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Original Article

Validation of a Comprehensive Ergonomic Risk Assessment Technique for Tea Harvesting Farmers and Comparison with some Techniques

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Abstract

Background: We aimed to validate a thorough ergonomic risk assessment method for tea harvesting farmers. A comparative analysis with established methods such as OWAS (Ovako Working Posture Assessment System), RULA (Rapid Upper Limb Assessment), and REBA (Rapid Entire Body Assessment) was also conducted.

Methods: The research was carried out in 2023 in Guilan Province. The research consisted of three phases: identifying risk factors influencing Musculoskeletal Disorders, validating these factors using the fuzzy Delphi technique (FDT) and fuzzy analytic hierarchy process (FAHP) methods, and developing a method that included a customized posture evaluation technique and questionnaire design. The criteria were categorized into personal, task-related, tools and equipment, environmental, and organizational factors. A team of experts evaluated the validity and reliability of the developed method.

Results: Out of 60 identified risk factors, 43 were approved. Task-related factors were deemed the most important, while organizational factors were considered the least important by experts. A comparison of evaluator agreement across different tasks using various evaluation methods revealed good agreement in the developed method and REBA, but low agreement in the other two methods. Kappa coefficients for reliability assessment ranged from 0.61 to 0.80 among expert groups.

Conclusion: The proposed developed technique had acceptable validity and reliability. In addition to posture evaluation, this technique evaluates personal, environmental, and organizational items using a questionnaire. Comparisons with established methods, including OWAS, RULA, and REBA, revealed that the developed method demonstrates a stronger correlation with disorders due to shared characteristics.

Keywords: Musculoskeletal disorders; Risk assessment; Tea harvesting workers; Fuzzy Delphi method

Introduction

Tea harvesting occurs in mountainous areas, often using traditional methods despite technological advances. Workers face physical hazards like poor posture, repetitive movements, and long hours, leading to health issues. Environmental factors, such as varying weather, along with individual aspects like age and fitness, contribute to musculoskeletal disorders. Additionally, psychosocial pressures, including time constraints and job insecurity, exacerbate these problems (1, 2).

Despite many workers in tea harvesting facing poor conditions and risks, studies on musculoskeletal disorders (MSDs) in this field are limited, both globally and in Iran. A study in India found 83.6% of tea farmers experienced musculoskeletal pain in the past year, with shoulder and lower back injuries being most common (3). In Iran, 27% of workers had critical postures per the OWAS method, and 38% were in the worst category per RULA (4). A study revealed 80.9% of tea garden workers reported symptoms, particularly in the shoulder, with female workers more affected in the neck and also increased working hours correlated with back symptoms (5). To address the high prevalence of musculoskeletal disorders in tea harvesting, it is essential to identify and evaluate risk factors using various assessment methods, including OWAS, QEC, REBA, RULA, and specific tools like MAPO and ROSA. The MAPO method, developed in 1997, assesses risks from manual patient transfers through supervisor interviews and on-site evaluations. The ROSA method, introduced in 2011-2012, quickly evaluates ergonomic risks in office settings. Additionally, the Agricultural Whole-Body Assessment (AWBA) tool was developed to assess risks in agricultural work, showing alignment with expert evaluations of risk levels (6-8).

Preliminary studies indicate that ergonomic risk assessment methods for musculoskeletal disorders have primarily focused on industrial settings, with limited application in agriculture. Existing tools often assess lower extremities as a whole, complicating the identification of specific at-risk areas like the knee. Tools like PLIBEL and LERA aim for more precise evaluations; PLIBEL identifies risk factors in various lower limb areas but lacks quantification, while LERA is semi-quantitative and focuses solely on the knee, incorporating individual factors. However, many tools overlook individual and organizational factors, and methods like WERA and LUBA have their own limitations in assessing physical risks and simultaneous evaluations (9-12).

