Information about task duration, maximum weight handled, hand force exertion, vibration, visual demand of the task and subjective responses to the work is also obtained from the worker. The magnitude of each assessment item is classified into exposure levels and the combined exposures between different risk factors for each body part are implemented by using a score table, in which higher scores are given to the combination of two higher-level exposure of risk factors than the combination of two lower-level exposures. Up to five pairs of combination /interaction are considered for obtaining overall exposure scores of the back, shoulder /upper arm, hand /wrist and neck, i.e. posture versus force, movement versus force, duration versus force, posture versus duration, and movement versus duration. Field tests have also been conducted using the system to assess 60 tasks in different occupations (Li and Buckle, 1998, 1999).QEC has a high level of usability and sensivity. This method can be used by the therapist as it has the advantage for quick assessment of the exposure to risks for work related musculoskeletal disorders.

3.4 RULA (Rapid Upper Limb Assessment) is designed for assessing the severity of postural loading and is particularly applicable to sedentary jobs (McAtamney and Corlett, 1993). The method adopts the concept of OWAS, using numbers to represent postures with an associated coding system (Karhu et. al. 1977). The range of movement for each upper body part (head, trunk, upper and lower arm, wrist) is divided into sections that are numbered. Number 1 is given to the range of movement or working posture where risk factors causing load on the structures of the body segment are minimal, and higher numbers are given to parts of the movement range with more extreme postures. If an abduction or rotation is involved, the scoring is described beside the diagram. In addition to posture recordings, RULA also considers the load on the musculoskeletal system caused by static or repetitive muscle work and force exertion. This method can even help the therapist to accurately estimate the level of intervention required reducing the risks of injury due to physical loading on the operator and thus preventing work related musculoskeletal disorders.

3.5 REBA (Rapid Entire Body Assessment) is developed on the basis of the RULA system, but it is appropriate for evaluating tasks where postures are dynamic, static or where gross changes in position take place. To use the tool, the observers select the posture or activity to be assessed and score the body alignment using the REBA diagrams. This is then combined with a load score to form the 'coupling scores', which are further processed into a single combined risk score using the table provided (Hignett and McAtamney, 2000). The therapist can use this method for rapid assessment of standing work and can suggest necessary ergonomic interventions.

3.6 OWAS (Ovako Working Posture Analyzing System), as developed by the Ovako Oy Steel Co. in Finland and described in details in several papers (Wilson & Corlett, 2010). The system defines the movements of body segments around the lower back, shoulder and lower extremity (including the hip, knee and ankle) as four types: bending, rotation, elevation and position. To use this system, the analyst makes an instantaneous observation of the posture and records a four-digit code, representing the positions of the back (four choices), the arms (three choices), the legs (seven choices) and force. The recording procedure requires only a few seconds and can be used in conjunction with random schedule of observations to obtain a summary description of posture. OWAS also has action categories to reflect the magnitude of risks. The OWAS method (or its modified form) has been used in several ergonomic or epidemiologic studies, such as surveillance for ergonomic hazards at work (Karhu et.al.1981), identification of strenuous tasks and activities in particular jobs, (Kant et. al.1990, Scott and Lambe, 1996) characterization of exposure in epidemiologic studies and evaluation of the effectiveness of ergonomic controls (Kivi and Mattila, 1991).This method if used by therapist will provide earlier risk detention capabilities and consequent prevention of work related musculoskeletal disorders.

3.7 (LMM) The lumbar motion monitor is a triaxial electrogoniometer that was developed to record three dimensional components of trunk position, velocity and acceleration (Marras et. al.1992). The system is designed to be worn on the back of the worker and to track the worker's trunk motion during work. Marras (1992) reported that the LMM is about twice as accurate as a video-based motion evaluation system. The electro-goniometer system adopts a simple concept, i.e. direct measurement of joint angles. It is easy to use and the recording has been found to be sufficiently accurate and reliable for epidemiologic studies (Smutz et. al. 1994). If a patient or client experiences decreased range of motion of spine due to any mechanical deficit, the therapist can use LMM to assess the range of motion before manual therapy, and then make sure it is working by using the LMM in subsequent interventions.

