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Effect of MSDs and scope of ergonomic interventions among rubber processing workers: a systematic review

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Keywords: agriculture; ergonomics; musculoskeletal disorders; rubber processing workers

Abstract:

Background: *The rubber processing workers experience various types of musculoskeletal disorders (MSDs) due to awkward postures, repetitive movements, and manual loads etc. Research on MSDs and ergonomic interventions in this area is limited. Therefore, the present systematic review aims to (i) identify various operations done by rubber processing workers and their associated MSDs, (ii) explore the ergonomic intervention and post-intervention study and its impact among the workers, (iii) identify the research gaps in MSDs and ergonomic interventions through bibliometric analysis.* **Methods:** *Comprehensive electronic searches were conducted in Web of Science, ScienceDirect and PubMed for the search term "Ergonomics" or "Musculoskeletal disorder" and "Rubber" for the article published before 2020. Eleven papers were identified for the review of MSDs and ergonomic interventions; data were extracted to summarize sample size, data collection methods, analyzing tools, various operations, MSDs, and ergonomic interventions.* **Results:** *The reviewed article is classified according to various operations such as rubber tapping, latex collection, rubber sheeting and sheet pressing. The review reveals that most of the workers experience lower back pain, which involved a traditional way of operating. Every author is trying to recommend some interventions, but post-intervention studies are limited.* **Conclusions:** *Due to the limited post-intervention study, there is a scope of ergonomic interventions in every operation. So, the implementation of a proper ergonomic tool with adequate awareness improves the MSDs among the rubber processing workers. The review will help to identify the various intervention gaps in different operations associated with rubber farming.*

1. Introduction

1.1 Background and Motivation

Malaysia, Indonesia, Thailand, Brazil and India are the top five producers of natural rubber, with a cultivated area of 11,739,333 hectares worldwide [1]. Based on the area of cultivation, there is a minimum of ten million rubbers processing workers involved (about one tapper per hectare) [2]. However, research on musculoskeletal disorders (MSDs) and the ergonomic interventions among workers involved in rubber processing is limited.

A study conducted among rubber processing workers from Colombia found that tapping and collecting latex, mixing in two roll mills, and operating metallic moulds were the four major tasks involved in rubber processing [3]. The result shows that the prevalence of MSDs is due to manual loads handling, frequent movements, and awkward postures. Based on the hierarchy of risk controls by the National Institute for Occupational Safety and

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Health (NIOSH), the MSDs can be improved by ergonomic interventions through the use of personal protective equipment (PPE), implementation of administrative and engineering controls, and elimination and replacement of hazards [4].

The studies from other agricultural fields recommend appropriate ergonomic interventions to overcome the prevalence of MSDs. A study reports of an ergonomically designed basket developed in India for tea plucking workers, which improved the MSDs in the neck and lower back due to prolonged standing posture with slight bending. The newly designed basket is lightweight and can accommodate more leaves. It fits the curvature of the worker's back, keeping the basket in place, and the post-intervention study shows that MSDs are improved [5]. Kishtwaria and Rana made an ergonomic intervention by improving traditional tools such as weeder, kutla and hoes used in weeding operations among the hill farmworkers based on anthropometric data and physical fitness levels [6]. The results proved a reduction in postural stress and intensity of pain in different parts of the body. A modification of the shoulder strap used for the apple harvesting basket reduced compression and surface friction with the incorporation of a hip belt that supports the shoulder to displace the weight [7]. In another study, May et al. had compared a traditional blueberry harvesting rake with a modified long-handled rake [8]. The long-handled rake improves posture in forward bending and squatting, which reduce pain in mid-low back pain. Ojha and Kwatra also compared the traditional uprooting and transplanting operation in rice cultivation with the mechanized method, which improves body posture and reduces drudgery [9].

However, all these studies concerned the improvement of productivity in the different agricultural crops. But studies proposing the MSDs and ergonomic interventions among the rubber processing workers are limited. Further, post-intervention studies among rubber processing workers are also scarce. Therefore, it has become imperative to conduct studies on the various MSDs associated with various operations and also recommend appropriate ergonomic interventions to improve productivity.

