Implementation of A Deep Learning-based Application for Work-related Musculoskeletal Disorders' Classification in Occupational Medicine

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Abstract. This research aims to develop an AI-based Ergonomics risk hazard posture recognition system to help reduce the risk of injury to workers and improve work safety in factories and warehouses. The background shows that ergonomic risk hazards are one of the most important risk factors in the workplace, among which the risk of posture hazards is higher when the human body is carrying objects. Otherwise, KIM-LHC (Key Indicator Methods - Lifting/Holding/Carrying) was used as the basis for posture determination, and the human posture information was converted into data by Movenet, and then build the neural network classification model used to recognize and analysis human pose, finally integrated into the app built by flutter. The app built by Flutter is finally integrated. In order to verify the performance of the system, it conducted experiments by actual video recording, and the results showed that the verification accuracy of the app could reach over 97%, and successfully identified the dangerous postures that might cause injury risks to workers, and the app was easy to understand and practical. In summary, this research developed an AI-based Ergonomics risk-hazard posture recognition system, which is important for improving workplace safety.

Keywords: Ergonomics, work-related musculoskeletal disorders, KIM-LHC, occupational medicine

1 Introduction

Ergonomics [1] is the research of the relationship between people and the interactions between tools, machines, equipment and the environment in human daily life at work. Aim to enhance these interactions by adapting them to the individual's abilities, constraints, and requirements. Ergonomics is a specialized field that aims to improve the congruence between human interactions and tools, machines, equipment, and the environment through thoughtful design. If not well implemented, poorly designed Ergonomics can lead to various direct and indirect effects on workers. These include contributing to human errors, accidents, musculoskeletal injuries, illnesses, reducing the quality of work life, poor production performance, and inducing worker fatigue, all of which can seriously affect the health, safety, and overall well-being of workers. Additionally, occupational accident survey statistics from various regions including the United States, Japan, Europe, and Korea highlight the impact of musculoskeletal injuries and illnesses. These conditions, accumulated over time, have led to a significant number of lost workdays. On average, these cases account for 38% in the European Union, 32% in the United States, 41.2% in Japan, and 40% in the United Kingdom. In recent years, the overall loss caused by repetitive musculoskeletal injuries and illnesses is about US$216 billion in the EU, accounting for 1.6% [3] of the overall GDP of the EU; and about US$168 billion in the US, accounting for 1.53% [4] of the US GDP. According to the survey report [5], the number of people suffering from work-related musculoskeletal injuries in Korea increased from 124 in 1998 to 6,234 in 2009; in the 1990s, musculoskeletal injuries accounted for only 10% of all occupational injuries in Korea; But increased to 70% in 2009. Although this is related to the inclusion of musculoskeletal injuries as an occupational disease, it also shows the prevalence of musculoskeletal injury problems. Therefore, in order to eliminate or reduce work-related musculoskeletal injuries, advanced industrial countries have been making efforts to promote the prevention and control of repetitive musculoskeletal injuries in recent years.

Heavy lifting and repetitive lifting operations are the most common causes of occupational diseases in the workplace. These operations often result in work-related musculoskeletal disorders (WMSD) [6] and cumulative musculoskeletal disorders (CTD) [7] [9]. The proportion of injuries varies by site, with the main causes of these disorders being prolonged repetitive operations and poor posture, leading to fatigue and inflammation of the associated musculoskeletal tissues, which can result in injury. Due to the high prevalence and long duration of musculoskeletal injuries, they have a significant impact on workers, businesses, and the nation.

Thus, society shoulders a heavier burden related to labor insurance and social relief, alongside the substantial depletion of medical and social resources. In the past, the mainly dependence on physicians' clinical expertise to discern whether repetitive tasks resulted in musculoskeletal injuries and to quantify the harm, substantially strained on-site who were tasked with precisely determining the scope of musculoskeletal injuries and ailments within a limited time frame., posed a formidable challenge. Summary, this methodology frequently culminated in inexact evaluations, exorbitant costs, and laborious procedures.

