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Risk Factors for Musculoskeletal Symptoms among Tea Pluckers in Sylhet with a Proposed Ergonomic Basket Design

Syed Sabbir Hasan, Achia Khatun, Md. Mushtaq Tahmid, Mohammad Iqbal and Syed Misbah Uddin
Department of Industrial & Production Engineering
Shahjalal University of Science and Technology
Sylhet-3114, Bangladesh
iqbalm-ipe@sust.edu, syed034.ipe.sust@gmail.com, achiakhatun409@gmail.com, mushtaqtahmid1311@gmail.com, misbah-ipe@sust.edu

Abstract

This article aims to evaluate the prevalence of musculoskeletal disorders and also assess the risk factors among tea pluckers at the Tarapur tea estate in Sylhet. A cross-sectional survey was conducted among 183 workers using the Standardized Nordic Questionnaire to record symptoms in nine body regions associated with sociodemographic factors, including age, height, weight, Body Mass Index (BMI), experience, and work fatigue. Pearson's chi-square tests have been used to unveil the relationships between sociodemographic factors and body parts. A sample size of 183 was calculated using the Slovin formula with a confidence interval (CI) of 95 percent. The results showed that the effect of musculoskeletal risk (MSDs) occurred mainly in the lower back, shoulders, and hands. However, age, height, weight, BMI, and fatigue at work demonstrated a strong correlation with musculoskeletal symptoms in several regions of the body. This article helps tea workers who have involved in high repetitive tasks by designing an ergonomic tool that can mitigate health-related issues and thus reduce the risk of musculoskeletal disorders.
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Keywords
Musculoskeletal Disorders, Tea Leaves Pluckers, Risk Factors, Ergonomics, Basket Design.

1. Introduction
Tea production in Bangladesh is considered a cornerstone of its agricultural sector, particularly in the Sylhet region. The national economy largely gains from the tea industry in Bangladesh, as Sylhet is the principal tea-gardening region. The area for cultivating tea seeds expanded by 1.89% per year thereby the production yield increased by 0.98% per year. The production of tea increased 54% reporting from 2012 to 2021 (Ryan et al.,2023).Tea production in Bangladesh encompasses with more than one hundred sixty estates and tea cultivation is mostly happened in Sylhet and Chittagong (Saha et al., 2021).In 2021, the consumption of tea was 95.81% whereas in 2022, it rose to 98.21% domestically(Boonerjee ei al., 2024).As a large workforce is directly and indirectly involved in this process, the health issues among the workers are frequently observed due to prolonged standing, repetitive hand movements, awkward postures, carrying heavy loads, long working hours, and insufficient rest or job rotation (Kairi & Dey, 2022). Tea plucking requires workers to perform continuous reaching movements while bending their upper body forward and standing for extended periods while carrying heavy loads. Manual agricultural work exposes workers to these risk factors which produce musculoskeletal symptoms while generating pain in the lower back and shoulders and upper limbs. The latest studies combine these mechanisms to show which ergonomic solutions work best in similar work environments(Benos et al., 2020).

Musculoskeletal disorders (MSDs) stand as a leading occupational health problem across global workplaces, while they create major productivity declines and work absences and long-term disabilities throughout agricultural industries(Punnett & Wegman, 2004). A recent meta-analysis shows that agricultural workers in low- and middle-income countries suffer from low back pain at a rate exceeding 50% during a 12-month period, while they also face comparable levels of shoulder and upper limb pain(Shivakumar et al., 2023). Recent scientific investigations in Sylhet have revealed that tea garden workers face nutritional deficiencies together with BMI differences, which could increase their chances of developing MSDs(Hossain et al., 2025). Tea leaf plucking is considered a highly repetitive and physically demanding job that requires walking on a hilly mountain, standing for a prolonged period on uneven ground, and bending forward to pluck tea leaves. Thereby, the workers involved in this task substantially experience musculoskeletal disorders (MSDs) due to awkward postures, repetitive motions, heavy load carrying, and long working hours. Longer time standing and higher age are considered to be the most vulnerable reasons for health-related issues(Chakraborty et al., 2021). These workers are highly prone to developing musculoskeletal disorders (MSDs), i.e., lower back, neck, shoulder, and wrist (Vasanth et al., 2015) (Marak et al., 2020). Several factors have been identified that significantly affect physical health. Work-related factors include forward bending movement, overhead reaching, and carrying a bulk amount of weights, which unveils the risk of having MSDs issues(Marak et al., 2020). Work-related fatigue also happens due to working for a long period of time without having any microbreaks. There are several environmental factors, including rain, leeches, heat, and workplace factors such as steep slopes, uneven and slippery ground, which may contribute to workplace fatigue and risk of injury. Other factors include psychosocial and organizational factors (Low wages, time pressure, lack of providing supportive tool for plucking operation) enlarge the chance of having MSDs in this process (Kouhnavard et al., 2025).

A few studies have been performed considering the tea garden workers in Bangladesh. There is a scarcity in gathering and associating MSD-related data to investigate the risk factors and their impact. Also, there is no research work which can provide the ergonomical tool design to reduce the pain of the tea pluckers during their activities. This study provides a comprehensive analysis and deployment of an ergonomical kit which fills the gap considering the prevalence of musculoskeletal disorders and their relationship with job factors in a tea estate in Sylhet. This study ultimately addresses the MSD risks of tea pluckers, which thereby aid not only individual working professionals but also the impact on public health and economic development.

