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ORIGINAL RESEARCH

The cost of a harvest: sickle-related injuries

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Abstract

Background: Agricultural injuries caused by hand-held tools, such as sickles, remain an underrecognized yet preventable public health challenge. Despite increased mechanization, hand-held tools are still widely used, especially in rural areas in low- and middle-income countries, where significant injuries are reported. Sickle injuries, in particular, frequently lead to amputations, tendon disruptions, and permanent neurovascular damage. This study examined the demographic, seasonal, and clinical patterns of sickle-related injuries and their treatment outcomes at a tertiary care center in South India. **Methods**: A retrospective observational study was conducted at a tertiary care teaching hospital in South India; patient records from January 2021 to December 2023 were reviewed to identify sickle-related injuries receiving surgical or nonsurgical treatment in the Emergency Department. Demographic details, injury patterns, seasonal trends, clinical interventions, and treatment outcomes were collected and analyzed quantitatively through descriptive and inferential statistics. **Results**: The study included 108 patients, predominantly males (78%), with the majority of the injuries occurring among the middle-aged population (40–60 years). Most injuries occurred in the morning and peaked during the crop harvest season (September–December). Upper limb injuries, particularly to the left hand, were most common, with lacerations being the predominant type of injury. Surgical interventions were required for 68% of the patients, and a significant correlation was observed between injury severity and length of hospital stay. **Conclusions**: Sickle-related injuries are a significant occupational hazard among agricultural workers in rural India, often resulting in disability and financial hardship. Middle-aged male farmers are disproportionately affected, with a clear seasonal and temporal pattern linked to agricultural activity. Upper limb trauma, particularly lacerations and neurovascular damage, is common. Despite existing legislation, policy gaps persist regarding nonpowered tool safety. Our findings highlight a persistent, underrecognized public health issue and the urgent need for targeted safety training, ergonomic tool redesign, and policy reform.

Keywords

Sickle-related injuries; Sickle cut; Agricultural injuries; Trauma; Hand injuries; Emergency medicine

1. Introduction

In India, agriculture is a major source of income, employing a significant share of the Indian population and contributing substantially to global food security. India accounts for nearly 10% of the world's agricultural workforce, with approximately 242 million people working in this sector [1]. Despite mechanization and other advances in agricultural technology, many farming activities in India, especially in the southern part of the country, still rely on hand-held tools, such as sickles, spades, pickaxes, hand hoes, chaff cutters and sprayers, making them prone to the inherent risks posed by these tools, which are often utilized on a large scale in the resource-poor regions of the country [2, 3].

Agricultural injuries due to hand-held tools are among the main contributors to farm injuries and even deaths in the practicing population in India. These manifestations range from superficial cuts to amputations, together with neurovascular damage, and can significantly impact the physical and financial well-being of workers [4]. In India, sickle-related injuries are frequently reported and account for almost 46% or more of agricultural injuries [5]. The sharp and curved blade of the sickle, in addition to its poor biomechanical and ergonomic design, intensifies the risk of cuts and other injuries. In rural India, there are almost 1700 manual tool-related injuries for every 100,000 field workers, indicating the high burden of these injuries. This significantly reduces agricultural productivity during rehabilitation, which costs up to 24,000 days for every 100,000 farm workers annually [6]. Sickle-related injuries represent a significant yet underrecognized public health challenge in India, with inappropriate prehospital management and delayed presentations to healthcare facilities leading to complications such as functional deformities and chronic disabilities.

According to the Agricultural Injury Study (AIS), which was conducted in Arunachal Pradesh from 2000 to 2005, there were 6.4 injury incidents per 1000 workers annually, 40% of which were caused by agricultural equipment, and 30% of the casualties were between the ages of 40 and 49. This reiterated the fact that "the economic loss due to agricultural injuries is more severe than loss to the workers due to absence from work" [7].

Unavailability of timely medical attention to farm injuries results in long-term disabilities, leading to chronic unemployment or underemployment. In India, it is estimated that agriculture-related injuries cause 10.5 million units of disability-adjusted life years (DALYs) to be lost every year [8]. These injuries not only cause individual losses, but also have economic and social costs since they reduce the overall productivity of the agricultural sector.

In an effort to reduce these agricultural injuries, the Dangerous Machines (Regulations) Act was passed in 1983 in India. Its purpose was to regulate trade and commerce in the production, supply, distribution, and use of products from any industry that produced dangerous machines. This was done to ensure the safety of workers who operated these machines, to provide compensation for workers who were killed or suffered physical harm while operating them, and to address other related or incidental matters. However, this act is not comprehensive enough and does not include injuries sustained by hand-held tools, such as sickles [9]. Their use and, more importantly, their design have hardly changed over time, which highlights the need for community health awareness and preventive measures. Some attempts have been made previously to change certain features of the design of the sickle to make injuries less likely, but this has not been the case on a large scale.