The systematic review would help to identify the prevalence of MSDs and the recommendation of ergonomic interventions among rubber processing workers, conducted among six countries which are the maximum rubber producers' countries in the world. The reviewed research works are classified into the rubber processing operation in Tapping, Harvesting, Sheeting and Pressing. This will provide a direction to researchers for future research. Moreover, this will provide an idea about the various ergonomic risk assessment methods adopted in different articles related to rubber processing. Further, the details of data collection methods adopted, and data analyses techniques applied are also tabulated. In a nutshell, this review would help researchers and practitioners in the field of ergonomic interventions in various rubber processing operations. Hence a series of research questions are formulated in the following sub-section.

1.2 Research Questions

The systematic review aims to identify MSDs experienced among rubber processing workers, the scope of ergonomic interventions, and the effect of these interventions in the post-intervention studies. With this aim, the following specific research questions were formulated: (i) does a hierarchical framework exists to implement ergonomic interventions among rubbers processing workers?; (ii) what are the various operations associated with rubbers processing workers?; (iii) what are the impacts of various operations on the formation of MSDs among rubbers processing workers?; (iv) what are the methods adopted by researchers for the assessment of ergonomic risks among rubbers processing workers?

1.3 Research Objectives

The literature review aims to identify MSDs associated with the various operations of rubber processing workers and to explore the newly improved design, ergonomic interventions, and its assessments. This review will also shed light on gaps in the realization of ergonomic preventive measures for different operations, the various interventions, and their

effectiveness. Hence the scope for implementing ergonomic preventive methods can be determined through the review. In a nutshell, the objectives of the literature review are as follows: (i) to propose a hierarchical system for implementing ergonomic interventions among rubbers processing workers; (ii) to categorize the various operations associated with rubbers processing workers; (iii) to identify the impacts of various operations on the formation of MSDs among rubber processing workers; (iv) to explore different ergonomic risk assessments methods adopted among rubber processing workers.

Section 2 presents the various methodologies adopted for the review. Section 3 proposes a framework based on the hierarchy of risk controls by NIOSH. The literature reviews on the evaluation of MSDs, ergonomic interventions and post-intervention studies are deliberated in Section 4. The bibliometric analysis was performed with the selected literature discussed in Section 5. Section 6 sets forth an elaborate discussion and unravels the scope of further research on ergonomic interventions among rubber processing workers. Section 7 concludes this paper.

2. Systematic Review Methodology

The methodology used is based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to summarize evidence accurately and reliably [10, 11]. Figure 1 depicts the details of the PRISMA Flow Diagram for searching and screening of literature review.

2.1 Inclusion Criteria and Exclusion criteria

Literature review papers are included as per the inclusion criteria and exclusion criteria.

2.1.1 Inclusion criteria

- Field study conducted among rubber processing workers;
- Work-related musculoskeletal disorders among rubber processing workers;
- Ergonomic intervention study and post-intervention study among rubber processing workers;
- Published between 2000 & 2020.

2.1.2 Exclusion criteria

- Review papers, case studies etc. were not included;
- Non-English language research journals were not included;
- Papers related to rubber industrial workers were excluded.

2.2 Search Strategy and Identification

The search was conducted mainly in three online databases: Web of Science, PubMed and ScienceDirect, in literature published from 2000 to 2020. The main search term included "Ergonomic" or "Musculoskeletal disorders" and "Rubber". The search results provided 41, 41 and 8465 articles from Web of Science, PubMed and Science Direct, respectively and four journals from another source are also included. The duplicate article was identified and removed; finally, a total of 11 articles are included in the systematic review.

2.3 Screening and Selection

Initial screening was conducted by evaluating the title and abstract of the article based on the inclusion and exclusion criteria. Duplicate articles and papers from other languages (other than English) were removed. Review articles and case studies were also excluded from the review. The articles which are related to work-related musculoskeletal disorders and ergonomic interventions among rubber industrial workers were not eligible for the review.