2. Literature Review

In this section, several research works have been organized based on prevalence, risk factors, and methodology used to investigate MSDs among tea pluckers. This section also highlights the potential issues, scope of the problem, and a scalable way for preventing problems. (Vasanth et al., 2015) conducted a cross-sectional study including 195 tea pluckers in Tamil Nadu, India, reporting that 83.6% of the total participants experienced musculoskeletal symptoms during work. This one-year survey demonstrated that the shoulders and lower back were the most affected areas, and higher age was directly correlated with MSD pain.(Marak et al., 2020c) used RULA and REBA methods to assess the prevalence of musculoskeletal issues among women tea pluckers in Meghalaya on a 5-point scale rating. The result highlighted the severity of the pain reported by the participants was in the head (4.5), neck (4.3), upper back (4.3), lower back (4.4), fingers (4.2), and feet (4.3) during plucking work. (Chakraborty et al., 2021b) surveyed 210 female tea garden workers who had experienced 92.4% MSD-related issues during the plucking task. This study reported that the cause of MSDs was most significant due to higher altitude gardens, longer job duration, higher body mass index, and increased ergonomic risk scores (REBA). To reduce the prevalence, this paper suggested that mechanical assistance should be incorporated with their plucking task. In Bangladesh, a few studies have been performed on the musculoskeletal-related issues among the tea garden workers. (Kairi & Dey, 2022b) performed a cross-sectional study in Moulvibazar tea garden, highlighting that 80.9% of workers had experienced musculoskeletal symptoms in the past 12 months. According to this study, the most frequently affected site was the shoulder (78.2%), followed by the upper back (56.1%) and the lower back (32.5%). (Gupta et al., 2025a) conducted another survey in the Sylhet tea garden, and found an immense number of MSD-related issues in the lower back (77.6%). Age and gender were considered as highly correlated factors with MSDs. (Vasanth et al., 2015c) reported that older workers are prone to experiencing high exposure to MSDs. (Kairi & Dey, 2022b) Female workers reported a higher prevalence rate during work. (Chandrasekara et al., 2020) highlighted that longer experience in the tea leaf plucking process was a key indicator of MSDs among Sri Lankan tea workers. It is also reported that 20 years of experienced workers had two times higher pain compared to newer workers.

3. Methodology

3.1 Study Area and Population

Bangladesh has over 150 tea estates, and the majority are located in the Sylhet division, the center of the country's tea industry. The districts of Sylhet, Moulvibazar and Habiganj are particularly important because they have the right environmental conditions for tea and the most estates. The hilly topography, fertile soil and humid climate make for the best growing conditions. Important estates, such as Malnichhera, Lakkatura, Tarapur, and Ali Bahar contribute nationally to tea production. Along with contribution to the national economy, the estates are providing alternative livelihoods for thousands of workers, many of whom are women from marginalized and indigenous communities(Gupta et al., 2025) (Figure 1).

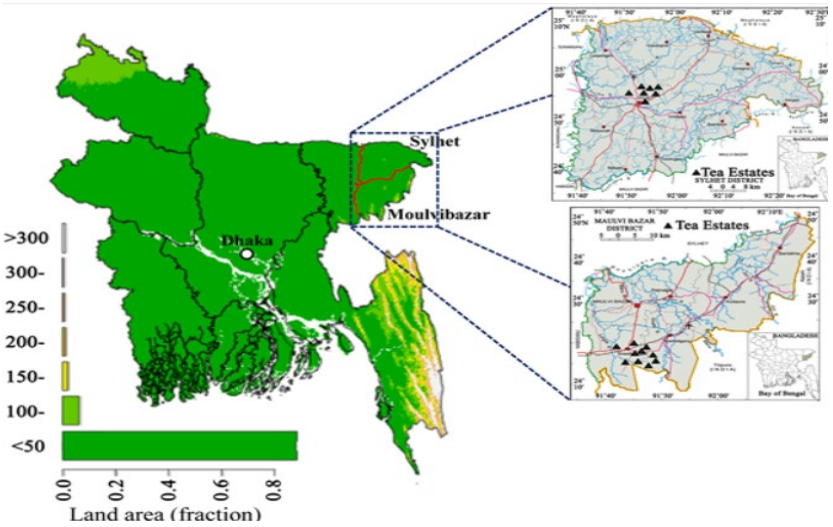

Figure 1. Selected tea estates map located in Sylhet (Farukh et al., 2020).

3.2 Statistical Method

A cross-sectional study was performed at the Tarapur Tea Estate, Sylhet. The sample size for this study consisted of 183 workers derived from a population of 338, using Slovin's formula at 5% error. As a data collection tool, a structured questionnaire (developed from the Standardized Nordic Musculoskeletal Questionnaire (Kuorinka et al., 1987), was used to elicit worker demographics, nature of work, environmental exposures, and pain/discomfort in specified anatomical body areas. Data were analyzed to assess the frequency and severity of pain and to correlate it with various demographic and workplace variables. The Slovin's formula is stated below(Irwanti et al., 2024):

n = Sample size,
N = Total population,
e = Error tolerance level. (For this study, e = 0.05)

$$n = \frac{N}{1 + Ne^2}$$

3.3 Data Processing tools

In this study, the exploratory data analysis and Data visualization were performed using python programming language virtually in Google Colab and Chi-square test result was analyzed using SPSS (Statistical Package for the Social Sciences) software version 26.0.

