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RESEARCH ARTICLE

Ergonomic Studies on Occupational Health of Women Workers Involved in Agricultural Industries: A Systematic Review

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ABSTRACT

This study undertakes a systematic review focusing on occupational health hazards and related issues experienced by women in the agriculture sector. Women engage in diverse and demanding farm operations, involving substantial energy expenditure, prolonged hours, and awkward postures, contributing to both drudgery and occupational health risks. Understanding the root causes of these conditions and establishing effective measurement methods is crucial. Moreover, identifying strategies to mitigate these hazards is imperative. A comprehensive literature review on women in agriculture illuminates various health concerns, their origins, analytical approaches, and potential enhancements to working conditions. To conduct a systematic review, the study adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method, incorporating 79 relevant articles from Scopus and PubMed, following strict inclusion and exclusion criteria, published between 1989 and 2022. The findings revealed a concerning trend wherein female workers increasingly assume precarious, underpaid, and labour-intensive roles within the agricultural sector. Occupational health risks are heightened due to factors such as heat exposure, pesticide use, injuries, incontinence, awkward postures, and activities prone to drudgery. Ergonomically designed technology is pivotal in alleviating women's occupational challenges, although this area remains relatively underexplored. To address these occupational hazards and health concerns effectively, there is a need for governmental intervention. Establishing a dedicated task force or committee is recommended. Furthermore, a multi-stakeholder network comprising government bodies, non-profit organizations, and civil soci-

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ety groups is proposed to enhance the well-being of women working in agriculture collaboratively. This study is the first of its kind that effectively highlights the multidimensional health issues women workers face, shedding light on their working conditions in the agriculture industry.

Keywords: Underpaid; Occupational Health; Women Workers; Agriculture; Meta-Analysis

1. Introduction

Like renewable energy, human resources play a pivotal role across diverse sectors such as agriculture, industry, transport, and services [1]. Human resources play a crucial role in agriculture by fostering diversity, ensuring fair treatment, and promoting the well-being of employees, with a particular focus on women. Women in agriculture often face barriers such as limited resource access, unequal pay, and under representation in leadership roles. Human resources can address these challenges by implementing targeted recruitment, creating inclusive policies, and advocating for gender equity. This empowers women and enhances productivity and sustainability in agriculture [2–4]. In agriculture, human resources are complemented by machinery and tools, including tractors, ploughs, and hand carts [5]. Despite a global population exceeding 7.5 billion, where half are part of the labor force and nearly 40 percent of those are women, the participation and well-being of women in the workplace continue to be largely overlooked [6]. Since women represent a significant portion of a country's potential human resources, prioritizing their health becomes imperative for national development.

In India, the working conditions of women in agriculture are particularly poor, marked by extended work hours, lack of organizational support, and a prevalence of musculoskeletal diseases (MSDs). MSDs manifest as discomfort or pain in joints, muscles, and nerves, most commonly found in limbs, neck, and lower back [7–10]. Contributing factors include poor posture, repetitive tasks, body vibration, and static positions [11–13] collectively termed as work-related musculoskeletal diseases (WMSDs) and extensively studied by various researchers and organizations [14–17].

While WMSDs have been predominantly studied in the general labor force [18–22]. Rregrettably, limited attention has been directed towards the health of women engaged in agriculture [23, 24]. A comprehensive understanding of occupational health conditions, their causes, and measurement methodologies is crucial, as is identifying effective interventions to reduce their impact. This paper aims to review existing studies on ergonomic risk factors in women working in agriculture, shedding light on the ergonomic aspects of occupational health in agro-industries and highlighting common protective and risk factors women workers face.

As a multidisciplinary science, Ergonomics seeks to enhance workplace conditions and worker well-being by studying human interactions within socio-technical environments [25, 26]. Within agriculture, ergonomics becomes a valuable tool for mitigating risks associated with machinery, labor, and vehicles, aligning with the principles of sustainable agriculture [18, 27]. Agriculture, despite being an essential activity, continues to be fraught with hazards due to its heavy reliance on manual labor, posing significant threats to physical and mental health [28–30].

Many individuals engaged in agriculture, particularly in rural areas, lack knowledge or awareness of their health-related challenges [24, 31, 32]. Despite their myriad responsibilities, women often find themselves excluded from performing various tasks both within and outside the home [33]. Women in agriculture undertake various tasks, from transplanting and weeding to harvesting, processing, marketing, and selling food grains, fruits, and vegetables [27]. These activities, characterized by drudgery-prone demands on energy and time and often requiring awkward body postures, necessitate a thorough understanding of the associated occupational health hazards, their causative factors, measurement methods, and effective interventions. Through a systematic review of the literature on women in agriculture, this study aims to identify various health conditions, their causative factors, methods of analysis, and interventions to alleviate drudgery and enhance occupational health.

