SYSTEMATIC REVIEW

Ergonomics Risk Assessment Tools: A Systematic Review

Zayyinul Hayati Zen[1,2] , Mirta Widia[1,3], Ezrin Hani Sukadarin[1,4]

[1] Faculty of Industrial Sciences and Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, 26300, Kuantan, Pahang, Malaysia.
[2] Industrial Engineering Department, Faculty of Engineering, Universitas Muhammadiyah Riau, 28294, Indonesia.
[3] Centre for Advanced Industrial Technology, Universiti Malaysia PahangAl-Sultan Abdullah, 26600, Pekan, Pahang, Malaysia.
[4] Department of Chemical Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussien Onn Malaysia, 86400 Parit Raja, Johor, Malaysia.

ABSTRACT

Introduction: The ergonomic approach involves a careful examination of a job task, worker actions, and critical job information. This approach detects ergonomic risks. Identifying and managing ergonomic risk variables during risk assessment is crucial to designing and planning work activities to reduce injury risk. This study aims to investigate existing ergonomic risk assessment techniques and specific areas related to those in Ergonomic Risk Assessment (ERA) tools. **Materials and methods:** The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) review technique was used to find articles on ERA tools from Scopus, PubMed, Science Direct and Google Scholar between 2010 and 2021. Twenty-two publications were selected following PRISMA guidelines based on the inclusion and exclusion criteria set. This review is divided into two sections: (1) Ergonomic Assessment Techniques and; (2) Identify specific concerned areas related to the terms Task, Individual, Load, Environmental or Other Factors (TILEO). **Results:** The findings address the significant ERA technique commonly utilised in the tool. The observation-based methods (67%), computer-based applications (20%), checklists, surveys and reports (10%), while the direct measurement methods (3%) of the ergonomic assessment techniques. **Conclusion:** It was highlighted that most ERA tools concern the task, individual and load area. Meanwhile, other factors include repetition, duration and contact stress. Furthermore, many ergonomics risk assessment tools specialise in manual materials handling tasks but focus only on assessing the physical risk factors. This review's results can help ergonomist acquire an overview of the overall ergonomic risk factors that are most likely to present in the current ergonomic risk assessment tool.
Malaysian Journal of Medicine and Health Sciences (2024) 20(5): 289-300. doi:10.47836/mjmhs20.5.35

Keywords: Ergonomic risk assessment, Ergonomic risk assessment tools, Risk factor, Manual material handling tasks, Occupational Safety and Health

Corresponding Author:
Mirta Widia, PhD
Email: mirta@umpsa.edu.my
Tel : +60162378749

INTRODUCTION

Workplace characteristics that cause considerable wear and tear on the body and might result in injuries are known as ergonomic risk factors. Any feature, attribute, or exposure that contributes to musculoskeletal issues can become a risk factor. It is more challenging to control risk factors connected to job activities, behaviours or conditions that harm the musculoskeletal and ergonomic systems. When two or more risk factors tend simultaneously, the likelihood of disease increases, potentially increasing the risk of some people developing a musculoskeletal disorder over time (1,2).

Previous research indicated that the workplace and increased physical demands of occupations such as lifting heavy things, repetitive movements and awkward postures (including activities of twisting, bending, kneeling and putting arms on the shoulders) are the leading causes of MSDs in workers (3). The ergonomic approach, when correctly performed, comprises a detailed study of the nature of a job task, the activities performed by workers throughout the task, as well as the acquisition of critical job information. This method determines the presence of any ergonomic risk factors. Identifying and managing ergonomic risk factors during the risk assessment process is essential to ensure that work activities are designed and planned to minimise the risk of injury (4). Other studies also shown that the job duration, bending or twisting postures, and environmental factors have been identified as important risk factors for manual handling workers (36).

Ergonomic risk encompasses factors within a work setting or employee behavior, along with the overall working environment, that could potentially impact both the performance of the system as a whole and the well-being of individuals involved (5). Concurrently, ergonomic risk assessment refers to a structured approach, whether in the form of a program, process, or investigation, aimed at analyzing, assessing, and prioritizing any risks associated with ergonomic concerns within the workplace (6). Various tools are available for evaluating tasks and postures (6,7,8), movement frequency (9, 10) and force exertion (11,12) within the work environment to gauge ergonomic risks. These tools, tailored to assess ergonomic risk factors linked to musculoskeletal disorders, have been utilized across diverse industries such as manufacturing industry (2, 12, 14–16), construction (13, 17, 18), palm oil industry (19), logistic industry (20), and others, each adapting to the specific demands of different workplace activities.

Although many ergonomic risk assessment tools have been developed and used in various workplaces, a systematic review of the techniques used and specific concerned areas (Task, Individual, Load, Environment and Other Factors - TILEO) in each ergonomic risk assessment tool is yet to be done. In manual handling assessment tool, understanding TILEO is crucial. By adapting the TILEO categorization in a systematic literature review, deep understanding may be obtained andarea or item improvement for future tool development become easier to be explored. Therefore, this study investigates the existing ergonomic risk assessment techniques and specific areas concerning those discovered in the ergonomic risk assessment tools. Through this investigation, it's possible to pinpoint the shortcomings of current tools, paving the way for the future enhancement of ergonomic risk assessment tools.

MATERIALS AND METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were used as the methodology for this systematic literature review (14). The approach used to retrieve articles relating to risk factors for manual materials handling tasks is described in this section. The PRISMA approach incorporating directories including Scopus, PubMed, Science Direct and Google Scholar was adopted in this review.

A systematic literature review (SLR) is a well-structured, organised, and transparent procedure that follows repeatable protocols at each step to identify, study and analyse literature systematically connected to earlier studies or research. Metanarrative and mixed study reviews are commonly used to describe systematic reviews (15).

Identification

The identification technique was the first step in the systematic review method. The identification procedure was completed in August 2021. The survey questions and goals were explicitly defined during this phase. The four primary indexing databases used in this review were Scopus, PubMed, Science Direct and Google Scholar, which were chosen to ensure the quality of the papers assessed in this work besides ensuring established indexing methods for citations. Furthermore, studies published in peer-reviewed journals are well-regarded and represent scholarly research in the field. This approach found 114 articles from Scopus databases, 1.579 articles from PubMed, 1.002 articles from Science Direct and 1.660 articles from Google Scholar. The combination of keywords and related words was used such as “ergonomic risk assessment”, “ergonomic risk assessment tools”, “risk factor”, “risk assessment”, "assessment", "technique", and “tool”. All the keywords were selected via functions of phrase searching and the Boolean operator (OR, AND).

Scopus search string: TITLE-ABS-KEY ((“ergonomic risk assessment*” OR “ergonomic risk assessment tool*” OR “risk factor*” OR “risk assessment*”) AND (“assessment*” OR “technique*” OR “tool *”)). The process of searching occurs in title, abstract and the keyword of manuscript.