4. Data Analysis

4.1 Data acquisition

Data analysis unveils the hidden patterns and help for taking informed decision making for reducing the musculoskeletal pain of the tea garden workers. Below the process from stating the problem to the product deployment has been shown (Figure 2- Figure 4):

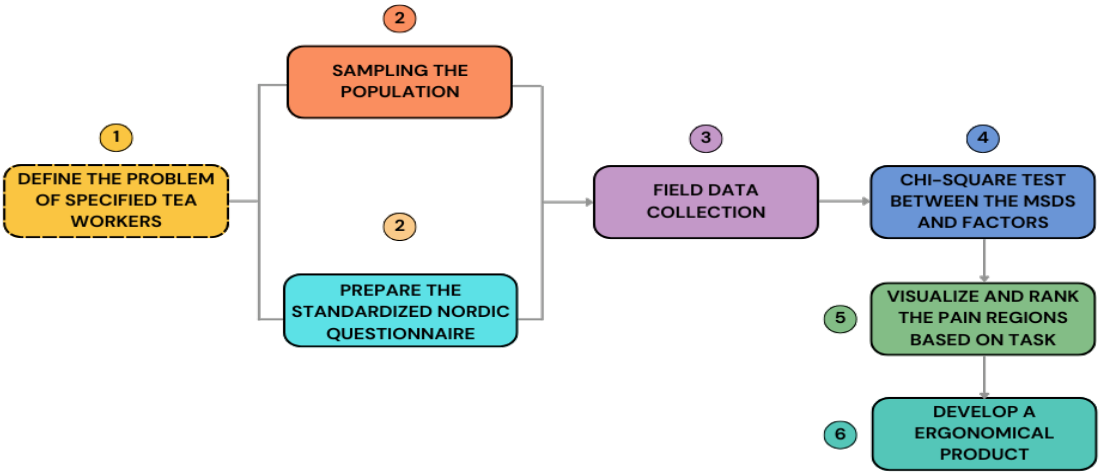

Figure 2. Process flow diagram and steps of this study

Step - 01: The study begins from the gap analysis and stating the problem. The main goal of this study is to estimating the risks of different body regions based on socio-demographic factors and design a tool which substantially reduce the risk of MSDs during plucking activity.

Step - 02: Calculating the sample of the population using the Slovin's formula and prepare the Standardized Nordic Questionnaire for gathering data from the tea workers addressing the risk associated with the plucking activity.

Step - 03: Data is collected from the Tarapur tea estate, Sylhet. The data is collected from 2 shifts both during plucking and drying process of the tea.

Step - 04: The correlation between factors and pain regions is calculated using Chi-Square test in SPSS software. The significant relationship between the factors is stated when p value is less than 0.05.

Step - 05: Data visualization is performed using Google Colab environment which unveils the hidden scenario of the result and also rank the pain regions based on the higher relationships.

Step - 06: Ergonomical tool is created designing a tool for plucking and handling tea leaves during their work. The tool is designed in CAD model and implement this to real world scenario to mitigate the risk of MSDs specially for women workers.

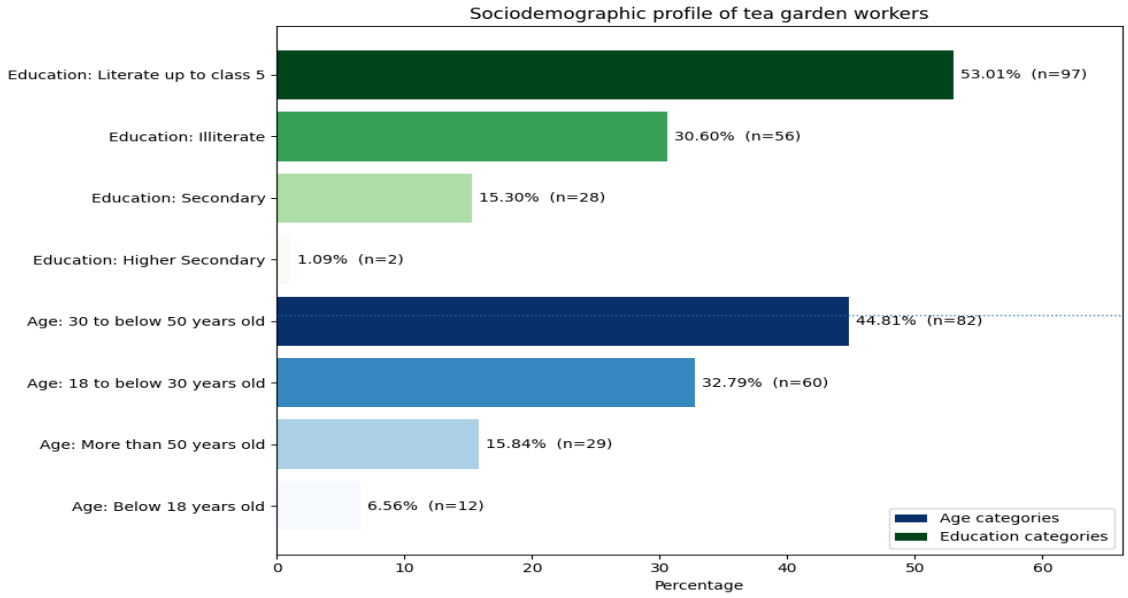

Figure 3. Socio-demographic profile of tea plucking workers

In Figure 3, almost half (44.81%) of participants were within the age range of 30-50 years with the mean of 35.89 and the standard deviation of ±13.89 years. Only very few (1.09%) participants had received higher secondary level of education.