Sickle-related injuries may be classified as simple, such as superficial cuts, or complex, such as amputations or injuries involving tendons and neurovascular structures. Sickle-related injuries often require early medical attention to limit permanent disability. Multispecialty management, including emergency medicine, plastic surgery, and hand surgery teams, is often needed to manage these cases effectively [10]. Despite the complexities in the treatment of these injuries, the majority of studies on these injuries have been conducted through questionnaires rather than hospital-based analyses, leaving critical gaps in understanding their varied presentations and clinical outcomes.

The lack of robust data on the prevalence of injury patterns, length of hospital stay, neurovascular involvement, and clinical implications of sickle-related injuries mandates more research in this area. This study hopes to fill these gaps by performing a retrospective study of records of patients who sustained sickle-related injuries and attended a tertiary care facility in Southern India. By reviewing three years of data, this research was conducted to understand the demographics, seasonal patterns, and treatment outcomes.

This study had several key objectives: to assess the demographic features of patients with sickle-related injuries, determine seasonal and temporal variations, and analyze injury mechanisms and injury sequelae. By pursuing these objectives, the study intends to reinforce appropriate hospital readiness, improve strategies for managing sickle-related injury patients, and relate evidence-based institutional and policy recommendations for stakeholders that will provide insight into how to minimize the prevalence and impact of such injuries.

2. Materials and methods

2.1 Study characteristics

This was a retrospective observational study spanning three years, from January 2021 to December 2023, at a tertiary care teaching hospital in South India. Records of patients who had sickle-related injuries as the primary diagnosis, including those requiring surgical or nonsurgical treatment in the Emergency Medicine Department, were reviewed. Approval from the Institutional Ethics Committee of Kasturba Medical College (approval number IEC1: 187/2024) was sought prior to the commencement of the study to assure compliance with human research ethics throughout the entire research process. All patient data were deidentified to ensure privacy and confidentiality, adhering to principles outlined in the Declaration of Helsinki.

2.2 Study population

The study population included patients who presented to the Emergency Department with a history of sickle-related injuries during the specified period. Eligible participants were identified through a detailed review of medical records. The inclusion criterion consisted of all participants, regardless of their age or sex, who had documented evidence of sickle-related injuries. Patients with incomplete medical records or who presented with injuries other than sickle-related injuries were excluded.

2.3 Data collection

Data collection was conducted via a structured proforma, designed to extract relevant clinical and demographic details from patient records. The proforma included variables such as the following:

- Demographic Information: Age, sex, and occupation were recorded to assess trends across different population groups.
- Temporal and Seasonal Trends: The date and time of injury were noted to identify seasonal variations and trends in the timing of incidents.
- Injury Characteristics: Type, severity, and anatomical location of the injuries were documented, along with information on whether neurovascular structures were involved.
- mHISS Scoring: To assess the severity of the injuries, the Modified Hand Injury Severity Score (mHISS) [11] was used for standardized evaluation.
- Treatment Provided: Specifics of surgical interventions, neurovascular repairs, and other clinical management strate-

gies were recorded as planned at disposition in the emergency department.

● Outcomes: Information on the duration of hospital stay, interventions received, need for intensive care unit (ICU) admission, and disposition plan was recorded.

2.4 Data analysis

The data were analyzed via descriptive and inferential statistical techniques using Microsoft Excel (Version 365, Microsoft Corporation, Redmond, WA, USA) and R Statistical Software (Version 4.4.0, R Foundation for Statistical Computing, Vienna, Austria) so that summary statistics for the categorical and continuous variables could be derived. The analysis involved the following steps:

● Demographics: Patients were categorized into pediatric (0–18 years), adult (18–40 years), middle-aged (40–60 years), and elderly (60+ years) groups to identify trends in injury occurrence across life stages.

● Seasonal and Temporal Patterns: Frequencies and percentages were calculated to identify correlations between injury incidence and specific times of the year or day.

● Injury Pattern Analysis: Anatomical locations and types of injuries were assessed, along with the involvement of neurovascular structures.

● Inferential Analysis: Trends in injury characteristics and outcomes were compared with those of the mHISS across demographic subgroups to explore potential predictors of severity and recovery.

● Outcomes: Proportions were calculated for outcomes such as hospital stay duration, interventions received, need for ICU admission, and discharge status.

3. Results

3.1 Demographic characteristics

The study included 108 patients with sickle-related injuries; the majority were males (n = 84). Most patients were aged between 40–60 years (n = 47), followed by those aged 18–40 years (n = 40). The majority of the patients were farmers (n = 65), whereas fewer were housewives (n = 14) or students (n = 8) (Table 1).

