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Developing a Decision Aid Tool for selecting pen-paper observational ergonomics techniques: a quasi-experimental study

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Abstract

Background: *A significant error that may occur during ergonomic risk assessment and invalidate assessment reliability corresponds to technique selection. This study aimed to develop a new tool called the Decision Aid Tool (DAT) to reduce pen-paper observational technique selection errors.* **Methods:** *This quasi-experiment before-after study was performed in three phases. In the first phase, the participants' skills in technique selection were examined by showing them twenty videos of different single-task jobs. In the second phase, the DAT was designed using pen-paper observational techniques. Finally, in the third phase, 115 occupational health specialists included in the study through purposive sampling of experts evaluated the tool's efficacy.* **Results:** *The results of the first phase showed that 62% of participants made an error in selecting the proper technique. The mean and standard deviation scores from the first and third phases were 11.4±6.59 and 39.01±1.89, respectively. The mean scores increased significantly after using DAT, and 97.5% of participants could correctly select task techniques.* **Conclusions:** *The efficacy of DAT was confirmed in a quasi-experimental before-and-after study. Using DAT increases the participants' ability to choose the correct technique. The DAT can be functional for practitioners to select the pen-paper observational techniques correctly under the purpose of assessment, the body areas, and the characteristics of the task to be assessed.*

1. Introduction

Ergonomic workplace assessment plays a crucial role in preventing and reducing the risk of work-related musculoskeletal disorders (WMSDs). Many tools identify and assess factors associated with the increased risk of WMSDs. These tools include direct, observational-based, and worker self-report methods, each with certain advantages and disadvantages [1-4]. Direct methods refer to those using sensors attached directly to the subject to measure certain variables. Electromyography

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(EMG) recording of muscle action, goniometers, optical scanning, sonic system, electromagnetic system, and accelerometer-based systems are the most used direct measurement methods. These methods are more accurate than observational and worker self-report methods. However, the problem lies in the high cost of these methods and the need for special equipment and skilled technical staff, which limit their use in the workplace. Worker self-report methods have low validity and reliability when ergonomic interventions are aimed in real work environments [3, 5, 6].

Observation-based methods are usually more straightforward for practitioners to implement and apply to a wide range of tasks at a relatively lower cost. These methods are better suited to the needs of practitioners, so they are currently considered the first and most common methods used by occupational safety and health (OSH) practitioners [1, 3, 5-7]. Many techniques used to assess the risk of WMSDs are based on direct observation of workers while performing their tasks. Each method has been developed for a specific purpose. The techniques differ depending on the characteristics of the task, body areas, and the risk factors that should be assessed. These differences make selecting and applying the methods challenging for practitioners [5, 6, 8]. Takala et al. reviewed thirty-two pen-paper observational techniques and concluded that, despite the large number available, none is perfect, nor could any of them cover all purposes [6].

The selection of a technique should be based on the purpose of risk assessment, characteristics of the task, body areas, and risk factors to be assessed. Therefore, despite the simplicity of pen-paper observational techniques, a certain level of knowledge and skill is required for their proper use. Otherwise, errors may occur in using these techniques, which can distort the risk assessment results [5-8]. A study that identified common mistakes in pen-paper observational techniques in twenty Spanish-speaking countries reported that practitioners made errors in 30.3% of their assessments [5]. Some studies have stated that practitioners rarely know about more than a minimal selection of ergonomics techniques. There are geographical differences between countries and continents using various ergonomic risk assessment methods [4, 6, 7, 9].

Two types of errors that may occur during ergonomic risk assessment and invalidate the reliability of the appraisal are technique selection errors and application errors. Errors in selecting the technique invalidate assessment reliability and indicate that the practitioner does not know how to choose the correct approach. The mistakes in ergonomic risk assessment arise from improper application of methods and lead to over- or under-estimate the risk. The method selection may be appropriate, but a lack of skill and knowledge of its rationale can lead to an improper risk assessment [5, 7].

When selecting a technique, the practitioner should consider its validity, reliability, applicability, strengths, and weaknesses [6]. Each pen-paper observational process has drawbacks, and no technique includes all the tasks. However, if the method is used correctly, it can play an essential role in a comprehensive ergonomics program [8]. Therefore, selecting the proper technique is a significant step in the risk management of musculoskeletal disorders in the workplace [5, 7, 10].

One of the factors that increase the error in technique selection is the frequent use of one or several limited techniques to assess all types of tasks [2, 3, 6]. Studies on the frequency of pen-paper observational methods in the United States, Canada, Iran, and twenty Spanish-speaking countries have shown that practitioners often use limited techniques to evaluate various tasks [1, 2, 7]. In a study by Tajvar et al., Iranian practitioners used only four methods in 68.4% of their assessments. Moreover, 53.3% of the practitioners' risk assessments were erroneous in the technique selection process [7]. Inadequate knowledge of practitioners about the types of ergonomic risk assessment techniques, the lack of a decision aid tool to choose the correct method, and the lack of serious supervision over the technique selection process have led practitioners to use a limited number of techniques to assess different tasks [1-3, 5].

This study aimed to develop a new tool called the Decision Aid Tool (DAT) to assist in the choice of the proper technique in the risk management of WMSDs, thereby reducing method selection errors and geographic differences between countries/continents. This new tool allows practitioners to select the proper pen-paper observational techniques based on the task type, the purpose of assessment, and the body areas to be assessed.

2. Methods

This study was conducted in three phases. (i) The participants' skills in selecting the correct pen-paper observational technique were examined in the first phase. (ii) In the second phase, DAT was designed, and in the third phase (iii), the efficacy of this new tool was evaluated. All participants participated voluntarily and signed a written informed consent form. This study received the approval code #IR.SUMS.REC.1399.858 from the ethics committee of Shiraz University of Medical Sciences.