1.1 Significance of the Study

Considering the aforementioned aspects of women workers, this study is necessary because it addresses a critical gap in the understanding of the occupational health challenges women face in agriculture, particularly in rural areas. Given the drudgery and demanding nature of these tasks, which often require awkward body postures and long hours, there is a pressing need to understand the specific health hazards they face. This study focuses specifically on women's occupational health challenges in rural agriculture, a group often overlooked in broader research. It distinctively emphasizes the physical demands, such as drudgery and awkward postures, that women face during tasks like weeding and harvesting. By conducting a systematic literature review, this research aims to provide a comprehensive understanding of the health risks, their causes, and measurement methods, ultimately developing targeted interventions to improve the well-being and productivity of women in agriculture. Therefore, the primary aim of this study is to comprehensively assess the occupational health challenges faced by women in rural agriculture, focusing on the physical demands of their work, and to develop effective interventions that can alleviate drudgery and improve their overall well-being and productivity.

1.2 Research Questions

1) What are the common health conditions experienced by women engaged in agricultural activities in rural areas?
2) What are the primary factors contributing to these health conditions?
3) How do the physical demands of agricultural tasks, including drudgery and awkward postures, impact women's health?
4) What methods are currently used to measure and analyze the occupational health risks faced by women in agriculture?
5) What interventions can be developed and implemented to reduce drudgery and enhance women's occupational health in rural agricultural settings?

1.3 Material and Methods

For a rigorous and transparent systematic review, this study utilized the PRISMA method, developed by Cardona et al. in 2016. The study employed search terms from the DeCS and MeSH thesauruses to ensure comprehensive coverage and combined them with Boolean operators for specificity. The review was conducted on Scopus and PubMed in May 2022, focusing on literature published between 1989 and 2022. Search terms included "occupational health", "women", "agriculture", "musculoskeletal disorder", and "ergonomics" with relevant combinations tailored to each database. Filters were applied to restrict the search to the specified publication years.

Inclusion and exclusion criteria were established based on the nature and character of the study. Articles published in English were exclusively considered due to the broader English-speaking audience and the researcher's language proficiency. The methodology of the included studies was required to extract elements pertinent to the definitions of agricultural occupational health. Articles presenting empirical evidence on agricultural occupational health were included; while those relying solely on in vitro models or laboratory settings were excluded.

Data extraction from the selected studies involved the following key aspects: general information (title, journal name, publication year, and study location); agricultural occupational health topics addressed (occupational exposure to pesticides or chemicals, agricultural health and safety, medical training, and agricultural health); study type (retrospective, prospective, cohort, qualitative, exploratory, cross-sectional, case-control study); and the organizations involved in each study's execution (academic institutions, public institutions, and government agencies) [31–35]. This comprehensive approach allowed for a thorough analysis and synthesis of relevant information for the systematic review.

1.4 Results

After an initial search, 4018 studies were identified (Scopus 2127, PubMed 1891). Among these, 1835 articles from 1989 to 2022 were found (Scopus 1119,

PubMed 816). Following title screening, 844 studies were selected (Scopus 634, PubMed 201). After removing duplicates (n = 189), 369 publications were excluded from full-text reading, as they did not meet inclusion criteria based on abstracts and titles, providing no relevant information for the review. Applying exclusion criteria, 193 of the 286 remaining studies were deemed ineligible for full-text reading. Consequently, 93 articles were included for detailed analysis. Fourteen studies were excluded due to lack of relevance, resulting in a final analysis of 79 articles. Refer to **Figure 1** for an overview of the screening and selection process.

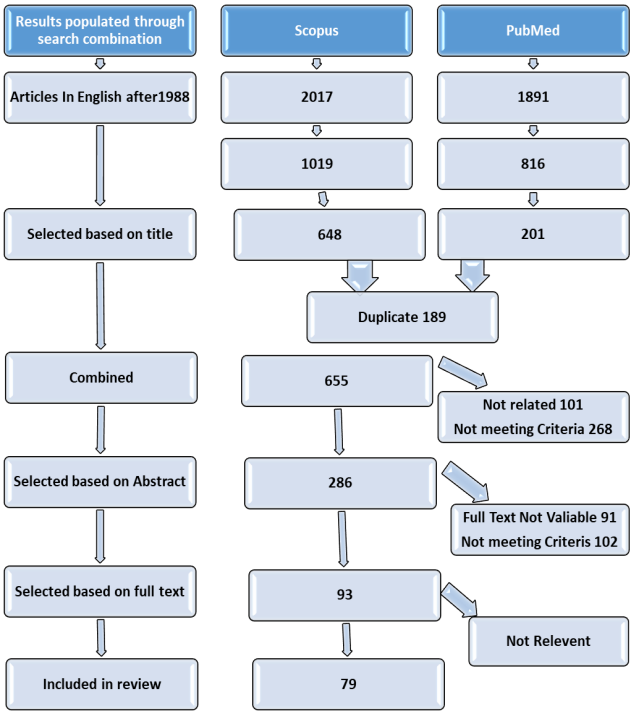

Figure 1. The article selection process.

The articles predominantly focused on assessing factors influencing the safety and health of women across various sectors, with a notable emphasis on common occupational injuries [27, 36–38]. Some authors took a qualitative approach, detailing accidents with variables such as nature, area, consequences, context, moment, place, and causal agent [39, 40]. Unfortunately, the reviews lacked sufficient attention to the impact of work on women's health, including fatigue, toxicological and respiratory problems, as well as mental and emotional health. Identified occupational health issues for women workers were outlined. The results obtained from the studies reviewed are organized into three sections: Section 1 addresses occupational health and women workers, including general ideas related to agriculture and health. Section 2 reviews ergonomic studies in agro-industries; while Section III discusses major health issues faced by women workers in agro-industries.