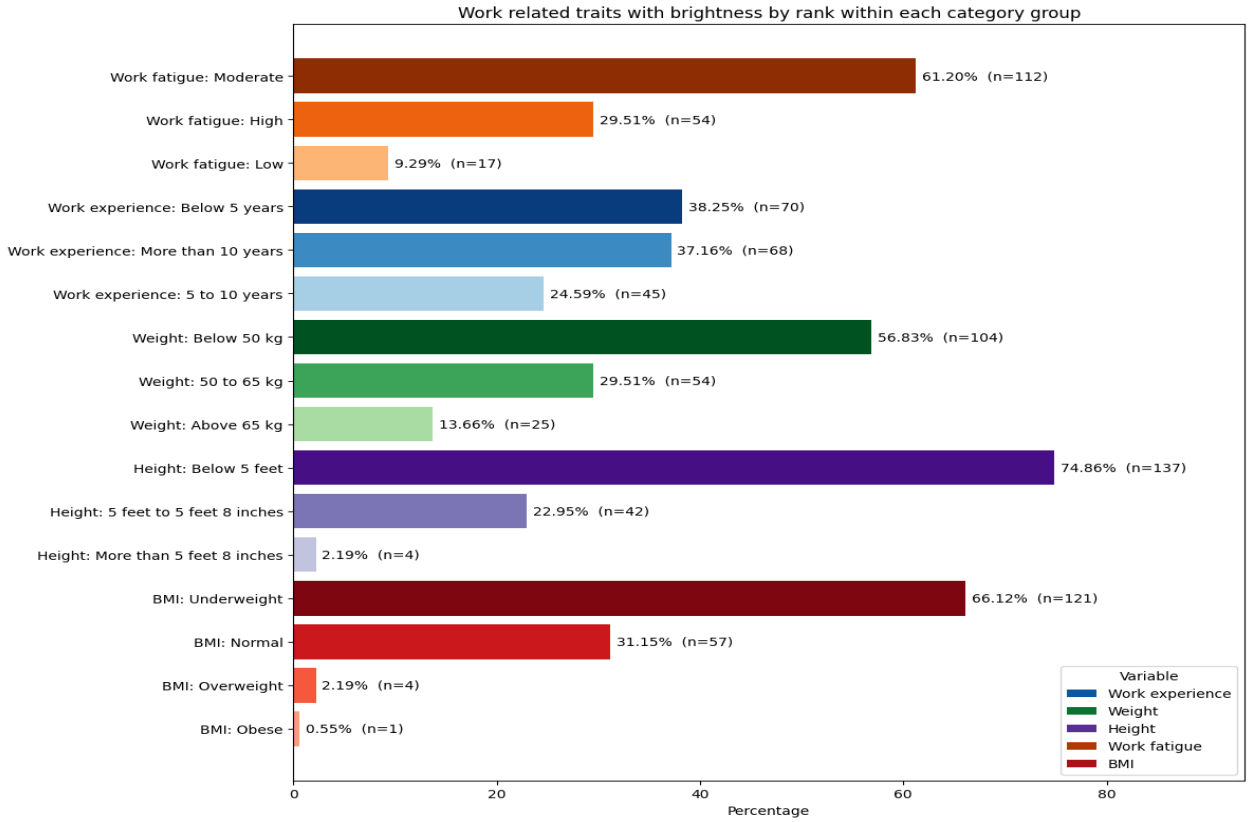

Figure 4. Work related profiles of tea garden workers

In Figure 4, work related information and characteristics of the selected tea garden workers is depicted. Among the all participants, most of the workers (38.25%) less than 5 years of experience, 37.16% had more than 10 years of work experience and only 13.66% had 5-10 years of work experience. Almost all workers (74.86%) in the tea garden were less than 5 feet while only a small portion (2.19%) were more than 5 feet 8 inches and 22.95% of workers fall in 5 feet to 5 feet 8 inches height range. More than half (56.83%) of the participants were below 50 kg, only 13.66% of workers were above 65 kg and 29.51% of workers were 50 kg to 65 kg. Among the workers, 66.12% of participants reported that they experienced moderate work fatigue while 29.51% of workers reported high work fatigue and only a few 9.29% of the workers among 183 participants reported low work fatigue during performing tasks. About 66.12% of the workers were underweight category while 2.19% of the workers fall in normal category and only a few 0.55% of the workers were in the obese category.

4.2 Hypothesis Testing

The Chi-square test results are summarized in the following Figures 5,6,7,8,9.

