Research Paper

Innovative Ergonomic Solutions for Saffron Flower Processing: Design of Ergonomic Table

Mohammad Hossein Beheshti[1], Maryam Borhani Jebeli[2], Marzieh Ghasemian[3], Akram Tabrizi[4*]

1. Department of Occupational Health and Safety Engineering, Faculty of Health, Social Determinants of Health Research Center, Gonabad University of Medical Sciences, Gonabad, Iran.
2. Department of Occupational Health, School of Health, Torbat Heydarieh University of Medical Sciences, Torbat Heydarieh, Iran.
3. Department of Occupational Health, School of Health, Iran University of Medical Sciences, Tehran, Iran.
4. Student Research Committee, Department of Occupational Health and Safety Engineering, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

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ABSTRACT

Background: Musculoskeletal disorders (MSDs) are a significant public health concern that can greatly affect individuals' health and well-being. Since Iran is a significant producer and exporter of saffron, with many workers engaged in this industry, the study aimed to design an ergonomic table for saffron flower processing to reduce MSDs, like back pain.

Methods: In this experimental study, the design process involved brainstorming and group meetings with 10 experts and ergonomics students, using anthropometric data from Iranian workers aged 20 to 60. The table was created using Rhino Software, version 6.

Results: The saffron flower processing table was designed ergonomically with the capability of rotation and height adjustment. For each component of the saffron processing process, a specific place was designated on this table, and these designated areas were determined according to the reach of individuals. The table's height ranged from 76 to 87 cm, with a total cross-section of, 6645 square cm.

Conclusion: The limitations of this study included the inability to generalize the results to other countries and different age ranges, as the anthropometric data of Iranian workers aged 20 to 60 years were utilized. An ergonomic solution that works well in one country may lead to an increase in MSDs in another country due to different body dimensions. While some risk factors are common across various agricultural activities, each presents its own unique ergonomic challenges and injury risks, emphasizing the need for appropriate approaches to ergonomic interventions.

Keywords: Ergonomic, Risk factor, Musculoskeletal, Disorders

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*** Corresponding Author:**
Akram Tabrizi, PhD.
Address: *Student Research Committee, Department of Occupational Health and Safety Engineering, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran.*
Phone: *+98 (919) 5411864*
E-mail: *tabrizi9@gmail.com*

Introduction

Ensuring the health of the workforce is essential for community development. Therefore, workers should be provided with a suitable working environment free from harmful factors to safeguard their physical and mental well-being. Just as the health of workers in industrial workplaces is important from an ergonomic point of view, the health and safety of vulnerable groups in public and social workplaces is also of particular importance. Among these groups, household jobs should be carefully considered from the point of view of health and safety for many reasons. Despite having limited access to production resources, rural women provide half of the world's food production and the driving force of agricultural work through important tasks in family farming, such as saffron. The planting of saffron, aside from employing men, has created seasonal jobs for a large number of rural women and girls. However, various issues and challenges related to saffron production and processing have led not only to a decrease in product quality but also to health and safety problems for the community and workers. An important point is that in the agricultural sector, productivity primarily relies on human labor. This is in contrast to the industrial sectors, where technology and machinery have largely replaced human labor. This situation has made the emphasis on the knowledge of productive groups in the agricultural sector highly significant.