2.1 First phase

The study's first phase aimed to assess participants' skills in selecting the correct pen-paper observational techniques. Initially, twenty videos of different single-task jobs were prepared purposefully in real work environments with the worker involved in work. In selecting these twenty videos, it was tried to cover all types of tasks, including agricultural, service-providing, industrial, and office tasks. For each video, a scenario was written highlighting the job, the purpose of the assessment, and the assessed body areas. Next, the participants were asked to watch each video, consider the scenario written for that video based on their knowledge and experience, and select the technique(s) that they found appropriate for assessing the risk of each task shown in each video. Each participant could choose one or more methods for each job displayed in the videos.

The research team, with three experienced ergonomists (more than ten years of experience in applying ergonomic risk assessment techniques), carefully reviewed the authentic scientific sources related to pen-paper observational methods. They finally considered these techniques' features, strengths, and weaknesses and then selected those that felt appropriate for each of the twenty videos. The choices made by the research team were used to assess the participants' skills in choosing the proper method. The participants were Iranian specialists in the field of occupational health with bachelor's degrees, selected through purposive sampling. After conducting the pilot study and considering 1.96 for $Z_{(1-\alpha/2)}$, 0.84 for $Z_{(1-\beta)}$, 3.7 for δ_d^2, and d^2=0.26, the sample size was determined to be 112. Inclusion criteria were as follows: (i) having at least one year of work experience, (ii) assessing ergonomic risk in the last six months, and (iii) participating in the first and third phases of the study. Those who did not participate in the two phases were excluded.

After preparing a list of eligible participants and providing them with the necessary information about the study's objectives, 152 participants agreed to participate. Among them, 16 participants were excluded due to failure to complete the checklist in the first phase, and 21 were later excluded because they did not meet the checklist requirements in the third phase. The remaining 115 occupational health specialists participated in the study. In the first phase, they were asked to select the technique(s) that they found appropriate for assessing the risk of each task shown in the videos and enter their selections into a checklist. The checklist was then compared with that completed by the research team. According to Table 1, each participant was given a score to indicate their skill in selecting the correct technique. Participants were given a score between 0 and 2, depending on how they chose the method to assess each task shown in the twenty videos. A wrong choice of the technique(s) is due to a conceptual error invalidating the assessment's reliability. These errors occurred when practitioners selected method(s) to assess the ergonomic risk of

Table 1. Classification of participants' scores in selecting pen-paper observational techniques.

Skill level classification	Score	Technique selection level
Good	2	The practitioner selected all the techniques correctly (absolutely correct).
Intermediate	1	The participant selected only some of the techniques correctly (relatively correct).
Weak	0	The participant selected the technique incorrectly (incorrect).

a task without considering its limitations and applicability, i.e. when the chosen method is designed for evaluating another risk factor or body area. For example, using the NIOSH lifting equation to assess pushing/pulling tasks or using the strain index technique to assess the whole body is wrong [2, 3]. Each participant's score ranged between 0 and 40 for 20 tasks. Finally, the scores were converted into percentages, and the ability of each participant to select the proper technique was classified into four levels: very weak (0-24%), weak (25-49.9%), good (50-74.9%), and very good (75-100%).

2.2 Second phase

The purpose of the second phase was to develop a new tool to help practitioners to select pen-paper observational techniques. Accordingly, the research team examined the features, strengths, and limitations of various pen-paper observational methods from authoritative scientific sources. It then developed DAT according to the characteristics of each technique [5-8, 11-17]. This tool was designed so a practitioner can find a suitable method(s) by answering a few questions. The practitioners are first asked to determine the type of job to be assessed. They should perform a job analysis before the technique selection process. When the task is set, specific questions should be answered about the purpose of assessment, the body areas, and how the task is to be performed.

The classification of tasks includes MMH, non-MMH, and special-purpose tasks. Depending on how they are performed, MMH tasks are divided into three categories, including lifting/lowering, carrying, and pushing/pulling loads. The variability of lift task characteristics during manual lifting jobs makes it hard to assess the risk of WMSDs. Therefore, for lifting tasks, four types of sub-tasks are defined: single, composite, variable, and sequential tasks. Once the sub-task type is specified, the practitioner can select the appropriate technique. Single-task manual lifting corresponds to lifting only once or when there is no significant variance from lift to lift. In composite tasks, the type and weight of loads are the same, but the load is lifted in different dimensions. In variable tasks, lifting and lowering the load are associated with a change in the load weight and horizontal distance and vertical height. Sequential manual lifting involves tasks in which a worker rotates between a set of single, composite, and variable lifting tasks. Moreover, the worker rotates between different workstations during shifts [5, 6, 8-10, 18-20].

For non-MMH tasks, depending on the purpose of assessment and the assessed body areas, practitioners can select the appropriate technique(s). Recently, certain techniques have been developed to evaluate the ergonomics of some jobs or tasks, such as computer work, assembly, patient transportation, and agriculture, defined in this study as special-purpose techniques; we tried to use these techniques in the development of DAT. [21-24].

2.3 Third phase

The purpose of the third phase was to evaluate the efficacy of DAT. This study phase was performed three months after the completion of the first phase with the same participants. In this phase, participants were first instructed on selecting a technique using DAT. They were then asked to re-perform the technique selection for the same twenty tasks in the first phase using DAT. Finally, the checklist completed in this phase was scored according to Table 1. For the twenty studied tasks, the score ranged between 0 and 40. Then, the scores were converted into percentages, and the ability of participants to select appropriate techniques was expressed in the following four levels: very weak (0-24.99%), weak (25-49.99%), good (50-74.99%), and very good (75-100%). Finally, to evaluate the efficacy of the new tool, the average technique selection scores in the first phase (before using DAT) and the third phase of the study (after applying DAT) were compared. Figure 1 summarizes the steps involved in each phase of the study.