2. Occupational Health and Women Workers

In the 18th century, Bernardini Ramazzini, considered the father of occupational medicine, linked musculoskeletal disorders to workplace factors in his treatise "De Morbis Artificum Diatriba" ("Diseases of Workers") [41, 42]. Musculoskeletal conditions affecting nerves, tendons, muscles, and supporting structures vary from mild to chronic, with exertion level, posture, and lack of sleep identified as key factors [43]. These conditions are the most common cause of disablement in working adults and were listed among the ten most serious occupational disorders by the US National Safety and Health in 1987.

Authors like [43–45] have explored the link between poor working posture and physical complaints. Work-related musculoskeletal conditions (WMSDs) contribute significantly to occupational health, economics, and personal well-being globally, with around 160 million work-related diseases estimated annually by the International Labour Organization [46].

[47] highlighted agriculture as a hazardous sector worldwide. Practical actions to reduce work-related illnesses and accidents in agriculture, especially among tea-picking women prone to musculoskeletal disorders [36, 48] are gaining attention. The bidirectional relationship between health and agriculture is evident, as health influences agriculture and vice versa [19, 29]. Various health problems women face in agriculture, such as those related to socioeconomic, political, cultural, and ecological dimensions, are outlined in **Table 1**.

Factors such as work patterns, undernutrition, occupational risks, stress, and exposure to pesticides and

Table 1. Main Concepts and occupational hazards reviewed from the studies.

Concepts	Source
Aims of Occupational Health To reduce the risk of death from livestock-handling-related injuries and to ensure compliance with recommended practices regarding safe livestock handling and proper facilities, especially when working with aggressive cattle.	[49, 50]
Health and safety in farms To implement better farm machinery, safety and hazard control measures such as reducing children's exposure to this machinery and mandatory wearing helmets when riding quad bikes, motorbikes, and horses.	[33, 51]
Occupational health and risks in agriculture for women To identify factors associated with work-related injuries in farmers. To provide better information about agricultural health policies and guidelines on good working practices to older farmers, such as policies governing the maximum work hours and the minimum rest hours per week, as well as guidelines about the proper distribution of farming tasks and information on ergonomic advances and new farm equipment and technology.	[24, 52]
Occupational risks and work-related injuries in farmers due to exposure to chemicals and the environment	[53, 54]
Agricultural health and safety To reduce the risk of work-related injuries in farmers through prevention initiatives to achieve a full public health model based on education interventions, safe farm equipment handling practices, and occupational safety and health regulations.	[55, 56]
Safety and agricultural health To eliminate occupational hazards, employ on-site inspections of farms, identify agricultural health-related concerns through clinical screenings, implement occupational health and healthcare education interventions aimed at these workers, and create incentives for meeting occupational safety targets in farms.	[50, 54, 56]

Sources: Author's creation.

machinery contribute significantly to serious health issues among women in agriculture [57]. The nation's infrastructure heavily depends on occupational health, which in turn influences economic and social development. Women in agriculture suffer from health issues that are more related to poverty and occupational hazards than lifestyle choices, highlighting the need to prioritize worker safety and health [57].

[55] recommend updating laws to address all physical, chemical, and biological hazards faced by workers. However, the occupational health of women workers is often undervalued compared to men, with a greater focus on their survival amid poverty rather than on the quality of their jobs [49, 58]. Occupational health, a continuous effort, aims to maintain the highest levels of physical, psychological, and social well-being for workers in all occupations. Women in agriculture, who often occupy the lowest rungs of the social hierarchy, face numerous threats to their mental and physical health, including low incomes, poor occupational health conditions, harsh weather, and job insecurity [54, 59]. In the stratified Indian society, many women lack access to essential health services [53, 59].

[51, 56] emphasize that occupational health is critical to agricultural productivity. They suggest that effective implementation of social security and welfare programs could significantly improve health outcomes across various sectors.

The previous section highlights occupational factors associated with physical diseases, including age, workforce management, ethnicity, types of products used, work practices, agricultural machinery, engineering controls, and personal protective equipment [54–56]. Notably, there are significant regional workforce variations and an increasing number of permanent employees outside specific sectors, leading to greater exposure

to occupational risks[60–62]. Additionally, with an average age of 49 years, women workers may be more vulnerable to the harmful effects of occupational exposure, increasing the risk of chronic diseases affecting the respiratory and locomotor systems[63, 64].

3. Ergonomic Studies in Agro-Industries

As evidenced by various researchers, ergonomic studies in agro-industries shed light on the multifaceted health challenges workers face and propose avenues for intervention. Borgohain and Gupta[22, 34] emphasize the adverse impact of weather conditions—heat, cold, and rain—on the health of tea industry workers. Meanwhile, Hazarika[65] delve into the posture and musculoskeletal problems unique to women in Assam's tea industry, identifying acute backache as a prevalent issue among women aged 36–45. Bhattacharya and Marak et al.[44, 66] further link work-related musculoskeletal disorders to occupational stress, particularly among women engaged in tea leaf plucking operations.