This research goal is to develop a tool leveraging the KIM-LHC [8] as a reference, focusing specifically on body parts most susceptible to injuries (see Fig. 1). This tool is designed to facilitate prompt and accurate determinations by physicians, thereby enhancing the precision and efficiency of their assessments regarding the scope of musculoskeletal injuries and disease hazards. As a result, it anticipate to drastically curtail the cost and time associated with injury and disease evaluation, poised to facilitate the implementation of early intervention measures. Also minimize further harm, expedite recovery, and lessen medical costs. Finally, the intent is to alleviate the impact on workers, businesses, and society, while promoting a healthier and safer work environment.

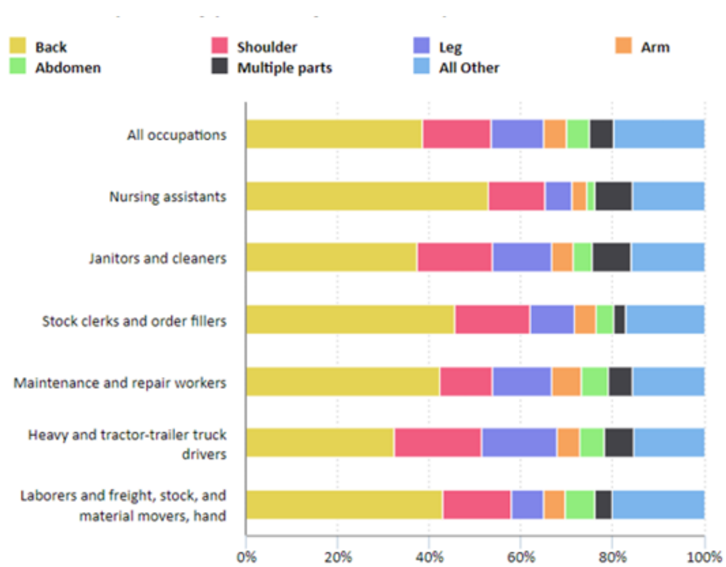

Fig. 1. The Back injuries prominent in work-related musculoskeletal disorder cases in 2016 [2].

The rest of this paper is organized as follows. Section 2 introduces the KIM-LHC method. In Section 3, the system design and implementation are presented. Finally, concluding remarks are given in Section 4.

2 The KIM-LHC Method

Musculoskeletal injuries are among the most common occupational diseases suffered by workers, and these occupational diseases often result in significant medical burdens and sequelae. The Key Indicator Method (KIM) was released as a draft in 2007 and contains three assessment scales (KIM-LHC, KIM-MHO, and KIM-PP), among KIM-LHC can use Body posture rating judgment table (see Fig. 2) cooperate with other Rating Judgment calculate risk score to quickly conduct a rapid assessment of Lifting/Holding/Carrying work situation is in a safe state or not, effectively Reduce the chance of WMSD in workers.