3.8 RPE (Borg Rating of perceived exertion scale) the measurement of work effort and fatigue was one of the earliest challenges that ergonomists faced. The performance of work in more deviated postures invariably requires more muscular effort, which in turn may accelerate muscular fatigue but none of the other physical methods used to assess discomfort or posture, yields information on the degree of work effort or on the level of accumulated fatigue that could amplify an injury risks. The scale grew linearly with workload and thus remained equidistant with regard to aerobic demands. By using 6 as the lowest number and 20 as the highest on the scale, a simple relation with heart rate for healthy middle aged people was obtained. The Borg Ratings of Perceived Exertion Scale provides a physiologically validated method for quantifying how much effort is involved in performing physical work (Borg, 1998). The therapist can monitor the intensity of exercise/ aerobics in healthy pregnant women by the mother's rating of perceived exertion, because it is not recommended using target heart rate to determine intensity of exercise during pregnancy, as there is increase in resting heart rate and decrease in maximal heart rate (Wolfe and Weissgerber , 2003).

There are computer based systems discussed in this review, that record work postures and activities either on-site with a computer, or on a videotape that is later analyzed using a computer. Two options can be used for the observation: time sampling or (simulated) real-time. The advantages of these systems include the ability to handle posture data in real time and the avoidance of observer bias, as body movements can be recorded without the presence of an observer. However, the analysis of the tape-recordings requires a well trained analyst so as to characterize the work postures correctly. But on other hand, if detailed posture information is to be obtained, a significant amount of time is required to analyze the data.

4. Blend of Rehabilitation and Ergonomics as a Part of Medical Management

As rehabilitation professionals turn to rehabilitation ergonomics as a specialty, they are bolstered by the scientific ongoing studies that describe the specifics of programs that have demonstrated effectiveness. Workers appreciate the ergonomic modifications, assistance with understanding their capacities and assistance with return to work at the worksite. The work is positively received by employers as well, since costs and days lost are decreased. The second positive effect of rehabilitation ergonomics is that re-injury rate can also be measured. In the 1990s, the focus on return to work outcomes became an important area of research.

Pransky, G. et al. (2002) comprehensive review of the literature categorized the variables that affect return to work. He concluded that the re-injury rates are increased in women with jobs that have both high pre-injury ergonomic risk and high post-injury ergonomic risk, dissatisfaction with work accommodation; negative employer reactions, dissatisfaction with the medical services and dissatisfaction with low back statistics. Staal, 2002 performed a descriptive review of return to work interventions for low back pain. He noted that multi-model treatment consisting of exercise, education, behavioral training and ergonomics would be the most promising.

Anema et. al. (2003), studied those with low back pain, acknowledged the use of ergonomics for prevention and added a study for disability management. When ergonomic suggestions and interventions were developed for low back pain patients, the results were positive. The ergonomic interventions were implemented and workers were satisfied with the solutions and reported that they had a stimulating effect. Loisel et al. (1994) developed the Sherbrooke Model, which postulated that ergonomic interventions should be used with clinical interventions in return to work. Another study demonstrated that the occupational interventions, combined with clinical interventions, saved days on benefits and saved costs Loisel et. al. (2002).

Lemstra and Olszynski, (2003) evaluated a industry in Canada and demonstrated the effectiveness of occupational management. This included a physical therapist onsite using ergonomic reassurance and encouragement to assist injured workers to be on the job safely. The work was based on the physical and functional information from the physical therapist. The blending of prevention and return to work ergonomics allowed the intervention to take place sooner. Upper extremity and back injury claims with the new model demonstrated decrease in days lost up to 91%. This was superior to the traditional medical model of standard care or a regime of clinical physical therapy service.

4.1Rehabilitation Ergonomics Components

Rehabilitation professionals have always treated workers with musculoskeletal injuries in their practice. In the 1980s, worker's compensation systems began to strongly emphasize reduction in work disability. As a result, rehabilitation professionals developed four specialties that bridge the gap between treatment and return to work. They are:

4.1a.Functional capacity evaluation (FCE)

FCE were developed to evaluate the physical work-related abilities of an injured worker (Hart et. al. 1993). The impetus came from workers' compensation administrators who determined that physician's restrictions alone did not provide adequate specific information for an employer to bring a worker back to work. Specific work functions were listed and physicians were asked to rate the worker on each category. In turn, *therapists* were called upon to develop an objective means to measure work function that could be used as an adjunct for the medical release to work. Functional evaluation is an objective measure of the ability of a worker to perform actual work tasks. FCE adds work relevance to testing by using functional activities such as lifting, pushing, pulling, carrying, gripping, climbing, walking, balancing, reaching, sitting, and standing. FCEs utilize the listing of job tasks developed by the U.S. (National Technical Information Service, Washington DC, 1993).