2.4 Statistical analysis

To evaluate the efficacy of DAT, a paired-samples T-test was used. For this purpose, the data's normality was first tested using the quantile-quantile (QQ) plot diagram and Kolmogorov-Smirnov statistical test. Then, the mean scores obtained from the

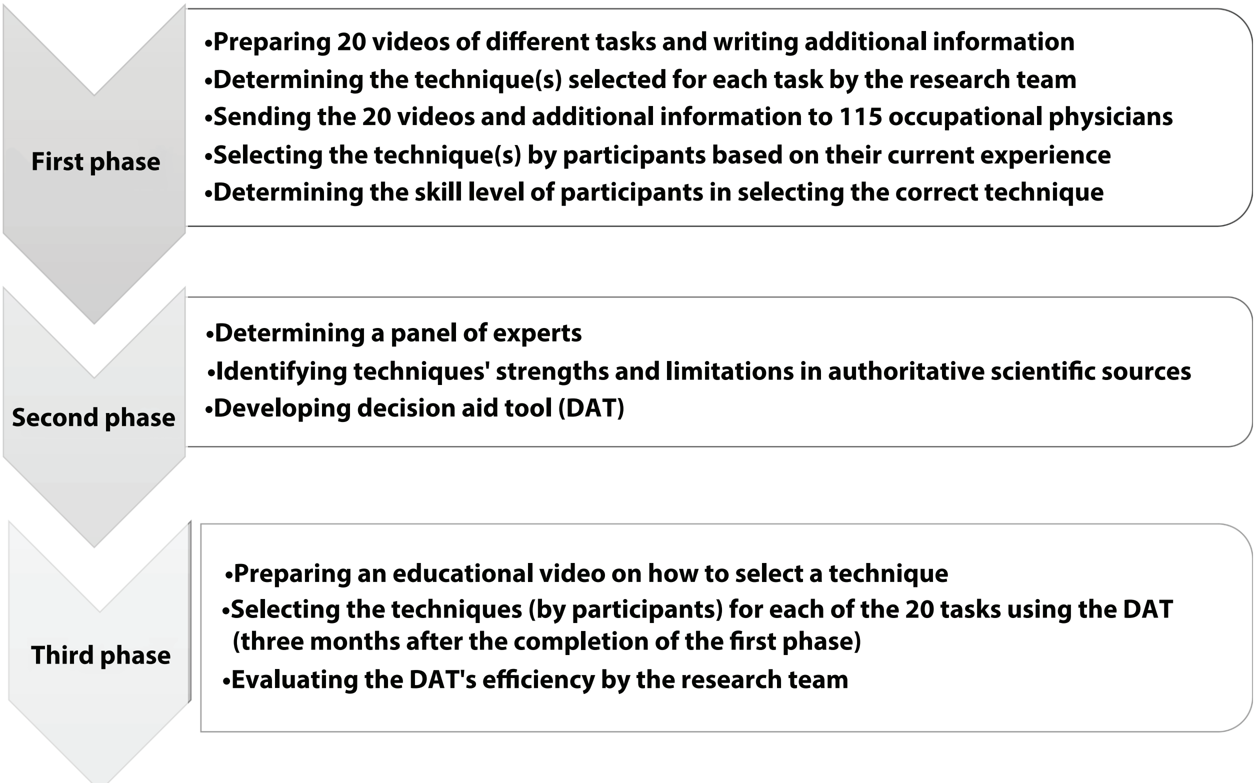

Figure 1. Summary of the steps in each phase of the study.

Table 2. Demographic details of participants (N=115).

Demographic characteristic	Category	Frequency	Percent
Gender	Male	48	41.7
	Female	67	58.3
Age (year)	30≥	51	44.3
	31≤	64	55.7
Work experience (year)	1-5	54	47
	6-10	32	27.8
	11≤	29	25.2

technique selection process were compared before and after applying DAT. All statistical analyses were performed using SPSS version 20.

3. Results

3.1 First phase

A total of 115 OSH specialists with an average age of 33.1±4.83 years participated in this study. Demographic details of the participants are summarized in Table 2.

Comparing the techniques selected by participants in the first phase and those chosen by the research team showed that only 19% of the participants could select the correct methods for all tasks demonstrated in the videos. Moreover, 62% of the participants chose the techniques incorrectly, and 19% identified only some of them correctly (considered relatively correct). The mean and standard deviation scores obtained from the first phase were 11.4±6.59. The maximum score that a participant could earn was 40.

After assessing the participants' skills in selecting the technique, it was found that 48.7% of the participants had a very weak level of skill; 33.9% had a weak level of skill; 12.2% had a good level, and only 5.2% had a very good level of skill. Table 3 shows the selection status of pen-paper observational techniques for twenty tasks presented in videos before applying DAT.

3.2 Second phase

Pen-paper observational techniques' characteristics, strengths, and limitations were carefully studied, twenty-eight techniques were chosen, and DAT was developed (see Figure S1). This tool was designed to help practitioners select the correct methods by specifying the type of task, the purpose of assessment, and the body areas to be assessed. Table S2 summarizes the selection criteria and limitations of the pen-paper observational techniques used in this study. In developing DAT, attempts were made to cover all types of tasks. First, tasks were divided into three general categories: MMH tasks, jobs with specific techniques (special purpose tasks), and non-MMH tasks. This tool assessed the body areas of the upper limbs (fingers, wrists, forearms, elbows, shoulders, arms, and neck), waist, and lower limbs.

Table 3. Pen-paper observational techniques for twenty tasks presented in videos before and after applying DAT: MAW = Maximum Acceptable Weight.

