Ergonomic Interventions in the Workplace: A Case Study

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人因工程在工作場所的改善介入:個案研究
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ABSTRACT

The purpose of this study was to assess the physical workloads for packing tasks in a printing ink manufacturing factory located in northern Taiwan, with an aim to lower the risk of musculoskeletal disorders (MSDs) among the workers. The BRIEF checklist and Key Indicator Method (KIM) were used to evaluate and identify the MSD risk factors associated with the ink packing tasks. The data collected include material weights, work posture, work pace, vertical distances, vertical lifting displacement, and lifting frequency. The ink-filling operator averagely filled 2000 1-kg ink cans per day and the ink-packing operator totally lifted 4166 times per day and the average lifting weight was 1.44 kg/lift. The BRIEF analysis results show that both of the operators have high possibility of developing MSDs. The KIM risk scores were evaluated as 40 (median high load) and 50 (high load) for the ink-filling and ink-packing operators, respectively. To reduce MSD risks for this work, a redesign worktable was suggested to replace the original one. This hardware intervention can allow the operators to move the ink cans more smoothly and efficiently without bending their backs as they pack the cans. Further, the estimated KIM risk scores were reduced to 20 and 30 for the ink-filling and ink-packing operators, respectively. This suggested change has been adopted by the ink company and will be implemented in the packing area.

Keywords: MSDs, manual lifting tasks, workstation design, ergonomic risk identification
人因工程在工作場所的改善介入：個案研究

摘要

本研究的目的是評估北臺灣一家油墨製造廠作業人員的勞動工作負荷，同時要設法降低勞工肌肉骨骼不適症的風險。運用人因工程因素基準線風險認定 (Baseline risk identification of ergonomic factors, BRIEF) 檢核表和關鍵指標法 (Key Indicator Method, KIM) 去評估與鑑定肌肉骨骼不適症的風險因子。現場收集的資料包括物料重量、工作姿勢、工作步調、垂直距離、垂直抬舉位移和抬舉頻率。油墨填裝作業人員平均一天要填裝 2000 個重量各為 1 公斤的成品罐；油墨包裝作業人員每天總共抬舉 4166 次，平均抬舉物重為 1.44 公斤。由 BRIEF 的分析結果得知：這兩種作業人員都很有可能罹患肌肉骨骼不適症。以 KIM 評估得知油墨填裝與油墨包裝作業人員的風險分數分別為 40 (中高負荷) 與50分 (高負荷)。為了減少此工作肌肉骨骼不適症的風險，建議把原來的工作桌重新設計並更換。這個硬體改善介入可以讓作業員包裝成品罐時不用彎腰就能很平順且有效率地移動罐子。此外，預估油墨填裝與油墨包裝作業人員的 KIM 風險分數分別可降到 20 和 30分。我們的建議已經被這家油墨公司採納，並且將會落實在包裝區。

關鍵詞：肌肉骨骼不適症，人工搬運作業，工作站設計，人因風險鑑別
1. Introduction

In industrialized countries, musculoskeletal disorders (MSDs) are a leading cause of work-related disability and productivity loss [1][2]. According to national occupational injury records, MSDs in Taiwan account for 33% of total work injuries in recent years [3]. Besides, the MSDs are also the most widespread occupational disease in Taiwan where the related medical loss of NT$ 2 billion was approximately 0.67% of Taiwan’s GDP for the year 2009 [4].

MSDs include a broad range of conditions affecting the muscles, tendons, ligaments, joints, and nerves. These include tendon inflammations (e.g. tenosynovitis), as well as low back pain, and other regional pain syndromes. The occurrence of MSDs is usually a result of factors such as excessive force, highly repetitive motions, awkward postures, prolonged static postures, muscle fatigue, and exposure to low temperature or vibration [5-9]. The body parts most often affected by MSDs are the lower back, neck, and upper extremities (shoulder, arm, and wrist). MSDs not only endanger worker’s health but also reduce their productivity. Therefore, it is crucial to lower the risk for the developing of MSDs among the workers to improve labor health and safety and increase business productivity.