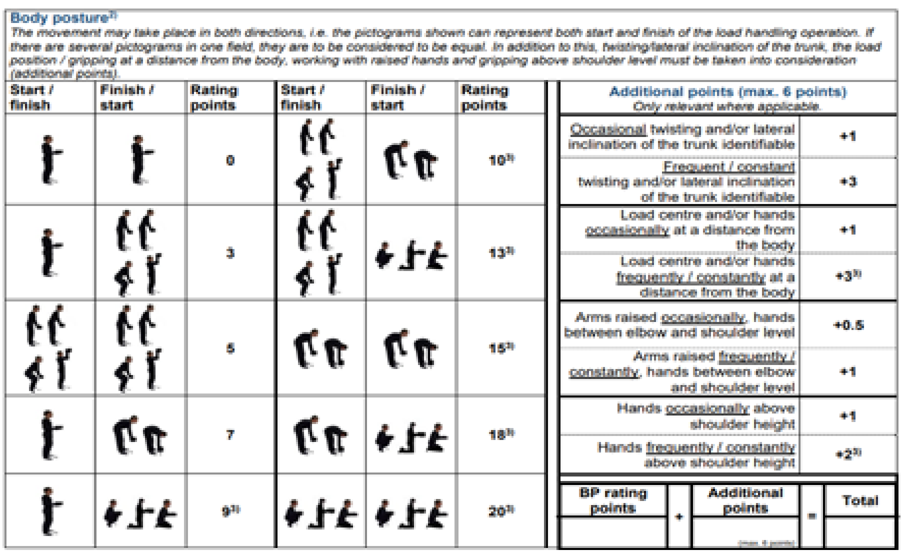

Fig. 2. The Body Posture Rating Table.

3 System Design and Implementation

3.1 System Design

In this part, we design a system to quickly assess the risk. The system is divided into four modules, which are presented in the following:
The system flowchart is shown in Fig. 3.

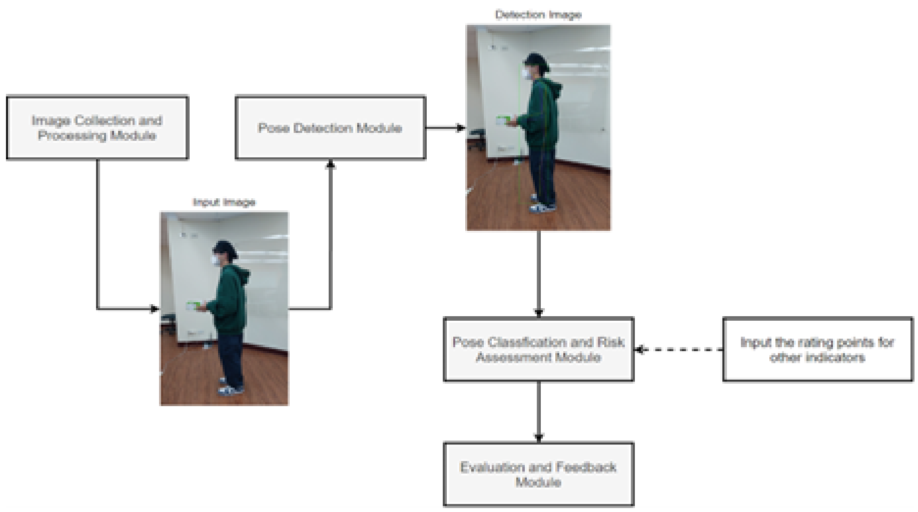

Fig. 3. The System Flowchart.

- The Video Image Collection and Processing Module: This module is mainly responsible for video image collection, image cropping and image scaling operations.
- The Pose Detection Module: This module is based on MoveNet [10, 11] to extract human 17-keypoints skeletion and obtain 2D coordinates of human keypoints.
- The Pose Classification and Risk Assessment Module: This module uses the neural network to determine the key point coordinates for classification, and it is also responsible for integrating the output of the neural network with the input job description data (e.g., time rating, load rating, and work condition rating) to calculate the posture risk value according to the KIM-LHC scale and obtain the corresponding risk assessment level.
- The Evaluation and Feedback Module: This module is responsible for generating WMSD real-time feedback analysis reports and recommendations, including KIM scores, risk level results and feedback recommendations. Users can quickly query the results and complete the whole evaluation process.