Hand plucking, a common practice in Assam, involves repetitive and forceful efforts, leading to discomfort and health issues. Okunribido[67] focuses on rural female farm workers in Nigeria, highlighting the need for ergonomically compatible machinery. However, Victor et al.[68] caution against adopting Western-designed tools for Indian farmers, emphasizing the significance of region-specific anthropometric data in machinery design.

Expanding beyond tea plantations, Dewangan et al.[29] analyze anthropometric data from the Northeastern region, advocating for equipment modifications and improvements to existing tools. Gangopadhyay et al.[69] examine the postures of preadolescent farmers, highlighting the risk of musculoskeletal disorders from strenuous positions, though they do not specifically address tools. Agrawal et al.[70] study anthropometric data from agricultural workers in Meghalaya, revealing gender disparities in weight and stature and stressing the importance of considering grip dimensions for hand tools.

Ergonomics has a global reach in agricultural practices. Bao et al.[71] demonstrate the positive impact of ergonomic tools in reducing muscle strain during Nicaraguan coffee harvesting. Phajan[71] highlight the prevalence of work-related musculoskeletal disorders among Thailand's sugarcane farmers, calling for further research into their causes. Kwatra and Ojha[31] focus on rice cultivators, revealing their vulnerability to muscular disorders from repetitive postures. Murgan[45] reflect on the prevalence of musculoskeletal conditions, cumulative trauma disorders, repetitive strain injuries, and repetitive motion injuries as significant occupational health issues in India's textile industry.

In Nigeria, Obi et al.[67] address the mismatch between tools and equipment for rural agricultural workers, emphasizing the need for comprehensive statistics and the correlation of anthropometric data with tractor seat dimensions. Koekoeh[72] examine the experiences of Indonesian farmers with hand tools, highlighting the importance of ergonomic designs. Tripathi et al.[66] study vegetable transplantation, revealing a lack of ergonomic knowledge and the need for suggestions on ergonomic tool design. The challenges extend to the coir industry, with Sivanesan[73] detailing the health problems faced by coir workers. Satheeshkumar and Krishnakumar[74] delve into the prevalence of musculoskeletal disorders among coir industry workers in Kerala, advocating for research focused on equipment and ergonomic solutions.

Sahu et al[40] conclude by addressing the health risks faced by workers in the coir industry, emphasizing the need for more extensive data and advanced analysis tools, particularly concerning postural issues. This comprehensive review of ergonomic studies in agro-industries highlights the complex challenges faced by workers, underscoring the need for context-specific ergonomic solutions to improve the overall well-being of agricultural laborers.

4. Major Health Problems Associated with Women Workers in Agriculture and Allied Sectors

4.1 Systematic Diseases

Grandjean[75] recommended maintaining a com-

fortable range of elbow angles between 100 and 110 degrees for optimal ergonomic conditions. Satheeshkumar and Krishnakumar [74] study on Kerala's coir industry revealed a significant 12-month prevalence of work-related musculoskeletal disorders (WMSDs), particularly in the lower back (58.6%). Both male (65.2%) and female (51.7%) workers experienced higher rates of WMSDs in the lower back. The knee was identified as the second most common site of WMSDs (58.0%), followed by the elbow (42.8%), neck (36.7%), upper back (36.7%), shoulder (37.6%), ankle (25.4%), hip (15.7%), and wrist (15.5%).

Phajan [69] investigated WMSDs in Thailand's sugarcane farmers, pinpointing repetitive motions, awkward postures, forceful exertion, and stress as contributing factors. Repetitive motions inherent in sugarcane harvesting and awkward postures during loading were identified as primary causes. Violent exertion and anxiety were also associated with increased WMSD risk [70].

Workers in the coir industry endure significant health hazards due to the physically demanding nature of coir fiber production, often carried out in dusty and noisy environments. Common health issues include respiratory conditions such as asthma, sinusitis, and bronchitis, along with eye problems, headaches, back pain, and muscular disorders. Additional complications like hand, leg, and knee pain, as well as ear and cold-related problems, further exacerbate the health risks faced by these workers [40].

In a study of vegetable farm workers in India, Tripathi [40] used the Rapid Entire Body Assessment (REBA) to analyze postures during phases of uprooting and transplanting. The study highlighted the physically demanding and repetitive nature of manual uprooting, which poses a significant risk of work-related musculoskeletal disorders among farm workers. Similarly, Robertoes [76] found that the use of non-ergonomic agricultural tools contributes to injuries among farmers. Variations in the shapes, sizes, and weights of these tools were shown to impact the frequency and severity of injuries, as well as workers' comfort and satisfaction levels, emphasizing the critical need for ergonomic tool design to mitigate these risks.

4.2 Enhancing Efficiency and Reducing Physiological Strain in Agriculture

The pulse serves as a crucial metric for gauging the physiological demands of labour in agriculture [77] Work demand encapsulates the stress imposed on cardiorespiratory systems within this context, integrating energy and cardiac labour costs [78]. Notably, the adoption of groundnut decorticator technology emerges as a transformative intervention, revealing a diminished physiological cost of labour and lower heart rates than traditional practices [79]. This innovation results in an impressive 83% reduction in the average cardiac cost per labour unit, concurrently elevating overall work output.