Screening

The second step was the screening process, which includes or excludes articles depending on the authors’ parameters using specialised databases. As shown in Table 1, the screening procedure identified eligibility, inclusion and exclusion criteria to seek relevant papers for the systematic review process. This study inspected 4.355 papers after the identification procedure. After the screening process, which covered the study period between January 2010 to July 2021 and focused solely on the ergonomic risk assessment and ergonomic risk assessment tools, 77 articles were presented. Journals that published systematic reviews or review papers were excluded, as well as conference papers, proceedings, book chapters, series of books and textbooks. The screening process included journal articles in English that utilised ergonomic risk assessment tools. English was included in the screening criteria since most of the papers published in reputable journals are in English. Finally, studies that did not use ergonomic risk assessment tools were excluded as the study goal is on assessing ergonomic risk factors.

Eligibility

Table I displays the inclusion and exclusion criteria in this study. The eligibility step was the third phase, which determines whether the papers are included depending on the authors' criteria. The following step removed 23 similar items from both databases, leaving 54 articles for the eligibility step. It is a manual screening of the preliminary screening steps for literature focusing on ergonomic risk assessment tools and criteria (inclusion and exclusion criteria).

Table I: The inclusion and exclusion criteria.

Criteria	Inclusion	Exclusion
Timeline for publication	January 2010–July 2021	2009 and before
Document Type	Journal (research articles)	Journals (systematic review), conference proceedings, book chapters, book series, and books
Language	English	Non-English
Content of writing	Paper used the ergonomic risk assessment tool	Paper did not use the ergonomic risk assessment tool

Quality appraisal

The remaining manuscripts were evaluated, assessed, and analysed with 22 of them (studies) receiving special attention for quality. The remaining articles were presented to two experts to ensure the quality of the article's contents. The articles were selected using the set criteria (timeline for publication, document type, language, and content of writing).

Thereafter, evaluation was done based on specific studies that addressed this study's research questions and goals, which are to investigate the existing ergonomic risk assessment techniques and specific areas related to those found in ERA tools, as well as to investigate the ergonomic risk variables included in an ergonomic risk assessment tool. By evaluating the titles, abstracts, and full transcript of the papers, the studies were extracted to uncover relevant themes and sub-themes for the current study.

Data abstraction and analysis

The final step was data abstraction and analysis. The remaining articles were evaluated, reviewed, and analysed, hence yielding 21 selected articles (studies) that were discussed in detail in this paper as tabulated in Table III and Table IV. The reviews were based on specific studies that matched the research questions and objectives of this study, which investigate the existing ergonomic risk assessment technique and specific areas related to those found in ERA tools. The summary of the SLR Ergonomic Assessment Techniques process is illustrated in Fig 2. The last step was to investigate the ergonomic risk factors that are most likely to be present in the current ergonomic risk assessment tools.

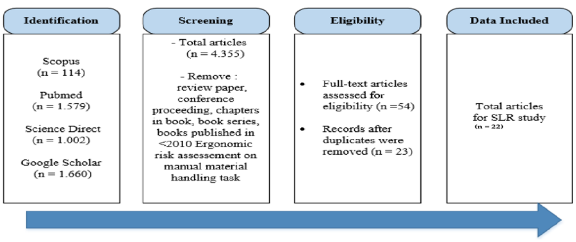

Fig. 1: PRISMA's steps for SLR studies
An adaptation of Moher et al. (2009) and Mohamed Shaffril et al. (2019)

Fig. 1 displays the PRISMA's steps for SLR studies. A thematic analysis describes themes among the ergonomic risk variables that should be included in an ergonomic risk assessment tool. The essential points, similarities, and differences among the 21 papers were identified and categorised. As described by Nowell, six steps should be observed in the thematic analysis and are appropriate for qualitative analysis in this SLR study (19). These steps are:

1. Learning about the data (understand and analyse the 21 studies),
2. Generating the first code (find the parallels and contrasts between the issues mentioned in the 21 studies),
3. Searching themes (generate or discover appropriate themes to design based on the 21 study's commonalities and differences),
4. Examining themes (confirming that proposed themes and subthemes are appropriate to each study's main theme),
5. Identifying and naming themes,
6. Producing a report (This refers to the SLR research in this case).

RESULTS

Background of selected articles

Table II presents the ergonomic risk assessment tools used in many research. Articles from 14 different countries were chosen; four (4) studies were conducted in Iran, four (4) in Malaysia, two (2) in Germany and one in India, Indonesia, North America, the United States of America, Spain, France, Portugal, Australia, Sweden, California, as well as the Philippines. In addition, table 2 reveals the business sectors involved in the articles. It was shown that ergonomic risk assessment tools are used in many business sectors. The manufacturing industry (57%) is the most dominant business sector in terms of the use of ergonomic risk assessment tools. Meanwhile, the construction industry represents 14% of the business sectors, followed by 29% of other business sectors (cleaning product industry, rubber industry, metal stamp industry, oil palm plantations and logistics industry). However, most of the tasks seen are manual activities, such as manual lifting, manual handling, casting, wall plastering, bricklaying, floor concrete work, metal stamping and all activities of moving goods.

Ergonomic assessment techniques

Table III lists the published papers based on ergonomic assessment techniques, which were categorised into four techniques: (1) checklists, surveys, and reports; (2) observation-based methods; (3) direct measurement methods; and (4) computer applications.

Checklists, surveys and reports are very helpful as they are simple and easy to use, can be utilised in a wide range of working situations, evaluate a large number of subjects at a low cost compared to other methods, as well as able to find high-risk occupation groups for further study (32). The observation-based methods frequently provide a risk score and a quantitative framework for analysing the risk of an ergonomic task. The main problem with these methods is that the risk analysis is limited or only looks at some risks (32,33). Direct methods comprise all procedures that permit measurements of the worker's risk exposure and musculoskeletal activity during the performance of tasks. This is typically accomplished by directly connecting various sensors to the worker's body. Meanwhile, computer-based techniques are often used in workplace ergonomic analysis and are generally based on frameworks and procedures built on a combination of observation, checklists and artificial intelligence methods (19–21,23,34).

Table II: Authors and ergonomic risk assessment tools according to business sectors and tasks.