A frequently reported problem among agricultural workers, especially farmers in rural areas, is the occurrence of musculoskeletal symptoms (MSS) in various parts of the body [1]. Among the non-fatal occupational illnesses appearing in farm workers, musculoskeletal disorders (MSDs) seem to be the most widespread [2]. The estimated lifetime prevalence of MSDs among farmers has been reported 90.6%, and the one-year prevalence of MSDs has been reported 76.9% [3]. These disorders are increasing as a specific risk of agricultural occupation. One of the key risk factors for developing MSDs is poor posture during work. In particular, repetitive lifting and moving of heavy loads, prolonged trunk flexion (also called stooping), intensive hand work, and working in awkward postures of wrist and trunk are tasks associated with the main risk factors regarding the reported MSDs [4]. For example, in a study, regarding the nordic questionnaire's results and its comparison with the Ovako working posture analyzing system (OWAS) postural analysis, it was concluded that it was of utmost importance to take corrective measurements to prevent the mentioned damages. Given the huge number of agricultural workers globally, ergonomic technologies have been developed, implemented, and evaluated as a means to attenuate the MSDs. These interventions intend to assist the agricultural workforce via optimizing the worker–workplace interface, improving the tools, as well as investigating ways to prevent workers from extravagant forces, repetitive motions, and awkward postures. Throughout systematic ergonomic efforts, it has been observed that even small changes translate to large differences in reported pains [5]. The ergonomic interventions seem to attenuate the MSDs to a great extent. However, international reprioritization of the safety and health measures is required in agriculture along with increase of the awareness of the risk factors related to MSDs [6]. A characteristic successful example was the use of tubs of smaller size regarding the harvesting of grapes. Another, also successful, simple ergonomic intervention was reducing the space between rungs in orchard ladders [5]. The use of extended-handle carriers was also tested for potted plants, a method that substantially diminished the stoop and squat with the intention of moving or lifting them [6]. Additionally, the incorporation of pneumatically-powered cutters during manual cutting demonstrated that even workers with partial disability, owing to the overuse of shears, could return to their occupational tasks. In general, the ergonomics indices in Iranian agriculture are important, and should be prioritized for corrective actions [7]. In a nutshell, ergonomics in agriculture is a versatile and interdisciplinary topic that involves the identification of the risk factors pertaining to MSDs, the determination of the root causes, as well as the development, implementation, and evaluation of ergonomic interventions [8]. One of the tasks of farmers, where static postures and consequently MSDs are frequently observed, is the planting and harvesting of saffron [9–11]. Saffron, scientifically known as *Crocus Sativus* L. is an agricultural product, for which a significant share of production and export belongs to Iran, with a large percentage of the world's saffron being produced in Iran. The comparative advantage and importance of this product in terms of production, cultivated area, and job creation in various regions of Iran, especially in Khorasan province, has granted it a special status. Labor plays a crucial role in the cultivation of this crop [12]. Producing and delivering a product of acceptable quality, based on customer and market needs and expectations, can lead to sustainable development in saffron trade. Thus, it is essential to properly carry out the stages of harvesting and processing saffron to achieve optimal quality and appropriate presentation [13]. In the processing stage of saffron flowers, which occurs after collecting the flowers from the fields, individuals typically spend hours sitting on the ground in a very non-ergonomic position. This can lead to the prevalence of MSDs in both the long and short term [14]. During the processing stage, the stigma is separated from the petals and other parts of the flower. A study by Sadeghi et al. on saffron growers in Gonabad city revealed that most saffron harvesters were at a very high ergonomic risk due to their physical condition. It is highlighting the urgent need for methods to improve their body posture [15].

Considering that in natural body positions, the trunk, arms, and legs are not engaged in static work, natural movements are one of the most important factors for performing tasks efficiently. Therefore, equipment should be designed to fit the dimensions of the human body. In such situations, knowing these dimensions is crucial for designing this equipment, which is significantly addressed by anthropometric data. Anthropometric data allows designers to create suitable designs for humans, covering as many of the target population as possible. This means minimizing the number of individuals excluded from the design coverage.

Humans differ in many dimensions, and anthropometry is used in various ways depending on the application. Based on the discussed points, examining the hard process of producing and processing saffron flowers in the country indicates that the postures and positions during these stages require significant review. This is especially true in processing and cleaning the flowers, where workers engage in long hours of static work. Therefore, it is essential to present control solutions to address these issues.

It should be noted that 86 thousand hectares out of the total of 105 thousand hectares of saffron cultivation land in Iran belong to Razavi Khorasan, among which Gonabad with 3 thousand and 500 hectares of saffron farm produces 12 tons of crops annually and half of the cultivated land in this city is devoted to saffron. The primary objective of this study was to design an ergonomic table specifically for processing saffron flowers, utilizing anthropometric data from the local user population.

