Ergonomic Redesign and Evaluation of Ice Hook in Ice Block Manufacturing

Haruetai Lohasiriwat, Phairoat Ladavichitkul

***Abstract*—While the foremost objective of ergonomic intervention research is the development and/or improvement of machine, tools, work methods, etc. which aim at risk reduction of work-related illnesses and injuries, intermediate steps are often required to illustrate the effectiveness and efficacy of the interventions. In this present study, the redesign rotated ice hook is made and laboratory evaluation is performed to demonstrate the efficiency of new design specifically to reduce non-neutral as well as extreme wrist postures in four fundamental wrist movements; flexion, extension, abduction, and adduction. Evaluation was conducted in two sessions, simulated lifting task performed within laboratory and actual use at a real workplace. The quantitative results (i.e. the level of wrist angles) indicating a significant reduction in the biomechanical stresses identified as percentage of time spending in both non-neutral and extreme range of motion. In conclusion, the redesign hook resulted in ranged between 70% and 100% reduction of time spending in non-neutral wrist posture under laboratory session and from 24% to 90% reduction in the real workplace. Time reduction of wrist spending under extreme posture found to be 100% for both testing sessions. More in depth follow-up field assessments are anticipated to further evaluate the effectiveness of these interventions and to begin the assessment of the potential effect of the intervention.**

***Index Terms*—Ergonomic, hand tool, hook, ice block.**

I. Introduction

The ice block manufacturing in Thailand commonly produces an 11 inch x 22 inch x 60 inch ice block which weighted approximately at 150 kg per block. Manual Material Handling (MMH) is a major transferring of the produced ice blocks from the ice making machine to the ice cutting machine. By observation, the ice block transferring can be separated into three major steps. Initial step is pulling or pushing the ice block along the floor to the cutting machine. The second step is cutting the ice block by moving (pulling) the saw blade onto the ice block which is maintained its position by workers manually. The third step is manually rolling and turning each divided ice block to tilt its side up. To perform this task, the only available hand tool used for years is a simple hook.

Manuscript received November 16, 2009.
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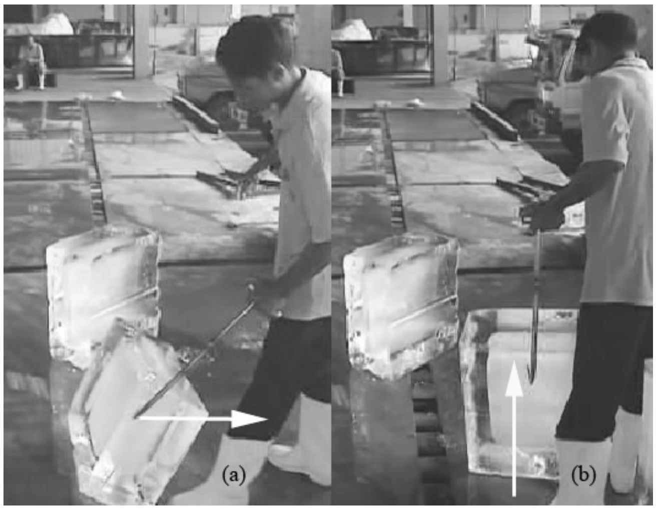

Fig. 1. Illustration of turning side up process starting with (a) Pulling, and then (b) lifting

At present, though the simple hook has been used widely in the ice block industry in Thailand and there is no new design developing for better assistance to workers. In the interview-based session with workers showed the prevalence of musculoskeletal complaints mainly from elbow joint to wrist joint whereas the most fatigue prone activity was in the third step. By observation, the task analysis suggested that the turning process (the 3rd step) was accumulated up to 38% of the time for all manual works while pushing and pulling (the 1st step) was at 20%, cutting (the 2nd step) was at 18%, walking and other activities were at 24%.

To turn the ice block side up, workers usually start from falling the ice down using hook while use their foot as the focal point. Just before the ice falling down to the floor, the hook will be used to hold its weight and turning it up as shown in Fig. 1a and 1b.

Apparently, this task requires experiences and a high physical capability worker in order to protect the falling ice block on their own feet accidently. Non-neutral wrist posture incorporates with repeated motions obviously demonstrate as risk factors in the activity. Therefore, user-centered ergonomic redesign of the hook was initiated with the major objective to reduce risk wrist posture during performing the studied task.

II. Methodology

A. *Subjective Interview*

An adapted body part discomfort scale from [1] is used to evaluate the respondent's direct experience of discomfort at different body parts through interviewing method.