Country	Author	Name of Tool	Business Sector	Task
Iran	Asadi et al., 2015 [11]	NIOSH lifting Equation WISHA Index	Manufacturing Industry	Manual lifting activities
	S.Shokria et al., 2015 [16]	Manual Handling Assessment Charts (MAC) Assessment of Repetitive Tasks (ART)	Cleaning products industry	Manual handling activities
	Mohammadi et al., 2013 [13]	Snook Tables (The Liberty Mutual MMH Tables)	Manufacturing Industry	Casting workers activities
	Abedini et al., 2013 [10]	NIOSH lifting Equation Manual Handling Assessment Charts (MAC)	Rubber Industry	Manual handling activities
Malaysia	Abd Rahman et al., 2011 [12]	The Workplace Ergonomic Risk Assessment (WERA)	Construction Industry	Wall plastering job, bricklaying job, and floor concreting job
	Halim et al., 2012 [17]	The Prolonged Standing Strain Index (PSSI)	Metal stamping industry	Standing posture in metal stamping process
	Sukadarin et al., 2016 [18]	Simple Ergonomics Risk Assessment (SERA)	Oil palm plantation	Manual handling activities
	DOSH, 2017 [2]	Initial ERA	Manufacturing Industry	Manual handling activities
Germany	Klussmann et al., 2010 [19]	The Key Indicator Method for Manual Handling Operations (KIM-MHO)	Manufacturing Industry	Machine operator activities
	Schaub et al., 2012 [20]	The ergonomic assessment worksheet (EAWS) Digital Human Model (DHM)	Manufacturing Industry	Movement activities
India	Ray et al., 2015 [21]	Biomechanic Analysis Ariel Performance Analysis System (APAS)	Construction Industry	Carrying and lifting of materials
Indonesia	Deviani & Triyanti, 2017 [22]	Rapid Entire Body Assessment (REBA) Job Strain Index (JSI) 2D Planar Static Model	Construction Industry	Lifting the pole and loading the goods
North America	Potvin et al., 2021 [23]	The Liberty Mutual manual materials handling (LM-MMH) equations	Manufacturing Industry	Manual handling activities
USA	Li et al., 2020 [24]	Rapid Upper Limb Assessment (RULA) Pose Detector	Manufacturing Industry	Manual lifting activities
Spain	Sanchez-Lite et al., 2013 [25]	Novel Ergonomic Postural Assessment Method (NERPA)	Assembly Industry	Manual assembly operations
France	Zare at al., 2014 [26]	SCANIA Ergonomic Standard (SES)	Manufacturing Industry	Movement activities
Portugal	Pires, 2012 [27]	NIOSH lifting Equation	Manufacturing Industry	Manual handling activities
Australia	Straker et al., 2011 [28]	Manual Task Risk Assessment (ManTRA)	Manufacturing Industry	Manual handling activities
Sweden	Lind et al., 2014 [29]	Risk Assessment and Management tool for manual handling Proactively (RAMP)	Manufacturing Industry	Manual handling activities
California	Yung et al., 2019 [30]	ACGIH's Hand Activity Level threshold limit values method (HAL)	Manufacturing Industry	Repetitive hand activity
Philippines	Gumasing et al., 2020 [31]	Rapid Entire Body Assessment (REBA) NIOSH lifting equation	Logistic company	Courier workers activities

Checklist, surveys, and reports method

The US Department of Labour (2001) encourages ergonomic risk factor safety evaluation techniques, which are frequently utilised for common work tasks. The

Great American Insurance Group, for example, provides ergonomic analysis spreadsheets and checklists that categorise each activity's risks depending on its general activity (36). The vast majority of ergonomic studies include checklists and surveys to look for individual risk factors at workplace, like uncomfortable postures and specific injury types, including carpal tunnel syndrome and cumulative trauma injuries (37).

Ergonomic assessment checklists are used during ergonomic assessments to ensure that workers and their environments are optimised for comfort and productivity while minimising the risk of a work-related injury. A checklist is often a list of items, which is convenient and quick to use. Paper-based and computerised work task assessments can be carried out by employees (personality surveys) or a director, supervisory, or experienced professionals. Worker's diaries are included in this category.

In this research, three previous studies were recorded using checklists, surveys and reports methods. The Risk Assessment and Management tool for manual handling Proactively (RAMP) is one of the risk assessment tools that use a checklist, surveys and reports [32]. A checklist (RAMP-I) and an assessment instrument (RAMP-II) are included in the RAMP tool. RAMP-I is a checklist with dichotomous questions designed to quickly screen manual handling activities for the existence or lack of physical risk factors. The user of RAMP-II can assess a variety of pressures and levels, as well as unpleasant variables.

Other previous research demonstrated that a questionnaire-based survey was utilised to conduct a biomechanical modelling approach for the ergonomic assessment of constructing jobs in India (21). The biomechanics analysis began with task approaches that rely on occupational risk levels of MMH tasks related to construction, as well as a questionnaire-based survey. Biomechanical modelling came next, followed by data gathering for biomechanical evaluation and finally data analysis. The motion analysis is part of the development process. The Ariel Performance Analysis System (APAS), a motion analysis system, was used in the study.

In general, an Initial Ergonomic Risk Assessment (ERA) checklist is used by Ergonomics Trained Persons (ETP) in Malaysia (2). The first level of ERA is used in the workplace to perform an initial ergonomic risk assessment. By utilising the Cornell Musculoskeletal Questionnaire (CMQ) and the DOSH Initial ERA Checklist, this Initial ERA primarily attempts to examine musculoskeletal issues and evaluate ergonomic risk factors at work. An initial ergonomics risk assessment (ERA) can help the management discover any problems that might endanger employee performance and well-being or constitute a risk at work. The outcome of this Initial ERA will determine whether or not a future Advanced ERA is performed (2).

Observation method

The most common observation-based methods provide a numerical framework for ergonomic occupational risk assessments, including relative risk. The limited or partial risk analysis is the key flaw in these methods, which concentrate on assessing work postures, with work rate and static loading coming in second and third. Typically, these methods provide the data and foundation needed to establish computer-based models for strategic planning and ergonomic analysis. A variety of video-based observational approaches are also available to discover postural alterations for highly dynamic tasks (Video review, SIMI Motion, Biomechanical Models and tri-axial-based video models). On the other hand, workplace onsite assessments do not lend themselves well to video-based assessment methods (32,33). Observation-based techniques have both advantages and disadvantages owing to the qualities that must be considered during the technique selection process.

Table III shows most of the tools used in this technique, namely KIM-MHO (19), WERA (12), ManTRA (19), PSSI (17), MAC (16), EAWS (38), NIOSH lifting Equation (27), NERPA (25), Snook Tables (The Liberty Mutual MMH Tables) (13), RAMP (29), SERA (18), REBA (22), (31), ACGIH's Hand Activity Level (HAL) permissible exposure values method (39) and RULA (24).

Direct measurement method

All techniques that allow assessment of the worker's exposure to risk and musculoskeletal activity while the tasks are being performed are considered direct measuring methods. This is commonly accomplished by directly connecting various types of sensors to the worker's body.