[79] highlight the economic advantages of groundnut decorticator technology, emphasizing its cost-effectiveness. The serrated sickle, a component of this technological advancement, emerges as a financially prudent choice, being 35% more economical per unit of output and boasting a 36.63% increase in efficiency [79] Similarly, the adoption of twin-wheel hoe weeding demonstrates superior efficiency compared to the traditional Khurpi, showcasing both time and output gains. The twin wheel hoe achieves an 18.88% increase in the percentage change of working heart rate, signifying improved physiological outcomes. In practical terms, the technology's enhanced efficiency results in a work output nearly three times higher than that achieved with traditional implements. Consequently, promoting twin-wheel hoes is recommended for optimizing agricultural operations [80] This section highlights the pivotal role of technological interventions in agriculture, enhancing efficiency and mitigating the physiological burden on labourers.

4.3 Work Conditions for Rural Women

Drudgery is a term commonly used to describe the physically and psychologically taxing conditions of work across various sectors. It encompasses physical and mental strain, fatigue, monotony, hardship, and the general wear and tear on the body and mind [80] In agricultural settings, the concept of drudgery is particularly relevant, especially for women who often bear a disproportionately heavier burden than men. This disparity is

rooted in the extensive and intensive nature of the tasks they perform [80].

Farm women, who are integral to both agricultural and domestic activities, experience high levels of drudgery due to the demanding and repetitive nature of their work. These activities, which range from planting and harvesting to food preparation and child-rearing, can lead to a variety of health issues, including chronic fatigue, musculoskeletal problems, and other conditions that impair their work efficiency and overall family welfare [81, 82]. Environmental degradation further exacerbates their workload, leaving women with even less time for rest compared to men.

In India and other developing countries, women not only manage most agricultural and household tasks but also take on the most labor-intensive and monotonous jobs [83]. The continuous demands of their multiple roles—both within the family and in society—often lead to severe fatigue, characterized by tiredness, sleepiness, physical and mental stress, exhaustion, and body pain [52, 83, 84]. Despite these challenges, the tools and equipment available to them are often outdated, unsafe, or entirely absent, which heightens the risks associated with their work. Consequently, women in agriculture are subjected to extreme drudgery, making their daily tasks not only exhausting but also hazardous to their health and well-being.

4.4 Physiological Stress on Women

While resting, the average heart rate for women was 77-81 beats per minute. When working in the kitchen, it was 84–110 beats per minute, and sitting down was 91–130 beats [36, 80] found that grinding was the most challenging work in the kitchen, while vegetable-cutting was the easiest for bpm. The physiological stress that women experienced while harvesting wheat caused their heart rates to average around 121.5 beats per minute [85]. The energy consumed was also measured at 15.5 kJ/min. This increased to 12.3 kj/min in the evenings [49]. It can be safely concluded that both unhealthy and healthy individuals are affected by factors such as poor workplace conditions and lack of access to better tools. These factors can also have a significant impact on body posture. This alters psychological functions and causes many musculoskeletal issues [50]. In developing countries, agricultural work can cause muscular-skeletal problems [56].

4.5 Muscular-Skeletal and Postural Disorders in Farm Women

Occupational ill-health, often stemming from muscularskeletal conditions, is a significant concern in industries characterized by physical labour [36]. Bad posture is a frequently identified culprit, contributing to disorders across various body parts, including the cervical spine, head, shoulders, elbows, wrists, and joints [52, 86, 87]. Muscular-skeletal problems, encompassing damage to muscles, joints, nerves, or tendons, manifest through initial signs of pain, swelling, and tingling, potentially evolving into chronic or acute issues if unaddressed promptly [53, 54, 88, 89].

Agriculture, recognized as one of the nation's most perilous industries, exhibits high rates of musculoskeletal disorders with identified ergonomic risk factors [72]. Chronic stress in this sector can lead to injuries and disorders in the musculoskeletal unit, potentially resulting in permanent or partial disability [36]. Women, particularly those aged 21–30, endure significant cervical and lumbar region deviations, contributing to musculoskeletal problems [49, 53, 88]. Prolonged sitting during wheat harvesting exacerbates issues, causing high rates of low back and knee pain [54].

Discomfort in agriculture is particularly pronounced during weeding, land preparation, and threshing, affecting both men and women [55] Interventions, such as using twin-wheel hoes, have effectively reduced drudgery and muscular stress among Indian farm women [51, 55]. Adopting improved techniques, supported by demonstrations promoting recommended work practices, has proven successful, emphasizing efficiency and reducing physical strain [54, 56].

The prevalence of lower back pain, neck problems, wrist troubles, and shoulder issues is alarming among workers engaged in post-harvesting jobs, often attributed to challenging work postures [36, 89] Modernizing fertilizer-handling methods has shown promise in decreasing pain experiences among workers [90, 91]. In summary, addressing musculoskeletal challenges

in agriculture necessitates a comprehensive approach, combining ergonomic interventions, improved work practices, and the adoption of advanced technologies to ensure the well-being of laborers.