2.4 Data Extraction & Bibliometric Analysis

The extracted data included the title, name of the author, publication year, demographic information, sample size, and geographical region. Papers are arranged based on the types of operations. The evaluation was based on MSDs, ergonomic interventions, mode of data collection, analysis tool and

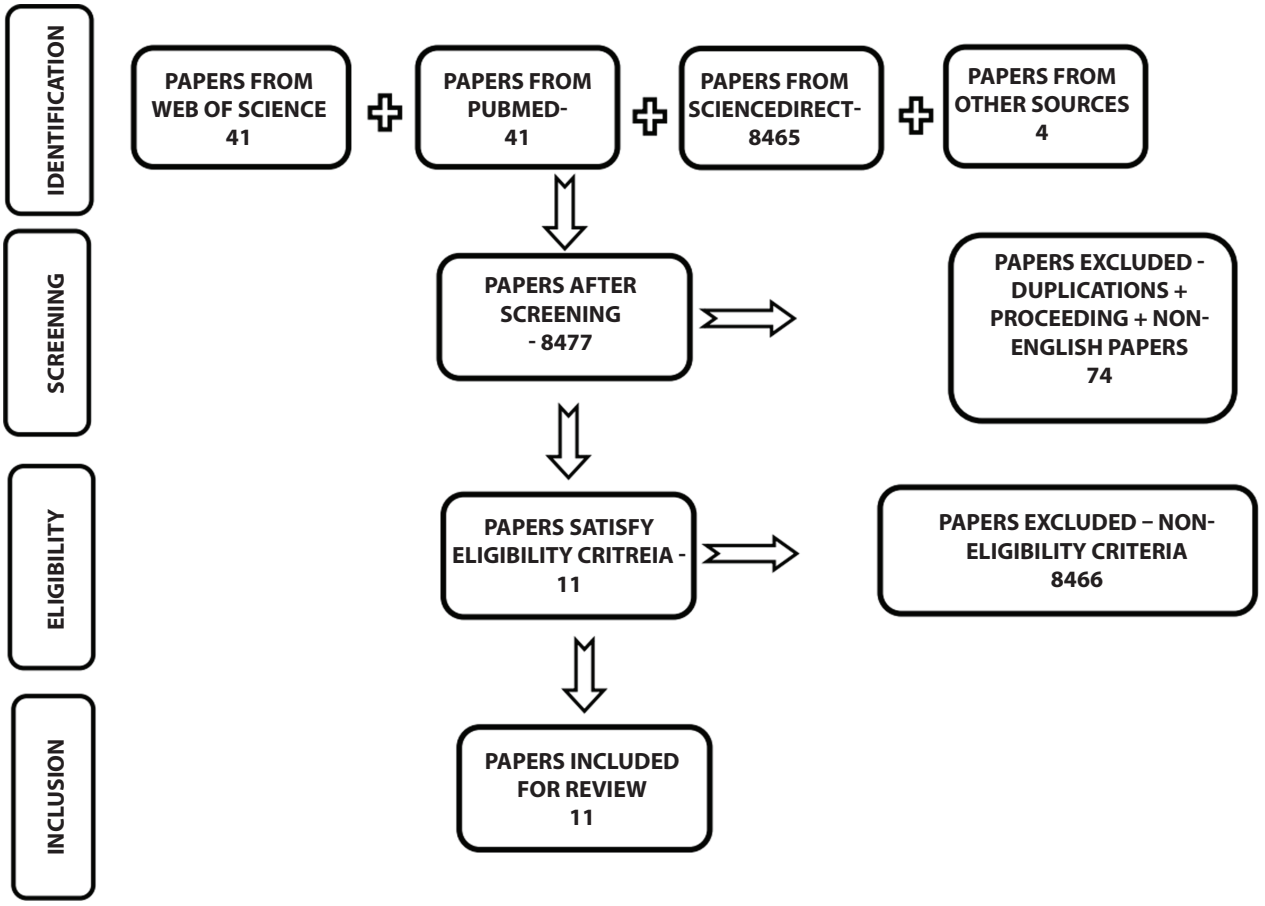

Figure 1. PRISMA Flow diagram for searching and screening of literature review.

agriculture operations. Mendeley reference management software was used for reference management, and a reference list was downloaded for bibliometric analysis. BibExcel software was used for analyzing the journal title, keywords, and author's information.