The SCANIA in-house Ergonomic Standard approach is one of the methods used to assess the possible ergonomic risk in the simulated job stations (SES). This method is meant to analyse multi-task workstations and is customised to the ergonomic risk criteria in assembly manufacturing. SES assesses force, lifting tasks and postures in addition to postures. To describe its ergonomic standards, 20 factors are categorised into five groups. In the earlier experiment, the initial step was to choose sensors that could track repeated movements, postures and body parts (26).

Computer-based method

In the ergonomic analysis of the workplace, computer-based applications are commonly used. The majority of these are based on frameworks and procedures that combine observational, checklist and artificial intelligence methods. The observation-based and computer-based applications are combined in the Ergonomic Assessment Worksheet (EAWS) and the Digital Human Model (DHM). Finally, the EAWS is a tool for assessing physical demands holistically. It can be used throughout the entire product lifetime, including during the digital factory phase (20). Other previous studies presented REBA, Job Strain Index and Chaffin's 2D Planar used by ErgoIntellegence to perform the risk assessment analysis of manual materials handling activities static model (22).

Computer-based observation models include the OWAS work posture analysis, RULA and REBA. ERGOBUILD is an example of an observation-based computer model (40) built to initiate the development of integrating both ergonomic and productivity concepts in panelled wall residential construction projects and is meant to be used on residential construction projects that use panelled walls. Other research has sought to develop a ground-breaking vision based real-time RULA assessment method. It offers RULA evaluation of a single image acquired by a conventional RGB camera quickly and effectively. During daily activities and lifting, the method is developed and validated with postures (24). It is a combination of observation-based and computer-based applications.

In India, Ariel Performance Analysis System was combined with Biomechanics Analysis based on a questionnaire-based survey (APAS). It calculated joint angular excitations along all three dimensions using a motion analysis system for the joints and segments examined with a significant number of frames for each work cycle (maximum, minimum, and average) [26] as an example of the checklists, surveys and reports assessment techniques with computer-based applications.

Table III: Results of ergonomic assessment techniques.

References	Name of Tool	Ergonomic Assessment Techniques			
		Checklists, surveys and reports	Observation-based methods	Direct measurement methods	Computer-based applications
Klussmann et al., 2010 [19]	The Key Indicator Method for Manual Handling Operations (KIM-MHO)		✓		
Abd Rahman et al., 2011 [12]	The Workplace Ergonomic Risk Assessment (WERA)		✓		
Straker et al., 2011 [28]	Manual Task Risk Assessment (ManTRA)		✓		
Halim et al., 2012 [17]	The Prolonged Standing Strain Index (PSSI)		✓		
Abedini et al., 2013 [10]	NIOSH lifting Equation Manual Handling Assessment Charts (MAC)		✓		
Schaub et al., 2012 [20]	The ergonomic assessment worksheet (EAWS) Digital Human Model (DHM)		✓		✓
Pires, 2012 [27]	NIOSH lifting Equation				
Sanchez-Lite et al., 2013 [25]	Novel Ergonomic Postural Assessment Method (NERPA)		✓		
Mohammadi et al., 2013 [13]	Snook Tables (The Liberty Mutual MMH Tables)		✓		
Zare at al., 2014 [26]	SCANIA Ergonomic Standard (SES)		✓	✓	
Lind et al., 2014 [29]	Risk Assessment and Management tool for manual handling Proactively (RAMP)	✓	✓		
Asadi et al., 2015 [11]	NIOSH lifting Equation WISHA Index		✓		
S.Shokria et al., 2015 [16]	Manual Handling Assessment Charts (MAC) Assessment of Repetitive Tasks (ART)		✓		
Ray et al., 2015 [20]	Biomechanic Analysis Ariel Performance Analysis System (APAS)	✓			✓
Sukadarin et al., 2016 [18]	Simple Ergonomics Risk Assessment (SERA)		✓		
Peres et al., 2017 [35]	Self-report Ergonomic Assessment Tool (SEAT)				✓

CONTINUE

Table III: Results of ergonomic assessment techniques. (CONT.)

References	Name of Tool	Ergonomic Assessment Techniques			
		Checklists, surveys and reports	Observation-based methods	Direct measurement methods	Computer-based applications
Deviani & Triyanti, 2017 [22]	Rapid Entire Body Assessment (REBA) Job Strain Index (JSI) 2D Planar Static Model		✓		✓
DOSH, 2017 [2]	Initial ERA	✓	✓		
Yung et al., 2019 [30]	ACGIH's Hand Activity Level threshold limit values method (HAL)		✓		
Li et al., 2020 [24]	Rapid Upper Limb Assessment (RULA) Pose Detector		✓		✓
Potvin et al., 2021 [23]	The Liberty Mutual manual materials handling (LM-MMH) equations		✓		✓

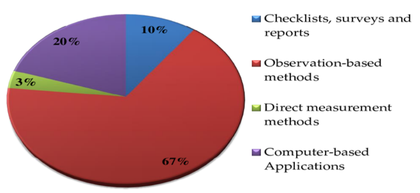

Fig 2. Percentage distribution of ergonomic assessment techniques.

Fig. 2 shows the percentage distribution of ergonomic assessment techniques. The observation-based methods accounted for 67%, while computer-based applications accounted for 20%, followed by checklists, surveys and reports representing 10%, and the direct measurement methods accounted for 3% of the ergonomic assessment techniques. Direct measurement methods used in SCANIA Ergonomic Standard (SES) were seen combined with observation-based methods. SES uses direct measurement methods to measure the repetition, movements and postures of body regions, then observational methods to evaluate the potential ergonomic risk in the simulated job stations (26). Furthermore, checklists, surveys and reports methods were shown in three previous articles representing about 10% (20,28,2). Observation-based techniques have advantages and disadvantages that must be considered during the technique selection process. There are two types of observation-based techniques, namely simple observation-based techniques and advanced observation-based techniques (34). Simple observation-based techniques are practically used in various workplaces, best suited for static posture assessment and simple repetitive tasks and offer good applicability for various risk factors. However, the techniques have several drawbacks, including being subject to inter- and intra-observer variability when choosing between different levels of exposure, having limited epidemiological data as a baseline assessment, and a scoring system that is very hypothetical. Advanced observation-based techniques typically involve the real-time recording of variations in worker posture, analysis of multiple joint segments simultaneously, defining dimensions such as travel distance, change in angle, speed and acceleration, as well as having the capability to record and analyse simulated tasks. The conclusion is that observation-based methods are the most ergonomic assessment techniques used in some ergonomic assessment tools.