Given the lack of previous research in this area within the country, this study aimed to establish a standard design that addresses the unique needs of saffron processors. The hypotheses of this study are that the implementation of an ergonomic table will improve the hygienic quality of saffron flower processing, resulting in a safer final product, and that the introduction of an ergonomic design will significantly decrease the incidence of MSDs among workers involved in saffron processing. This study will provide a design for an ergonomic table that can be utilized in saffron processing.

Methods

In this experimental study, the saffron flower processing table was designed ergonomically with the capability of rotation and height adjustment based on anthropometric data of humans. For each component of the saffron processing process, a specific place was designated on this table, and these designated areas were determined according to the reach of individuals. This allows people to perform the processing tasks for extended periods with significantly less fatigue compared to traditional processing methods. The use of this table not only reduces the pressure on the intervertebral discs, thereby helping to decrease MSDs, but it will also improve the speed and accuracy of saffron processing. The steps of the study: The present study was conducted in several stages as follows:

Design of the ergonomic table plan for saffron flower processing

To gain a precise understanding of the saffron flower processing process, visits were conducted from October to December 2022, which is the saffron flower harvesting season. These visits were made to several workshop and home units engaged in this work. It is worth mentioning that saffron flower processing is usually done while sitting on the ground, or in rare cases, using ordinary tables and chairs.

To provide ergonomic solutions, a focus group discussion was held with five faculty members from the university who have relevant practical and research experience. The ergonomic aspects related to the saffron flower processing process were examined, and ultimately, the design of the ergonomic table was proposed.

Additionally, in student sessions, the ergonomic table design was discussed, leveraging the experiences of five students (especially local students from the province who often have direct or indirect experience in processing and cleaning saffron flowers). Their suggestions were also presented and examined in subsequent meetings with the expert team. Role-play brainstorming and basic brainstorming used for the brainstorming session.

Extraction of required anthropometric dimensions for table design

In this stage, the necessary anthropometric dimensions for designing the ergonomic table were extracted through observation. These dimensions included seated head height, seated elbow height, thigh thickness, reach distance, arm length, body distances, etc.

Determining the size of required anthropometric dimensions

In this stage, the sizes of the anthropometric dimensions necessary for table design, which were extracted in the previous step, were determined. Considering that the anthropometric data of workers aged 20 to 60 years were collected and published by the Environmental Health and occupational health office of the ministry of health, these data were used for table design (Table 1). These data were used for the design of the table and are applicable to the Iranian population.

For ergonomic table design, attention must be paid to the user population and the necessary range for adjusting the dimensions of the workstation. Additionally, the acceptance of economic costs of the design must also be considered. In design issues, percentiles are used as a basis for making decisions regarding the proportion of individuals who are significantly above or below the design limits. Since designing for all individuals in a society is not economically feasible, the needs of the majority of the population (90% of individuals) were taken into account in this design. Therefore, the 5th, 50th, and 95th percentiles of body dimensions were considered for the design range. Generally, for different parts that are designed, one of the following types of designs was selected and utilized:

Design for extreme individuals (very large or very small)

In this design, the upper limit (95th percentile) and the lower limit (5th percentile) of the population, for which the design is being conducted are considered. In this design, sometimes the upper limit is used, for example, to determine the reach of individuals, and sometimes the lower limit is used, for example, to determine the maximum elbow height of individuals.

Design for average individuals

In this design, the information is based on the 50th percentile of the population. This percentile is generally used for designing common tools and equipment, such as the seat height for chairs and tables, thigh thickness dimensions, and similar aspects.

Computer-aided design and design analysis

Rhino software, version 6 was used in this research to assist in the development of the ergonomic table design. Based on the analysis conducted, which involved comparing design standards with the anthropometric data of workers in Iran, this tool enables researchers to obtain precise dimensions.

