Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 3, 2982-2986
2025
Publisher: Learning Gate
DOI: 10.55214/25768484.v9i3.5897
© 2025 by the author; licensee Learning Gate

Suggestion of ergonomic evaluation index for agricultural ladders considering human-machine interaction

Seung-Min Mo[1*]
[1]Department of Occupational Safety and Health Management, Osan University, 45 Cheonghak-ro, Osan-si, Gyeonggi-do 18119, Republic of Korea; smmo@osan.ac.kr (S.M.M.).

Abstract: The purpose of this study is to suggest an ergonomic evaluation index, considering human-machine interaction, to ensure the fundamental safety of ergonomic equipment. To systematically investigate and analyze accident cases involving ladder-related injuries among agricultural workers, which is one of the most frequently used equipment in agricultural work, the 'Agricultural Safety 365' database, operated by the Rural Development Administration of Republic of Korea, was utilized. This study conducted two focus group interviews (FGI) for consulting on the ergonomic evaluation index of agricultural ladders: one group consisting of agricultural safety experts and the other of agricultural workers. The causes of ladder-related accidents were classified into seven types, with most accidents occurring due to unstable floor conditions in agricultural work environments. As for the mechanical/equipment/tool related causes, accidents involving ladders (type A) were frequently found to occur due to the failure or absence of the device that secures the ladder's extension. This study suggested the ergonomic evaluation index focusing on safety and usability indicators to consider human-machine interaction. The evaluation indices were derived using criteria such as accident probability, stability, effectiveness, and comfort, including factors like step anti-slip features, ease of ascension, anti-leg spreading devices, and the height/width between steps. Based on the results of this study, it can ensure fundamental safety from the design and production stages of ergonomic equipment and contribute to the creation of a safer agricultural work environment.

Keywords: *Accident, Agriculture, Ergonomics, Evaluation index, Human-machine interaction, Ladder.*

1. Introduction

Agriculture is a key sector that drives the economy of nations worldwide. However, compared to industrial workplaces, agricultural workers are exposed to relatively complex risk factors [1]. The incidence of injuries and fatal accidents during work is high [2]. Agricultural workers often perform tasks such as planting, irrigation, soil management, pruning, harvesting, cleaning, sorting, packaging, and transportation, which involve awkward postures and repetitive motions, increasing the risk of musculoskeletal disorders. Due to the nature of agricultural work, workers are often exposed to unpredictable weather conditions, and a high proportion of tasks are carried out in outdoor environments. Additionally, irregular tasks are frequent, and during peak seasons such as the harvest period, work is concentrated over long hours, leading to high cumulative physical strain, which further weakens safety [3].

In general, ergonomic equipment for agricultural work is used to reduce the workload of agricultural workers and improve productivity. However, agricultural accidents are often caused by the use of machinery and tools. For example, in Bangladesh and India, a significant portion of injuries occur due to agricultural machinery and small tools, and machinery-related accidents also account for a significant proportion in countries like New Zealand and Canada [4]. In South Korea, more than half of

© 2025 by the author; licensee Learning Gate
History: Received: 23 January 2025; Revised: 19 March 2025; Accepted: 24 March 2025; Published: 29 March 2025
* Correspondence: smmo@osan.ac.kr

agricultural accidents are similarly linked to the use of machinery and small tools. Agricultural accidents often result in fatal injuries, lead to permanent disabilities, and incur high economic costs [5]. Although injuries and accidents caused by small tools during agricultural work may have lower severity, their frequency is high, and they could potentially be a source of fatal accidents in the future.

Previous studies have been conducted to improve the safety of agricultural tools and machinery. Son and Shin [6] classified agricultural tools and proposed safety guidelines for ergonomic design, including control panels, steering levers, frame size, and shape, necessary for ergonomic equipment. Kee, et al. [7] reported key indicators for the improvement of agricultural ergonomic equipment and reported that ergonomic design could enhance safety. Benos, et al. [8] found that ergonomic agricultural equipment can economically improve repetitive manual material handling and reduce the physical strain of long-duration work, thereby enhancing safety and comfort. The use of ergonomic equipment in agricultural work is expected to continue to increase, and the design of such equipment, considering usability for the prevention of musculoskeletal disorders and improvement of safety, is becoming increasingly important [9].

Therefore, the purpose of this study is to suggest an ergonomic evaluation index, considering human-machine interaction, to ensure the fundamental safety of ergonomic equipment. It could improve the safety of frequently used ergonomic equipment in agricultural work environments and contribute to the creation of a safer agricultural workplace.

2. Materials and Methods

2.1. Accident Case

To systematically investigate and analyze accident cases involving ladder-related injuries among agricultural workers, which is one of the most frequently used equipment in agricultural work, the 'Agricultural Safety 365' database, operated by the Rural Development Administration (Republic of Korea), was utilized. The search period for accident cases was from 'before 2000 to 2019,' and the search was limited to 'ladders' as the type of agricultural equipment.