3. Hierarchical Framework for Ergonomic Intervention among Rubber Processing Workers

A hierarchical framework for implementing ergonomic interventions in a workspace has been proposed by the National Institute for Occupational Safety and Health (NIOSH) [4] to mitigate occupational hazards. The framework suggests that the occupational hazards and safety can be improved through the following methods: (i) eliminate the working conditions, (ii) replace the working conditions, (iii) redesign the working condition, (iv) train for safety and health, and (v) use of personal protective equipment. Although elimination and replacement of the working conditions is the most effective hierarchy of risk controls, it is very difficult to implement these controls among rubber processing workers and hence are beyond the scope of intervention. Therefore, level 1 and level 2 have been excluded from the proposed framework. Hence a revised hierarchy framework for ergonomic interventions among rubber processing workers has been proposed and is shown in Figure 2.

As a first step and an effective way of prevention, working conditions should be redesigned (level 1) to modify the worker's way of working. The working condition can be redesigned by implementing work equipment like power operated tools, hand tools, mechanical harvesters, ergonomically designed tools, lightweight equipment, properly maintained machines etc. After implementing the

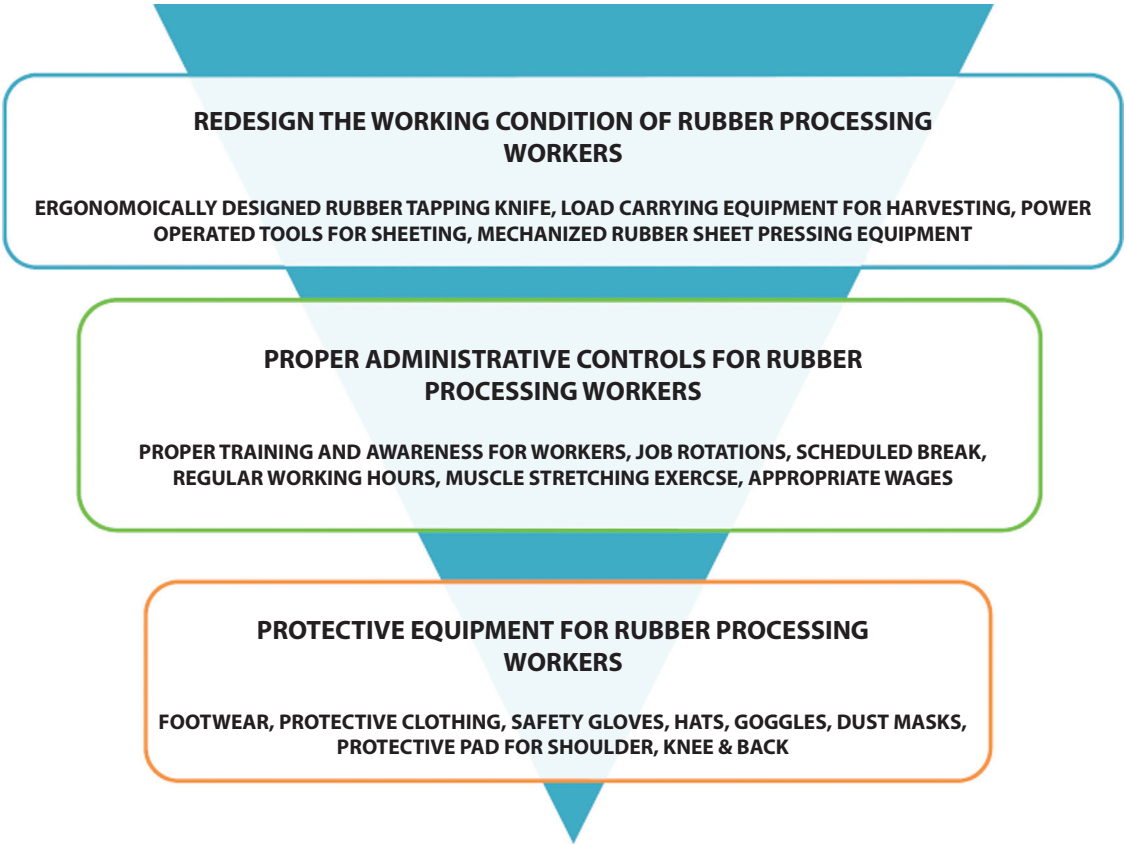

Figure 2. Proposed hierarchical framework for ergonomic intervention among rubber processing workers.