Rhinoceros, commonly known as Rhino, is one of the most popular 3D modeling software programs offered by Mc Neel Company. This software is used to create realistic and functional 3D models. The design of Rhino (literally meaning "rhinoceros") is based on baseline curves and mathematical logic known as non-uniform

Table 1. Standard guidelines for work table design

Dimension	Standard	Standard Range for Each Dimension (mm)
Reach range	Front reach accessibility for Iranian workers (95th percentile) [16]	84
Table height	ISO 21016:2007(E)* [17]	950
	Office ergonomics guidance sheet (University of Toronto) [18]	575-1237
	Ghorbanpour [19]	700
	Table height for Iranian workers (95th percentile) [16]	Elbow support height (95th percentile)+seat surface height

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*ISO 21016:2007 is an international standard that examines and defines ergonomic requirements for the design and evaluation of hand-held equipment and tools. The main objective of this standard is to enhance the safety and comfort of users while using these tools.

rational B-splines (NURBS). Due to its capability to create curves and freeform surfaces, Rhino is a powerful 3D modeling tool for complex shapes and volumes. Since NURBS curves have mathematical definitions, the drawing of dimensions and geometries using this software is more accurate than mesh-based software, like 3ds Max software, version 6, SketchUp software, version 6, AutoCAD, etc. The definition of geometry with mathematical curves has made Rhino superior in converting geometry into real-world samples compared to other modeling software. Another advantage of this software is the modeling of complex shells with simple commands. The design of complex surfaces produced with Rhino is significantly lighter compared to similar surfaces produced with mesh software. Additionally, the ability to create and model freeform 3D shapes, exceptional accuracy, design, prototyping, engineering, analysis, documentation, and construction of anything in varying sizes, unlimited editing and renaming, 2D drafting and visualization, compatibility with various software and hardware have made this software much more advanced and practical for various design objectives [20–23].

Results

Saffron flower processing is typically carried out in such a way that one or two people cut the flower stems with scissors (this action separates the petals, stigmas, and stamens from each other), while one or two others perform the separation of the stigma from the other parts (which are referred to as flower waste at this stage). The ergonomic table for saffron processing is designed for specific positions, and due to the table's rotational capability, it allows for task changes among individuals, helping to prevent fatigue. This table is suitable for various processing methods that differ across regions (in some areas, the stem is cut, and then the stigma is separated, while in other areas, processing is done in batches, meaning the stem is not cut).

The designed table for saffron flower processing can be used simultaneously by four people, but by adding a larger surface, it can accommodate more individuals. Activities can be conducted individually or in groups. On both sides of the table, there are designated spots for placing containers specifically for saffron stigma. Additionally, on all four sides of the table, opposite the positions of the individuals, there are cut-out areas where garbage bags can be attached. These bags are specifically for the waste generated from saffron flowers, which includes petals, stamens, and styles created during the separation of the stigma from the flower. These wastes contain significant amounts of natural coloring compounds and quickly wilt after production, producing a colored sap that can severely dirty the environment. The ergonomic table design for saffron processing derived from the current research is shown in Figure 1.

By using the designed ergonomic table, the flower waste is collected in the designated bags, which has the advantage of preventing the waste from being a nuisance to individuals and allowing for easy collection in the garbage bags. The positioning of the flowers, the stigma, and the special plastic bags for waste are shown in Figure 2.