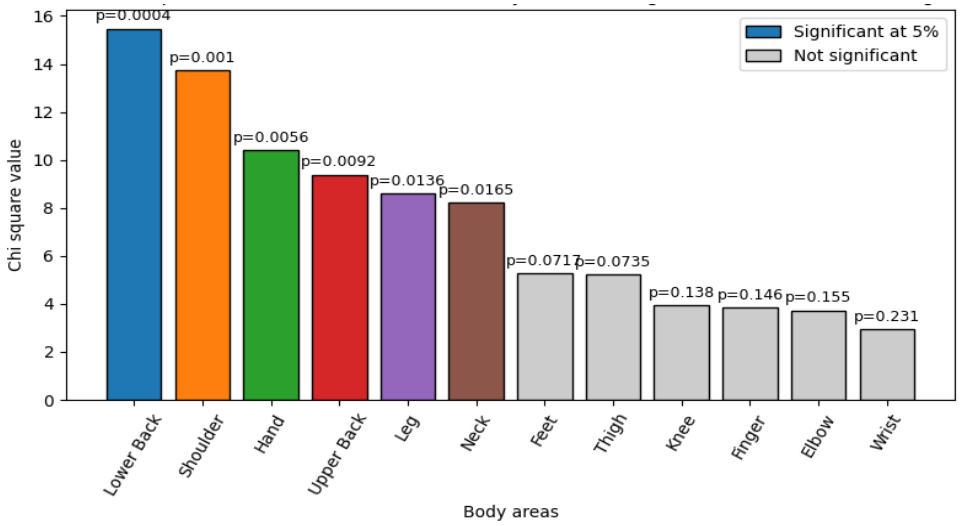

Figure 5. Chi-square test of MSDs in different body regions and age factors

In Figure 5, it is seen that lower back (p=0.0004), hand pain (p=0.0056), upper back pain (p=0.0092), shoulder pain (p=0.001), leg pain (p=0.0136), and Neck Pain (p=0.0165) show significant relationships with a variable (workers' age). In contrast, other pain types do not exhibit substantial associations because they have a lower chi-square value than the critical value, and the p-value is greater than 0.05. it is seen that most significant relationships of MSDs related to the age factors observed in lower back, shoulder, Hand, upper back, leg, and Neck regions.

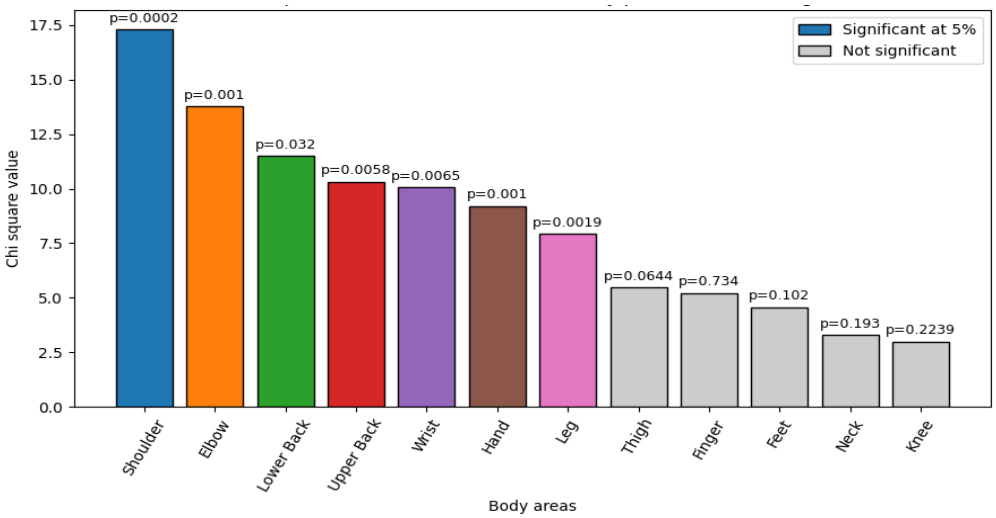

Figure 6. Chi-square test of MSDs in different body regions and work fatigue

In Figure 6, lower back pain (p=0.0032), hand pain (p=0.001), upper back pain(p=0.0058), wrist pain(p=0.0065), shoulder pain(p=0.0002), leg pain(p=0.0191), and elbow pain(p=0.0010) showed significant relationships with a categorical variable (worker's weight). In contrast, other pain types did not exhibit significant associations because they had a lower chi-square value than the critical value, and the p-value was> 0.05. It is seen that most significant relationships of MSDs related to the work fatigue observed in shoulder, elbow, lower back, upper back, wrist, hand, and leg body regions.

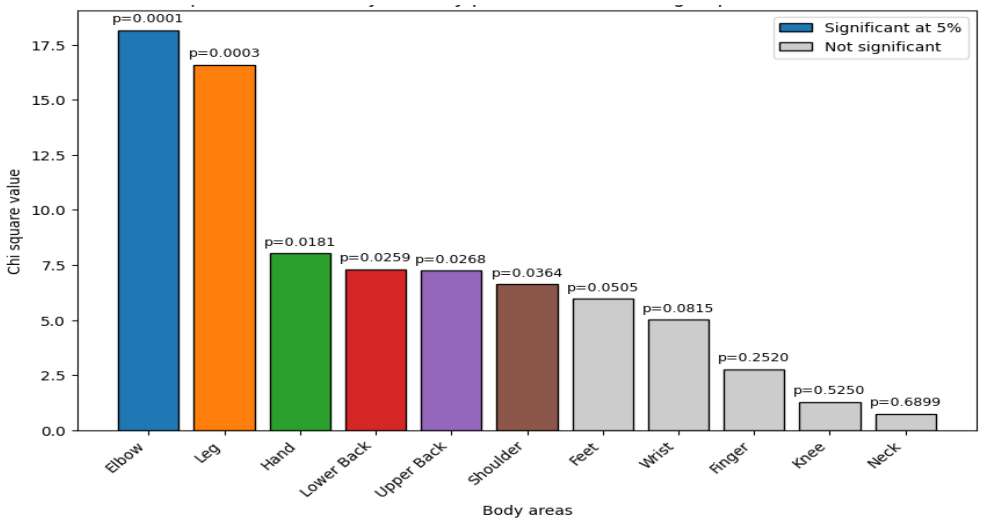

Figure 7. Chi-square test of MSDs in different body regions and worker height

As shown in Figure 7, lower back pain (p = 0.0259), hand pain (p = 0.0181), upper back pain (p = 0.0268), shoulder pain (p = 0.0364), leg pain (p = 0.0003), and elbow pain (p = 0.0001) showed significant relationships with a categorical variable (worker's height). In contrast, other pain types did not exhibit significant associations because they had a lower chi-square value than the critical value, and the p-value was greater than 0.05. It is observed from the analysis that Elbow and leg pain revealed that the MSDs prevalence among workers highly significant with the worker height.