		Selection status of techniques					
		Before (%)			After (%)		
Video #	Purpose of assessment	Incorrect	Relatively correct	Correct	Incorrect	Relatively correct	Correct
#1	MAW for MMH-single task	73.9%	24.3%	1.7%	21.7	-	78.3
#2	MAW for pushing/pulling	80%	18.3%	1.7%	-	-	100
#3	MAW for handling with both hands	79.1	20	0.9	-	-	100
#4	MAW, for handling with on one hand	89.6	9.6	0.9	-	-	100
#5	MAW for lifting with 2 or more people	93	6.1	0.9	-	-	100
#6	Carrying patient	60	-	40	-	-	100
#7	MWA for MMH-composite tasks	73	20	7	13.9	-	86.1
#8	MAW for MMH-variable tasks	77.4	17.4	5.2	14.8	-	85.2
#9	Assessment of whole body for MMH	46.1	53	0.9	-	-	100
#10	Screening lifting tasks by 2 or more	79.1	-	20.9	-	-	100
#11	Assessment of wrist in repetitive tasks	52.2	26.1	21.7	-	-	100
#12	Assessment of hand activity and peak force	67	-	33	-	-	100
#13	Assessment of repetitive movements of upper extremities	50.4	-	49.6	-	-	100
#14	Assessment of upper limb repetitive actions	53.9	27	19.1	-	-	100
#15	Screening pushing/pulling tasks	83.5	-	16.5	-	-	100
#16	Assessment of a single body side	5.2	17.4	77.4	-	-	100
#17	Assessment of lower limb	27	73	-	-	-	100
#18	Assessment of Computer work	16.5	-	83.5	-	-	100
#19	Assessment of Agricultural work	100	-	-	-	-	100
#20	General assessment of whole body	33	67	-	-	-	100

Table 4. Comparison between the mean scores of technique selection obtained before and after using DAT.

Phase of study	Mean	Std. Deviation	Mean Difference	95% CI of Mean		t statistics	p-value
				Lower	Upper		
Before	11.40	6.59	27.60	26.49	28.72	48.98	<0.001
After	39.01	1.89					

Note: Paired samples T-test was used to evaluate the efficacy of DAT.

After determining the type of task, the practitioner should specify the purpose of the assessment; e.g., for jobs involving MMH, the practitioner should specify whether the purpose of the evaluation is to determine the maximum acceptable weight, screen MMH tasks, or assess the whole body. If the objective was to determine the maximum allowable weight or to screen MMH tasks, then it was necessary to specify how to handle the load manually by lifting/lowering, carrying, and pushing/pulling the load. Concerning non-MMH tasks, the practitioner could select the appropriate technique after determining the purpose and the body areas to be evaluated. If the job to be considered was defined as non-MMH, and the objective was to assess the upper limb, then the practitioner must specify the upper limb segment.

In assessing the whole body, the practitioner should select the type of technique according to the purpose of the assessment. If the aim is to evaluate the left and right sides of the body separately, the methods developed for this purpose should be used (e.g., RULA and REBA). RULA/REBA assess the upper/entire body providing a final RULA/REBA score (an overall risk level). However, if there is a significant difference between the two sides, two separate assessments could be appropriate [25, 26]. Accordingly, other techniques (e.g., OWAS or WERA) should be used instead [25-28]. There are particular techniques for assessing ergonomic risk in some tasks or jobs, such as agriculture, patient transportation, and work with computers, which are defined in this study as special-purpose techniques. There are many such techniques, and we have mentioned only three of them in the design of DAT. (Figure S1).

3.3 Third phase

The mean and standard deviation of the scores obtained after the third phase were 39.01±1.89. A comparison of methods by participants in the third phase with those selected by the research team showed that 97.5% of the participants who used DAT correctly identified the technique(s) for the twenty studied tasks. Only 2.5% of participants in the third phase made an error selecting the method for lifting jobs. Table 3 shows the selection status of pen-paper observational techniques for twenty tasks presented in videos after applying DAT.

The results showed a statistically significant difference between the technique selection scores obtained before and after applying DAT. The mean score increased by 27.6 after the participants used DAT in selecting the technique (Table 4).

4. Discussion

This study was designed to develop a new DAT tool to reduce errors in selecting pen-paper observational techniques. This study was conducted in three phases. The purpose of the first phase was to assess the participants' skills in selecting pen-paper observational methods. The second phase aimed to develop DAT, and the purpose of the third phase was to evaluate the efficacy of DAT.

The results of the first phase showed that 62% of participants made an error in selecting the correct technique for twenty tasks presented in the studied videos. These results are consistent with a previous study by Tajvar et al., who showed that a high percentage of Iranian practitioners (53.3%) made an error in selecting the correct technique [7]. Moreover, it was found that the skill level of 48.7% of participants was very weak, and that of 33.9% of them was weak. Although all participants had a bachelor's degree in occupational health and more than one year of experience in applying ergonomic risk assessment techniques, most did not have sufficient knowledge and skill to select the correct method.

Most practitioners are familiar with a few techniques but don't know the new ones [6]. The frequency of applying pen-paper observational methods in the United States, Canada, Iran, and twenty Spanish-speaking countries has also shown that practitioners often use a limited number of techniques to assess various tasks [1, 2, 7].

There are several reasons for this information gap, e.g. language limitations [5-7]. Ergonomic risk assessment techniques are usually presented in English in scientific journals and media. Most non-English practitioners with low English proficiency have difficulty accurately translating or understanding these techniques [6, 7]. Therefore, if the practitioners' performance is not closely monitored, they may prefer to use the same limited number of methods they have already learned to assess various tasks [7].

Each technique has its limitations and is designed for specific purposes, and its use for assessing all types of tasks is inappropriate and can lead to selection error [6]. Tajvar et al. reported that 53.3% of risk assessments performed by Iranian practitioners were based on wrong techniques because critical factors, such as the assessment's purpose, the task type, and the body parts to be assessed, had been overlooked. These practitioners used only four techniques in 68.4% of their assessments [7]. It is suggested to plan the translation, dissemination, and training for non-English speaking countries to update practitioners' information.