While functional testing is a specialty for therapists, the resultant findings and recommendations are stronger when the therapist is also a rehabilitation ergonomist. The knowledge of the worksite, the jobs and the job modification opportunities provide information for a stronger resolution of the return to work objective (Marras & Karwowski, 2006).

4.1b.Work rehabilitation

Work-related rehabilitation provides a structured regime that allows the injured worker to increase function and regain work capabilities whose physical limitations prevent return to work at their previous job or at full duty. In addition to traditional therapeutic exercise, work rehabilitation includes actual or simulated work task and work behavior management (Susan J. Isernhagen, 1988)). Its use of work simulation ensured that work behaviors would be addressed and that return to actual work would be the goal. An atmosphere is created in which the clients are responsible for their own progress. The therapist is a guide and assists, but the worker does the work to accomplish the goals (Marras & Karwowski, 2006).

In the 1980s Matheson et. al. (1985, 1987) defined and described work hardening. The Commission on Accreditation of Rehabilitation Facilities (CARF) developed the first work hardening standards. It defined work hardening as a multi-disciplinary program including physical, psychological and vocational components. In response to CARF, the American Physical Therapy Association determined that there were two types of work rehabilitation programs; work hardening and work conditioning. Work hardening was defined in similar terms as CARF. Work conditioning emphasizes physical and functional strengthening for return to work (Marras & Karwowski, 2006).

4.1c.Functional Restoration

Mayer et al. designed a multi-disciplinary program to return chronically injured workers to the work-place. Objective measurements were emphasized, including those from isokinetic exercise technology (Mayer et. al.1985).

4.1d.Job modification

At the worksite, modifications match the work to the capacity of the worker to promote return to work and prevention of re-injury. Both FCE and work rehabilitation focus on the functional ability of the worker. If a worker has demonstrated capacities to do the essential functions of his/her job, then the rehabilitation ergonomist provides assurance, answers questions and facilitates communication with the supervisor and coworkers. If there is not a match, however, modifications of job tasks are necessary to protect the worker and yet allow essential functions to be performed productively.

Many modifications are time-limited, as the worker's function should improve with physical work and continuation of the healing process. If a condition is permanent (e.g., spinal fusion, neurological damage), the modification may also be permanent (Marras & Karwowski, 2006).

4.1e.Early intervention

Immediate intervention when a work injury or illness threatens work ability reduces the lost time for the worker and increases healing and functional work capability. Thus, innovative programs were designed to bring an injured worker very early for evaluation and treatment of their musculoskeletal injuries (Susan J. Isernhagen, 1988, 1995 and Pransky et. al. 2002). Once the early intervention process is in place, education for workers and supervisors is necessary for early symptoms of musculoskeletal disorders to be recognized. Workers must be aware of the early stages of carpal tunnel syndrome, tendonitis, strains, and others, in order for the system to work.

Intervention includes evaluation of the condition, assessment of current functional capacity to determine if the worker can continue to work, institution of functional treatment and modification of the job when early return to work can be accomplished. Early intervention is best done onsite or in a clinic that is close to the worksite. The effectiveness of early intervention compared to previous traditional treatment is analysis to identify jobs or job tasks in the workplace where problems occur most frequently. The therapist or rehabilitation ergonomist as part of the team, can then institute prevention measures. These may be ergonomic redesign, new tools, education, improved job training, stretching, ergonomic postures and problem solving. Early intervention is a bridge between injury prevention and injury management.

Rehabilitation Ergonomics is still in its early stages, while it gives immense innovative scope for physiotherapists/physical therapist to act as one. The employers are looking for further better methods to return injured workers to work, by help of these experts professionals. Early intervention bridge the gap between return to work and prevention of injury. Job modifications begin with individual patients and advances into wider use in musculoskeletal injury prevention.

5. Conclusions

The range and scope of the physiotherapist/physical therapist discussed in this review provide them with ergonomic tools to undertake a range of studies including rehabilitation, epidemiological, clinical and ergonomic research, evaluation of ergonomic programs and design interventions, surveillance of workplace ergonomic hazards, and the detection and quantification of exposures to adverse workplace physical ergonomic stressors. Armed with this battery of tools, the physiotherapist with the knowledge of ergonomics will be well positioned to systematically tackle a wide range of rehabilitation and clinical issues to further implement effective solutions to the problems that are uncovered.