Minimizing worker discomfort by reducing task exertions is one approach that may reduce MSDs risks as task exertion is related to workload [10-12]. In addition, several ergonomic interventions, such as workstation redesign, employee training, and working conditions improvement, have been reported to mitigate risk factors causing MSDs. This paper presents a case study in which risk factors of MSDs in an ink manufacturing company were evaluated.
and identified. In addition, ergonomic interventions were also recommended and implemented to enhance the health and safety of the company employees and productivity. The aim of this paper is to illustrate a good example of the ergonomic application in a small enterprise.

2. METHODS

(1). Ergonomic assessment tools

This research used the following two approaches to assess the MSD risks at the packing area of a printing ink manufacturing company.

A. Baseline risk identification of ergonomic factors (BRIEF)

The BRIEF checklist was designed to quickly identify occupational ergonomic risk factors in the workplace [13]. This checklist can evaluate six body parts: hands and wrists, elbows, shoulders (all have right and left sides for the above three parts) along with neck, back, and legs. The main risk factors evaluated by the BRIEF tool are force, posture, repetitiveness, and work duration. Tasks associated with other risk factors, such as exposure to vibration, mechanical pressure, and low temperature, should be referred to professional personnel for further analyses. According to the guidelines of the BRIEF method, if two or more risk factors are identified for a given body part, this body part has a strong possibility of developing MSD.

The BRIEF checklist has been used for identifying ergonomics risk factors in steel manufacturing factory workers [14], elevator assemblers [15], etc. Lu et al. [16] compared three different kinds of checklists (BRIEF MSDs, and SEMI standards) through field tests and ques-
tionnaires to determine which checklist is more suitable for the semiconductor industries. The results show that the BRIEF checklist is an effective and rapid screening instrument to monitor the potential ergonomic risk of cumulative trauma disorders (CTD) for upper arm. Wu et al. [15] also indicated that the results from the BRIEF checklist in examining the neck, shoulder and back symptoms were identical with that of the questionnaire survey. Therefore, the BRIEF checklist is suitable for identifying the risk factors associated with this ink-packing task involved mostly manual operations to prevent the occurrence of work-related upper musculoskeletal disorders.

BRIEF is a quick screening tool to find the potential MSDs problems in specific body parts. However, BRIEF can not evaluate the whole-body physiological load of the work. The other tools (e.g. KIM) are required to analyze the overall work load for a task and then decide whether this task is considered as overload.

B. Key Indicators Method (KIM)

KIM was developed by Germany’s Federal Institute for Occupational Safety and Health (BAuA) and Committee of the Länder for Occupational Safety and Health (LASI) according to the European Council Directive 89/391/EEC of 12th June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work [17]. This method evaluates relevant activity data called key indicators. The indicators include duration, frequency and distance with a multiplier for weight, posture and working conditions. The method is quite suitable for application to industrial practice. KIM simplifies the assessment procedure into the three following steps:
(A). Determine the time rating point: Identify the task as a lifting, holding, or carrying task and then determine the corresponding time rating point from the KIM rating table, according to the number of daily lifts, the holding duration, or the carrying distance.

(B). Determine the rating points for load, posture, and working conditions: With the KIM rating table, look up the load rating points for male or female operators that correspond to the effective load (the real action force that is necessary for moving the load). Identify the typical working posture and load position of the task in order to determine the rating points for posture. The rating points for working conditions account for the presence of environmental hazards such as workspace limitation, physical obstacles, uneven or unsteady flooring, inadequate lighting, or poor gripping conditions, etc.

(C). Compute risk score and determine risk level: Compute the total risk score of the task by multiplying the time rating point by the sum of the rating points for load, posture, and working conditions. Measure the task’s risk level by consulting the KIM defined risk score range (level 1: risk score < 10; level 2: 10 ≤ risk score < 25; level 3: 25 ≤ risk score < 50; level 4: risk score ≥ 50).

This classification of the risk scores gives an indication of any load bottlenecks. KIM only evaluates whether the work is overload; it can not indicate which body part will suffered from MSDs. We still need the other tool (e.g., BRIEF) to obtain the details information regarding the risk of specific body parts.