There is a need to ensure practitioners have enough knowledge and skill in pen-paper observational techniques. Updating scientific resources, modifying the educational curriculum, creating stricter regulations regarding the qualification of practitioners and monitoring their performance, and purposefully holding retraining workshops are some of the measures that can increase the knowledge and skills of the practitioners. As suggested by David, practitioners would benefit from developing a decision aid tool that would allow them to make an informed selection [1]. Therefore, the research team concluded that perhaps a Decision Aid Tool could help the practitioners to select appropriate technique(s) according to the objectives of the assessment, body areas, and the type of task to be assessed. With such a tool, it can be expected that the possibility of error in the choice of technique will be significantly reduced, and occupational health and safety inspectors can monitor the performance of the practitioners better and more accurately.

The second phase aimed to develop a new Decision Aid Tool to reduce practitioners' errors in selecting pen-paper observational techniques. In this regard, the research team carefully examined the features, strengths, and limitations of various pen-paper observational methods in authoritative scientific sources. This tool is designed so that practitioners can select appropriate techniques by answering a few specific questions.

Evaluating the tool's efficacy showed a significant difference between the technique selection mean scores before and after applying DAT; the mean scores increased significantly after using DAT. It can be concluded that using DAT increases the participants' ability to select the correct technique(s). Because the technique selection in DAT was based on specific instructions, the error probability of technique selection was significantly reduced, and the risk assessment results were more reliable.

The results of the third phase showed that 97.5% of participants were able to correctly select the techniques for the tasks shown in the videos after using DAT. However, in the first phase, only 19% of participants could choose the correct methods. Among participants in the third phase, only 2.5% made errors in technique selection, corresponding to the choice of the proper technique for lifting tasks. To assess the maximum acceptable weight in load lifting, the practitioner must first identify the type of lifting task, which includes simple, complex, variable, and sequential tasks. If the practitioner fails to correctly recognize the lifting task type, a technique selection error may occur. Therefore, the main reason for making errors can be the participants' inability to distinguish tasks.

4.1 Limitations of the study

According to the study's objectives in the development of DAT, twenty-eight pen-paper observational techniques that existed in Persian sources or have been used by Iranian researchers were used. Many other methods may be used in different countries and can be included in this tool. They can be added to this tool, but due to the unfamiliarity of Iranian practitioners with them, we could not use them in this study. In addition, newer and more up-to-date techniques may emerge over time. Therefore, this tool presents only a few of many pen-paper observational methods and will need to be updated.

5. Conclusion

The high error rate of practitioners in selecting ergonomic risk assessment techniques is a matter of concern. The present study aimed to design a new Decision Aid Tool (DAT) to reduce the error rate in technique selection. In this tool, twenty-eight pen-paper observational techniques that have been published in authentic scientific sources were used. The efficacy of DAT was confirmed in a quasi-experimental before-and-after study. Therefore, DAT can be instrumental in choosing the pen-paper observational techniques per the purpose of assessment, body areas, and characteristics of the task to be assessed. Furthermore, this new tool can also reduce geographic differences between countries/continents in pen-paper observational techniques.

Supplementary Materials: Figure S1: Decision aid tool, Table S1: Abbreviation for pen-paper observation techniques with their expanded names and Table S2: the selection criteria and limitations of the pen-paper observational methods.

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Informed Consent Statement: All participants participate voluntarily and sign a written informed consent form.

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Original article

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Appendix A-FigureS1:

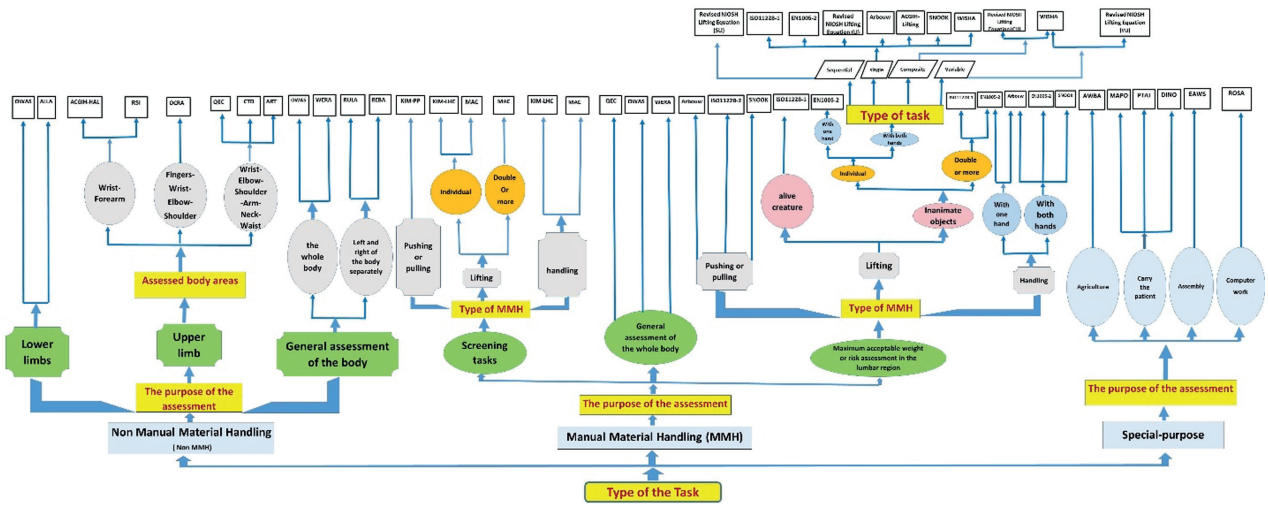

Figure S1: Decision Aid Tool.