3.2 Time and month of the incident

Sickle-related injury incidents were frequent in the morning (43 cases) but also occurred during the night (n = 39) and afternoon (n = 26). Seasonally, many incidents were reported between September and December (42 cases), which coincides with the harvest season (Table 1).

3.3 Injury characteristics

Site of Injury: Injuries were mostly observed in the upper limb, predominantly the left hand (n = 38), followed by the left forearm (n = 17) and left wrist (n = 15). Lower limb injuries were less common. Other injury sites included the ankle, knee, and facial regions (Figs. 1,2).

Nature of Injuries: The most frequently observed injuries were lacerations (n = 27), followed by muscle injuries (n = 17), tendon injuries (n = 16), and nerve injuries (n = 10). Vascular injuries were relatively rare (n = 4). Ten patients required amputation (Table 2).

TABLE 1. Demographic characteristics of the 108 patients and temporal details of the incident.

Demographic variable	Total, n (%) (n = 108)
Gender	
Male	84 (78%)
Female	24 (22%)
Age group (yr)	
0–18	1 (1%)
18–40	40 (37%)
40–60	47 (43.5%)
60–80	20 (18.5%)
Occupation	
Agriculture	65 (60%)
Housewife	14 (13%)
Student	8 (7.4%)
Working	6 (5.6%)
Retired	4 (3.7%)
Unspecified	11 (10.3%)
Time of incident	
Morning	43 (40%)
Afternoon	26 (24%)
Night	39 (36%)
Month of incident	
January–April	26 (24%)
May–August	40 (37%)
September–December	42 (39%)

TABLE 2. Types of injuries.

Injury Type	Frequency, n (%)
Amputation	10 (9.3%)
Tendon injury	16 (14.8%)
Nerve injury	10 (9.3%)
Laceration	27 (25%)
Muscle injury	17 (15.7%)
Vascular injury	4 (3.7 %)