During the European inspection and communication campaign “LIGHTEN THE LOAD”, the KIM was translated into all European languages and can be accessed via Internet [18]. Since then, it has been adopted and used by several other EU countries for risk assessment of
manual load handling. In Taiwan, Sung et al. [19] used the KIM to assess the operational workloads for five workstations in a Taiwan metal manufacturing factory. The KIM risk scores for two of five workstations were determined between 25 and 50 (risk range 3), indicating highly increased load situation where redesign of the workplace is recommended. Based upon the evaluation, simple lower-budget interventions like worktable redesign, tilted-surface high chair, etc. were provided to improve the health and safety for the metal manufacturing workers.

Takala et al. [20] indicated that only a small number of instruments or methods assessing biomechanical exposures in occupational settings have been tested in a systematic manner for validity, reliability, objectivity, or other aspects related to their practical application. The KIM was field-tested for feasibility at 112 workplaces in 2005 [21]. At every workplace, the KIM was completed and discussed with the respective occupational health and safety officers in the companies, and then further developed and improved iteratively. According to expert discussions after the 112 field tests, the results seemed to be plausible to the experts involved and consulted. With this knowledge, the KIM provides a better classification of occupational hazards with regard to musculoskeletal upper limb diseases. In addition, this might lead to more specific prevention strategies for industries. Currently, a revised KIM draft is under evaluation and will be presented publically in spring/summer 2011 [21].

(2). Ergonomics investigation process

The ergonomic risk evaluation process included a formal meeting and a tour of the shop floor (onsite inspection). In the meeting, the chief inspector first introduced the ergonomic risk
evaluation process and then dialogued with the employers and major crewmembers to gather an overview of the work and the key problems experienced by the studied company. During the tour, inspectors collected field data of specific tasks by talking with individual operators, taking photographic and video evidence of manual materials handling tasks, and measuring task demands and physical dimensions of inspected workstations. BRIEF and KIM tools that enabled the quantification of ergonomic risk were then used for explaining potential causes of MSDs. Two weeks later, the inspectors drafted and sent the company an inspection report with improvement suggestions, and a follow-up meeting was arranged afterward to discuss the efficacy of the ergonomic interventions.

3. ERGONOMIC PRACTICES

(1). Operation statement

In the factory’s ink packing station, operators filled ink into 1-kg cans and packed every 12 of those ink cans into a paperboard box. The working area was about 33 meter-square, with a mixer barrel, a filtering tank, a capping machine on a worktable, and paperboard boxes on pallets. The filtering tank was fixed on a steel frame (120-cm from the floor) of 50-cm height and 50-cm diameter. The dimensions of the capping machine were 52-, 46-, 60-cm in length, width, and height, respectively, and it was situated on a worktable of 150-, 70-, and 54-cm in length, width, and height, respectively. The dimensions of the pallets and paperboard boxes used for packing ink cans were $1.2 \times 1.2 \times 15$ cm and $53 \times 40 \times 16$ cm in length, width, and height, respectively. A team of two workers, aged from 35 to 45 years, was employed to complete the ink packing tasks.
The shop floor tour inspected the ink filtering, 1-kg can filling and weighting, and paperboard box labeling procedures. At first, one operator (shown in Figure 1) sitting in front of the filtering tank filled the ink can to 1 kg weight. This operator was sitting with neck flexed to gaze the weight scale and to control the ink filling valve at the bottom of the filtering tank. After filling, this operator carried the can from the weight scale onto the table at her left hand side. Then, the other operator cleaned the can body, carried the can onto the capping machine (Figure 2), and putting the cans into the paperboard box with a flexed trunk (Figure 3). When the paperboard box had 12 ink cans, the paperboard box was moved onto the pallet.

(2). MSDs risk evaluation

The operator conducted the filling task with her neck flexed looking at the weight scale. This static and non-neutral posture could lead to muscle fatigue of the neck and shoulders. Moreover, in order to accurately filling 1-kg of ink into each can, the operator repetitively flexed and extended her dominant wrist to control the outlet valve of the ink (see Figure 1). According to BRIEF analysis (as shown in Table 1), this operator had a risk score of 2 at her wrist due to a radial deviation and holding duration > 10 sec; a risk score of 3 at her shoulder due to an elevation angle > 45°, and maintaining an award posture >10sec with a frequency > 2 times/min; a risk score of 3 at her neck and back due to maintaining a forward bending and twisting posture > 10sec with a frequency > 2 times/min. The operator had regional risk score at wrist, shoulder, neck, and back all greater than or equal to 2, indicating high probability of musculoskeletal disorders and need for improvement. For the same operator, KIM assessment showed that lifting a 1-kg can for 2000 times/day with slightly bending and twisting trunk
had rating points of 10 (time), 1 (load), and 2 (posture), as shown in Table 2. Due to movement confinement caused by the workspace arrangement, the rating point of the work environment was estimated as 1. Her total KIM risk score was computed as 40 (risk level 4), indicating a highly increased load situation, with physical overload possible for the average persons. Hence redesign of the workstation was recommended according to KIM assessment.