4.6 Technology for Women in Drudgery

Women in agriculture are the result of the fact that they are often employed in operations that are not mechanized or less mechanized [62]. The labour costs of the shovel, paddy thresher, and wheelbarrow technology were higher than those using old techniques [56]. A study on the effects of farm implement changes on women, such as improved sickle or tubular maze-cob Sheller, revealed that 75% of those surveyed considered the sickle profitable (76.77%), compatible (76.77%), triable (75%), observable (73.33%) [92, 93]. Women-friendly farm equipment is better for harvesting [65]. However, the Naveen sickle is better than the local one. Most of the work was done by women, including seed treatment, transplantation and raising nursery, weeding and pruning, grain storage, manual harvesting, picking vegetables, collecting animal dung, and transporting it to fields [94]. Participants had almost zero knowledge about drudgery-reducing tools and Occupational Well-being. The knowledge level of the women about drudgery reduction was 74.6% higher after being trained [36].

4.7 Tasks at Hand in Agricultural Activities

The physiological cost of operation will be affected by the health of the operators, their nutrition, basal rate, and energy expended while at work. This can be indirectly measured through measuring pulse and oxygen consumption [95]. The subjective experience of a particular workload or labor rate is generally more closely related to pulse than oxygen consumption during labor [96]. Many researchers have used pulse to assess the physiological workload of workers [97]. The results showed that farm women felt less exertion when using the new tools than traditional tools [98, 99]. Accordingly, the impact of drudgery is on women because many respondents suffer from physical strain and stress due to work overload, i.e. Tarai and the hill area, 88.34 and 98.34, respectively. In addition, fewer respondents have the problem related to the incidence of miscarriage, i.e. 10 and 12 percent in Tarai and Hill [100].

4.8 The health Hazards for Farm Workers

Driscoll [101] highlight the significant impact that occupational hazards have on worker mortality and morbidity, particularly in the agricultural sector. These hazards stem primarily from two sources: the use of toxic chemicals in farming practices and the biomechanical demands placed on workers' bodies [63, 102, 103]. Farm women are especially vulnerable, often finding themselves in uncomfortable and strenuous positions during various agricultural activities. This leads to widespread discomfort and physical ailments, with an overwhelming 98.16% of farm women reporting joint issues in their wrists, 86.33% experiencing problems in their knees, backbone, and shoulders, 75.00% in their neck, and 73.33% in their elbows [63, 104, 105].

In addition to joint problems, farm women frequently suffer from a range of other physical issues. During transplantation tasks, 95.33% report body pain, 92.20% experience persistent tiredness, and 90.93% suffer from stress. Skin diseases are also common due to prolonged exposure to harsh environmental conditions, with heat stroke affecting 84.16%, heat prostration impacting 68.133%, and mycosis troubling 23.33% of these women [36, 106].

To alleviate some of these challenges, innovations in agricultural tools have been developed. The hexagonal tubular maize sheller, for example, is designed to be user-friendly, reducing muscle strain, cardiac stress, and overall energy expenditure compared to traditional methods [36, 107, 108]. Similarly, the in-wheel hoe is recognized for its effectiveness in minimizing environmental and occupational health risks associated with farming, while simultaneously improving the efficiency of agricultural workers. These advancements demonstrate the critical need for ergonomic solutions in agriculture to address the widespread occupational health concerns faced by farm workers, particularly women.

An overview of common occupational hazards and health concerns can be found in **Table 2**.

Table 2. Common occupational hazards and their respective health issues.

Causative Factors	Occupational Health Problems
Physical hazards: heat and humidity, solar rays, cold, noise, vibration, poor illumination, long hours of continuous work, repetitive motion for work, forceful motions, postural changes, bending posture, immersion of hands and feet continuously in water, slips and falls due to wet fields, continuous movement, carrying a heavy load of materials, contact with soil, mud, dust, water and manure, contact with insects, contact with scorpions, snakes and other poisonous animals, contact with wild mammals, felling of trees	Physical health: back pain, joint pain, leg pain, headache, dust allergy, swellings in joints, fever, cold and cough, general malaise, chest pain, pain in shoulders, eye problem, hearing problem, respiratory problem, throat infection, skin irritation, nervous problem, abdominal pain, constipation, urinary infection, mouth infection, cuts and wounds, musculoskeletal disorders
Chemical hazards: insecticides, herbicides, rodenticides, bactericides, fungicides, larvicides, using chemicals for treating land	Gynaecological and menstrual health: problems in childbirth, frequent abortion, vaginal discharge, burning sensation during urination, frequent and urgent need to urinate, severe pain in the pelvis, sores/ lumps in the genital area, severe bleeding, bleeding between periods, irregular periods, painful cramps
Mechanical hazards: poorly maintained tools and equipment—spade and sickle, axe, the noise of vehicles—tractors, vibration and noise of farm equipment, felling from the tractor, electric water pumps, electric shock	Psychological health: disturbance in sleep, the anaemic, problem with a spouse, problems with children, behavioral issues, burnout syndrome, betel leaves/ other chewing products, alcoholism, social insecurity, alienation, no entertainment
Biological hazards: infections due to bacteria, viruses, parasites, fungi and working with cattle	Communicable diseases: malaria, typhoid, hepatitis, jaundice, leptospirosis, diarrheal diseases, cholera, hookworm infection, influenza, filariasis, tuberculosis, HIV/AIDS, polio, rabies
Psychosocial hazards: occupational stress, lack of job satisfaction, insecurity, problems in relationships, emotional tension, unemployment, lack of an alternative job, low payment for work, poverty, etc.	Non-communicable diseases: rheumatism, hypertension, cardiac diseases, cancer, wheezing, asthma, kidney disease, lung disease, cataract

Sources: [36, 109–116].