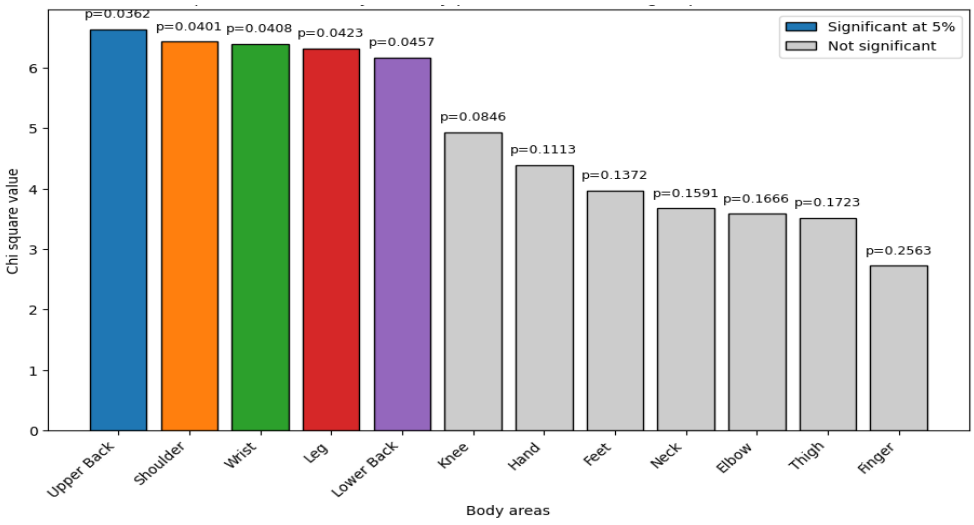

Figure 8. Chi-square test of MSDs in different body regions and worker weight

As shown in igure 8, it is seen that lower back pain (p = 0.0457), upper back pain (p = 0.0362), wrist pain (p = 0.0408), shoulder pain (p = 0.0401), and leg pain (p = 0.0423) showed significant relationships with the categorical variable (worker weight). In contrast, hand pain (p = 0.1113), finger pain (p = 0.2563), neck pain (p = 0.1591), elbow pain (p = 0.1666), knee pain (p = 0.0846), foot pain (p = 0.1372), and thigh pain (p = 0.1723) did not exhibit significant associations because their chi-square test values were less than the critical value and p values were greater than 0.05.It is overserved from the figure that, the prevalence of MSDs is highly correlated with the worker weight in the upper back, shoulder, wrist, leg and lower back.

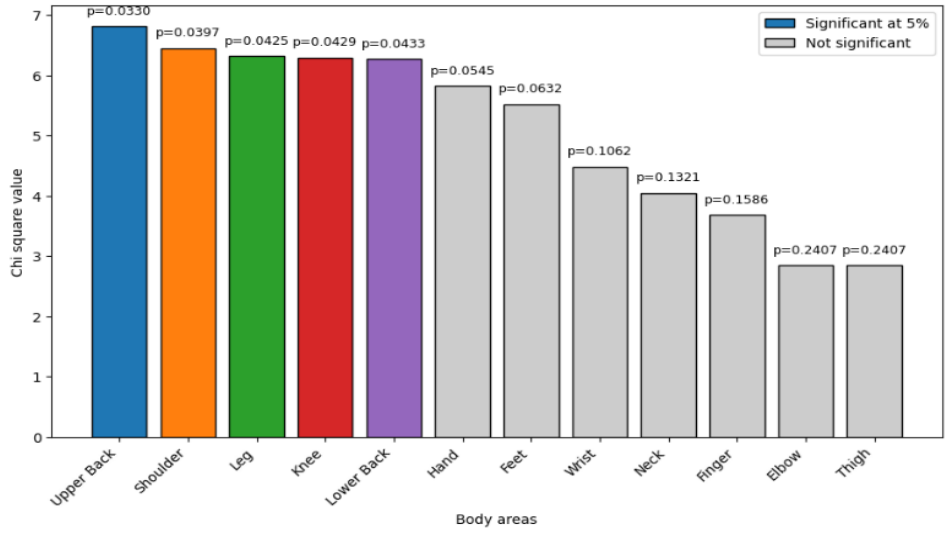

Figure 9. Chi-square test of MSDs in different body regions and worker BMI

As shown in Figure 9, lower back pain (p = 0.0433), upper back pain (p = 0.0330), shoulder pain (p = 0.0397), leg pain (p = 0.0425), and knee pain (p = 0.0429) showed significant relationships with the BMI, as their chi-square values exceeded the critical value (5.99146), and the p-values were less than 0.05. This implies that these types of pain are significantly associated with categorical variables. In contrast, hand pain (p = 0.0545), wrist pain (p = 0.1062), finger

pain (p = 0.1586), neck pain (p = 0.1321), elbow pain (p = 0.2407), foot pain (p = 0.0632), and thigh pain (p = 0.2407) did not show significant associations, as their chi-square values were less than the critical value and the p-values exceeded 0.05. It is observed from the figure that, the prevalence of MSDs is highly correlated with the worker weight in the upper back, shoulder, leg, knee and lower back regions.