ACGIH-HAL: American conference of governmental industrial hygienists-Hand activity level, ART: Assessment of repetitive tasks of the upper limbs, QEC: Quick exposure check, OWAS: Ovake working posture analyzing system, KIM-PP: Key indicator method for pulling and pushing, KIM-LHC: Key indicator method for lifting, holding and carrying, MAC: Manual handling assessment charts, DINO: Direct nurse observation, MAPO: Movement and assistance of hospital patient, Revised NIOSH Equation(CLI): Revised National institute for occupational safety and health lifting equation(Composite Lifting Index), Revised NIOSH Equation(VLI): Revised National institute for occupational safety and health lifting, equation (Variable Lifting Index), Revised NIOSH Equation(SLI): Revised National institute for occupational safety and health lifting equation(Sequential Lifting Index), CTD: Cumulative trauma disorder risk assessment model for the upper extremities, OCRA: Occupational repetitive action index, PTAI: Patient transfer assessment instrument, REBA: Rapid entire body assessment, ROSA: Rapid office strain assessment, RULA: Rapid upper limb assessment, WERA: Workplace ergonomic risk assessment, WISHA: Washington industrial safety and health act lifting analysis, ALLA: Agricultural lower limb assessment, AWBA: Agricultural Whole-Body Assessment, ACGIH-Lifting TLV: American conference of governmental industrial hygienists lifting threshold limit values, EAWS: Ergonomic assessment worksheet, EN 1005-2: European Standard 1005-2, ISO 11228-1: International Organization for Standardization 11228-1, ISO 11228-2: International Organization for Standardization 11228-2, RSI: Revised Strain Index.

Appendix B-Table S1

Table S1: Abbreviation for pen-paper observation techniques with their expanded names.

#	Abbreviation	Expanded name	Reference
1	ACGIH-HAL	American conference of governmental industrial hygienists-Hand activity level	American Conference of Governmental Industrial Hygienists (ACGIH). TLVs and BEIs. Cincinnati: American Conference of Governmental Industrial Hygienists; 2000.
2	ART	Assessment of repetitive tasks of the upper limbs	Ferreira J, Grey M, Hunter L, Birtles M, Riley D. (2009). Development of an assessment tool for repetitive tasks of the upper limbs (ART). UK: Health & Safety Executive.
3	QEC	Quick exposure check	David G, Woods V, Li G, Buckle P. The development of the Quick Exposure Check (QEC) for assessing exposure to risk factors for work-related musculoskeletal disorders. *Appl Ergon*. 2008;39 (1), 57-69.
4	OWAS	Ovake working posture analyzing system	Karhu O, Kansi P, Kuorinka I. Correcting working postures in industry: a practical method for analysis. *Appl Ergon*. 1977;8 (4), 199-201.
5	KIM-PP/KIM-LHC	Key indicator method for pulling and pushing/Key indicator method for lifting, holding and carrying	Steinberg U. New tools in Germany: development and appliance of the first two KIM (lifting, holding and carrying, pulling and pushing) and practical use of these methods. *Work*. 2012; 41(Supplement 1),3990-3996.
6	SNOOK	Liberty Mutual Manual Materials Handling Tables	Snook SH, Ciriello VM. The design of manual handling tasks: revised tables of maximum acceptable weights and forces. *Ergonomics*. 1991;34(9), 1197-1213.
7	MAC	Manual handling assessment charts	Tapley SE. Reliability of manual handling assessment charts (MAC) developed for health and safety inspectors in the UK: A field study. *HSE*. 2002;UK.
8	DINO	Direct nurse observation	Johnsson C, Kjellberg K, Kjellberg A, Lagerström M. A direct observation instrument for assessing patient transfer technique (DINO). *Appl Ergon*. 2004;35(6),591-601.
9	MAPO	Movement and assistance of hospital patient	Battevi N, Menoni O, Ricci MG, Cairoli S. MAPO index for risk assessment of patient manual handling in hospital wards: a validation study. *Ergonomics*. 2006;49(7),671-687.
10	Revised NIOSH Equation(CLI)	Revised national institute for occupational safety and health lifting equation (Composite Lifting Index)	Waters TR, Putz-Anderson V, Garg A, Fine LJ. Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics*. (1993);36(7):749-776.
11	Revised NIOSH Equation(VLI)	Revised national institute for occupational safety and health lifting equation (Variable Lifting Index)	Waters T, Occhipinti E, Colombini D, Alvarez-Casado E, Fox R. Variable Lifting Index (VLI) A New Method for Evaluating Variable Lifting Tasks. *Hum Factors*. 2016;58(5),695-711.

Table S1 (*Continued*)