References

1. Anema, J. R., Steenstra, I. A., Urlings, I. J. M., Bongers, P. M., De Vroome, E. M. M., & Van Mechelen, W. (2003). Participatory ergonomics as a return-to-work intervention: A future challenge? *American journal of industrial medicine*, *44*(3), 273-281.

2. Borg, G. (1998). Borg's perceived exertion and pain scales. Human kinetics.

3. Crawford, J. O. (2007). The Nordic musculoskeletal questionnaire. *Occupational Medicine*, *57*(4), 300-301.

4. De Looze, M. P., Van Rhijn, J. W., Van Deursen, J., Tuinzaad, G. H., & Reijneveld, C. N. (2003). A participatory and integrative approach to improve productivity and ergonomics in assembly. *Production Planning & Control*, *14*(2), 174-181.

5. Edwards, I., Jones, M., Carr, J., Braunack-Mayer, A., & Jensen, G. M. (2004). Clinical reasoning strategies in physical therapy. *Physical Therapy*, *84*(4), 312-330.

6. Forsman, M., Sandsjö, L., & Kadefors, R. (1999). Synchronized exposure and image presentation: Analysis of digital EMG and video recordings of work sequences. *International journal of industrial ergonomics*, *24*(3), 261-272.

7. Fransson-Hall, C., Gloria, R., Kilbom, Å., Winkel, J., Karlqvist, L., & Wiktorin, C. (1995). A portable ergonomic observation method (PEO) for computerized on-line recording of postures and manual handling. *Applied Ergonomics*, *26*(2), 93-100.

8. Halpern, M., Hiebert, R., Nordin, M., Goldsheyder, D., & Crane, M. (2001). The test–retest reliability of a new occupational risk factor questionnaire for outcome studies of low back pain. *Applied Ergonomics*, *32*(1), 39-46.

9. Hart, D. L., Isernhagen, S. J., & Matheson, L. N. (1993). Guidelines for Functional Capacity Evaluation of People With Medical Conditions 1. *Journal of Orthopaedic & Sports Physical Therapy*, *18*(6), 682-686.

10. Held, J., Bruesch, M., Krueger, H., & Pasch, T. H. (1999). The FIT-system: A new hand-held computer tool for ergonomic assessment. *Medical & Biological Engineering & Computing*, *37*(supl 2), 862-863.

11. Hignett, S., & McAtamney, L. (2000). Rapid entire body assessment (REBA). Applied ergonomics, 31(2), 201-205.

12. Hildebrandt, V. H., Bongers, P. M., Van Dijk, F. J. H., Kemper, H. C. G., & Dul, J. (2001). Dutch Musculoskeletal Questionnaire: description and basic qualities. *Ergonomics*, *44*(12), 1038-1055.

13. Jakobsson, M. (2003). Assessment of the work place by workers and observer A comparison. *Advances in Industrial Ergonomics and Safety V*, 182.

14. Jarebrant, C., Mathiassen, S. E., Öjmertz, B., & Winkel, J. (2004, August). Ergonomic value stream mapping—An ergonomic complement to a rationalization tool. In *Proceedings from the Nordic Ergonomcis Society 36th Annual Conference, Kolding, Denmark*.

15. Kadefors, R., & Forsman, M. (2000). Ergonomic evaluation of complex work: a participative approach employing video–computer interaction, exemplified in a study of order picking. *International Journal of Industrial Ergonomics*, *25*(4), 435-445.

16. Kant, I., Notermans, J. H. V., & Borm, P. J. A. (1990). Observations of working postures in garages using the Ovako Working Posture Analysing System (OVVAS) and consequent workload reduction recommendations. Ergonomics, 33(2), 209-220.

17. Karasek, R., Brisson, C., Kawakami, N., Houtman, I., Bongers, P., & Amick, B. (1998). The Job Content Questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. *Journal of occupational health psychology*, *3*(4), 322.

18. Karhu, O., Kansi, P., & Kuorinka, I. (1977). Correcting working postures in industry: a practical method for analysis. *Applied ergonomics*, *8*(4), 199-201.

19. Karhu, O., Härkönen, R., Sorvali, P., & Vepsäläinen, P. (1981). Observing working postures in industry: Examples of OWAS application. Applied Ergonomics, 12(1), 13-17.

20. Kemmlert, K., and Kilbom, Å. (1987). Method for identification of musculoskeletal stress factors which may have injurious effects. In *The XIth World Congress on the Prevention of Ovvupational Accidents and Diseases, Stockholm*.