4.3 Design of Ergonomic Basket

The design of the ergonomic basket aims to reduce the musculoskeletal load and improve the worker productivity. The description of the basket has shown in Figure 10(a,b,c).

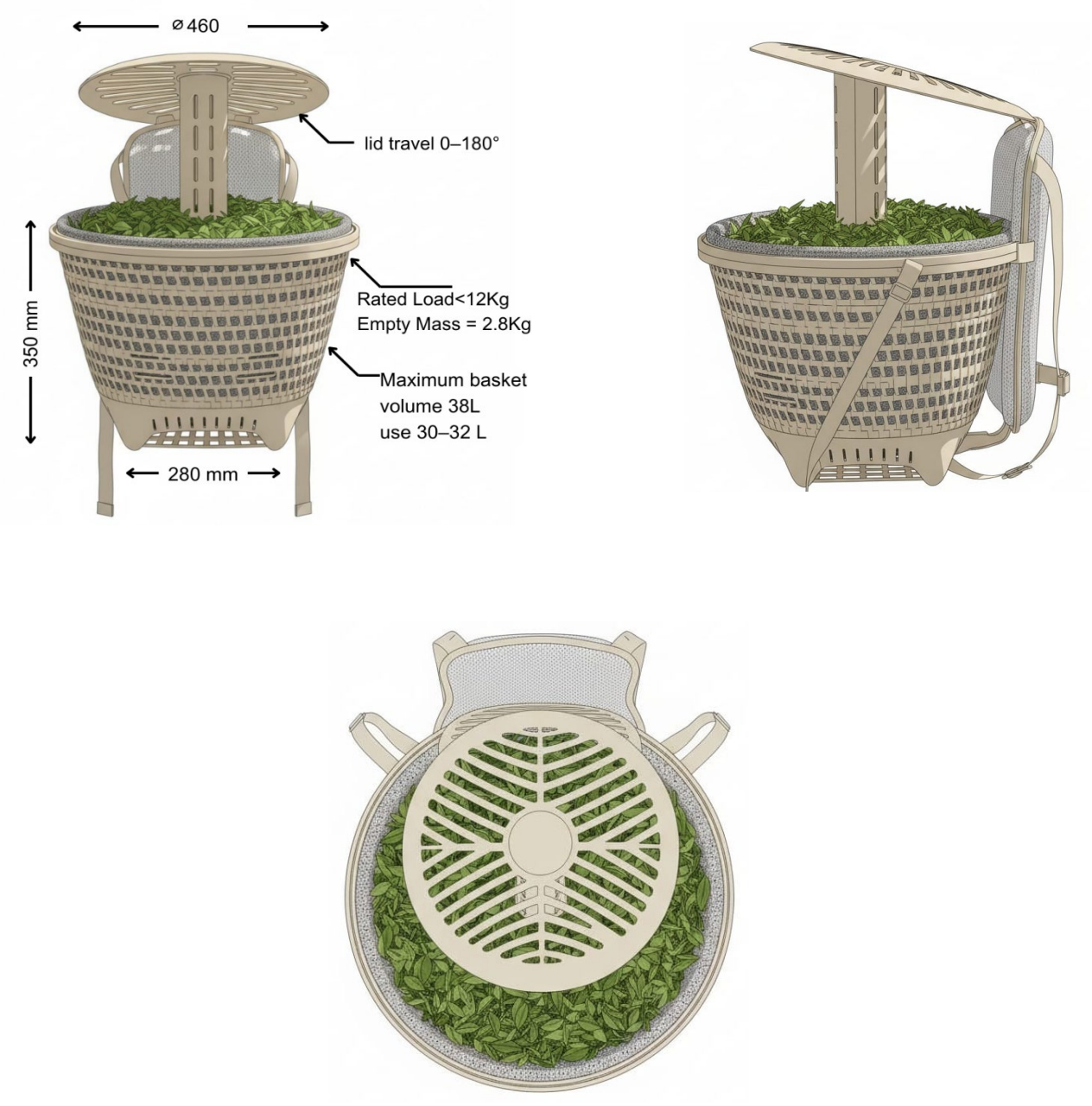

Figure 10. Ergonomic Basket Design

Specification of Ergonomical Basket:

- Materials: Food-grade UV stabilized PP, 3-3.5mm thickness
- Spring assisted lid, prevents tea leaves from rain, dust
- Height of the basket: 350 mm
- Lid outside diameter: 460 mm, travel angle 0-180 degree
- Load Capacity: 12kg, empty mass: 2.8Kg
- Maximum volume capacity: 38L

Ergonomic Benefits:

- Neural wrist or minimal flexion.
- Reduces the shoulder pain due to use of foam coating that support the back and reduces the load exerted in shoulder area.

Economic Benefit:

- Small hollow chamber inside the basket enables quick soaking the tea leaves under sun light.
- The chimney at the middle of the basket provides support the lid also vaporizes the water and keep the leaves in dry condition. The soaking time of tea leaves will be reducing thereby supply to the local market will be faster.
- The lid of the basket prevents the leaves from rain water and dust that ensures the quality of the tea leaves at required standard.