#	Abbreviation	Expanded name	Reference
12	Revised NIOSH Equation(SLI)	Revised national institute for occupational safety and health lifting equation (Sequential Lifting Index)	Waters T, Lu ML, Occhipinti E. New procedure for assessing sequential manual lifting jobs using the revised NIOSH lifting equation. *Ergonomics*. 2007;50(11), 1761-1770.
13	CTD	Cumulative trauma disorder risk assessment model for the upper extremities	Seth V, Weston RL, Freivalds A. Development of a cumulative trauma disorder risk assessment model for the upper extremities. *Int J Ind Ergon*. 1999;23(4), 281-291.
14	OCRA	Occupational repetitive action index	Occhipinti E. OCRA: a concise index for the assessment of exposure to repetitive movements of the upper limbs. *Ergonomics*. 1998;41(9),1290-1311.
15	PTAI	Patient transfer assessment instrument	Karhula K, Rönnholm T, Sjögren T. A method for evaluating the load of patient transfers. Occupational Safety and Health Administration. Occupational safety and health publications, 2009;83.
16	REBA	Rapid entire body assessment	Hignett S, McAtamney L. Rapid entire body assessment (REBA). *Appl Ergon*. 2000;31(2),201-205.
17	ROSA	Rapid office strain assessment	Sonne M, Villalta DL, Andrews DM. Development and evaluation of an office ergonomic risk checklist: ROSA-Rapid office strain assessment. *Appl Ergon*, 2012;43(1),98-108.
18	RULA	Rapid upper limb assessment	McAtamney L, Corlett EN. RULA: a survey method for the investigation of workrelated upper limb disorders. *Appl Ergon*. 1993;24(2),91-99.
19	WERA	Workplace ergonomic risk assessment	Rahman MNA, Rani MRA, Rohani JM. WERA: an observational tool develop to investigate the physical risk factor associated with WMSDs. *J Hum Ergol.* 2011;40(1_2),19-36.
20	Arbouw	The Arbouw guidelines	Karwowski W. International Encyclopedia of Ergonomics and Human Factors, 3 Volume Set, CRC, Press, 2006,1471-1484.
21	ALLA	Agricultural lower limb assessment	Kong YK, Lee SY, Lee KS, Kim DM. Comparisons of ergonomic evaluation tools (ALLA, RULA, REBA and OWAS) for farm work. *Int J Occup Saf Ergon* 2018;24(2), 218-223.
22	AWBA	Agricultural whole-body assessment	Kong YK, Lee SJ, Lee KS, Kim GR, Kim DM. Development of an ergonomics checklist for investigation of work-related whole-body disorders in farming-AWBA: Agricultural whole-body assessment. *J Agric Saf Health*. 2015;21(4),207-215.
23	ACGIH-Lifting TLV	American conference of governmental industrial hygienists lifting threshold limit values	American Conference of Governmental Industrial Hygienists (ACGIH) (2004), Threshold Limit Values for Chemical Substances and Physical Agents & Bioloigical Exposure Indices, Cincinnati, OH.
24	EAWS	Ergonomic assessment worksheet	Schaub K, Caragnano G, Britzke B, Bruder R. The European assembly worksheet. *Theor Issues Ergon Sci*. 2013;14(6),616-639.

Table S1 (*Continued*)

#	Abbreviation	Expanded name	Reference
25	EN 1005-2	European Standard 1005-2	Colombini D, Occhipinti E, Alvarez-Casado E, Waters TR. Manual lifting: A guide to the study of simple and complex lifting tasks, CRC Press, 2012.
26	ISO 11228-1	International Organization for Standardization 11228-1	ISO. 2003. ISO 11228-1. Ergonomics-Manual handling-Lifting and carrying.
27	ISO 11228-2	International Organization for Standardization 11228-2	ISO. 2007a. ISO 11228-2. Ergonomics-Manual handling-Pushing and pulling.
28	RSI	Revised Strain Index	Arun Garg J, Moore S, Kapellusch JM. The Revised Strain Index: an improved upper extremity exposure assessment model. *Ergonomics*. 2017;60 (7), 912-922.

Appendix C-Table S2:

Table S2: The selection criteria and limitations of the pen-paper observational techniques.

	Selection criteria			
Technique	**Types of job/task**	**The purpose of the assessment**	**Body parts assessed**	**Limitations of the technique**
ACGIH-HAL	Tasks that involve the same, or very similar repetitive hand, wrist, or forearm exertions	to determine unacceptable levels of hand activity and force	Wrist-forearm	Only consider repetition and force applied to monotonous handwork performed for four or more hours per day.
ART	Repetitive tasks	To assess tasks that require repetitive moving of the upper limbs	Neck, lower back, and upper limb	Does not consider the lower limb. it is not intended for display screen equipment (DSE) assessments.
QEC	A wide range of tasks	to quickly assess exposure to WMSD risks for a wide range of tasks	Wrist-elbow-shoulder-arm-neck-waist	Not suitable when tasks are highly varied. The method only allows for looking at the worst possible work positions for each body part involved in a task. Does not consider the lower limb.
OWAS	A wide range of tasks	To assess stressful work postures	The whole body and lower limb	Does not separate right and lift upper extremities.posture coding crude for shoulders. does not consider repetition or duration of the sequential postures. assessments of neck and elbows/wrist are missing.
KIM-PP	Pushing or pulling load	Risk assessment of physical workload in pushing or pulling a load on the screening level	Trunk	Only suitable for screening pushing/pulling tasks. it provides a general risk level but cannot predict workers' injuries.
KIM-LHC	Lifting, holding or carrying a load	Risk assessment of physical workload in lifting, holding or carrying a load on the screening level	Trunk	Only suitable for screening lifting, holding, or carrying tasks and provides a general level of risk, but it cannot predict injuries to workers.
MAC	Lifting (and lowering), carrying, and team handling a load	To aid occupational health and safety inspectors assess the most common risk factors in lifting (and lowering), carrying, and team handling operations.	Back	Is not appropriate for tasks that involve pushing/pulling and is not designed to assess risks associated with workplace upper limb disorders.
DINO	Patient transfer tasks	To assess the work technique of nursing personnel during patient transfers	Back and shoulders	Only applicable for the risk assessment of patient manual handling in hospital yards. Non-applicability in some hospital wards e.g. resuscitation and psychiatry. It neglects all the other risk determinants (frequency, environment, work organization, etc.)

Table S2 (*Continued*)