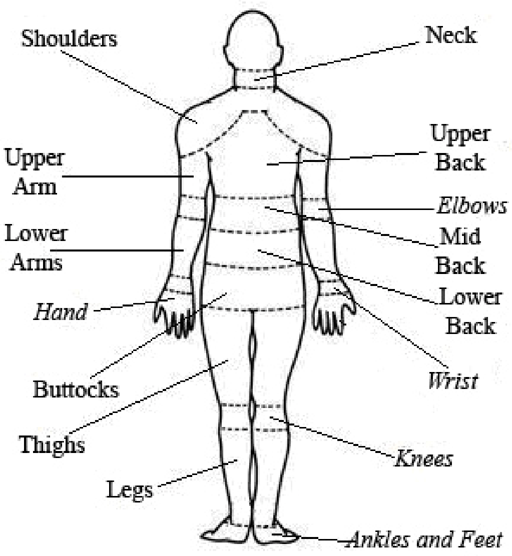

Fig. 2. Adapted Body Part Discomfort Survey.

Instead of divided arm into upper and lower arms, the adapted survey in this study has 5 separated sections on each arm including upper arm, elbow, lower arm, wrist, and hand. Similarly, for lower extremities, the body parts have divided into thigh, knee, leg, and ankle/foot. Body part discomfort scale used in this study is shown in Fig. 2. Parts written in italics demonstrated additional parts specified in the survey session.

From the interview session with the total of twenty workers who performing all manual tasks discussed earlier, there were 35% of respondent reports having discomfort feeling on both lower arm and wrist. Shoulder and upper arm discomfort were the next prevalence making up to 20%. Note also that discomfort feeling was reported only on all mentioned parts of the right arm, the skillful side used during all tasks.

B. Redesign Ice Hook

In order to develop the simple hook, the original T-shaped handle severely compressed between digits 3 and 4 during performing the task. No standardized in hook length was found. Through on-site measuring, the hooks were in variety in length from 43-65 cm. Hook length is normally decided based on user preference without any guidelines. However, diameter of the handle is approximately the same for all hooks at 3.3 cm. mainly due to available rod size. In order to result in effective redesign of hand tool, diverse characteristics should be considered including handle diameter, shape, length, and surface type [2]. Nevertheless, the primarily concentration on finding a standard size of the ice hook as dimensions in terms of handle diameter and hook length were found to effect grip fatigue in manual lifting more than handle shape [3] while final finishing for surface type was expected to be considered in the future.

Using ergonomic hand tool guidelines, the modified hook handle was designed to have its diameter at 3.5 cm. as it is suggested to provide highest power grip strength for small-size men [4] and Thai population are usually small-size in compared to western participants found in the referred study. The length of a new hook was decided by attempting to have workers staying in upright standing posture.

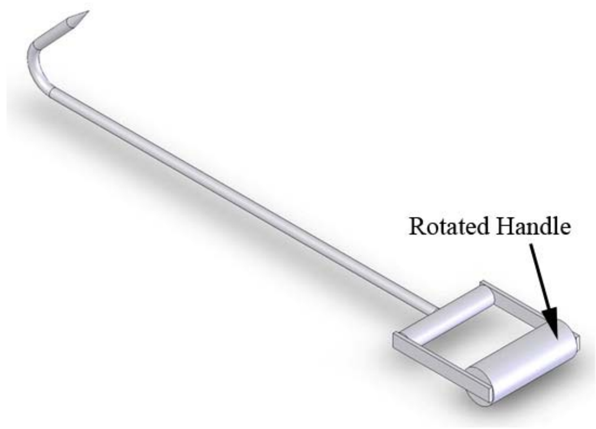

Fig. 3. Final Redesign of Ice Hook with rotated handle.

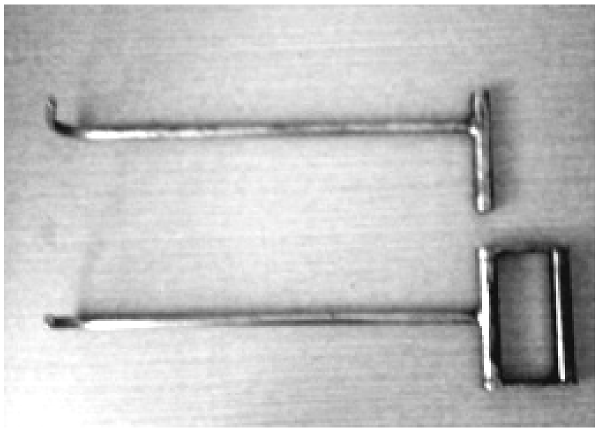

Fig. 4. Actual photos of simple (top) and redesign (bottom) ice hooks.