For the accident cases involving agricultural workers collected in this study, the accident scenarios were reconstructed by reviewing items such as the accident overview, details, and injury severity, based on the detailed information provided by the database. The collected accident scenarios were analyzed using the 4M approach, focusing on human (man), machine/equipment/tools (machine), environmental (media), and management (management) factors, to analyze the causes, contributing factors, and agents involved in the accidents from multiple perspectives.

2.2. Focus Group Interview

This study conducted two focus group interviews (FGI) for consulting on the ergonomic evaluation index of agricultural ladders: one group consisting of agricultural safety experts and the other of agricultural workers. The agricultural safety expert FGI group was composed of six experts in agricultural safety, health, hygiene, ergonomics, and machinery. The agricultural worker FGI group consisted of ten agricultural workers with more than 30 years of farming experience.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 3: 2982-2986, 2025
DOI: 10.55214/25768484.v9i3.5897
© 2025 by the author; licensee Learning Gate

Figure 1.
Example of focus group interview.

2.3. Evaluation Criteria

This study developed evaluation sheets focusing on safety and usability indicators to consider human-machine interaction. Based on previous research by Mo [10] evaluation indicators were derived using criteria such as accident probability, stability, effectiveness, and comfort. Interviews were conducted with the FGI groups to assess the necessity, appropriateness, and reliability of the derived evaluation indicators.

Table 1.
Evaluation index sheet.

Criteria	Evaluation index	Content
Usability	Effectiveness	Anti-slip for steps, Irregular ground adaptation
	Ease of control	Reinforced step
	Comfortness	Ease of transport (portability)
Safety	(Accident) Probability	Anti-leg spreading device, Ladder weight capacity
	(Accident) Severity	Ladder leg slip prevention, Step height spacing
	Stability	Safety bar

3. Results and Discussion

3.1. Accident Case

The causes of ladder-related accidents were classified into seven types, with most accidents occurring due to unstable floor conditions in agricultural work environments (Media), such as sloped or irregular surfaces, which are primarily influenced by environmental characteristics (Figure 2). As for the mechanical/equipment/tool (Machine) related causes, accidents involving ladders (type A) were frequently found to occur due to the failure or absence of the device that secures the ladder's extension. Also, accidents where workers fell while working at the top of the ladder were also analyzed, often resulting from unsafe behaviors and non-compliance with proper work procedures due to human error. In addition, accidents were analyzed where ladders were improperly used for tasks, or where workers slipped and fell while climbing or descending a ladder due to worn-out shoe soles.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 3: 2982-2986, 2025
DOI: 10.55214/25768484.v9i3.5897
© 2025 by the author; licensee Learning Gate

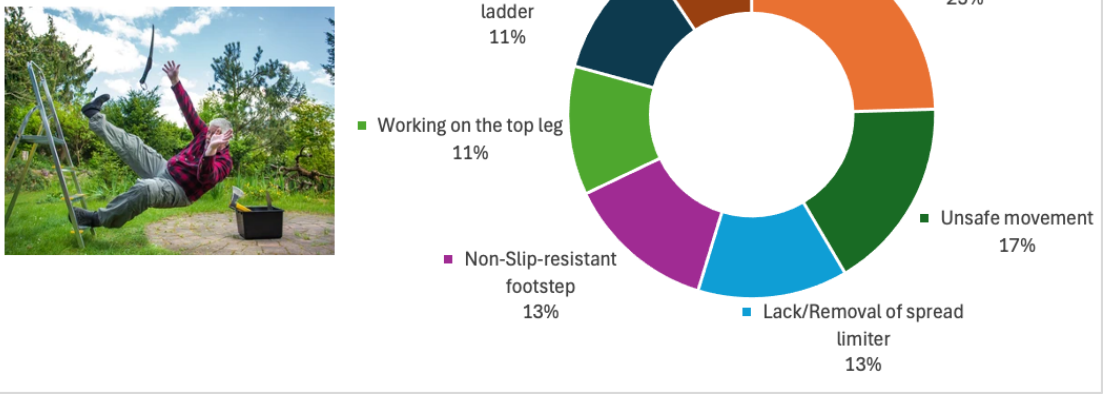

Figure 2.
Proportion of causes of ladder accidents in agricultural work.

3.2. Focus Group Interview

According to the FGI results, the key indicators for evaluating the usability of ladders in agricultural work were found to be anti-slip for steps, the presence of sharp edges, and ease of mobility and elevation. For evaluating the safety of ladders, important indicators included devices to prevent ladder leg spread, anti-slip features on the ladder legs, and the height/width between the steps.