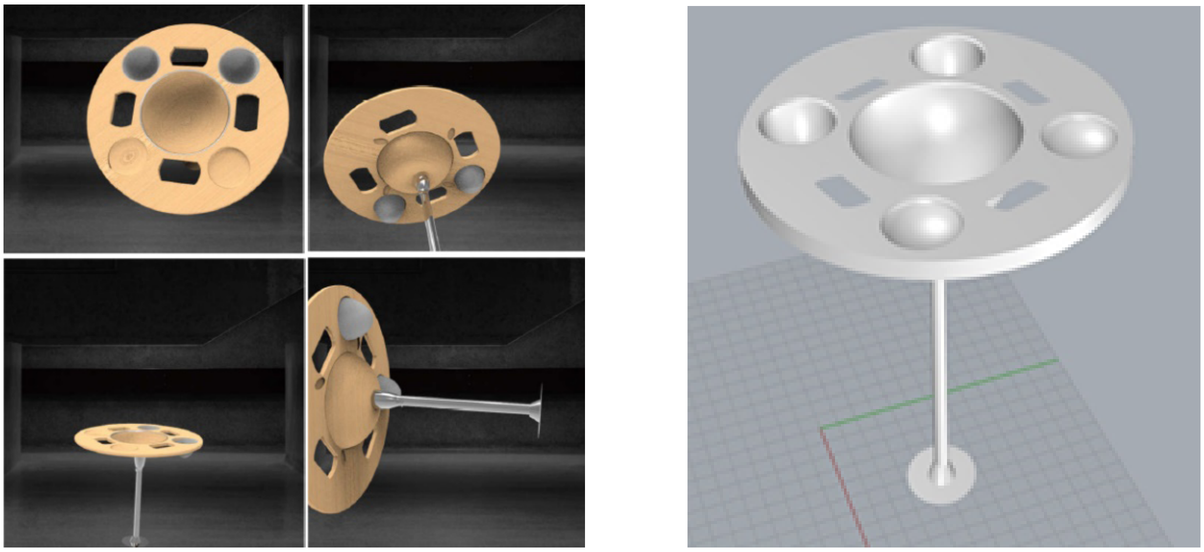

Figure 1. Ergonomic table design for saffron flower processing

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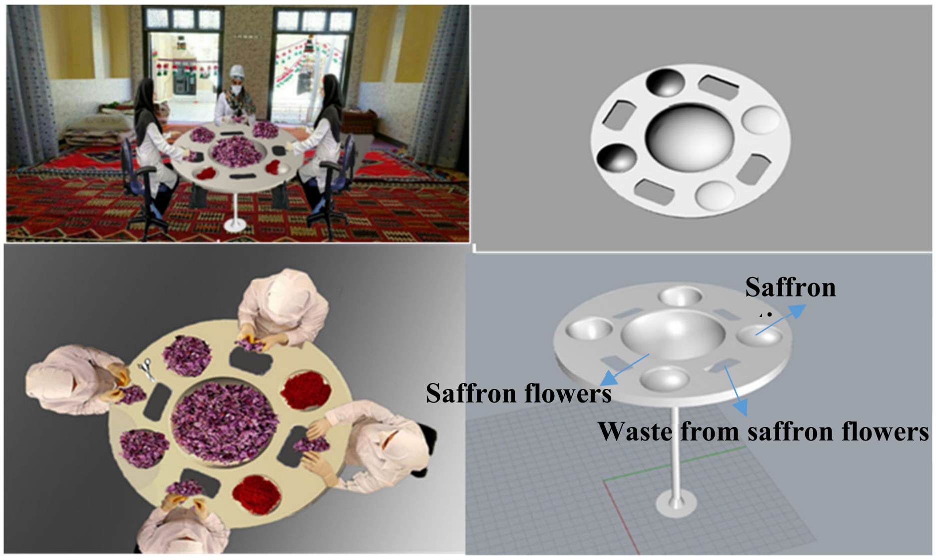

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Figure 2. Positioning of individuals and placement of flowers, stigmas, and waste bags in the ergonomic table for saffron flower processing

The dimensions of the various parts of the table were determined using anthropometric data from workers aged 20 to 60 years in the country, published by the office of environmental health and occupational health of the Ministry of Health. Based on the results of this study, the overall height of the designed table, using anthropometric data from Iranian workers aged 20 to 60, was determined to be between 76 to 87 centimeters, and the total cross-sectional area of the table was found to be 6645 square centimeters. The dimensions of the different sections of the table are shown in Figure 3.