Considering the special characteristic of tea workers in the involvement of all body parts during the activity, the variety of job duties, and that the common methods of ergonomic risk assessment, despite the validity and various applications in industrial and even agricultural environments, but have limitations such as (failure to consider individual, environmental and organizational factors) which cannot be used in tea making because of these weaknesses. Therefore, we aimed validate a comprehensive method of ergonomic risk assessment of risk factors related to musculoskeletal disorders in tea harvesting workers and comparing it with OWAS, RULA and REBA methods.

Methods

The total steps of this study included identification of factors affecting musculoskeletal disorders, their validation and method development.

Phase One: Identification of risk factors affecting Musculoskeletal Disorders

Effective factors in producing musculoskeletal disorders were identified via the semi-structured interview with the tea farmers.

Semi-Structured Interview

The first phase of the study was qualitative, in which directed content analysis was used to analyze the data (13). In this study, the analysis focused on the five components of the SEIPS model and the aim was to identify the factors affecting work-related MSDs based on the lived experiences of the participants.

The study population was selected from the tea farmers of Guilan Province in Iran (year 2023). Purposive and Snowball sampling with maximum variation method was employed in order to increase the transferability of the results (14,15). The participants were tea harvesting workers with at least five years of work experience who were able to answer the research questions and were willing to cooperate and participate in this study. Data collection was done using semi-structured interviews, whose steps were:

1. Determining the purpose of the interview,
2. Preparing questions based on the dimensions of the model,
3. Conducting a pilot interview,
4. Selecting participants,
5. And conducting the interview.

The interview protocol comprised three parts: outlining goals (confidentiality and consent), gathering background information (age, gender), and key questions. Data collection spanned three months, with interviews lasting 30-50 minutes. Participants were informed of the research purpose and could withdraw anytime. Interviews were held in quiet locations and recorded for transcription. Each began with an open-ended question, followed by inquiries based on the Carayon model (SEIPS) for deeper insights. Data saturation was reached after 12 interviews, with two additional interviews yielding no new information, totaling 14 participants. Data analysis utilized guided content analysis, generating codes inductively and classifying them deductively within the SEIPS framework, using MAXQDA 12 software (15,16).

Phase Two: Validating Risk factors Affecting Musculoskeletal Disorders

Fuzzy Delphi Method and FAHP

This section presents 60 variables related to musculoskeletal disorders in tea harvesting workers, categorized into five groups: individual, task-related, tools and equipment, environmental, and organizational factors. A panel of 12 experts, including academic and industrial specialists, was selected based on their expertise in occupational health and ergonomics. Informed consent was obtained from all participants. A semi-closed questionnaire utilized a 5-point Likert scale to assess the impact of each variable, allowing experts to suggest additional factors. After the fuzzy Delphi process, variables were prioritized using fuzzy hierarchical analysis with Chang's method, analyzed via Excel 2019.

Phase Three: Method Development

First section: Posture evaluation

The OWAS (19), RULA (20), and REBA (21) techniques are effective for assessing tasks involving various body dimensions, with RULA and REBA clearly delineating body parts. These user-friendly methods are well-suited for tea harvesting, particularly OWAS, which enhances foot posture assessment by considering seven points compared to two in RULA and REBA. Recognizing the importance of foot placement in tea harvesting, this study refined these methods based on initial research findings, leading to a new assessment technique. This technique segments the body into Groups A and B, adjusting scores for shoulders, forearms, wrists, and lumbar and neck areas to fit tea harvesting tasks.

Group A: shoulder/arm, forearm, wrist and hand (left and right hands are evaluated separately)

Group B: neck, back, foot and ankle

The differences of this method with OWAS, RULA and REBA techniques:

1- Adding a speed score to section A due to the type of activity

2- Adding the score of hand tool cross movements in section A due to working with special tools

3- Upgrading the grades of the feet section to 5 grades according to working conditions

4- Adding the kneeling position in the leg position

5- Adding the condition of road slope in foot points due to work conditions

6- Adding manual handling score to section B

The additional items were determined using the fuzzy Delphi and fuzzy AHP methods, and their validation was also confirmed through expert opinions.