TILEO Assessment

Table IV describes the authors, country, year of publication, the tool's name and the specific area concerning the 22 articles. There are five areas included in the TILEO acronym: (1) Task; (2) Individual; (3) Load; (4) Environment and (5) Other Factors. TILEO covers the five most important areas of manual handling. Pushing, pulling, lifting, and carrying are examples of manual handling tasks that fall under this category. Conditions vary from person to person. Gender, age, BMI, and work rate, among others, are displayed to the person. The qualities of the load that must be managed constitute the load itself (size and weight of the load). Several studies have looked into environmental and other factors. The setting is the physical characteristics of the place of work where the manual handling task is carried out (workstation design). Meanwhile, other factors include repetition, duration and contact stress.

Ergonomic considerations in risk evaluation involve matching skills and interests with the needs of the workplace instead of fitting people to the requirements of the job. The ergonomics approach demonstrates how focusing solely on lifting capacity is an oversimplifying issue that can result in faulty inferences. Instead, the risk of injury can be determined, while corrective actions can be indicated by an ergonomic evaluation based on a variety of relevant criteria (43). Task, Individual, Load, Environment and Other Factors (TILEO) consider each critical aspect of the initiative to minimise the risk of injury. The term TILEO can be used to evaluate each manual handling activity inside an organisation, according to the Manual Handling Operations Regulations (MHOR) 1992 (44). TILEO is an acronym that aids organisations in conducting dynamic risk assessments or on-the-spot evaluations.

Task-Individual-Load-Environment-Other Factors (T-I-L-E-O)

TILEO addresses every crucial area of the endeavour to reduce the risk of injury. It is presented with five assessment tools, namely The Key Indicator Method for Manual Handling Operations (KIM-MHO) (19), the Workplace Ergonomic Risk Assessment (WERA) (12), Risk Assessment and Management tool for manual handling Proactively (RAMP) (29), the combination of Manual Handling Assessment Charts (MAC) and Assessment of Repetitive Tasks (ART) (16) and the Initial ERA (2). KIM-MHO is a useful module for analysing the risk factors for work-related musculoskeletal disorders. The manual handling task is the emphasis of KIM-MHO. The daily duration of manual labour processes, type, duration, as well as the frequency of executing forces, body posture and hand-arm posture during manual work processes, are all used as KIM-MHO indicators. Workplace organisation and conditions should also be considered (19). WERA records the risk factors comprising six physical risks inc(uding posture, repetition, forceful, vibration, contact stress and task duration (12).

RAMP also displays the specifics of the evaluation of TILEO. Awkward and static work postures, lifting of loads, pushing and pulling of loads, repetitive work, recovery time and variation, hand grip, vibration, heat and cold stress, psychosocial factors, as well as complaints of physically demanding work and pain, are among the risk factors covered by the instrument (29). Other TILEO tools include a combination of MAC and ART, as well as Initial ERA. MAC is a checklist used by safety and professional health inspectors to examine typical risk issues associated with lifting, lowering, as well as individual and group lugging. This method examines a set of 11 manual handling risk factors using four colour codes and calculated scores. ART not only identifies the dangers of repetitive-motion jobs but also improves working conditions by prioritising steps required to reduce potential risks (16). The Initial ERA was a Department of Occupational Safety and Health (DOSH) developed tool covering the TILEO assessment process. Repetition, forceful and sustained exertions, awkward postures, static and sustained postures, contact stress, vibration and environmental factors are all ergonomic risk factors.

Task-Individual-Load-Environment (TILE)

Five tools in this research displayed the Assessment concerning Task - Individual - Load - Environment (TILE). There were the ergonomic assessment worksheet (EAWS) and Digital Human Model (DHM) (20), Novel Ergonomic Postural Assessment Method (NERPA) (25), SCANIA Ergonomic Standard (SES) (26), Biomechanics Analysis and Ariel Performance Analysis System (APAS) (21), as well as Self-report Ergonomic Assessment Tool (SEAT) (35).

EAWS is now the only ergonomics assessment approach that involves worker working postures, action forces, manual materials handling tasks and repetitive upper-limb loads (20). It is a screening tool designed for a specific work environment in which it is used. Meanwhile, the NERPA involves the development, implementation and evaluation of a postural assessment approach for use in a manual assembly environment. The 3D graphic simulation tool is used to test NERPA methods. In each of these lines, different workstations are investigated, each with its own set of tasks (25).

The next tool is SCANIA Ergonomic Standard (SES) (26). SES is a multi-task workstation assessment system tailored to the ergonomic risk requirements of assembly manufacturing. SES examines not only postures but also force and lifting tasks. SES is used as the goniometer for assessing individual wrist postures. To prioritise the assessments, there are five categories to define ergonomic criteria shown by using colours (green, yellow, red or double red). Generally, SES is applied to the workstation or layout of research. In the same case, biomechanics analysis and Ariel Performance Analysis System (APAS) (21) are also applied to the workstation. This tool differs in that it assesses individual factors more thoroughly (anthropometric attributes, body postures, form and dimension of the tool/mechanical handling, height of the mechanical handling aid and load to be handled, mass of the object, as well as list of presumptions). Furthermore, Self-report Ergonomic Assessment Tool (SEAT) (35) also shows Assessment concerning Task - Individual - Load - Environment (TILE). SEAT specifically includes items that would address each of the ergonomic risk factors and individual body regions. Other risk factors considered are posture force/load, exertion, duration repetition and environment.

Task-Individual-Load (T-I-L)

There are nine of 21 previous studies showing the assessment tools which specific area concerning Task - Individual - Load (TIL), namely Combined tools of NIOSH lifting Equation, Manual Handling Assessment Charts (MAC), Snook Tables (The Liberty Mutual MMH Tables), WISHA Index, combining Rapid Entire Body Assessment (REBA), Job Strain Index (JSI) and 2D Planar Static Model. ACGIH's Hand Activity Level threshold limit values method (HAL) and The Liberty Mutual manual materials handling (LM-MMH) equations only concern Task - Individual - Load (TIL). Tasks, Individuals and Load are the dominant areas in the assessment. Load factor affects human performance in Manual Material Handling Tasks (42). Environment and Other Factors are non-dominant areas in the TILEO assessment.