3.2 System Implementation

The implementation steps are given below:

- Step.1 The Dataset acquisition: According to KIM-LHC, we designed different posture hazard level to shoot human key point dataset.
- Step.2 Building classification model: We use MoveNet to construct the human skeleton and key points, and then use the acquired human key point coordinates are used to train the classification model. The training flow of the neural classification model of this work is shown in Fig. 4

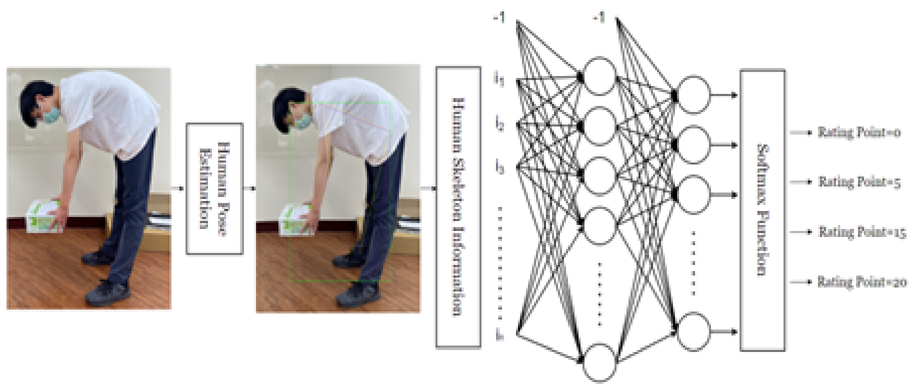

Fig. 4. The training flow of the neural classification model of this work.

- Step.3 Constructing APP:
  - The Photography: Make each frame into MoveNet through camera plugin.
  - The User status: Change status and save information via buttons.
  - The Report download: calculate risk rating, give user advice and help doctor treatment.
- Step4. The Calculation of Musculoskeletal Injury Risk: The musculoskeletal injury risk calculation (See Fig. 5.) will be performed according to the approach designed in [8] and feedback will be given according to different levels of risk.

	Men	Women
Effective load weight		
Load handling conditions +		
Total body posture +		
Unfavourable working conditions (∑ IRP) +		
Work organisation / temporal distribution +		

Time rating points	x	Total of indicator rating points:	Men	Women	=	Results Men	Results Women

The risk score calculated and the table below can be used as the basis for a rough evaluation:

Risk	Risk range		Intensity of load[1]	a) Probability of physical overload b) Possible health consequences	Measures
	1	< 20 points	low	a) Physical overload is unlikely. b) No health risk is to be expected.	None
	2	20 - < 50 points	slightly increased	a) Physical overload is possible for less resilient persons. b) Fatigue, low-grade adaptation problems which can be compensated for during leisure time	For less resilient persons, workplace redesign and other prevention measures may be helpful.
	3	50 - < 100 points	substantially increased	a) Physical overload is also possible for normally resilient persons. b) Disorders (pain), possibly including dysfunctions, reversible in most cases, without morphological manifestation	Workplace redesign and other prevention measures should be considered.
	4	≥ 100 points	high	a) Physical overload is likely. b) More pronounced disorders and/or dysfunctions, structural damage with pathological significance	Workplace redesign measures are necessary. Other prevention measures should be considered.

Fig. 5. The Risk Calculation Table.

- Step5. Model deployment: The trained classification model is lightly processed, converted to tflite and ported to the APP.
- Step6. Model optimization: Optimize the computational speed of neural networks on cell phones.
- Step.7 System testing: Conduct contextual tests and debug step by step.

4 Conclusion

In this work, we have developed an ergonomic risk hazard posture recognition system based on the human pose estimation technology, in which the KIM-LHC was used as the basis for posture judgement and the MoveNet pose estimation model was also used for recognition and classification. In addition, we have built a cross-platform App with Flutter framework. Through actual video recording, the system can successfully identify dangerous postures that may cause injury risks to workers. This system is important to improve workplace safety.

In the future, we plan to combine the system with KIM-PP (Key Indicator Methods-Pushing/Pulling) and KIM-MHO (Key Indicator Methods-Manual Handling Operating Tasks) of the KIM scale, hope this system can be further applied to various industries and work situations. Through actual verification and system improvement, we can realize the rapid detection of work safety to prevent workers from suffering from musculoskeletal injuries such as WMSD due to wrong work posture.

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