Discussion

Incorporating ergonomic principles into the design of farm tools and equipment is crucial for improving the health and safety of farmworkers while also enhancing productivity. Engineers, scientists, and machinery designers leverage anthropometric data and muscle strength information from the user population, applying appropriate biomechanics principles and ergonomic design guidelines to develop effective specifications for tools and equipment [24].

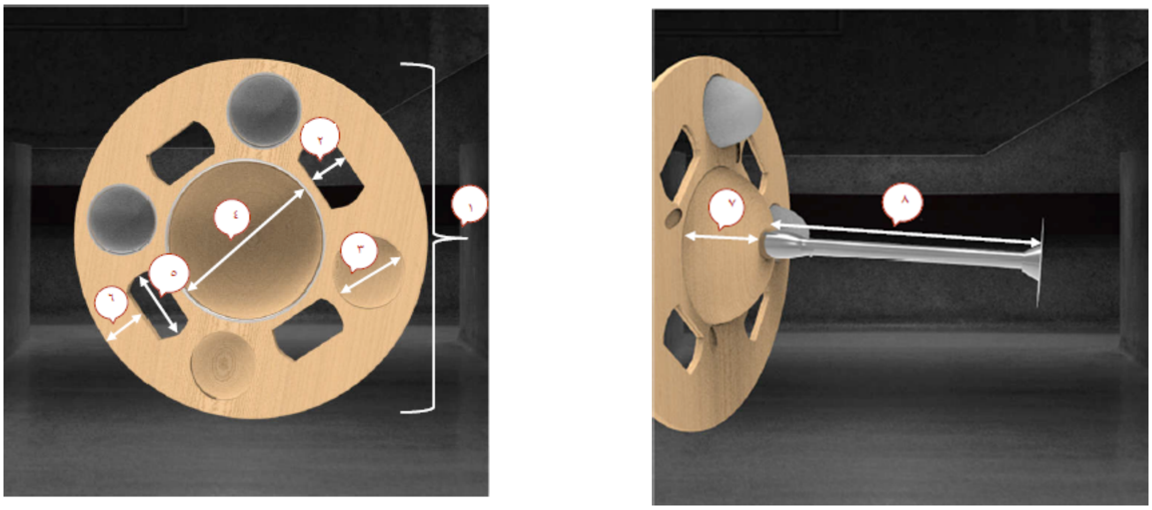

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Figure 3. Dimensions of the various sections of the ergonomic table for saffron flower processing; 1) 92cm, 2) 8 cm, 3) 17 cm, 4) 40 cm, 5) 15cm, 6) 13cm, 7) 15 cm and 8) 61-72 cm

In the present study, the ergonomic design of a saffron flower processing table was introduced for the first time. Considering that saffron flower processing is generally performed in workshops and homes by groups of individuals, the table was designed to accommodate at least 4 and a maximum of 6 people seated around it. Since saffron processing is a continuous and entirely static task that leads to fatigue and excessive wear on individuals over limited periods, tasks, such as stem cutting and stigma separation are typically rotated among individuals, allowing them to switch activities. Therefore, the table's surface was designed to enable individuals to easily change and shift their activities by rotating the table, facilitating both individual and group work. For the table surface, wooden or plexiglass sheets can be used. These sheets can be cut into circular shapes of specified sizes using a laser or handheld milling machine.

Processing methods for saffron flowers vary somewhat across different regions of the country, and the table design is suitable for all types of methods. The use of the ergonomic saffron processing table enhances quality and somewhat reduces ergonomic risk factors; however, since the work is performed while seated, the risk of MSDs still exists.

he study by SammakAmani et al. [25] focuses on the design of a desk converter for sedentary workstations, while the present study centers on the design of an ergonomic table for processing saffron However, both studies utilize anthropometric data from Iranian populations.

The study by Toktam et al. aimed to design a new ergonomic workstation for using microscopes based on the anthropometric dimensions of Iranian microscope users and to investigate its effect on the users' posture. The results of this research showed that the application of design principles and ergonomics in the development of the new ergonomic workstation has significantly contributed to the creation of a natural and near-normal posture in the users. This may prevent the development of cumulative MSDs in users during prolonged work with the microscope [26]. The purpose of this study is the same.