The packing operator made repetitive lifting movements (see Figure 2): carrying the cans onto the capping machine, packing the paperboard boxes with cans, and laying them on pallets. He lifted 4000 times of 1-kg can per day on average, and lifted and laid 12-kg boxes on pallets over 166 times per day. The BRIEF analysis results are (listed in Table 1): this operator had a risk score of 2 at his wrist due to a ulnar deviation and holding weight > 10 pound; a risk score of 1 at his elbow due to force > 10 pound; a risk score of 2 at his shoulder due to an elevation angle > 45° and producing force > 10 pound; a risk score of 3 at his back due to maintaining a forward bending and twisting posture with a frequency > 2 times/min and handling weight > 20 pound; a risk score of 1 at his leg due to squat posture. The operator had regional risk score at wrist, shoulder, and back all greater than or equal to 2, indicating high probability of musculoskeletal disorders and need for improvement. For this packing operator, KIM analysis showed that total lifting frequency of 4166 times/day and average lifting weight of 1.44 kg/lift rating points of 10 (time), 1 (load), and 4 (posture), as shown in Table 2. His total KIM risk score was computed as was 50 (risk level 4), indicating a highly physical overload for a healthy person. Therefore, redesign of this task was recommended according to KIM assessment.
(3). Ergonomic interventions

The inadequate table height (57 cm) caused the operators to adopt awkward postures. A new workstation (as illustrated in Figure 4) was thus devised to reduce stress on the operators due to inappropriate working posture. Figure 4 was generated by SolidWorks 3D CAD software. The newly designed workstation was L-shaped with 70-cm table height; the base of the mixer tank was raised from 70 cm to 140 cm accordingly. Two fillisters, one on each end of the table, were designed to position the weight scale and capping machine, respectively. The sunken depth of each fillister was designed to keep the surface of the scale and the capping machine at the same level of the table surface so that the ink cans could be moved easily on the surface level. The capping machine was rotated 90° from its original orientation to have its entry aligned with the moving path of the cans. Furthermore, the manufacturing cost of this newly designed workstation is estimated to be 300 US dollars.

The 3D models shown in Figure 4 were all imported into the virtual environment generated by Jack software. Figure 5 shows the computer simulation of ink packing operation in the newly designed workstation. Two 3D digital manikins were created by Jack software and were set to pack the ink cans. The new worktable design allows operators to push cans horizontally to the capping machine after filling them without any lifting and laying activities. After workstation adjustment, the weight scale was elevated to a level that allows the operator to read its value comfortably. Furthermore, commercially available tilting devices, located at both ends of the worktable, could be used to raise and tilt a container or paperboard box. This ar-
rangement could facilitate operators taking out empty cans from the container or putting filled cans into the paperboard boxes and sealing them.

(4). Efficacy of the ergonomic interventions

The proposed workstation redesign can improve work postures for the filling, weighing, and packing operators. The use of tilting devices can further prevent operators from bending their trunks and picking up empty cans from floor level. In addition, the muscle strain in their waists and upper extremities can be reduced. According to BRIEF analysis, all the regional risk scores can be reduced to 1 or 0 for both ink-filling and ink-packing operators (Table 1). Therefore, no awkward operator postures are expected to develop if the suggested workstation could be implemented.

For the ink-filling operator, KIM analysis shows that the rating points for posture can be reduced from 2 to 1, and the rating points for work environment can be lowered to 0 by means of the suggested workspace rearrangement. Further, the risk score for the ink-filling operator can be reduced from 40 to 20 after interventions, indicating physical overload is unlikely for healthy adults (Table 2).