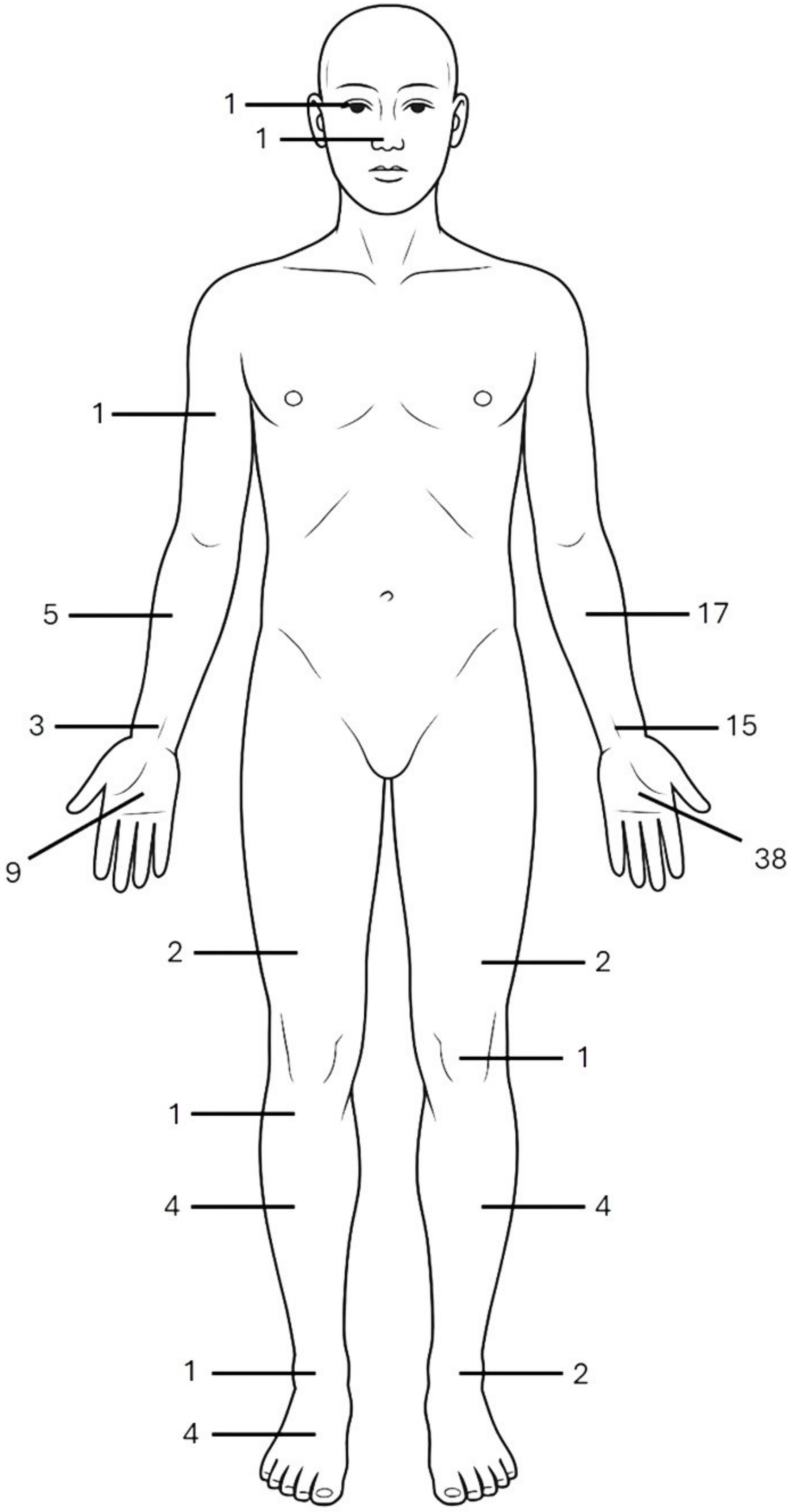

FIGURE 1. Sites of injuries. Each number represents how many injuries occurred in that anatomical location.

FIGURE 2. Spectrum of clinical presentations of sickle-related hand injuries. (a) Regionally used farming sickle. (b) Laceration over the dorsal surface of the left hand. (c) Complete amputation of the tips of the right thumb and right index finger, with associated laceration wounds over the right middle and ring fingers. (d) Palmar aspect of the left hand showing a sickle-cut injury with a cut lacerated wound over the left thenar eminence and complete amputation at the distal interphalangeal (DIP) joint of the left ring finger. (e) Complete amputation of the right little finger at the DIP joint.

3.4 Management and outcomes

Among the patients, 73 (68%) underwent surgery, 30 (28%) were managed conservatively and 5 cases (4%) had missing data. Fourteen patients (13%) were admitted to the ICU, and three patients (3%) received blood transfusions.

3.5 Disposition outcomes

Among the total of 108 patients, 73 (68%) were admitted, 21 (19%) were discharged, and 14 (13%) left against medical advice. The distribution indicates a high burden of injured patients requiring admission (Fig. 3).

3.6 Relationship between total mHISS score and hospital stay

The total Modified Hand Injury Severity Score (mHISS) had a weak positive correlation with the length of hospital stay (Pearson's correlation coefficient (r) = 0.22). Regression analysis indicated a significant positive relationship ($\beta = 0.0189$, $p = 0.046$), suggesting that higher total mHISS scores are associated with longer hospital stays (Fig. 4).

3.7 mHISS component analysis

The neurovascular component of the mHISS was the only significant predictor of the length of hospital stay ($\beta = 0.027$, $p = 0.037$). The integument, motor, and skeletal scores were not significantly different ($p > 0.05$) (Fig. 5).

4. Discussion

4.1 Demographic and occupational comparisons

As with the previous literature attributing male predominance to high-risk tasks, our study showed that males accounted for 78% of the injuries, similar to a study of Hmong farming operations, which identified similar patterns, attributing male injuries to their direct involvement with heavy tools and machinery [1]. Similar studies in rural India have shown that agricultural and farm-related injuries are relatively more common in men because of their role in strenuous manual labor and machinery operation [2, 5]. However, Patel *et al.* [3] reported a lower male predominance (68%) in Northeast India and suggested that injury risk may be influenced by regional variations in gender roles. In our cohort, the 40–60 years age group was frequently affected (43.5%). Similarly, studies undertaken in Central India have shown that middle-aged individuals are the most affected, owing to their involvement in heavy farm work [4].

The occupational profile in our study revealed that 60% of the injuries occurred among farmers, which reaffirmed their susceptibility to agricultural injuries. Similar findings have been reported from agricultural injury studies worldwide, where a lack of protection from agricultural tools, tasks requiring repetitive motion, and the use of machines are the main contributors to injuries [7, 8]. Notably, the representation of housewives (13%) and students (7.4%) in our dataset is consistent with findings that family members who help on the farm are also at a high risk of being injured. These observations