Ten cycles of ice turning process demonstrated that all workers usually start attached the hook tip at approximately 10 cm. from the floor. Therefore, new designed length is calculated by subtracting 10 cm. from the average workers' knuckle height, 66 $\pm$ 1.6 cm. given the modified hook length to be set at 56 cm. Also, as the simple hook results in high degree of wrist extension when lifting, "Bending the tool, not the wrist" principle is adopted as it was successfully applied to many other ergonomic interventions [5], [6]. New hook was designed so that it can rotate around the handle as demonstrated in Fig. 3, while Fig. 4 demonstrated the actual photos of both simple and redesign hooks.

After drawing the new hook, the mockup of a redesigned tool was created as shown in Fig. 4. The simple hook was designed using T-shaped handle while the redesign one was a true cylindrical handle. Major reason was that T-shaped handle would prohibit rotated function intended in the new design.

C. Evaluation of Redesigned Hook

Thirty volunteer subjects from the undergraduate students of Chulalongkorn University were age between 19-22 years. Since, all workers are limited to only young male under real setting (another classical sign calling for

ISBN: 978-988-18210-5-8
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

ergonomic attention), the study recruited only male participants.

Prior to the testing session, each participant was informed on experiment procedure and allowed to practice for up to 5 minutes. The participant was given both original/simple and redesigned hooks. Both hooks were newly fabricated using the same material. Additionally, the length of both hooks was the same for comparison purpose. Half of the participants started testing using the original tool while the other half started with the redesigned one for counterbalancing any possible carry over effects among trials. Both hooks were hung with two kilogram steel weight at the end and participants were asked to lift using the skillful hand by moving only the lower arm.

The starting and ending points for lifting was set at 10 and 40 cm. from the floor level respectively to simulate actual lifting distance. Video taping of several task cycles from actual circumstances and average directed measure was performed to define these two points. For each hook type, participants repeated the lifting task ten times consecutively. Between two designed hook trials, a one-minute resting period was allowed. Therefore, the total of 600 repetitions (30 participants x 2 hooks x 10 lifts) was collected. The lifting speed was not controlled; all participants performed under their preferred pace.

For data collection, a goniometer (Biometrics) twin axis type, SG 65, was attached to participant's testing wrist. Wrist angle data was continually collected via datalink system throughout the experimental session. Data acquisition software was used to display and save measured angle data. Then, acquired data was categorized as neutral according definition by [7]; between 0^{o} to 15^{o} respect to forearm in flexion, extension, and adduction deviation, between 0^{o} to 5^{o} respect to forearm in abduction deviation. For extreme posture, criteria is set according to [8]; over 45^{o} respect to forearm in flexion and extension, over 20^{o} for adduction and abduction deviation. Subsequently, percentage of time that wrist spending on each non-neutral and extreme posture groups as compared to the total lifting time were averaged across all participants and reported as dependent variable for the study to compare effect between original and redesign ice hooks.

After evaluation session in Ergonomic laboratory, the investigation was conducted at an ice block manufacturing site in Bangkok, Thailand. The total of five volunteered workers who reported no upper limb injuries at time was asked to perform ice block lifting action (Fig. 1b) for five repetitions, using both original and redesign hooks. Therefore, the total of 50 repetitions (5 participants x 2 hooks x 5 lifts) was collected. Wrist angle was recorded during all trials utilizing goniometer and datalog system in the same manner discussed earlier as in the simulated session. Participants performed under their preferences with five minute practicing period.

III. RESULTS

Using the graphical technique and Anderson Darling Test (AD), the dependent measures collected from laboratory session; time spending in non-neutral and extreme postures, was tested to be normally distributed. Therefore, the average value could be used as the representative of each data group.

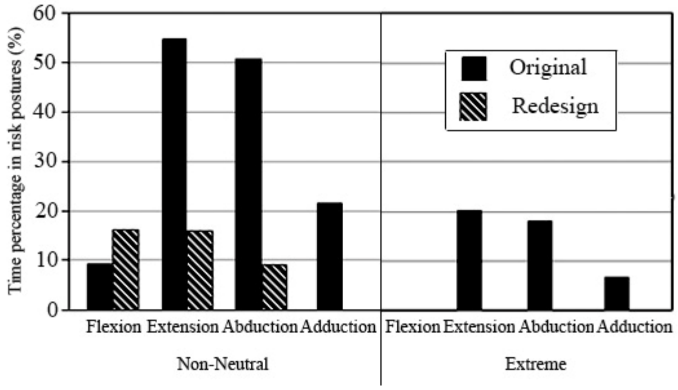

Fig. 5. Comparison of original and redesign ice hooks (laboratory session): Time percentage of wrist spending in non-neutral and extreme posture.