level 1 intervention, administration controls (level 2) like job rotations, scheduled breaks, regular working hours, training, awareness, stretching muscle exercise, appropriate wages etc., can be implemented. The next level, the wearing of personal protective equipment (level 3), can be executed to elevate the protection of workers by the implementation of footwear, protective clothing, safety gloves, hats; goggles, dust or gas masks, protective pad for shoulder, knee & back etc. to improve the safety.

4. Assessment of Musculoskeletal disorders (MSDs) and Ergonomic Interventions

4.1 Assessment of MSDs

MSDs are commonly observed in rubber workers having working posture risks due to repetetive movements, awkward postures and physical load handling during various operations involved in rubber processing. The assessment of MSDs reported in the literature has been classified according to various operations, such as rubber tapping, rubber collection, sheeting & sheet pressing. The details are depicted in Table 1.

4.1.1 Assessment of MSDs in rubber tapping

Rubber tapping consists of making an incision on the bark of the rubber tree with a tapping knife. Each worker has to tap 300 to 1000 trees daily in the early morning [12]. Pramchoo et al. have evaluated the MSDs using Boston Carpal Tunnel Syndrome Questionnaire [13], and Video Recording survey among 534 rubber tappers and the body posture analysis with RULA [14]. The result shows that the rubber tappers experience Carpal tunnel syndrome due to extreme ulnar deviation and flection of wrists during tapping [15]. Few other studies have also

Table 1. Summary MSDs based on the various operations.

Ref #	Job	Sample Size & Sex	Age	MSDs										Assessment Methods	Results of the Assessment	Reason for MSDs
				Neck	Shoulder	Wrist/ hand	Elbow	Finger	Lower Back	Upper Back	Hip/ Thighs	Knee/Leg	Ankles/ Feet pain			
8	Tapping	427 258 M 142 F	15-60	x		x			x					Face to Face Interview, Rapid Upper Limb Assessment using Direct Observation, Video Recording.	52.9% of the participants had low back pain: the prevalence of pain in the legs, upper arms, neck, wrists, and lower arms were 14.8%, 8.9%, 3.0%, 2.3%, and 2.1%, respectively. Average final RULA grand score of 5.25 corresponded to action level of 3.	Low-level tapping, trunk twisting, bending & extension during tapping, socioeconomic factors, perceived fatigue at work, low social support, education and income.
6	Tapping	534 280 M 254 F	20-60			x								Boston Carpal Tunnel Syndrome Questionnaire and, Video Recording Rapid Upper Limb Assessment, Statistical analysis using logistic regression models, Phalen's test and Tinel's sign.	Rubber tappers having the trees tapped at or below knee level and the tapping at higher than chest level involved significantly higher proportion of right wrist flexion and/or extension, and left wrist radial and/ or ulnar deviation and twist than tapping at a lower level.	Excessive ulnar deviation and wrist flexion.
17	Tapping	208 80 M 128 F	40-60			x								Face-to-face interviews using the Boston Carpal Tunnel Syndrome Questionnaire (BCTQ), Rapid Upper Limb Assessment (RULA), Statistical analysis using Paired t-test, McNemar's test, Phalen's test and Tinels's sign.	CTS symptom severity scores were significantly decreased and right wrist radial and/or ulnar deviation significantly reduced among tappers using the ergonomic knife compared with those of tappers using the traditional knife.	Excessive ulnar deviation and wrist flexion.

Table 1. Summary MSDs based on the various operations.