3.3. Ergonomic Evaluation Index

By combining the analysis of agricultural ladder accident cases and the FGI results, an ergonomic evaluation index and protocol were suggested, as shown in Table 2. The evaluation indices were derived using criteria such as accident probability, stability, effectiveness, and comfort, including factors like step anti-slip features, ease of ascension, anti-leg spreading devices, and the height/width between steps.

Table 2.
Ergonomic evaluation index for agricultural ladders.

Criteria	Evaluation index	Content	Protocol
Usability	Effectiveness	Anti-slip for steps	Has the surface of the steps been treated with an anti-slip coating?
	Ease of control	Sharp edges	Are there any sharp edges in areas that could come into contact with the body or clothing?
	Comfortness	Ease of ascension	Is the angle of the climbing surface (θ) less than or equal to 75°?
Safety	(Accident) Probability	Anti-leg spreading device	Is there a ladder leg spreading prevention device made from a non-elastic and durable material that is not easily damaged?
	(Accident) Severity	Slip resistance for ladder legs and steps	Has the ladder leg been treated to prevent slipping on the floor surface? (e.g., spikes, surface treatment, rubber materials, etc.) Has the surface of the steps been treated with anti-slip coating?
	Stability	Height/Width between steps	(Height) Does the height between steps meet the following criteria?" - 1st step: ≤ 350mm - 2nd step and above: 180–350mm (Difference between maximum and minimum height: less than 5mm) (Width) Is the width (front-to-back depth) of the steps at least 30mm?

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 3: 2982-2986, 2025
DOI: 10.55214/25768484.v9i3.5897
© 2025 by the author; licensee Learning Gate

4. Conclusion

Rural areas are already experiencing rapid aging, and the risk of accidents is increasing due to the climate crisis. Therefore, to ensure agricultural work safety, the physical risk factors in ergonomic equipment and work environments should be prioritized for improvement. As accidents involving ladder use are frequent in agricultural work, a design that ensures safety based on ergonomic evaluation indicators is necessary. Based on the results of this study, it can ensure fundamental safety from the design and production stages of ergonomic equipment and contribute to the creation of a safer agricultural work environment. In the future, as agricultural work becomes more dependent on machinery, it is hoped that the ergonomic evaluation index for ergonomic equipment will be legislated to prevent safety accidents.

Funding:

This work was carried out with the support of "Cooperative Research Program for Agriculture Science and Technology Development (Grant Number: PJ01709903)" Rural Development Administration, Republic of Korea.

Transparency:

The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Copyright:

© 2025 by the authors. This open-access article is distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

References

[1] R. Jadhav, C. Achutan, G. Haynatzki, S. Rajaram, and R. Rautiainen, "Risk factors for agricultural injury: a systematic review and meta-analysis," *Journal of agromedicine*, vol. 20, no. 4, pp. 434-449, 2015.

[2] G. M. Calvert, K. Lee, S. Roh, K. G. Davis, and S. Tak, "Promoting and protecting worker health and safety in the Republic of Korea agricultural sector," *Journal of agromedicine*, vol. 17, no. 3, pp. 326-337, 2012.

[3] F. A. Fathallah, "Musculoskeletal disorders in labor-intensive agriculture," *Applied ergonomics*, vol. 41, no. 6, pp. 738-743, 2010.

[4] P. K. Nag and L. P. Gite, *Human-centered agriculture: Ergonomics and human factors applied*. Singapore: Springer Nature, 2020.

[5] T. H. Cogbill, E. S. Steenlage, J. Landercasper, and P. J. Strutt, "Death and disability from agricultural injuries in Wisconsin: a 12-year experience with 739 patients," *Journal of Trauma and Acute Care Surgery*, vol. 31, no. 12, pp. 1632-1637, 1991.

[6] B.-C. Son and S.-H. Shin, "The development of design and evaluation guidelines of convenient equipments of farm work for the elderly," *Journal of the Ergonomics Society of Korea*, vol. 30, no. 4, pp. 451-458, 2011.

[7] D.-H. Kee, Y.-W. Song, and I.-S. Lee, "Analysis of cases of ergonomic improvements of agricultural work support equipments," *Journal of the Ergonomics Society of Korea*, vol. 30, no. 4, pp. 541-550, 2011.

[8] L. Benos, D. Tsaopoulos, and D. Bochtis, "A review on ergonomics in agriculture. Part I: Manual operations," *Applied Sciences*, vol. 10, no. 6, p. 1905, 2020.

[9] B. Qiu, Y. Zhang, H. Shen, J. Zhou, and L. Chu, "Ergonomic researches in agricultural machinery-a systematic review using the PRISMA method," *International Journal of Industrial Ergonomics*, vol. 95, p. 103446, 2023.

[10] S. M. Mo, "Ergonomic evaluation criteria of agricultural equipment: Focusing on the pruning shears," in *In Proc. 15th International Conference on Applied Human Factors and Ergonomics (AHFE 2024) and the Affiliated Conferences, Jul. 24-27*, 2024.