Second section: Questionnaire design

In order to enhance the methodology and analyze Personal, Environmental and Organizational factors based on studies and literature review, as well as the findings from the Delphi and AHP sections of prior research, a questionnaire was developed. The validity of the questionnaire items was assessed by determining the CVR and CVI scores.

Evaluation of the Validity and Reliability

Experts in occupational health and ergonomics (22 Expert) were used to evaluate the validity and reliability of the developed method. These evaluators are the people who conducted job evaluations using this method. One of the common methods to evaluate the concurrent validity of a technique is to compare the results obtained using this technique with the results obtained from other techniques (22). The results obtained after evaluation with this method were compared with the results obtained using the common and widely used methods of RULA, REBA and OWAS in evaluating a task.

To assess the reliability of the method, a training session was conducted for participants, featuring a pilot assessment using pre-recorded images and videos of tea growers. Observers discussed the technique's purpose, instructions, and scoring for 30 minutes before evaluating the recorded tasks. If needed, videos were replayed to ensure all assessments were completed. Reliability was measured by agreement rates and linear weighted κ values, with Altman's criteria categorizing agreement strength from "poor" (<0.20) to "very good" (0.81-1) (23).

Results

Phase One: Identification of risk factors affecting Musculoskeletal Disorders

In total, 60 effective risk factors were identified through conducting semi-structured interviews. These factors were categorized into five groups: Personal (12 risk factors), Task-related (19 risk factors), Tools and Equipment (10 risk factors), Environment-related (10 risk factors), and Organizational (9 risk factors). The average age of the participants in semi-structured interview was 40.6 years and out of 14 participants, 10 were men. Their average work experience was 17.9 years. In terms of marital status, 3 people were unmarried and 11 people were married. In total, 214 primary codes, 38 variables, 19 subcategories and 5 main categories were obtained from the analysis of semi-structured interviews, which were classified and named according to the five dimensions of the SEIPS model.

Phase Two: Validating risk factors Affecting Musculoskeletal Disorders

Results of Fuzzy Delphi and FAHP methods

Factors influencing musculoskeletal disorders were identified through expert opinions and the fuzzy Delphi method, conducted in three stages. Variables eliminated included education level, accident history, local shoe use, rain gear practices, tea harvesting area type, and employer-related issues like lack of medical exams and support. After expert validation, 17 out of 60 risk factors were removed, leaving 43 for further method development.

The fuzzy AHP method prioritized variables from the fuzzy Delphi, revealing that task-related factors 0.247 were most significant, while organizational factors 0.186 were least important for tea growers' Musculoskeletal disorders. Key subcategories included demographic characteristics 0.623, improper posture and manual handling 0.221, non-ergonomic tools 0.673, workspace environment 0.354, and organizational aspects like employer and salary 0.333.

Phase Three: Method Development

First section: Posture Assessment

To address posture in groups A and B, the worst and most frequent positions were evaluated, and their final scores were determined using tables. The final score of each item related to area A and B is obtained from the following equation 1:

C score = work speed score + hand tool score + cross movement score + force score + A group score

D score = standing time score + manual handling score + force score + B group score

In Figs. 1 to 4 scores are given for each body parts and the user manual of the Posture assessment worksheet.

A Group score

Arm score	Forearm score	Wrist score					
		1	2	3	4	5	6
1	1	1	2	2	3	3	3
	2	2	2	3	3	3	3
	3	2	3	3	3	4	4
2	1	2	3	3	4	4	4
	2	3	3	3	4	4	4
	3	3	4	4	4	5	5
3	1	3	3	4	4	5	5
	2	3	4	4	4	5	5
	3	4	4	4	5	5	5
4	1	4	4	4	5	5	5
	2	4	4	4	5	5	5
	3	4	4	5	5	6	6
5	1	5	5	5	6	6	7
	2	5	6	6	6	7	7
	3	6	6	7	7	7	8
6	1	7	7	7	8	8	9
	2	8	8	8	9	9	9
	3	9	9	9	9	9	9

Fig. 1: Score of body parts in posture evaluation (A Group score)