21. Kemmlert, K. (1995). A method assigned for the identification of ergonomic hazards—PLIBEL. *Applied Ergonomics*, *26*(3), 199-211.

22. Keyserling, W. M., Armstrong, T. J., & Punnett, L. (1991). Ergonomic job analysis: A structured approach for identifying risk factors associated with overexertion injuries and disorders. *Applied Occupational and Environmental Hygiene*, *6*(5), 353-363.

23. Kines, P., Lappalainen, J., Mikkelsen, K. L., Olsen, E., Pousette, A., Tharaldsen, J., & Törner, M. (2011). Nordic Safety Climate Questionnaire (NOSACQ-50): A new tool for diagnosing occupational safety climate. *International Journal of Industrial Ergonomics*, *41*(6), 634-646.

24. Kivi, P., & Mattila, M. (1991). Analysis and improvement of work postures in the building industry: application of the computerised OWAS method. Applied Ergonomics, 22(1), 43-48.

25. Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sørensen, F., Andersson, G., & Jørgensen, K. (1987). Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Applied ergonomics*, *18*(3), 233-237.

26. Laring, J., Christmansson, M., Kadefors, R., & Örtengren, R. (2005). ErgoSAM: A preproduction risk identification tool. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *15*(3), 309-325.

27. Lemstra, M., & Olszynski, W. P. (2003). The effectiveness of standard care, early intervention, and occupational management in worker's compensation claims. *Spine*, *28*(3), 299-304.

28. Li, G., & Buckle, P. (1998). A practical method for the assessment of work-related musculoskeletal risks-Quick Exposure Check (QEC). In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 42, No. 19, pp. 1351-1355). SAGE Publications.

29. Li, G., & Buckle, P. (1999). Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods. *Ergonomics*, *42*(5), 674-695.

30. Loisel, P., Durand, P., Abenhaim, L., Gosselin, L., Simard, R., Turcotte, J., & Esdaile, J. M. (1994). Management of occupational back pain: the Sherbrooke model. Results of a pilot and feasibility study. *Occupational and Environmental Medicine*, *51*(9), 597-602.

31. Loisel, P., Lemaire, J., Poitras, S., Durand, M. J., Champagne, F., Stock, S., & Tremblay, C. (2002). Cost-benefit and cost-effectiveness analysis of a disability prevention model for back pain management: a six year follow up study. *Occupational and Environmental Medicine*, *59*(12), 807-815.

32. Marras, W. S., Fathallah, F. A., Miller, R. J., Davis, S. W., & Mirka, G. A. (1992). Accuracy of a three-dimensional lumbar motion monitor for recording dynamic trunk motion characteristics. International Journal of Industrial Ergonomics, 9(1), 75-87.

33. Marras, W. S., & Karwowski, W. (2006). Fundamentals and Assessment Tools for Occupational Ergonomics (Occupational Ergonomics) Handbook, 2nd Edition, Chapter 22.

34. Marsot, J. (2005). QFD: a methodological tool for integration of ergonomics at the design stage. *Applied Ergonomics*, *36*(2), 185-192.

35. Matheson, L. N., Ogden, L. D., Violette, K., & Schultz, K. (1985). Work hardening: Occupational therapy in industrial rehabilitation. *The American Journal of Occupational Therapy*, *39*(5), 314-321.

36. McAtamney, L., & Nigel Corlett, E. (1993). RULA: a survey method for the investigation of work-related upper limb disorders. *Applied ergonomics*, *24*(2), 91-99.

37. Hignett, S., & McAtamney, L. (2000). Rapid entire body assessment (REBA). *Applied ergonomics*, *31*(2), 201-205.

38. Mukhopadhyay, S., Das, S. K., & Chakraborty, T. (2012). Computer Aided Design in Digital Human Modeling for Human Computer Interaction in Ergonomic Assessment: A Review. *International Journal of Advanced Computer Research*, *2*(4).

39. Munck-Ulfsfält, U. (2004). Requirement specification for load-ergonomic risk assessment with FMEA-Checklists: A model for risk assessment from design to production. In K. Olsen, & O. J. Teller (Eds.), *Nordic ergonomics society 36th annual conference* (pp. 149-152). Kolding, Denmark.

40. Nagamachi, M. (2002). Kansei engineering as a powerful consumer-oriented technology for product development. *Applied ergonomics*, *33*(3), 289-294.