Recently, applied research in the field of ergonomic design has attracted the attention of various researchers [27–30]. For example, ergonomic interventions have been assessed in various studies to reduce physical strain during harvesting. Silverstein et al. [31] introduced an ergonomically designed bag as an alternative to the traditional tied basket used during coffee harvesting, finding that basket users reported pain at a higher rate than those using the bag. Pranav and Patel [32] created an ergonomic tool for manual orange harvesting, specifically for hilly areas, and compared its effectiveness with two existing tools. Their results showed a significant reduction in damage and body discomfort, along with increased work output. Additionally, Pranav and Patel [32] tested a conveyor belt as a substitute for carrying boxes, which effectively reduced harmful stooping. Notably, when harvesting strawberries grown in pots, workers maintained a straight neck and back with lowered arms, whereas those working with raised beds often had to kneel or bend forward with straight legs, potentially leading to harmful lumbar compression. In one study, the results indicated that the effect of training pamphlets was greater than that of using kneepads, and it was stated that both interventional methods can be appropriate approaches to prevent and reduce knee and trunk discomfort among saffron pickers [10].

In another study by Ghofrani et al. the design of the drawing table and chair was based on anthropometry, following the 5873B model. The results showed that except for the seat height, there was a 100% compatibility with the body dimensions of the students in other parameters [33].

In a study, two methods of saffron harvesting were considered: The traditional method with two common postures (half sitting and bowing) and harvesting while sitting on a trolley. It was found that the most harm on the farmers occurs in their knees when using the half sitting posture. The evaluation of saffron harvesting with the trolley showed that it results in the least damage to farmers. Hence, this simple device is recommended for saffron harvesting [12]. Mechanizing the process and reducing human involvement in the workflow is also recommended. Mechanizing the saffron harvesting process (flower picking and stigma separation) can not only reduce production costs but also decrease microbial contamination of the stigma. Additionally, by eliminating ergonomic risk factors, it will play a significant role in reducing MSDs. Mechanization improves work efficiency and increases each worker's output. Compared to other agricultural products, the mechanization of saffron production has not developed well [30].

Anthropometric measurements of farmers are crucial factors in the design of agricultural tools and equipment and should receive greater attention than in the past. Research indicates that these measurements vary not only among farmers in different countries but also among those in various regions within the same country.

On the other hand, the limitations of this study include the inability to generalize the results to other countries and different age ranges, as the anthropometric data of Iranian workers aged 20 to 60 years were utilized. It is suggested that future studies utilize electromyographic (EMG) assessment methods of users' muscles to improve the ergonomic design of the saffron processing table.

Conclusion

In this research, the ergonomic design of the saffron flower processing table was successfully carried out in accordance with the body dimensions and anthropometric characteristics of Iranian workers to reduce MSDs in the workforce. The limitations of this study include the inability to generalize the results to other countries and different age ranges, as the anthropometric data of Iranian workers aged 20 to 60 years were utilized. An ergonomic solution that works well in one country may lead to an increase in MSDs in another country due to different body dimensions. While some risk factors are common across various agricultural activities, each presents its own unique ergonomic challenges and injury risks, emphasizing the need for appropriate approaches to ergonomic interventions.

In summary, the implementation of ergonomically designed tools, such as this processing table, is essential for improving the health and safety of workers. Prioritizing ergonomic principles in design can significantly decrease the prevalence of MSDs, ultimately leading to a healthier workforce and more sustainable production practices. Future research should continue to explore ergonomic innovations and their impact on worker health across various sectors.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Gonabad University of Medical Sciences, Gonabad, Iran (Code: IR.GMU.REC.1398.161).

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Authors' contributions

All authors contributed equally to the conception and design of the study, data collection and analysis, interpretation of the results, and drafting of the manuscript. Each author approved the final version of the manuscript for submission.

Conflict of interest

The authors declared no conflict of interest.

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