B Group score

Trunk score	Neck score	Leg score					
		1	2	3	4	5	6
1	1	1	1	2	3	4	6
	2	2	2	3	3	5	6
	3	2	3	3	3	6	7
	4	3	4	4	4	6	7
2	1	2	2	3	3	4	6
	2	2	3	4	4	5	6
	3	3	4	4	4	5	7
	4	5	5	6	6	7	7
3	1	3	3	4	4	5	6
	2	4	5	6	6	6	7
	3	4	5	6	6	7	8
	4	6	7	7	7	7	8
4	1	4	5	5	5	6	7
	2	5	5	6	6	7	8
	3	5	6	7	7	7	8
	4	7	7	8	8	8	9
5	1	5	6	6	6	7	8
	2	6	7	7	7	8	8
	3	7	7	8	8	8	8
	4	8	8	9	9	9	9
6	1	7	7	8	8	8	9
	2	8	8	9	9	9	9
	3	8	9	9	9	9	9
	4	9	9	9	9	9	9

Fig. 2: Score of body parts in posture evaluation (B Group score)

C score	D score																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	1	1	2	3	3	4	5	6	7	7	7	8	9	10	11	12	13	14	15
2	1	2	2	3	4	4	5	6	6	7	7	8	8	9	10	11	12	13	14	15
3	2	3	3	3	4	5	6	7	7	8	8	8	9	10	11	12	13	14	15	16
4	3	4	4	4	5	6	7	8	8	9	9	9	9	10	11	12	13	14	15	16
5	4	4	4	5	6	7	8	8	9	9	9	9	10	11	12	13	14	15	16	17
6	6	6	6	7	8	8	9	9	10	10	10	10	11	11	12	13	14	15	16	17
7	7	7	7	8	9	9	9	10	10	11	11	11	11	12	13	14	15	16	17	18
8	8	8	8	9	10	10	10	10	10	11	11	11	12	12	13	14	15	16	17	18
9	9	9	9	10	10	10	11	11	11	12	12	12	12	13	13	14	15	16	17	18
10	10	10	10	11	11	11	11	12	12	12	12	12	12	13	14	15	16	17	18	19
11	11	11	11	11	12	12	12	12	12	12	12	12	12	13	14	15	16	17	18	19
12	12	12	12	12	12	12	12	12	12	12	12	12	13	14	14	15	16	17	18	19
13	13	13	13	13	13	13	13	13	13	13	13	13	14	14	15	16	17	18	19	20
14	14	14	14	14	14	14	14	14	14	14	14	14	14	15	15	16	17	18	19	20
15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	16	17	18	19	20
16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	17	18	19	20	20
17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	18	19	20	20	20
18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	19	20	20	20	20

Fig. 3: Score of posture evaluation (A and B Group score)