Table IV: TILEO (Task, Individual, Load, Environment, Other Factors)

Author	Name of Tool	Assessment on: (specific area concerning)				
		T	I	L	E	O
Pires, 2012 [27]	NIOSH lifting Equation	✓	✓	✓		
Mohammadi et al., 2013 [13]	Snook Tables (The Liberty Mutual MMH Tables)	✓	✓	✓		
Yung et al., 2019 [30]	ACGIH's Hand Activity Level threshold limit values method (HAL)	✓	✓	✓		
Gumasing et al., 2020 [45]	Rapid Entire Body Assessment (REBA) NIOSH lifting equation	✓	✓	✓		
Li et al., 2020 [24]	Rapid Upper Limb Assessment (RULA) Pose Detector	✓	✓	✓		
Potvin et al., 2021 [23]	The Liberty Mutual manual materials handling (LM-MMH) equations	✓	✓	✓		
Abedini et al., 2013 [10]	NIOSH lifting Equation Manual Handling Assessment Charts (MAC)	✓	✓	✓		
Asadi et al., 2015 [11]	NIOSH lifting Equation WISHA Index	✓	✓	✓		
Deviani & Triyanti, 2017 [22]	Rapid Entire Body Assessment (REBA) Job Strain Index (JSI.) 2D Planar Static Model	✓	✓	✓		
Schaub et al., 2012 [20]	The ergonomic assessment worksheet (EAWS) Digital Human Model (DHM)	✓	✓	✓	✓	
Sanchez-Lite et al., 2013 [25]	Novel Ergonomic Postural Assessment Method (NERPA)	✓	✓	✓	✓	
Zare at al., 2014 [26]	SCANIA Ergonomic Standard (SES)	✓	✓	✓	✓	
Ray et al., 2015 [21]	Biomechanics Analysis Ariel Performance Analysis System (APAS)	✓	✓	✓	✓	
S. C. Peres et al., 2017 [35]	Self-report Ergonomic Assessment Tool (SEAT)	✓	✓	✓	✓	
Sukadarin et al., 2016 [18]	Simple Ergonomics Risk Assessment (SERA)	✓	✓	✓	✓	
Straker et al., 2011 [28]	Manual Task Risk Assessment (ManTRA)	✓	✓	✓	✓	✓
Halim et al., 2012 [17]	The Prolonged Standing Strain Index (PSSI)	✓	✓	✓	✓	✓
Klussmann et al., 2010 [19]	The Key Indicator Method for Manual Handling Operations (KIM-MHO)	✓	✓	✓	✓	✓
Abd Rahman et al., 2011 [12]	The Workplace Ergonomic Risk Assessment (WERA)	✓	✓	✓	✓	✓
S.Shokria et al., 2015 [16]	Manual Handling Assessment Charts (MAC) Assessment of Repetitive Tasks (ART)	✓	✓	✓	✓	✓
DOSH, 2017 [2]	Initial ERA	✓	✓	✓	✓	✓

* Task (T), Individual (I), Load (L), Environment (E), Other Factors (O)

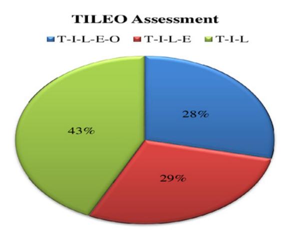

Fig. 3: Percentage of TILEO Assessment.

Fig. 3 shows the percentage distribution of TILEO Assessment. About 43% of the ergonomic risk assessment tools are concerned with three specific areas, which were Task-Individual-Load (TIL), Task-Individual-Load-Experiment (TILE) accounting for 29%, and the Task-Individual-Load-Environment-Other Factors (TILEO) representing 28%.

DISCUSSION

The results of this systematic review show a clear preference for observation-based ergonomic risk assessment methods, which accounted for 67% of the studies. This is consistent with previous research that highlights the practicality and ease of use of these methods in real-world settings. Observation-based methods are favored because they allow for rapid assessment and are applicable across various industries, especially in manual labor tasks such as those found in manufacturing and construction. However, their reliance on human judgment can introduce variability and limit the scope of the risk factors being assessed.

Interestingly, this review found that direct measurement methods were used in only 3% of the studies. Although these tools provide real-time, accurate data on workers' biomechanical exposures, their low adoption may stem from the high costs and complexity associated with their use. Previous research has similarly identified these barriers, noting that direct measurement methods often require specialized equipment and trained personnel, making them less accessible for many workplaces [46], [47]. This suggests that future research should explore hybrid approaches that integrate direct measurement tools with observation-based methods, thus enhancing accuracy without compromising usability.

The review also revealed that the majority of tools focus on physical risk factors related to the task, individual, and load. This aligns with the dominant focus on manual material handling in industries like manufacturing and logistics. However, the relatively low consideration of environmental factors and other factors such as repetition, duration, and contact stress suggests an opportunity for more comprehensive assessment tools [46]. These factors, while secondary, can significantly contribute to musculoskeletal disorders (MSDs) and should not be overlooked. Additionally, many existing tools were found to specialize in manual material handling tasks but did not extend their focus to other critical risk factors, such as psychosocial and cognitive load, which are increasingly recognized in ergonomics research. The predominance of checklists, surveys, and reports (10%) further highlights the simplicity of current tools. However, there is a growing need for tools that can handle more complex, multi-dimensional risks.

The TILEO model was a useful framework for categorizing the focus areas of ergonomic risk tools. While Task, Individual, and Load were well-covered, Environmental factors and Other factors (such as repetition and contact stress) were only partially addressed. Given the significance of these factors in affecting workplace ergonomics, future tool development should aim to integrate these aspects more thoroughly. For instance, factors like the design of the work environment and the frequency of repetitive tasks can have profound impacts on worker health, yet they remain underassessed. Finally, this review has identified a trend toward the increased use of computer-based applications (20%), which offer the potential for more advanced, data-driven ergonomic assessments. These tools, often combined with observation methods, allow for more sophisticated analyses of worker movements and postures. As technology continues to evolve, it is anticipated that more ergonomic risk assessment tools will adopt artificial intelligence and machine learning algorithms to provide real-time, adaptive assessments that can offer greater accuracy and efficiency.

CONCLUSION

This review has analysed various relevant research studies that used ergonomic risk assessment tools to assess ergonomic risk factors. To investigate the substantial ergonomic risk assessment approaches commonly utilised on the ergonomic risk assessment tool, the findings from 21 studies were extracted and analysed. Previous research has shown that the existing ergonomic risk assessment techniques by researcher (the observation-based methods accounted for 67%). Furthermore, the ergonomic risk assessment tool mainly concerns the task, individual and load (TIL) areas. It has been observed that only a few research have looked into the environment and other factors. The layout and terrain of the workplace where the manual handling task is performed are referred to as the environment (workstation design). Other factors include repetition, duration and contact stress. Additionally, it was revealed that many ergonomics assessment tools specialise in manual materials handling tasks but focus only on assessing the physical risk factors such as posture, repetition and load. This review's results give the overall view of the assessment techniques employed and the specific area of concern regarding ergonomic risk assessment tools, where further research is required. Subsequently, assessment tools designed to reduce musculoskeletal discomfort associated with manual materials handling should take into account environmental factors (such as the workplace's layout and terrain) as well as other variables (including repetition, duration, and contact stress), in addition to the widely recognised physical risk factors. The findings of this research have the potential to assist the development of an ergonomic risk assessment tool for manual material handling duties that involve human performance and capability.