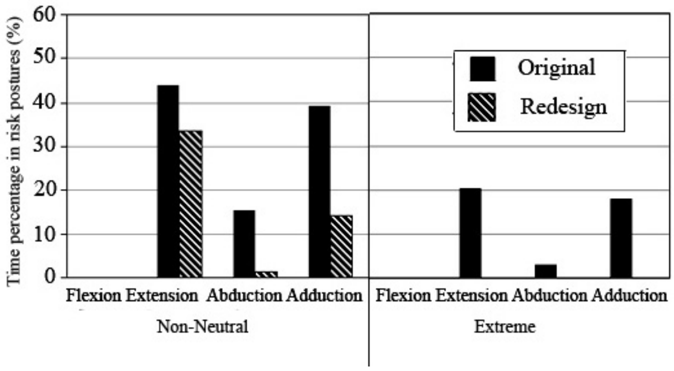

Fig. 6. Comparison of original and redesign ice hooks (worksite session): Time percentage of wrist spending in non-neutral and extreme posture.

The results of two sample t-test assume unequal variance showed that there were significant differences ($p<0.01$) in all non-neutral (reduction of 71% for extension, 82% for abduction, 100% for adduction). Similarly, all extreme wrist postures were eliminated (100% reduction in all postures) as shown in Fig. 5. Since the redesign hook data had no non-neutral adduction and extreme wrist postures as mentioned above, statistics were not tested in those related data groups.

In conclusion, the redesign hook had significantly reduced ergonomic risk posture in terms of exposure time which wrist had to spend within the risk range except for flexion category where significantly increased risk was conversely found.

On the other hand, data collected from worksite session were found that their distributions were not normal. Nonetheless, as shown in Fig. 6, the redesign hook tends to reduce time percentage of wrist spending in the predefined risk ranges. For non-neutral criteria, there were 24% reduction for extension, 90% for abduction, and 64% for adduction. Similar result was found for extreme criteria in both laboratory and worksite sessions, 100% reduction in all postures was found.

IV. DISCUSSION

Two main conclusions could be drawn from this study. First, possible ergonomic risks were present in using the original hook to turn ice block due to repetitive motion with awkward risk posture and combined with required forceful exertion. Second, the redesign hook with self-rotated handle had reduced prevalence of non-neutral and extreme wrist

ISBN: 978-988-18210-5-8
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

posture during lifting task in most of the wrist movement directions as compared to one conventionally employed by the ice block manufacturing workers.

However, as in the laboratory evaluation, the higher level of non-neutral flexion was found in the redesign hook than the original hook and also in the student group than the worker group. This finding may cause by human tendency to pull the load closer to the body in order to reduce physical workload particularly in the case of lower capability participants (student group) as compared to the real workers.

In comparison between two testing sessions, data also demonstrate another unlike action. Under industrial setting, lifting ice block was related more with adduction deviation than the abduction as shown in Fig.6 while under laboratory setting, the data established oppositely. Possible explanation was that under real setting, workers normally had to lift the ice block along the coronal or frontal plane, as in fact the ice fell from the front side (Fig. 1a. and 1b.) whereas the laboratory participants performed the lifting motion along the sagittal plane at all time. As adduction deviation was quoted to be major risk factor than others [9], higher percentage of time in worker lifting indicates even more intense problem in the existing task.

The short interviews with workers also reveal one negative effect on the intervention. As a result of freely rotated handle, all workers reported of feeling loose and lower ability to control the new hook movement that might reduce the likelihood of implementation and enhance worker resistance to change. It was suggested to reduce the movable range to some extent or preferably to be the function of hook load (i.e. only movable when lift). On the other hand, all participants in laboratory study express preference toward the new rotated hook by subjectively report higher comfort to perform simulated lifting task. At present, further redesign in more detail and follow-up field assessments particularly conducting test on other manual tasks required the use of same hook are anticipated.

ACKNOWLEDGMENT

The authors give special thanks to all workers at Kraiwanwattana Ice Block Manufacturing, Samutprakarn, Thailand for helpful inputs and comments on the redesign as well as for being volunteers in this study. Special gratitude was given to the plant manager for allowing the experiment on site. The devoted research assistances, Kun Luksanapisitkul and Kongpop Sahusakul, were also contributed sufficient time during data collection process. This research would not have been possible without the support from them.

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