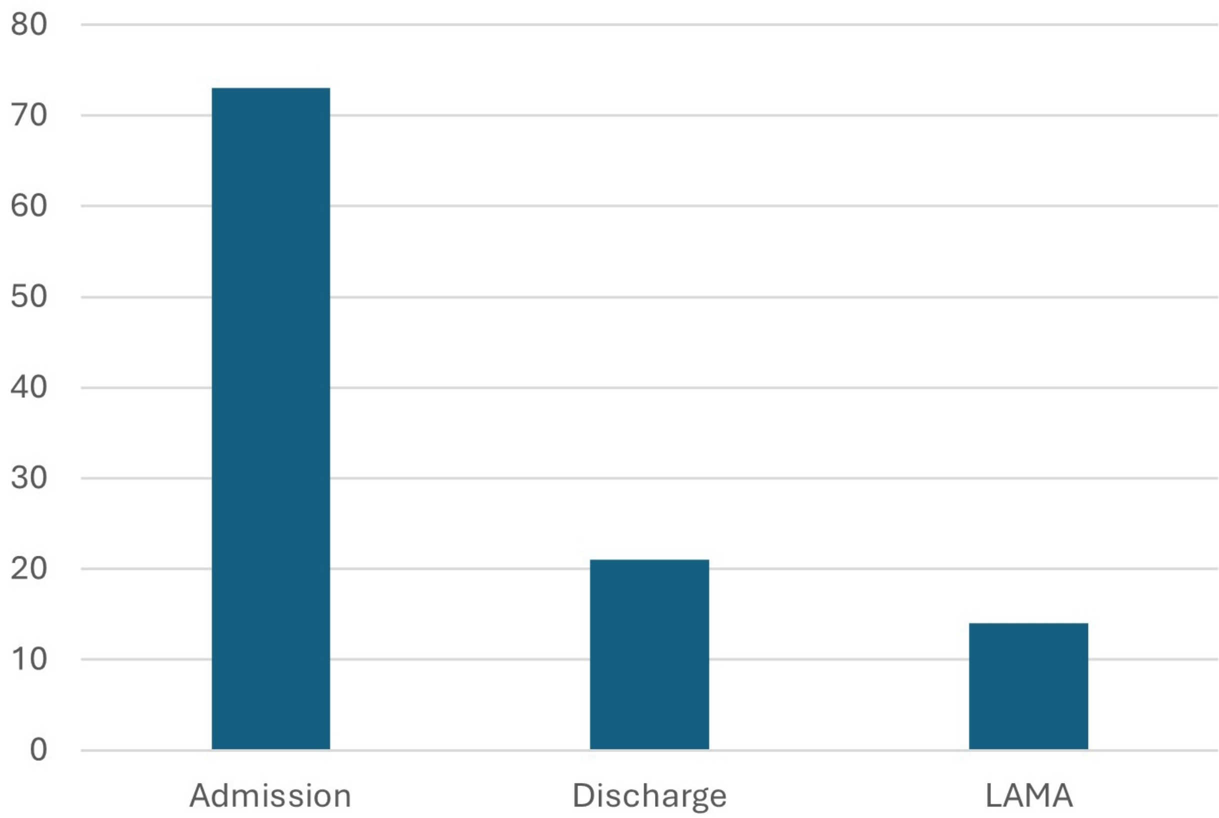

FIGURE 3. Disposition outcomes of patients. LAMA: Leave Against Medical Advice.