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				Neck	Shoulder	Wrist/ hand	Elbow	Finger	Lower Back	Upper Back	Hip/ Thighs	Knee/Leg	Ankles/ Feet pain			
12	Tapping	300 117 M 183 F	21-89	x	x				x	x				Nordic Musculoskeletal Questionnaire, Quick Exposure Check (QEC) Statistical analysis using Log-binomial regression.	66% of rubber tappers experience MSD. Ergonomic exposure levels were very high in the back (94.4%), shoulders (96.7%), and neck (83.3%). Female rubber tappers, age, working two jobs, alternating tapping hands, and depression were significantly associated with increased risk of MSDs.	Age, primary job, alternating tapping hands, depression.
11	Tapping	419 M	39-66	x	x				x					Standardized Nordic Questionnaire (SNQ) and Job Content Questionnaire, Statistical analysisusing Chi-square test.	Prevalence of Neck Pain among the rubber tappers was 59.9% due to age, working hours per day and physical workloads includes neck flexion or rotation, awkward postures, repetitive motion and static postures.	Neck flexion or rotation, awkward postures, repetitive motion and static postures, age.
10	Tapping	343	28-62		x	x	x		x	x	x	x	x	Nordic Musculoskeletal Questionnaire (NMQ).	Lower back had highest prevalence of MSD among rubber tappers with 74.4% followed by shoulder (53.5%), neck (48.8%) and wrists/hands (48.8%).	Old trees should be tapped above the head level, Extreme force was required on neck, shoulders & forearm, BMI, ethnic, marital status, education level, smoking habit, duration of working and trees tapped per day.

Table 1. (*Continued*)

Table 1. Summary MSDs based on the various operations.

Ref #	Job	Sample Size & Sex	Age	MSDs										Assessment Methods	Results of the Assessment	Reason for MSDs
				Neck	Shoulder	Wrist/ hand	Elbow	Finger	Lower Back	Upper Back	Hip/ Thighs	Knee/Leg	Ankles/ Feet pain			
22	Tapping, Collecting, Sheeting	433 140 M 293 F	Mean 45.14						x					Standardized Nordic Questionnaire, Pulmonary function tests, Statistical analysis using t-test & c2 test.	Prevalence of Neck Pain among the rubber tappers was 72.2% followed by Low back pain (66.2%), shoulders pain (44.9%), knee pain (55.8%), ankles/feet pain (34.4%), elbow pain (33.2%), upper back pain (30.8%), wrists pain (50.1%) and hip/thighs pain (15.3%).	Tapping below knee level & Tapping below waist level.
23	Tapping, collecting, sheeting	327 111 M 216 F	18-70						x					Global Physical Activity Questionnaire (GPAQ) ,Face-to-face interviews and Objective Examination, Statistical analysis using Chi-square analysis, Multivariate logistic regression.	Low back pain is common among rubber farmers and prevalence of Lower Back Pain among the rubber farmers was 55.7%. BMI, primary school education, exposure to pesticides, and tapping below knee level factors were identified as being associated with the high prevalence of Lower Back Pain	Environment, their work load, and their speed of work, job strain.
3	Tapping, collecting, sheeting	3 M	17-26						x	x				Job Content Questionnaire–Thai version (TJCQ), Statistical analysis using Univariate Cox regression.	History of Lower Back Pain and active job are predictors for the occurrence of Lower Back Pain in rubber farmers. Such information is important in the prevention or reduction of new onset or recurrent LBP in this population.	Awkward postures, Repetitive movements, Manual handling of loads in the workplace, Mechanical entrapment risk.

Table 1. Summary MSDs based on the various operations.