ACKNOWLEDGEMENT

The authors would like to thank the Ministry of Higher Education for providing financial support under the Fundamental Research Grant Scheme (FRGS) No. FRGS/1/2021/SKK06/UMP/02/2 (University reference RDU210156) and Universiti Malaysia Pahang for additional financial support under Internal Research grant PGRS220372.

REFERENCES

1. N. Jaffar, A. H. Abdul-Tharim, I. F. Mohd-Kamar, and N. S. Lop, "A literature review of ergonomics risk factors in construction industry," *Procedia Eng.,* vol. 20, pp. 89–97, 2011, doi: 10.1016/j.proeng.2011.11.142.
2. DOSH, *Guidelines On Ergonomics Rick Assessment At Workplace 2017*. 2017.
3. OSHA, *Identifying and Addressing Ergonomic Hazards Workbook*, vol. 3. 2018. [Online]. Available: https://www.osha.gov/sites/default/files/2018-12/fy15_sh-27643-sh5_ErgonomicsWorkbook.pdf
4. HSA, *Managing Ergonomic Risk in the Workplace to Improve Musculoskeletal Health.* 2019.
5. M. Widia, S. Z. Md Dawal, and N. Yusoff, "The relation of risk factors and musculoskeletal discomfort among manual material handling workers in Malaysian automotive industries," *Malaysian J. Public Heal. Med.*, vol. 1, no. Specialissue1, pp. 124–133, 2016.
6. SAIOSH, "Ergonomics Regulations," 2019.
7. DOSH, *Guidelines for Manual Handling at Workplace 2018.* 2018.

8. O. Karhu, P. Kansi, and I. Kuorinka, “Correcting working postures in industry: A practical method for analysis,” *Appl. Ergon.*, vol. 8, no. 4, pp. 199–201, 1977, doi: 10.1016/0003-6870(77)90164-8.
9. Y. K. Kong, S. yong Lee, K. S. Lee, and D. M. Kim, “Comparisons of ergonomic evaluation tools (ALLA, RULA, REBA and OWAS) for farm work,” *Int. J. Occup. Saf. Ergon.*, vol. 24, no. 2, pp. 218–223, 2018, doi: 10.1080/10803548.2017.1306960.
10. F. Caputo, A. Greco, M. Fera, and R. Macchiaroli, “Workplace design ergonomic validation based on multiple human factors assessment methods and simulation,” *Prod. Manuf. Res.,* vol. 7, no. 1, pp. 195–222, 2019, doi: 10.1080/21693277.2019.1616631.
11. R. Abedini, A. Choobineh, A. Soltanzadeh, M. Gholami, F. Amiri, and A. A. Hashyani, “Ergonomic Risk Assessment of Lifting Activities; a Case Study in a Rubber Industry,” *Jundishapur J. Heal. Sci.,* vol. 5, no. 1, pp. 9–15, 2013.
12. N. Asadi, A. Choobineh, S. Keshavarzi, and H. Daneshmandi, “A Comparative Assessment of Manual Load Lifting Using NIOSH Equation and WISHA Index Methods in Industrial Workers of Shiraz City,” *J Heal. Sci Surveill. Sys January,* vol. 3, no. 1, pp. 8–12, 2015, [Online]. Available: https://jhsss.sums.ac.ir/article_42767.html
13. M. N. A. Rahman, M. R. A. Rani, and Jafri Mohd Rohani, “WERA: an observational tool develop to investigate the physical risk factor associated with WMSDs,” *J. Hum. Ergol. (Tokyo).*, vol. 40, no. 1–2, pp. 19–36, 2011, doi: 10.11183/jhe.40.19.
14. H. Mohammadi, M. Motamedzade, M. A. Faghih, H. Bayat, M. H. Mohraz, and S. Musavi, “Manual material handling assessment among workers of Iranian casting workshops,” *Int. J. Occup. Saf. Ergon.,* vol. 19, no. 4, pp. 675–681, 2013, doi: 10.1080/10803548.2013.11077021.
15. Schaub et al., “Ergonomic assessment of automotive assembly tasks with digital human modelling and the ‘ergonomics assessment worksheet’ (EAWS),” *Int. J. Hum. Factors Model. Simul.,* vol. 3, no. 3/4, p. 398, 2012, doi: 10.1504/ijhfms.2012.051581.
16. J. R. Potvin, V. M. Ciriello, S. H. Snook, W. S. Maynard, and G. E. Brogmus, “The Liberty Mutual manual materials handling (LM-MMH) equations,” *Ergonomics*, vol. 64, no. 8, pp. 955–970, 2021, doi: 10.1080/00140139.2021.1891297.
17. P. K. Ray, R. Parida, and E. Saha, “Status Survey of Occupational Risk Factors of Manual Material Handling Tasks at a Construction Site in India,” *Procedia Manuf.,* vol. 3, no. Ahfe, pp. 6579–6586, 2015, doi: 10.1016/j.promfg.2015.07.279.
18. Deviani and V. Triyanti, “Risk assessment of manual material handling activities (case study: PT BRS Standard Industry),” *IOP Conf. Ser. Mater. Sci. Eng.,* vol. 277, no. 1, 2017, doi: 10.1088/1757-899X/277/1/012043.
19. E. H. Sukadarin, B. Md Deros, J. A. Ghani, A. R. Ismail, N. S. Mohd Nawi, and N. Abdull, “Validity test for Simple Ergonomics Risk Assessment (SERA) method,” *Malaysian J. Public Heal. Med.*, vol. 1, no. Specialissue1, pp. 134–143, 2016.
20. M. J. J. Gumasing and R. C. J. Casela, “A biomechanical risk assessment of lifting tasks in the logistics industry in the Philippines,” *Proc. Int. Conf. Ind. Eng. Oper. Manag.*, vol. 0, no. March, pp. 1672–1678, 2020.
21. D. Moher, A. Liberati, J. Tetzlaff, and D. G. Altman, “Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement,” *PLOS Med.*, vol. 339, no. 7716, pp. 332–336, 2009, doi: 10.1136/bmj.b2535.
22. G. Wong, T. Greenhalgh, G. Westhorp, J. Buckingham, and R. Pawson, “RAMESES publication standards: Meta-narrative reviews,” *J. Adv. Nurs.*, vol. 69, no. 5, pp. 987–1004, 2013, doi: 10.1111/jan.12092.
23. N. I. Inyang, “A framework for ergonomic assessment of residential construction tasks,” 2013. [Online]. Available: http://ezproxy.library.usyd.edu.au/login?url=https://search.proquest.com/docview/1318837649?accountid=14757%0Ahttp://dd8gh5 yx7k.search.serialssolutions.com?ctx_ver=Z39.88-2004& ctx_enc=info:ofi/enc:UTF-8&rfr_id=info:sid/Public +Health+Database&rft_val_fmt=i
24. G. C. David, “Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders,” *Occup. Med. (Chic. Ill).*, vol. 55, no. 3, pp. 190–199, 2005, doi: 10.1093/occmed/kqi082.
25. N. Inyang, M. Al-Hussein, M. El-Rich, and S. Al-Jibouri, “Ergonomic Analysis and the Need for Its Integration for Planning and Assessing Construction Tasks,” *J. Constr. Eng. Manag.*, vol. 138, no. 12, pp. 1370–1376, 2012, doi: 10.1061/(asce)co.1943-7862.0000556.
26. P. K. Ray, “Ergonomic Analysis of Construction Jobs in India: A Biomechanical Modelling Approach,” *Procedia Manuf.*, vol. 3, pp. 4606–4612, 2015, doi: 10.1016/j.promfg.2015.07.542.
27. S. C. Peres, R. K. Mehta, and P. Ritchey, “Assessing ergonomic risks of software: Development of the SEAT,” *Appl. Ergon.*, vol. 59, pp. 377–386, 2017, doi: 10.1016/j.apergo.2016.09.014.
28. L. Li, T. Martin, and X. Xu, “A novel vision-based real-time method for evaluating postural risk factors associated with musculoskeletal disorders,” *Appl. Ergon.*, vol. 87, no. April, 2020, doi: 10.1016/j.apergo.2020.103138.
29. Alberta, “Lifting and Handling Loads – Part 2 : Assessing Ergonomic Hazards,” 2010.
30. W. M. Keyserling, M. Brouwer, and B. A. Silverstein, “A checklist for evaluating ergonomic risk factors resulting from awkward postures of the legs, trunk and neck,” *Int. J. Ind. Ergon.*, vol. 9, no. 4, pp. 283–301, 1992, doi: 10.1016/0169-8141(92)90062-5.