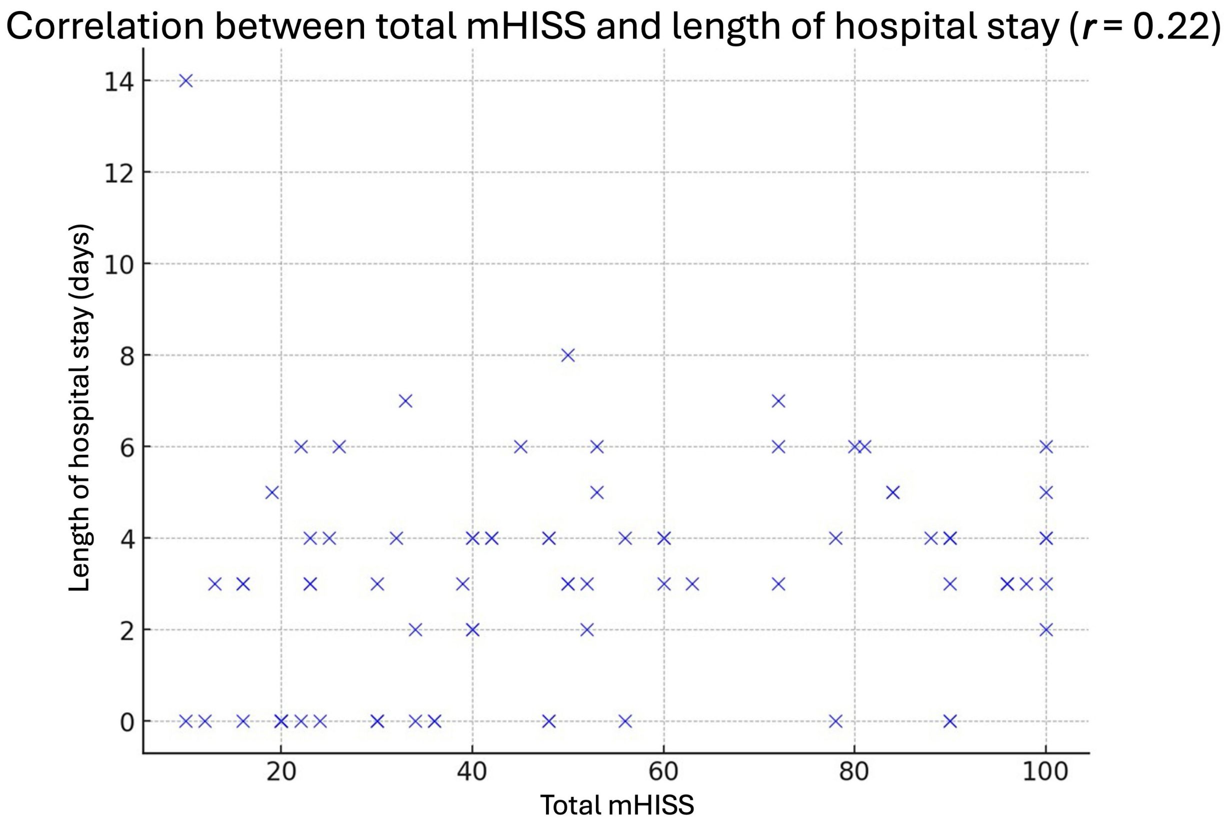

FIGURE 4. Correlation of total mHISS score with hospital stay. mHISS: Modified Hand Injury Severity Score.

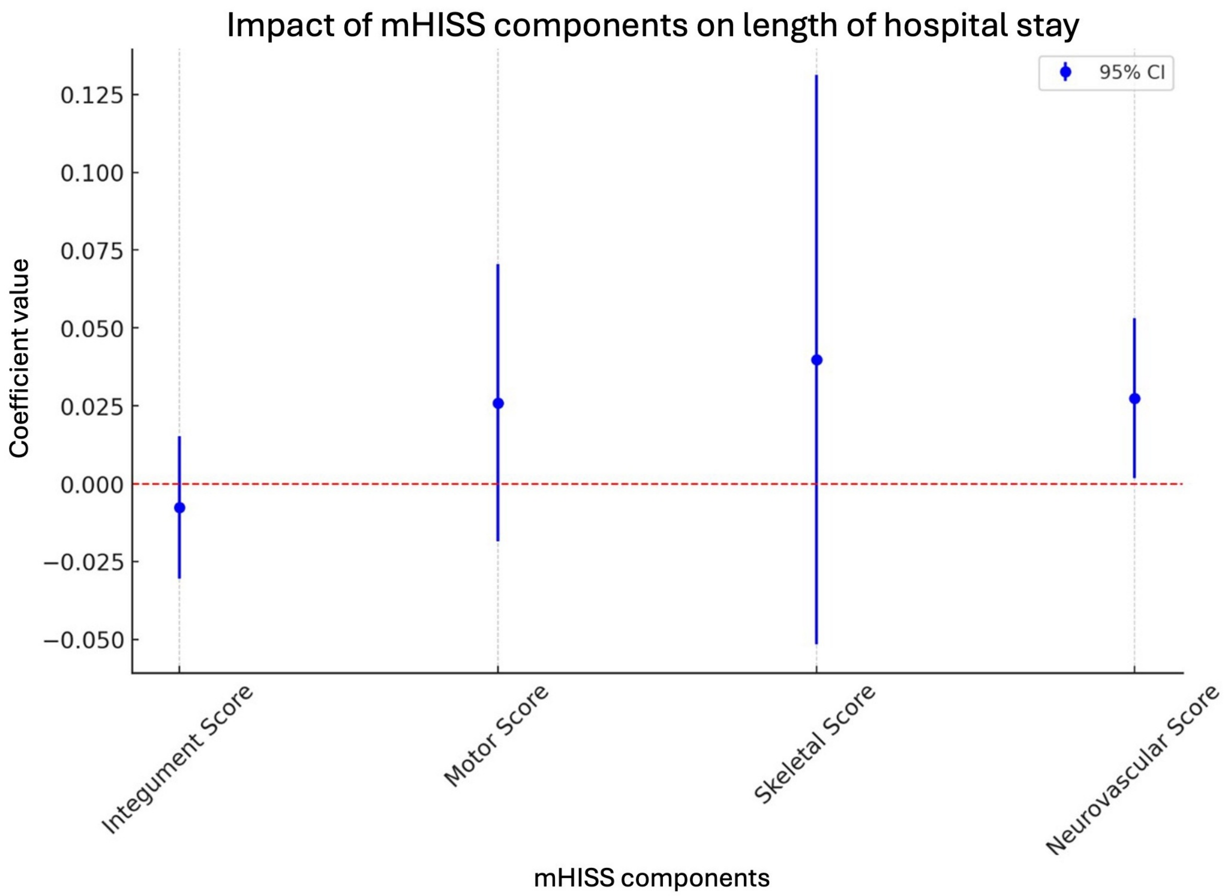

FIGURE 5. Regression analysis of total mHISS components with length of hospital stay. mHISS: Modified Hand Injury Severity Score; CI: Confidence Interval.

support the necessity for preventive safety campaigns addressing not only primary workers, but also household members.