5. Discussion

Based on the exploration of numerous studies highlighting the occupational health issues of women workers in agriculture-related industries, the following main findings have been identified across most of the reviewed studies:

(1) **Historical Context and Prevalence of Musculoskeletal Disorders:** Musculoskeletal disorders (MSDs), linked to workplace factors, are prevalent among women workers, particularly in agriculture. These conditions, highlighted as early as the 18th century by Bernardini Ramazzini, are the leading cause of disablement among working adults globally, with a significant impact on occupational health, economics, and personal well-being.

(2) **Occupational Health in Agriculture:** Women in agriculture face severe health risks due to poor working postures, undernutrition, occupational hazards, and exposure to pesticides and machinery. The bidirectional relationship between health and agriculture is evident, with work-related musculoskeletal disorders (WMSDs) being a common issue, particularly among women involved in manual, labor-intensive activities like tea leaf plucking.

(3) **Ergonomic Challenges and Interventions:** Ergonomic studies reveal that women in agro-industries, particularly in tea plantations and the coir industry, suffer from significant muscu-

loskeletal disorders due to repetitive, strenuous tasks. There is a critical need for ergonomically compatible tools and technology designed to reduce physical strain and improve efficiency. The introduction of tools like the groundnut decorticator and twin-wheel hoes has demonstrated significant reductions in physiological strain and increased work output.

(4) **Systemic Health Issues:** Women workers experience high rates of WMSDs, particularly in the lower back, knees, and elbows, due to repetitive motions, awkward postures, and forceful exertion. Respiratory issues, eye problems, headaches, and muscular disorders are also prevalent, especially in dusty and noisy environments like the coir industry.

(5) **Impact of Drudgery:** The physical and psychological strain, or drudgery, experienced by women in agriculture leads to significant health problems, reducing work efficiency and family welfare. Women often face longer working hours without breaks, contributing to fatigue, stress, and musculoskeletal issues.

(6) **Physiological Stress and Musculoskeletal Disorders:** High physiological stress, measured by heart rate and energy expenditure, is common among women performing agricultural tasks. Poor workplace conditions and lack of ergonomic tools contribute to postural disorders and musculoskeletal problems, particularly in the cervical and lumbar regions.

(7) **Health Hazards and Technology Gaps:** The use of non-ergonomic tools and exposure to toxic chemicals in agriculture pose serious health risks to women workers. There is a need for improved and ergonomically designed tools to reduce these hazards and enhance worker safety and efficiency.

(8) **Technological Interventions:** The adoption of women-friendly agricultural tools and machinery can significantly reduce drudgery and physiological strain. Training and knowledge dissemination regarding drudgery-reducing tools have been effective in improving the occupational well-being of women in agriculture.

The geographical distribution of studies highlighting the diverse health issues women faced in agriculture related industries. **Figure 2** is a representation of each country's participation in highlighting such issues, with the colour red serving as the countries with high contribution (51) of scientific literature. The blue represents the countries with medium contribution (20) in identifying the women related health issues. Whereas, green highlights the countries with low contribution (8) in literature related to women workforce agriculture related health issues. According to **Figure 2**, the USA, UK, and India are the nations that actively engage in exploring health issues of women workers.

6. Limitations of the Study

The study faces several limitations, including a geographical focus that may not reflect global conditions, a gender bias that could overlook issues faced by men or other gender groups, and potential gaps in data accuracy due to reliance on outdated or incomplete information. Additionally, it may not fully evaluate the effectiveness of agricultural tools across different practices or address the complete range of health issues, such as mental health concerns

7. Conclusions

The extensive review of literature highlights the significant and complicated occupational health challenges faced by women workers in agriculture and allied sectors. From the tea plantations of Assam to sugarcane farms in Thailand and coir industry workers in India, a recurring theme emerges—the prevalence of musculoskeletal disorders (MSDs) and occupational hazards. Historically recognized since the 18th century, musculoskeletal disorders (MSDs) have consistently emerged as prevalent issues linked to workplace factors such as poor posture, repetitive motions, and strenuous labor. Women in agriculture are particularly vulnerable to these conditions due to the nature of their work, which often involves prolonged physical exertion, exposure to hazardous chemicals, and the use of non-ergonomic tools.