Ref #	Job	Sample Size & Sex	Age	MSDs										Assessment Methods	Results of the Assessment	Reason for MSDs
				Neck	Shoulder	Wrist/ hand	Elbow	Finger	Lower Back	Upper Back	Hip/ Thighs	Knee/Leg	Ankles/ Feet pain			
24	Rubber sheet production- adding formic acid, squashing, cleaning, pressing, patterning,	25 18 M 7 F	Not Mentioned						x	x		x		Interviews, Direct observation, Photographs and Videos, Ovako Working Posture Analysing System, Methodology developed by the National Institute for Occupational Safety and Health of the United States (NIOSH).	Rubber tappers are unaware of the risks associated with their tasks, so some education in ergonomic aspects could avoid habits that are potentially harmful to their health and welfare. During tapping forearms and wrists must maintain a degree of flexion while the trunk was leaning forward and lateral rotated. The level of flexion or rotation depended on the height of the level of bleeding.	Pouring the latex, cleaning and pressing processes are at high risk due to bent and twisted back.

been conducted among rubber tappers and identified MSDs in the lower back, followed by shoulder, neck, wrist/hand, upper back, elbow, knee, and angle foot due to age of the tree, tree height, surface of the plot, number of trees tapped daily, sharpness of the knife and physical condition of the tappers [16, 17]. Other reasons for MSDs among tappers are the age of workers, tapping as a secondary job, alternate tapping hand, awkward posture, repetitive movements, BMI, ethnic, marital status, education level and education level [18-21].

4.1.2 Assessment of MSDs in rubber collection

Rubber collection is the process of collecting rubber (latex) from a latex cup attached to the rubber tree after tapping, using a bucket and scrubber/hand [12]. Udom et al. have done a survey on various operations among the rubber workers. In most situations (88.1%), both the tapping and latex collection are done by an individual [22]. Therefore, the MSDs experienced by workers are due to the combined effect of tapping and latex collection. Velásquez et al. conducted a posture risk analysis in latex collection and identified possible MSDs such as Cervical tension syndrome, Rotator cuff tendinitis and deviation of the spine (lordosis or scoliosis) due to awkward postures during the collecting latex from the bottom of the tree, slope terrain etc. and repetitive movements like collecting 400 to 600 cups every day [3]. Udom et al. identified that work experience, latex collecting level and job duration are the reasons for MSDs among rubber collectors [23].

4.1.3 Assessment of MSDs in rubber sheeting

Rubber sheeting process of converting collected latex into a sheet involves various processes like pouring latex, adding formic acid, mixing, and removing bubbles [24]. They found that the process of pouring latex has a high risk since the load by these postures imposed a detrimental effect on the musculoskeletal system. Velásquez et al. also identified several possible MSDs in the sheeting process: muscle contractures, Sciatica, frequent muscle spasms, and pain associated with the compression of the lumbar vertebrae (lower back pain) due to squinting and bending during the operation [3].

4.1.4 Assessment of MSDs in Sheet Pressing

The sheet pressing process of rolling the coagulated sheet through rollers several times is used for removing the water content and converted it to a thin sheet. Velásquez et al. also identify various several possible MSDs such as amputation of fingers or hands, back symptoms, spinal deviation (lordosis or scoliosis), muscle contractures, Sciatica, frequent muscle spasms due to load applied on the hands and back during rolling, roller height and repetitive movements during rolling [3].

4.2 Percentage of MSDs

Figure 3 shows the percentage of MSDs among the agriculture workers from the reviewed journals and shows maximum in MSDs in lower back.

4.3 Assessment of Ergonomic Interventions

The assessment of ergonomic interventions is based on the various operations among rubber

Figure 3. Percentage of MSDs among rubber tapping workers.

processing workers. So, research gaps can be easily identified, and researchers can implement appropriate interventions in operation.

In rubber tapping, the Carpal tunnel syndrome due to extreme ulnar deviation and flexion of wrists was improved using an ergonomically designed tapping knife and a post-intervention study was carried out [25]. Meksawi et al. and Shan et al. recommended that ergonomic and industrial hygiene, health promotion activities and guidelines are needed to prevent lower back pain of the rubber tappers [16, 19]. The appropriate interval during tapping and latex collection improves workers' performance, and, also, the use of mechanical aids for lifting and transport of latex collection drum would reduce the MSDs [3]. They also recommended that height-adjustable tables, mechanized presser and awareness between workers and employers would improve the work conditions. Use of PPE, proper training and exercise, proper health check-up and food among the rubber tappers improves work-related injuries and accidents [26]. Detailed items recommended by the reviewed article are listed in Table 2.