4.2 Temporal patterns

Many injury incidents in our study occurred in the morning (40%) and peaked in the harvesting season from September to December (39%). These findings support other Indian studies, which highlighted an increased frequency of injuries during and post-harvest seasons, mainly due to increased use of tools and machinery and other time-bound activities [2]. Morning-related peaks have also been documented in previous studies, where harvesting and machinery setup usually take place in the morning, hence posing greater risks [6]. However, in some investigations conducted in Northeast India, late evening injury peaks have been reported because of prolonged working hours in peak agricultural seasons, highlighting the cultural and regional variation in injury patterns [7].

The seasonal clustering of injuries noted in our findings parallels the observations of Patel *et al*. [3], who reported that the injury rate was high during the harvesting season. Similarly, studies from other Asian agricultural regions emphasize the seasonal nature of farming injuries attributed to labor intensification and high workloads during specific months [9]. However, the results of our study also indicate that injuries occur during off-peak periods, which are likely the result of a more widespread cropping cycle in our region.

4.3 Injury characteristics

Site of injury: In our study, the upper limb, particularly the left hand (35%), was the most commonly injured site. This trend is consistent with findings in Central India, where hand injuries due to unprotected tool handling and direct contact with machinery are common [5]. Similar studies, such as Kumar *et al*. [6], reported the prevalence of hand injuries in manual farming environments, which were in part caused by a lack of protective equipment and inadequate tool maintenance. Nonetheless, studies in Northeast India have revealed that lower limb injuries are more prevalent, particularly in areas with increased mechanization, where such injuries are generally caused by accidents involving tractors and threshers [3].

Nature of injury: Lacerations were the most common type of injury sustained in our study cohort (25%), followed by tendon and nerve injuries, similar to the findings of other studies representing agricultural injuries across India [2, 9]. The occurrence of amputations (9%) is consistent with previous observations, indicating that severe injuries are prevalent, particularly on small-scale farms, because of the unsafe use of outdated and poorly maintained tools [6]. Comparatively, studies on global agricultural injuries also report a high incidence of lacerations and amputations, attributing such findings to poor safety standards and the unavailability of protective gear in low- and middle-income settings [8].

4.4 Management and outcomes

Our study revealed that 68% of cases required surgical intervention, reflecting the severity of injuries. Similar trends have been noted in the past in rural Indian settings, where agricultural injuries often require surgical management due to delayed presentations [5]. In contrast, studies from regions with better healthcare infrastructure reported higher rates of conservative management, possibly due to community awareness of injury prevention and early access to care [7].

The correlation between injury severity (total mHISS score) and duration of hospital stay, as observed in our findings, aligns with trends in the literature, where higher severity scores generally predict longer recovery times. Neurovascular injury was found to be the strongest predictor of length of hospital stay, similar to findings from previous studies, indicating the impact of neurovascular damage on recovery trends [10].

4.5 Differentiating sickle injuries from other hand tool injuries

While our study specifically examines injuries from sickles, distinguishing these from injuries caused by other hand-held tools is vital for targeting prevention and clinical care. Kumar *et al*. [6] (2008) reported that hand tools caused more than half of all farm-related injuries, with spades, hoes, axes, and sugarcane cutters typically inflicting lowerlimb trauma through downward or impact forces. In stark contrast, sickle injuries—stemming from simultaneous cutting and gripping actions—primarily affect the upper extremities, particularly fingers of the non-dominant hand, and often involve deep lacerations with tendon and neurovascular damage. This pattern aligns with our findings.

Further, activity context influences injury patterns. Tasks like irrigation and digging predominantly lead to spade or hoe injuries, whereas harvesting and bundling drive sickle-related accidents. Kumar *et al*. [6] also highlighted that incidental exposure—such as handling sickles during transport—contributes notably to injury risk, a nuance often overlooked in safety interventions.

Adding regional insight, Kot *et al*. [5] (2023) found that sickles accounted for nearly half of all hand-tool injuries in tribal central India, with finger injuries being most common. This confirms that sickle injuries are not only mechanistically distinct, but also culturally and geographically prevalent.

Understanding these differences is more than academic—it shapes prevention strategies. Ergonomic redesign efforts must adapt to the specific mechanics of sickle use, such as improving blade guards or cushion grips, rather than simply adapting broader tool-safety measures. Public-safety campaigns must similarly address contextspecific risks, including safe harvesting and bundling practices, rather than generalized agricultural tool safety.