5. Result and Discussion

This study investigated the risk factors of musculoskeletal disorders (MSDs) among 183 tea pluckers at the Tarapur tea estate. The findings revealed a significant occupational health issue and thus informed the need for an ergonomic tool to prevent their risk of experiencing MSDs. The analysis showed that the lower back, shoulders, and hands are highly prevalent regions for MSDs. The findings also provided a significant correlation between sociodemographic and work-related factors. Among them, workers' age and experience were found to be strong predictors and responsible for enhancing the risk of MSDs. The pain mainly occurred in the lower back, shoulders, and neck ($p < 0.05$). The article showed that the majority of the workers were underweight (66.12%) and under 5 feet tall (74.86%). Moreover, BMI was significantly responsible to spread the pain in back, shoulders, and legs. The article also highlighted that work fatigue was strongly linked to discomfort in the upper extremities and back. Repetitive motion, awkward postures, and carrying heavy loads are primarily responsible to the risk of MSDs. This study thus proposes a solution providing an ergonomic basket that not only provide comfort the worker but also mitigate the hazard related to this risk. The key benefits of using this basket are foam coated support in back reduce the direct pressure on the shoulders and back, better load management which prevent from overloading, the basket enables a neural posture during the plucking task. The basket ultimately incorporates to maintain better tea quality protecting it from environmental damage. This design ensures the product quality and improve the long-term well-being to the tea pluckers.

6. Conclusion

This study aims to estimate and rank the pain regions among tea pluckers and also develop a robust design to provide a tool which reduce the risk of MSDs during the plucking activities. This study applies chi-square analysis linking with age, height, weight, BMI and work fatigue criterion. According to the result, this study successfully demonstrates the highly prevalent MSDs in different body regions. Thereby, this study also provides a design of basket which reduce the risk of MSDs developed due to high repetitive motions and loads. The limitations of this study include small sample size, one estate sample only. It is recommended to expand the work from different tea estates with larger sample, use different risk assessment methodologies including RULA, REBA and OWAS in future work.

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Biographies

Dr. Engr. Mohammad Iqbal is a professor (on leave) of Industrial and Production Engineering at Shahjalal University of Science and Technology, Sylhet, Bangladesh. A founding lecturer of the department, he led it for thirteen years as the head of the department and served as Dean of the School of Applied Science and Technology for two years. He was a visiting research scholar at the Mary Kay O'Connor Process Safety Center, Texas A & M University, Texas, USA. His teaching and research expertise span ergonomics and human factors, process and industrial safety, production systems, CAD/CAM and virtual reality, environmental studies, and technology adoption. He has more than thirty-five journal papers and over ninety conference publications. Dr. Iqbal is the president of the Ergonomics Society of Bangladesh. He has held leadership roles in the IEOM Society Bangladesh Chapter & International Conference Chair, and advises the Sylhet Chamber of Commerce and Industry. He earned a Ph.D from Dublin City University (Ireland) an M.Sc in Engineering from BUET (Bangladesh) and a B.Tech in Mechanical Engineering from Sri Venkateswara University (India). Currently, Dr. Iqbal is the Vice Chancellor of North East University, Bangladesh, Sylhet, Bangladesh.

Syed Misbah Uddin is a professor of Industrial and Production Engineering at Shahjalal University of Science and Technology, Sylhet, Bangladesh. He earned a B.Sc in Industrial and Production Engineering from BUET (Bangladesh), and an M.Sc in Industrial Systems Engineering from the University of Regina (Canada). His research focuses on Industry 4.0, circular economy, and ergonomics, including projects on supply chain sustainability in small and medium enterprises and readiness for Industry 4.0 in the RMG sector. He has published in journals and conferences on ERP adoption, grip strength and work capacity, forecasting, and sustainable manufacturing practices. Furthermore, his honors include a University of Regina entrance scholarship, a research award, and placement on the BUET Dean's list. Also, Syed Mesbah Uddin is a moderator, Ergonomic Society of SUST.

Syed Sabbir Hasan is an undergraduate student pursuing a Bachelor of Science (B.Sc.) in Industrial and Production Engineering (IPE) at Shahjalal University of Science and Technology (SUST), Sylhet, Bangladesh. He has completed his research in Ergonomics, Safety & Health, Human Factors under the supervision of Dr. Mohammad Iqbal. He is keen on applying his academic knowledge to practical industrial problems, focusing on enhancing system performance and sustainability. His research interests include Machine Learning, Human Factors and Ergonomics, Digital Manufacturing, Digital Twin, Simulation, Optimization, and Productivity Improvement.

Achia Khatun is an undergraduate student pursuing a Bachelor of Science (B.Sc.) in Industrial and Production Engineering (IPE) at Shahjalal University of Science and Technology (SUST), Sylhet, Bangladesh. She has completed her research in Ergonomics, Safety & Health, Human Factors under the supervision of Dr. Mohammad Iqbal. She is keen on applying her academic knowledge to practical industrial problems, focusing on enhancing system performance and sustainability. Her research interests include Machine Learning, Human Factors and Ergonomics, Digital Manufacturing, and Productivity Improvement. She is also interested in applying innovative techniques in areas such as microfluidic device design, simulation, and optimization for practical and research-based problem solving.

MD Mushtaq Tahmid is an undergraduate student pursuing a Bachelor of Science in Industrial and Production Engineering at Shahjalal University of Science and Technology, Sylhet, Bangladesh. He has completed his research in Ergonomics, Safety & health, Human factors under the supervision of Dr. Mohammad Iqbal. He is keen on applying his academic knowledge to practical industrial problems, focusing on enhancing system performance and sustainability. His research interests include Supply Chain, Industry 4.0, and Ergonomics.