Technique	Selection criteria: Types of job/task	Selection criteria: The purpose of the assessment	Selection criteria: Body parts assessed	Limitations of the technique
MAPO	Patient manual handling	To assess the risk exposure level of patient manual handling in hospital wards	Low back	Only applicable for the risk assessment of patient manual handling in hospital yards. variables such as psychosocial factors and overtime hours are not included in the risk assessment of patient manual handling.
Revised NIOSH Equation(CLI)	Lifting/ lowering load(single-task)	To determine the recommended weight limit of a load base on lifting/ lowering characteristics and to estimate the relative magnitude of physical stress for a task or a job	Low back	This technique cannot be used for: one-handed lifting/lowering, lifting/ lowering tasks that are done for more than eight hours, lifting/lowering while seated or kneeling, lifting/lowering in restricted workspaces, lifting/lowering of unstable objects, people, or animals, carrying/pushing/pulling tasks (including use of a wheelbarrow or shovel), lifting/ lowering on slippery surfaces, lifting/ lowering in unfavorable environments and Lifting/lowering with high speed motion (faster than about 30 inches/ second).
Revised NIOSH Equation(VLI)	Lifting/ lowering load(variable-tasks)			
Revised NIOSH Equation(SLI)	Lifting/ lowering load(sequential-tasks)			
CTD	Industrial jobs based on task and hand motion parameters	To predict CTD incidence rates or a relative risk potential for the upper extremities.	Wrist-elbow-shoulder-arm-neck-waist	Is not applicable for jobs with cycle times under four seconds.
OCRA	Tasks that involve repetitive movements of the upper limbs	To identify a procedure for calculating a concise index of exposure to the risks of WMSDs associated with repetitive movements of the upper limbs.	Fingers, wrist-elbow-shoulder	The use is time-consuming. Well-trained observers needed.
PTAI	Patient transfers	To evaluate the load of patient transfers	Upper limb, trunk, lower back, and lower limb	Only applicable for evaluating the load of patient transfers in the healthcare sector.
REBA	Tasks that involve the types of unpredictable working postures found in health care and other service industries.	To quick postural analysis for whole-body activities, both static and dynamic.	The whole body	The right and left hands have to be assessed separately and there is no method to combine this data, duration, and frequency of items not included. This method is not recommended for assessing tasks that are primarily manual material handling tasks. The method is not suitable for assessing jobs that involve a number of different and varying tasks.

Table S2 (*Continued*)

Technique	Selection criteria: Types of job/task	The purpose of the assessment	Body parts assessed	Limitations of the technique
ROSA	Computer work	To quickly quantify risks associated with computer work and to establish an action level for change based on reports of worker discomfort.	The whole body	Only applicable for computer work in the office environment.
Arbouw	Lifting and carrying, pushing /pulling, static postures, and repetitive work	To develop guideline instrument for assessing physical workload	Lower back	Relative time-consuming but does not give very detailed information.
RULA	Tasks where the worker uses primarily the upper limbs to complete the task.	To provide a method of screening a working population quickly, for exposure to a likely risk of work-related upper limb disorders.	Upper limb /the whole body	The right and left hands have to be assessed separately and there is no method to combine this data. Does not consider the duration of exposure. It is appropriate for tasks that typically, the worker is seated or standing without much movement when performing the task.
WERA	The wide range of job/task	To assess the physical risk factors associated with work-related musculoskeletal disorders	The whole body	As with most techniques, do not consider psychosocial factors and the interaction of the risk factors.
SNOOK	Lifting, Lowering, Pushing, Pulling, Carrying tasks	To provide guidelines for predicting the maximum weights and workloads that are acceptable to different percentages of the male and female industrial population.	Low back	Does not consider any trunk rotation/ twisting that may take place while performing the task. This method is not suitable for use when the task involves one-handed lifting, lowering, carrying, pushing, or pulling. The method is also not useful for tasks that involve throwing or catching objects.
ALLA	Tasks that involve the types of postures for farm work	To assess lower limb postures for farm work	Lower limb	Only applicable for the risk assessment of the lower limb. As with most techniques do not consider psychosocial factors and the interaction of the risk factors.
AWBA	Agriculture	To assess various postures in agricultural work	The whole body	Only applicable for the risk assessment of agricultural work. Does not consider psychosocial factors and the interaction of the risk factors.

Table S2 (*Continued*)

	Selection criteria			
Technique	**Types of job/task**	**The purpose of the assessment**	**Body parts assessed**	**Limitations of the technique**
ACGIH-Lifting TLV	Tasks that involve Lifting /lowering a load	To provide guidance on acceptable weight limits for lifting tasks.	Low back	This technique is not applicable for use with other material handling tasks such as carrying, pushing, and/or pulling and should not be used if any of the following is true: - the trunk/twists rotate more than 30 degrees to either side; - more than 360 lifts per hour are required; - lifting is done for more than eight hours a day; - a constrained body posture is used when lifting (kneeling, restricted head room, seated, crouching); - one-handed lifting is required; - lifting is done in high heat and/or humidity; - the objects being lifted are unstable (containers with shifting center of mass, people, animals); - the object being lifted has poor hand holds or grasping points; - theworkers" footing is unstable (slippery floor, unstable ground/or surface).
EAWS	Assembly tasks	To assess physical workload in cyclic work	The whole body	Cannot be used for ergonomic job rotation planning as the sequence and the load characteristic of the tasks (e.g. aggravation of fatigue or recovery aspects) are not considered. The application is complex and requires intensive training.
EN 1005-2	Tasks that involve the manual handling of machinery, component parts of machinery, and objects processed by the machine (input/output) of 3 kg or more, for carrying less than 2 m.	To assess manual handling of machinery and component parts of machinery.	Lower back	Does not cover the holding of objects (without walking), pushing or pulling of objects, hand-held machines, or handling while seated.
ISO 11228-1	Tasks that involve Lifting and Carrying a load	To set recommended limits for the mass of objects being manually handled.	Lower back	Does not include holding objects, pushing or pulling objects, lifting with one hand, or manual handling while seated.

Table S2 (*Continued*)

Technique	Selection criteria			Limitations of the technique
	Types of job/task	The purpose of the assessment	Body parts assessed	
ISO 11228-2	Tasks that involve Pushing and Pulling a load	To determine whole-body pushing and pulling force limits, according to specific characteristics of the population and the task.	The whole body	Only applicable for tasks that involve Pushing and Pulling a load.
RSI	Repetitive "hand intensiv" tasks	To assessa distal upper extremity physical exposure	The wrist, forearm	Only applicable for simple,mono-task jobs where the constituent variables do not change substantially between different exertions during a task cycle and the worker does not rotate between different tasks during a work shift.