5. Result and Discussion

The systematic review was conducted to explore the MSDs and ergonomic interventions among the rubber processing workers, which would help the agricultural ergonomists to contribute more to the rubber processing field. For the review, 11 articles were selected from five countries to study the prevalence of MSDs. The highest number of articles were identified from Thailand, the country having the highest production of rubber. The systematic review includes types of operations in rubber processing and associated MSDs, ergonomic interventions, sample size, method of data collection, analysis tools and bibliometric analysis.

The reviewed article contains various data collection methods, including self-reported study, video and photograph and direct measurement. Most of the articles use self-reported studies for data collection and use more than one method to improve the reliability of the data. In the self-reported study, most of them are using Standard Nordic Questionnaire Survey [27]. The collected data are evaluated using various analyzing methods such as OWAS [28], RULA [15], REBA [29], QEC [30] and Statistical analysis methods using various software such as SPSS, SAS etc. The articles had different sample

Table 2. Summary of Ergonomic intervention based on the operations.

Operations	Recommended Ergonomic Interventions (From articles)	Author
Rubber Tapping	Ergonomic rubber tapping knife to improve wrist postures among rubber tappers.	17
	Development and implementation of programs using ergonomic and industrial hygiene.	6
	Health promotion activities and guidelines to empower workers.	11, 17
	Ergonomic and industrial hygiene improvements are needed to prevent low back pain.	8
	Appropriate intervals during tapping.	3
Latex Collection	Create awareness among workers and employers.	3
	Appropriate intervals during collection.	3
	Use of mechanical aids such as carts for lifting and transportation of collection drums.	3, 20
Rubber Sheeting	Redistribution of workplace.	3
	Height adjustable table.	3
	Healthy working condition and Job satisfaction.	24
Sheet Pressing	Mechanized Sheet presser.	3
	Height adjustable table.	3
	Healthy working condition and Job satisfaction.	24

sizes, ranging from 3 to 534 participants. All the articles include male and female in sample selection expect one research work.

The assessment of MSDs is based on the various operations such as rubber tapping, collection, sheeting and rolling, results in pain in various body parts like the neck, shoulders, wrists/hands, elbow, lower back, upper back, hips/ thighs, knees/leg, ankles/ feet pain and most of the rubber processing workers experiences lower back pain (86%). The body posture associated with each operation cause MSDs in every part of the body. In the case of rubber tapping and collection, excessive ulnar deviation and wrist flexion with a traditional knife cause Carpal tunnel syndrome, the height of the tapping causes trunk twisting and bending causes neck, shoulder and lower back pain and repetitive motion. For sheeting and pressing, manual handling of loads, height of sheeting and pressing platform, and repetitive movements cause back pain. Age is also a factor for improving performance, age and performance make an inverted U graph [21]. Use of PPE, proper training and exercise, proper health check-up and food among the rubber tappers improves work-related injuries and accidents.

The prevalence of MSDs can be improved by applying various ergonomic interventions in each operation. In the case of rubber tapping, a modified ergonomic tapping knife improves the wrist posture; appropriate interval during tapping reduces the repetitive movements. For rubber collection, the use of mechanical aids for carrying loads and appropriate interval during latex collection improves repetitive movements. Height-adjustable table, the redistribution of workplace and mechanized sheet pressing are recommended ergonomic interventions for rubber sheeting and sheet pressing.

6. Conclusions

The present review summarizes the prevalence of MSDs among rubber processing workers from 11 articles and classified into four major operations, including rubber tapping, latex collection, rubber sheeting and sheet pressing. The review found that most workers suffer from MSDs in the lower back and followed by upper back, hands/wrists, neck, shoulder, knees/legs, elbow, ankles/feet, and hip/ thigh, due to awkward postures during various operations, repetitive movements in operation, physical load handling manually in the workplace, less awareness etc. The MSDs can be improved by various ergonomic interventions through various engineering control methods, administration control and use of protective equipment. So, the systematic review would guide the researchers to the scope of interventions in each operation through various recommendations from different journals.

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Declaration of Interest: The authors declare no conflict of interest.

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