By identifying sickle-related injuries as a discrete subset within hand-tool trauma, our study paves the way for targeted policy, tool redesign, and community-level safety education—an imperative when such injuries remain underrepresented in existing legislation and occupational health discourse.

4.6 Implications and recommendations

4.6.1 Safety training & injury prevention programmes

The lack of formal safety training emerged as a critical issue in our study. Research conducted in Southeast Asian countries has shown that regular education campaigns and safety workshops significantly reduce the occurrence of agricultural injuries by educating farm workers about proper tool handling and the use of protective equipment [3, 7].

4.6.2 Ergonomic tool designs

The frequent occurrence of upper limb injuries, particularly to the left hand, highlights the need for safer, ergonomic designs of traditional tools, such as sickles, in addition to the use of appropriate safety equipment. Collaborating with agricultural engineers can help in the development of tools that reduce biomechanical strain and injury risk.

4.6.3 Community-level awareness campaigns

Public health initiatives should focus on raising awareness of the risks associated with nonmotorized tools apart from agricultural machines and the importance of timely medical care. Educational campaigns can also help emphasize the importance of protective equipment and proper postinjury care practices to minimize long-term disabilities.

4.6.4 Improved rural healthcare infrastructure

The high proportion of delayed presentations requiring surgical interventions and prolonged hospital stays in our study highlights the need for improved healthcare infrastructure in rural areas. Previous studies have similarly emphasized the importance of equipping rural hospitals with specialized care facilities, including surgical units and rehabilitative services, to address the healthcare burden imposed by agricultural injuries [5, 8].

4.6.5 Policy and regulations

Our findings indicate that there is an urgent need for non-powered agricultural tools to be subjected to revised safety measures. Previous studies advocating for the revision of the Dangerous Machine Regulation Act (1983) emphasized this aspect as a recurrent theme [9]. Amendments and improved enforcement of these regulations could significantly reduce the high incidence of grave injuries, such as amputations and neurovascular damage, as observed in our study cohort.

5. Limitations

This study has several limitations. This was a retrospective analysis and therefore relied on preexisting medical records, which may include incomplete or inconsistent documentation. The study was performed in a single tertiary care center, potentially limiting the generalizability of the findings to other regions. Seasonal and occupational factors influencing injury rates were inferred from data trends without direct field-level assessments. Additionally, the lack of long-term follow-up data limits the assessment of chronic disabilities or socioeconomic impacts. Finally, the study focused on sickle-related injuries only, potentially overlooking other significant agricultural hazards, which could provide a more comprehensive understanding of overall health challenges.

6. Conclusions

Sickle-related injuries are a significant occupational hazard for agricultural workers in rural India, often leading to physical disability and financial burden. This study highlights key findings, showing that middle-aged males and farmers were the most affected groups, with majority of the injuries occurring during the harvest season and morning hours. The frequent occurrence of upper limb injuries, particularly lacerations and neurovascular damage, highlights the risks posed by poorly designed hand-held tools, such as sickles. The correlation between injury severity and length of hospital stay, especially in cases involving neurovascular structures, emphasizes the importance of timely and specialized medical care. Despite existing legislation, such as the Dangerous Machines Regulation Act (1983), the lack of policies addressing nonpowered tool-related injuries remains a critical gap. This study calls for enhanced preventive strategies, including targeted community safety training, ergonomic tool designs, improved rural healthcare infrastructure, and amendments to existing policies and regulations to reduce agricultural injuries and their long-term impact.

AVAILABILITY OF DATA AND MATERIALS

Data available upon request from the authors.

AUTHOR CONTRIBUTIONS

ASD—conceptualized the study. KS and ASD—searched the records and collected patient data. KS—prepared the data tables and performed statistical analyses. AK and ASD—prepared the figures and contributed to drafting and revising the manuscript. AK—also contributed to data interpretation and was involved in revision, and final editing of the manuscript. All authors reviewed and approved the final version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All methods were carried out in accordance with relevant guidelines and regulations (Declaration of Helsinki). The study protocol was approved by the Institutional Ethics Committee, Kasturba Medical College, Manipal, Manipal Academy of Higher Education (MAHE), Manipal (Registration No. ECR/146/Inst/KA/2013/RR-19) (DHR Registration No. EC/NEW/INST/2022/0042) IEC1: 187/2024. For the clinical images, written informed consent was obtained from all participants. The consent process was conducted bilingually, in English and Kannada, by the treating physician, ensuring that participants clearly understood the purpose of the study, the voluntary nature of participation, and their right to decline or withdraw at any point without any impact on their clinical care. Confidentiality and anonymity were strictly maintained for all patient data and clinical images included in the publication.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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