41. Neumann, W. P., Wells, R. P., & Norman, R. W. (1999). 4D WATBAK: Adapting research tools and epidemiological findings to software for easy application by industrial personnel.

42. Neumann, W. P., Wells, R. P., Norman, R. W., Kerr, M. S., Frank, J., & Shannon, H. S. (2001). Trunk posture:: reliability, accuracy, and risk estimates for low back pain from a video based assessment method. *International Journal of Industrial Ergonomics*, *28*(6), 355-365.

43. Neumann, P. (2006). *Inventory of tools for Ergonomic Evaluation*. Arbetslivsinstitutet, förlagstjänst.

44. Occhipinti, E. (1998). OCRA: a concise index for the assessment of exposure to repetitive movements of the upper limbs. *Ergonomics*, *41*(9), 1290-1311.

45. Pareek, U. (1983). Organizational role stress. *Pfeiffer's Classic Inventories, Questionnaires, and Surveys*, 319-329.

46. Pousette, A., & Hanse, J. J. (2002). Job characteristics as predictors of ill-health and sickness absenteeism in different occupational types--a multigroup structural equation modelling approach. *Work & Stress*, *16*(3), 229-250.

47. Pransky, G., Benjamin, K., Hill-Fotouhi, C., Fletcher, K. E., Himmelstein, J., & Katz, J. N. (2002). Work-related outcomes in occupational low back pain: a multidimensional analysis. *Spine*, *27*(8), 864-870.

48. Scott, G. B., & Lambe, N. R. (1996). Working practices in a perchery system, using the OVAKO Working posture Analysing System (OWAS). Applied Ergonomics, 27(4), 281-284.

49. SMUTZ, P., SERINA, E., & Rempel, D. (1994). A system for evaluating the effect of keyboard design on force, posture, comfort, and productivity. Ergonomics, 37(10), 1649-1660.

50. Spector, P. E. (1997). *Job satisfaction: Application, assessment, causes, and consequences* (Vol. 3). Sage.

51. Staal, J. B., Hlobil, H., van Tulder, M. W., Köke, A. J., Smid, T., & van Mechelen, W. (2002). Return-to-work interventions for low back pain. *Sports Medicine*, *32*(4), 251-267.

52. Stanton, N. A., Hedge, A., Brookhuis, K., Salas, E., & Hendrick, H. W. (Eds.). (2004). *Handbook of human factors and ergonomics methods*. CRC Press.

53. Steven Moore, J., & Garg, A. (1995). The strain index: a proposed method to analyze jobs for risk of distal upper extremity disorders. *American Industrial Hygiene Association*, *56*(5), 443-458.

54. Sundin, A., Christmansson, M., & Larsson, M. (2004). A different perspective in participatory ergonomics in product development improves assembly work in the automotive industry. *International journal of industrial ergonomics*, *33*(1), 1-14.

55. Susan J. Isernhagen. (1988). *Work injury: Management and prevention*. Aspen Pub, Chap.15.

56. Susan J. Isernhagen. (1995). *The comprehensive guide to work injury management*. Aspen Pub. Chap. 13.

57. Vink, P. (1991). Towards a field usable biomechanical typology of work. *International Society of Electrophysiological Kinesiology*, 161-164.

58. Ware, J. E., Kosinski, M., Dewey, J. E., & Gandek, B. (2000). *SF-36 health survey: manual and interpretation guide*. Quality Metric Inc.

59. Waters, T. R., Putz-Anderson, V., Garg, A., & Fine, L. J. (1993). Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics, 36(7): 749-776.

60. Waters, T. R., & Putz-Anderson, V. (1999). Revised NIOSH lifting equation. In W. Karwowski & W. S. Marras (Eds.), The occupational ergonomics handbook. London: CRC Press.

61. Wiktorin, C., Mortimer, M., Ekenvall, L., Kilbom, A., & Hjelm, E. W. (1995). HARBO, a simple computer-aided observation method for recording work postures. *Scandinavian journal of work, environment & health*, *21*(6), 440-449.

62. Wilson, J. R., & Corlett, N. (Eds.). (2010). *Evaluation of human work*. CRC Press. 662-713.

63. Wolfe, L. A., & Weissgerber, T. L. (2003). Clinical physiology of exercise in pregnancy: a literature review. *Journal of obstetrics and gynaecology Canada: JOGC= Journal d'obstetrique et gynecologie du Canada: JOGC*, *25*(6), 473-483.