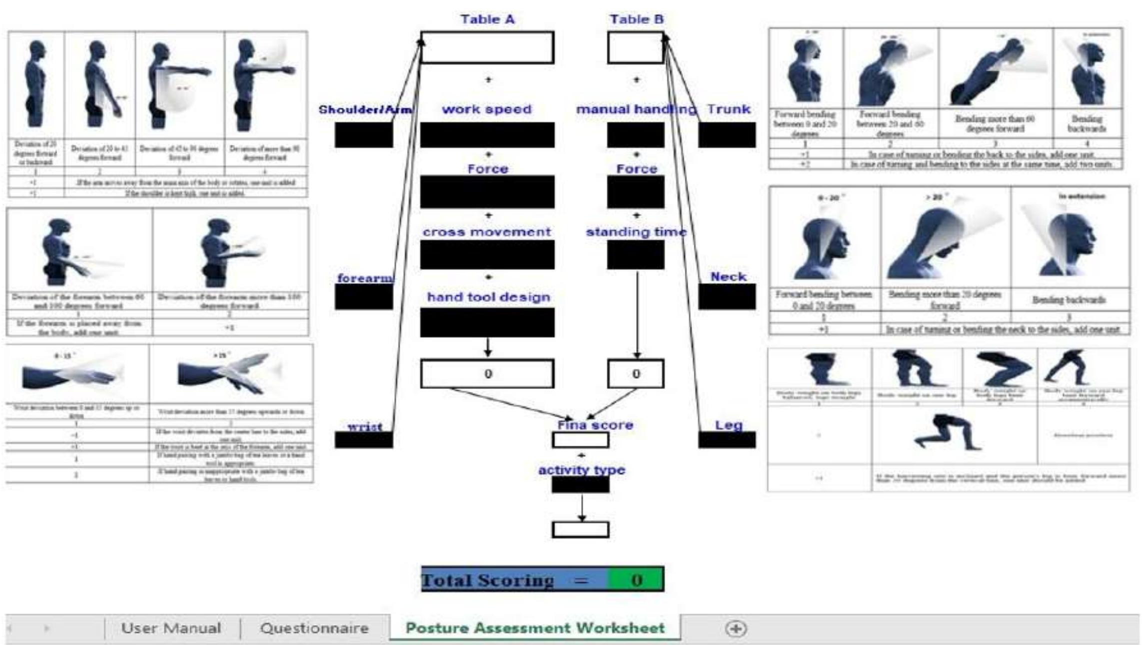

Fig. 4: The user manual of the Posture assessment worksheet (Researcher-made)

Second section: Questionnaire design

The questionnaire included 16 questions related to the personal characteristics (5 questions), Organizational characteristics (8 questions) and Environmental conditions (3 questions). The scoring method of the questionnaire was designed using a 5-point Likert scale (the lowest score is 0 and the highest score is 4). Also, in order to check the coefficients of each section and its use in the final equation, the weight of the variables was obtained using the fuzzy AHP, which can be seen in Equation 1.

Equation 1:

$$QSc = (0.22 \times A) + (0.09 \times WE) + (0.42 \times GH)$$
$$\times JB) + (0.65 \times T) + (0.24 \times JT) +$$
$$\times SS) + (0.06 \times JS) + (0.84 \times ST) +$$
$$\times L)$$

Where in

QSc: final score of the questionnaire, A: age, WE: work experience, GH: general health, PA: amount of sports activity, BH: carrying a baby on the back, JB: feeling tired and job burnout, T: training to do the job correctly, JT : Sufficient time to perform job duties, RT: Sufficient time to rest, CS: Coworker support, SS: Employer support, JS: Job security, ST: Specific tasks and determination, SWE: Slippery and uneven workplace ground, D: high density of bushes, L: access to all working space. As suggested from equation 1, the total score of the questionnaire will be between 0 and 23.

The Final Risk of Score

As shown in equation 2, the final risk score will be will calculated as a combine of the two scores discussed above.

Equation 2:

$$Total\ Scoring = (0.5 \times RA) + (0.5 \times QSc)$$

Where in

Total Scoring: the final score of the designed method, RA: the score of the posture evaluation method and QSc: the final score of the questionnaire. The coefficient of 0.5 was chosen for each of RA and QSc variables based on the previous studies of Yazdani-Rad et al (24, 25).

Finally, the prioritization of the risk level of the method with the classification of the final score of the method is shown in Table 1.

Table 1: Determination of risk level and priority of corrective action

The necessity of action and its time	Priority level of corrective actions	Risk level	The final score of the method
It may be necessary	1	Low	1-6
Necessary	2	medium	7-12
necessary (as soon as possible)	3	high	13-18
Urgent (immediate)	4	very high	19-23

Results of the Validity and Reliability

148 working postures were evaluated using these 4 methods. To evaluate the method, 4 frequent tasks including collecting tea leaves with tools, placing the bag on the shoulder, emptying the tea bag, pulling the bag on the bushes were selected according to the pictures below and presented to the evaluators for evaluation. The results of comparing the agreement of the evaluators in examining different tasks using different evaluation methods show that the agreement in the developed method and REBA is good and is low in the other two methods. The results of the risk level estimated using different methods in the 4 reviewed tasks are shown in Table 2.