For the ink-packing operator, KIM analysis indicates that the rating points for posture can be reduced from 4 to 2 by means of the suggested workstation redesign. Further, the risk score for the ink-packing operator can be reduced from 50 to 30 after interventions; physical load is reduced from high load to median high load (Table 2).

In addition to the reduction of MSDs risk, the ergonomic interventions would also improve productivity of ink packing. The newly designed workstation allows operators to push cans
horizontally to the capping machine, one second would be saved for handling each ink can. Consequently, the reduction of daily operation time for packing 2000 ink cans will be estimated to be 33 minutes. Although several studies have mentioned that ergonomic interventions may also have positive effect on quality [22][23], our case has no evidence to support that.

4. DISCUSSIONS AND CONCLUSIONS

This study conducted an ergonomic evaluation to reduce the identified risk factors associated with the developing of MSDs in a printing ink manufacturing plant. Based on the results of our ergonomic assessment, the worktable was redesigned to improve work postures for the filling, weighing, and packing operations. The new design can also reduce the repetition of can lifting for the filling operator. In addition, the design of the two fillisters will allow the operator to check the weight of ink in a neutral posture and to push the cans easily to the capping machine without extra effort. The use of tilting devices can further prevent operators from bending their trunks to pick up empty cans from floor level. In addition, the muscle strain in their waists and upper extremities can be reduced. Implementing these ergonomic interventions can not only improve work posture and increase worker comfort, but also reduce the risk of MSDs and potentially increase the productivity of this ink manufacturing factory.

Direct worker participation and a strong commitment of the management of the enterprise are the main issues in ergonomics improvements [24]. De Looze [25] added that a stepwise approach is recommended for the ergonomics improvements even though the main risks as well as the solutions might be quite obvious at first glance. To manage the ergonomics improvement process as a stepwise approach, Joseph [26] introduced an ergonomics process
developed by Ford Motor Company to manage issues related to injury and illness (e.g., MSDs) using joint labour and management teams to identify and evaluate jobs and develop and implement solutions. The manage events process uses the "job improvement cycle", a six step approach to practical ergonomics that includes methods for identifying priority jobs to fix, evaluating job stresses, developing and implementing job improvements, and documenting and following up on individual projects. Rostykus and Dwyer [27] introduced the steps and actions for managing workplace ergonomics following the safety system elements requirements of OSHA voluntary protection program (VPP) [28]. The steps for managing effective ergonomics improvement process included 1) analyze issues, 2) identify root causes, 3) identify improvements, 4) cost justification, and 5) follow-up analysis to verify improvement. The involvement of employee and management leadership and their responsibility, authority, and accountability were also specified in their ergonomics improvement process.

In this study, the application of ergonomics improvement is task-specific operation conducted by professional/experienced ergonomists instead of a process or a system with the involvement of workers, supervisors, and managers. Ergonomics often is most successful when it is carried out as an integral part of the organization’s Total Quality Management (TQM) or similar on-going program to improve the organization’s effectiveness that already has strong management support [29]. To further manage a continuous ergonomics improvement process, systematic approach should be followed and implemented in the ergonomics field to better the ergonomics improvement process.
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REFERENCES


Figure Captions

Figure 1. Ink filling task

Figure 2. Carrying two cans onto the capping machine

Figure 3. Packing the cans into the paperboard box

Figure 4. Fillister design for the weight scale and capping machine

Figure 5. Computer simulation of ink-packing tasks for the redesigned workstation

Table Captions

Table 1. BRIEF analysis results before and after ergonomic interventions

Table 2. KIM analysis results before and after ergonomic interventions
Figure 1. Ink filling task
Figure 2. Carrying two cans onto the capping machine
Figure 3. Packing the cans into the paperboard box
Figure 4. Fillister design for the weight scale and capping machine
Figure 5. Computer simulation of ink-packing tasks for the redesigned workstation
Table 1. BRIEF analysis results before and after ergonomic interventions

<table>
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<th>Shoulder</th>
<th>Neck</th>
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<td>3</td>
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<td><strong>Ink-packing operator</strong></td>
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<td>1</td>
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<td>0</td>
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<td>1</td>
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Table 2. KIM analysis results before and after ergonomic interventions

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<th>Posture rating point +</th>
<th>Working conditions rating point</th>
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