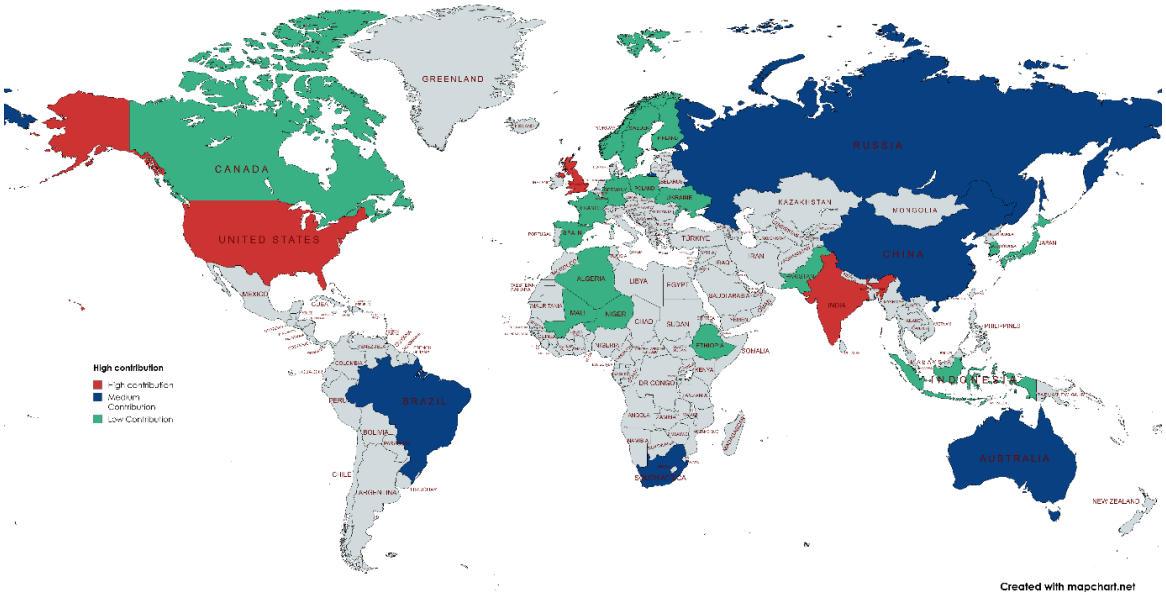

Figure 2. The geographical distribution of studies.

Agriculture remains one of the most hazardous industries globally, with women bearing a disproportionate burden of health risks. Factors such as undernutrition, occupational stress, and inadequate access to ergonomically designed equipment exacerbate the prevalence of MSDs and other health issues among female agricultural workers. The literature underlines the critical need for ergonomic interventions and the adoption of women-friendly technologies, which have been shown to reduce physical strain, enhance work efficiency, and improve overall well-being.

Moreover, the socio-economic and cultural dimensions play a pivotal role in shaping the occupational health landscape for women in agriculture. Issues such as limited access to healthcare, education, and training, coupled with societal norms that prioritize men's occupational health, further disadvantage women workers. Addressing these disparities requires a comprehensive approach that integrates ergonomic solutions, policy reforms, and targeted health and safety programs tailored to the unique needs of women in this sector.

Notably, advancements in technology, such as groundnut decorticators and twin-wheel hoes, showcase promising results in reducing the physiological cost of labour and improving work output. However, adopting ergonomic tools is not uniform across regions and industries.

Furthermore, the findings emphasize the need for region-specific anthropometric data and ergonomic designs, as the one-size-fits-all approach is inadequate. Studies from Meghalaya to Nicaragua underscore the importance of tailoring interventions to local agricultural communities' unique needs and dimensions.

In conclusion, ensuring the occupational health of women in agriculture is essential not only for their personal well-being but also for the sustainability and productivity of the agricultural sector as a whole. Implementing ergonomic interventions, promoting the use of appropriate technologies, and fostering an inclusive environment that prioritizes women's health can lead to significant improvements in their quality of life and work outcomes. Future efforts should focus on developing region-specific strategies, enhancing awareness, and strengthening policies to protect and empower women workers in agriculture, thereby contributing to broader socio-economic development and gender equity.

The study highlights the need for international policy action to address gender-specific occupational health risks in agriculture. Global bodies like the ILO should advocate for integrating gender-sensitive ergonomic standards into national labor laws. Increased international collaboration in research and policy-making is essential to reduce work-related musculoskeletal disorders among women. Incorporating occupational health into

global development goals and promoting educational initiatives will empower women in agriculture and improve their safety and well-being.

In conclusion, pursuing ergonomic solutions, coupled with understanding the specific challenges agricultural workers face, is crucial. Integrating ergonomics into the design of tools and machinery, accompanied by targeted awareness programs, can contribute significantly to mitigating occupational hazards and enhancing the overall well-being of those toiling in agriculture. As we progress, interdisciplinary collaboration, technological innovation, and a commitment to worker-centric practices will be pivotal in fostering a healthier and more sustainable future for agricultural labor.

Future research should focus on developing gender-specific ergonomic interventions tailored to various agricultural settings. Longitudinal studies are needed to explore the long-term effects of occupational exposure on women's health in agriculture. Additionally, cross-cultural studies could provide insights into effective policy implementations across different regions.

Author Contributions

The first and corresponding author, S.M., led the research design, analysis, interpretation, and manuscript writing. Co-authors, including D.B. and S.B., assisted S.M. with data collection and summarizing the results from the field survey.

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Data Availability Statement

The data are available upon request from the corresponding author

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Conflict of Interest

The authors declare no conflict of interest.

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