31. A. Klussmann, U. Steinberg, F. Liebers, H. Gebhardt, and M. A. Rieger, "The Key Indicator Method for Manual Handling Operations (KIM-MHO) - Evaluation of a new method for the assessment of working conditions within a cross-sectional study," *BMC Musculoskelet. Disord.*, vol. 11, no. November, pp. 1471–2474, 2010, doi: 10.1186/1471-2474-11-272.
32. I. Halim, A. R. Omar, I. Halim, and A. R. Omar, "Development of Prolonged Standing Strain Index to Quantify Risk Levels of Standing Jobs Development of Prolonged Standing Strain Index to Quantify Risk Levels of Standing Jobs," vol. 3548, no. March, pp. 84–96, 2012, doi: 10.1080/10803548.2012.11076917.
33. S. Shokria, "Manual material handling assessment and repetitive tasks with two methods MAC and ART in a subsidiary of a manufacter of cleaning product," *Sci. J. Rev.*, vol. 4, no. January, pp. 116–123, 2015, doi: 10.14196/sjr.v4i8.1899.
34. K. Schaub, G. Caragnano, B. Britzke, and R. Bruder, "The European Assembly Worksheet," *Theor. Issues Ergon. Sci.*, vol. 14, no. 6, pp. 616–639, 2013, doi: 10.1080/1463922X.2012.678283.
35. C. Pires, "Ergonomic assessment methodologies in manual handling of loads - Opportunities in organizations," *Work*, vol. 41, no. SUPPL.1, pp. 592–596, 2012, doi: 10.3233/WOR-2012-0215-592.
36. A. Sanchez-Lite, M. Garcia, R. Domingo, and M. Angel Sebastian, "Novel Ergonomic Postural Assessment Method (NERPA) Using Product-Process Computer Aided Engineering for Ergonomic Workplace Design," *PLoS One,* vol. 8, no. 8, pp. 1–12, 2013, doi: 10.1371/journal.pone.0072703.
37. C. Lind, L. Rose, H. Franzon, and L. Nord-nilsson, "RAMP : risk management assessment tool for manual handling proactively," *Hum. Factors Organ. Des. Manag.* -XI, pp. 107–110, 2014.
38. A. Antonucci, "Comparative analysis of three methods of risk assessment for repetitive movements of the upper limbs: OCRA index, ACGIH(TLV), and strain index," *Int. J. Ind. Ergon.,* vol. 70, no. January, pp. 9–21, 2019, doi: 10.1016/j.ergon.2018.12.005.
39. M. Zare, S. Biau, M. Croq, Y. Roquelaure, and A. B. Measurements, "Development of a Biomechanical Method for Ergonomic Evaluation : Comparison with Observational Methods," *Int. Sholarly Sci. Res. Innov.*, vol. 8, no. 1, pp. 218–222, 2014.
40. M. A. Nussbaum, J. P. Shewchuk, S. Kim, H. Seol, and C. Guo, "Development of a decision support system for residential construction using panellised walls: Approach and preliminary results," *Ergonomics,* vol. 52, no. 1, pp. 87–103, 2009, doi: 10.1080/00140130802480869.
41. DOSH, "Guidelines On Ergonomics Rick Assessment At Workplace 2017_July Edited Rev.002-unlocked.pdf." 2017.
42. NHS, *Moving and Handling of Inanimate Loads*. 2016.
43. HSE, *Manual Handling at Work*, vol. 3, no. 3. 2000. doi: 10.1016/0003-6870(89)90067-7.
44. S. Z. Siti, R. A. bin Raja Ghazilla, H. R. Zadry, M. Widia, and N. S. Abdullah, "Incorporating ergonomics evaluation in assembly and disassembly of repetitive task: Focusing on load task," *Adv. Mater. Res.*, vol. 712–715, pp. 2879–2883, 2013, doi: 10.4028/www.scientific.net/AMR.712-715.2879.
45. E. H. Sukadarin, B. M. Deros, J. A. Ghani, N. S. Mohd Nawi, and A. R. Ismail, "Postural assessment in pen-and-paper-based observational methods and their associated health effects: a review," *Int. J. Occup. Saf. Ergon.*, vol. 22, no. 3, pp. 389–398, 2016, doi: 10.1080/10803548.2016.1156924.
46. K. Eliasson, C. M. Lind, and T. Nyman, "Factors influencing ergonomists' use of observation-based risk-assessment tools," *Work*, vol. 64, no. 1, pp. 93–106, 2019, doi: 10.3233/WOR-192972.
47. G. Wilhelmus Johannes Andreas and E. Johanssons, "Observational Methods for Assessing Ergonomic Risks for Work-Related Musculoskeletal Disorders. A Scoping Review," *Rev. Ciencias la Salud*, vol. 16, no. Special Issue, pp. 8–38, 2018, doi: 10.12804/revistas.urosario.edu.co/revsalud/a.6840.