Table 2: The results of the risk level estimated using different risk assessment methods in 4 tasks

Task type	Number of observations	Method type and risk levels															
		OWAS				RULA				REBA				developed method			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Task 1	45	24	20	1	0	4	12	14	15	5	8	14	18	5	4	17	19
Task 2	36	4	13	19	0	3	14	12	7	4	6	17	9	2	5	19	10
Task 3	30	24	6	0	0	16	10	4	0	18	9	3	0	17	11	2	0
Task 4	37	16	14	7	0	8	14	12	3	9	12	15	1	9	11	15	2

The agreement between the evaluator groups in all aspects of the good agreement method is between 0.61 and 0.80, and this shows that the designed method has good reliability.

Discussion

We aimed to create and validate an ergonomic risk assessment method for musculoskeletal disorders in tea harvesters, comparing it with OWAS, RULA, and REBA. Validation revealed unique variables affecting these disorders in tea harvesting. The new method incorporates specific factors relevant to tea farmers, enhancing the assessment. Previous research supports that task-related and individual factors influence musculoskeletal disorders, with physical needs being the most significant. Overall, while task factors are crucial, considering individual characteristics can improve predictions of musculoskeletal symptoms (26, 27).

The developed method in this study comprises two main sections: one for scoring workers' posture and another for a questionnaire focusing on personal, environmental, and organizational information. The combination of both sections provides a comprehensive assessment. The posture evaluation section addresses various physical risk factors, including body posture, load carrying, strength, hand movements, and hand-to-load coupling, across six major body regions (arm, forearm, wrist, back, neck, and leg). Furthermore, the method delves into individual factors such as age, work experience, ergonomics training, and the level of support from employers and colleagues. Environmental conditions are also considered. The data for these factors are gathered through a questionnaire completed by the farmer.

Various observational methods assess risk factors for musculoskeletal disorders, including OWAS, RULA, REBA, and QEC. Newer methods like WERA, ERIN, and CRAMUD are not industry-specific, while others like ALLA, AWBA, and WEPAS cater to specific sectors. Each method evaluates factors like posture, work speed, and load handling. This study analyzes these methods, focusing on upper limbs and other body regions, incorporating specific sub-scores for job conditions. This tailored approach enhances the assessment of ergonomic risks in the workplace (24,25,29-33).

Most assessment methods for musculoskeletal disorders focus primarily on body posture, neglecting individual, environmental, and organizational factors. The QEC method evaluates body posture along with variables like vibration and working time through a worker-completed questionnaire, but it still lacks a comprehensive approach. The current study introduces a new assessment method that includes a 16-question questionnaire to evaluate additional aspects of musculoskeletal disorders. While some methods, like CRAMUD and MOREBA, have explored these dimensions, they do not assess posture. Other tools, such as LEAT and LERA, focus on specific body parts and occupational factors. Tatar et al (35) developed a method for tea harvest workers that combined Fine-Kinney and Fuzzy AHP-TOPSIS but did not separately evaluate posture or other influencing factors. This study aims to enhance existing methods by incorporating more variables in both posture evaluation and the questionnaire (24,25, 33-35).

Conclusion

Agricultural jobs, particularly tea harvesting, involve diverse tasks that contribute to musculoskeletal disorders, especially among women due to physical demands. Factors include improper posture, heavy loads (60-80 kg), traditional tools, environmental conditions (humidity, temperature), uneven terrain, and lack of training. The high pace of work and extended hours (over 12 hours) further exacerbates these issues.

The developed method in the present study, apart from its similarities with other methods, takes into account the specific factors related to tea farmers. It includes specific personal factors that significantly affect musculoskeletal injuries in scoring the method. The use of this method in the real work environment showed its high application among tea farmers. But one of the limitations of the current research is the challenge in generalizing the findings due to the use of a qualitative approach. Furthermore, research involving human subjects inherently faces limitations related to recall, honesty, and individual judgment, which are not excluded in this study.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Financial source

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Conflicts of interest

The authors declare that there are no conflicts of interest.

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