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The Effects of Coupling Repetitive Motion Tasks With a Thermally-Stressed Work Environment

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ABSTRACT

An ergonomic assessment was recently performed at a frozen foods manufacturing facility located in the southeastern United States. Complaints from employees at the facility ranged from disorders such as carpal tunnel syndrome to other ailments of components of the upper extremities. Nearly all of the complaints originated from employees in three key areas of the plant. The most effective solution for reducing complex multiple risk factors is by carefully analyzing what is currently being done and then developing the best solution to ultimately benefit both the worker and the employer. The method used to achieve this solution included a seven-step regimen. It was concluded that the occupational disorders were realized due to the synergistic effects associated with cold stress and repetitive production. A program was recommended that included engineering controls and personal protective equipment, coupled with minor process changes and an employee wellness program.

BACKGROUND

An ergonomic evaluation of a workplace environment, coupling both the effects of repetitive work assignments and cold temperatures, was conducted at a frozen foods manufacturing company in the southeastern U.S. over approximately a three-month period. The facility manufactured bakery items (e.g., cakes, cookies, breads, etc.) for grocery store chains. The operation ran three production shifts and the employees donned, at a minimum, long white coats, hairnets, and anti-slip shoe covers. While there were a few work centers that utilized automated equipment, the manufacturing environment was primarily labor-intensive with only a few key ergonomic problem areas.

The key areas of the assessment were designated at the onset as Cake Icing, Frozen Packaging, and Cake Packaging. Cake Packaging and Cake Icing were kept at a nominal temperature of 65 degrees F throughout the year, while the normal temperature in Frozen Packaging was approximately 45 degrees F. Nearly all of the past complaints of ergonomic disorders at this facility came from these three areas. Other than the extreme temperatures and the existence of relatively repetitive job tasks, these work areas were otherwise typical of the other production areas at this site. From the review of past complaints that had been documented, most of the disorders had been carpal tunnel syndrome or similar ailments of the wrist or other components of the upper extremity (e.g., fingers, hand, arm, elbow, etc.).

The increase in concerns for ergonomic issues in the workplace is well founded. According to the Bureau of Labor Statistics, more than 50% of all occupational illnesses reported in 1997 were associated with repetitive motion trauma. A repetitive motion injury is not an acute or short-term result of a one-time accident, but instead, the chronic result of gradual, repeated trauma. The three most common repetitive motion injuries are muscle, tendon, and nerve injuries.[1,2] In manufacturing environments resembling the one in this study, carpal tunnel syndrome is by far the most common form of repetitive trauma disorder.

Carpal tunnel syndrome (CTS) is the term used to describe the set of symptoms that result when the median nerve in the wrist is damaged or compressed.[2] The symptoms of CTS range from mild numbness or faint tingling to extreme pain and/or loss of the use of the thumb.[3] The most typical job activities that lead to this disorder are repetitive operations of 30 seconds per cycle or less.[2] CTS has shown up in studies of workers in frozen food plants, pork processing plants, and among supermarket workers.[4-7] By the inherent nature, light manufacturing operations such as buffing, grinding, cutting, and packing (as well as cake icing and pressing) could all result in prevalence of CTS cases. Other repetitive motion injuries of the upper extremity that could be related to the labor-intensive operations at this facility are deQuervain's syndrome (a thumb ailment resulting from forceful gripping or twisting) and tendonitis (the inflammation of the tendon resulting from repeated tension, motion, or bending in contact with a hard surface).

An added stress to the occupational environment of this study was the cold temperatures. Chronic exposures to low temperatures in workplace can contribute to such problems as numbness, diminished sensory feedback, and decreased flow of blood [8]. When this occurs, many times workers will try to compensate by increasing the force of their grip on either the tool or the part. This can lead to exerting unnecessary strain on the upper extremities and possible injury.[1,3,9] It is recommended that gloves be worn when environmental air is less than 20 degrees C for a prolonged period of time[1,10,11]. In addition, under cold-stressed conditions it is recommended that the worker be provided rubber or plastic handled tools to add insulation to the stress relief benefit.[2] However, both softer tools and glove wearing may cause a more forceful grip, thus causing more stress on the hands and wrist. As evidence, it has been found that gloves can reduce strength as much as 30% and delay task completion by up to 37%.[12-15]

Ergonomic problems like those realized in this study were most likely explained by the premise that the exposures are a part of a complex multiple risk factor function. It could be that the surfacing of the problem was likely due to the combination of synergistic effects resulting from the existence of repetitive tasks under both cold and humid conditions. For multiple risk exposures, the most effective solution is to reduce risk factors by carefully analyzing what was currently being done, and then come up with the best solution to ultimately benefit both the worker and the company[16,17]. The following methods were devised to best serve this objective.

METHODS

Since no applicable occupational exposure limits (OELs) currently exist for ergonomics or cold environments, the methods developed were mainly qualitative. The following methods, in chronological order, were used to evaluate ergonomics in the three production areas of concern:

1. Walkthrough with interview of safety staff.
2. Research of the literature.
3. Interview with effected employees.
4. Development and completion of qualitative ergonomics worksheets.
5. Videotaping of appropriate jobs.
6. Measurement of temperature and humidity conditions.
7. Evaluation of personal protective clothing (PPC).

Walkthrough:
The original walkthrough of the facility was conducted early on in the evaluation. It was used to primarily characterize the job functions and constraints of the workers. In addition, it aided in the familiarization of the various processes and work centers involved. The safety staff of the facility accompanied the researchers on the walkthrough and provided a history of the problem and identified the problematic areas.

Literature Review:
Subsequently, an effort was made to identify comparable studies that had been performed by other researchers. An EH&S database was utilized to research comparable studies written in the literature. While the research found was not extensive on ergonomic issues couple with thermally-stressed environments, the studies that were located aided in the recognition of potential ergonomic problems. The literature review began at the onset of the study and continued throughout the duration of the assessment.

Interviews:
Interviews were completed with 12 affected employees during the second and third week of the project. A representative sample was taken from each of the three high-risk areas of the facility. Arguably, the best source to learn about a process or a workstation is the operator(s). While it appeared to have some bias, the information gathered from the operators on individual worker history and questionable facility processes was

noteworthy and credible. Each worker was interviewed for approximately ten minutes. While the same exact questions were not asked of each employee, they were very similar in theme and scope. Specifically, the employees were anonymously asked questions that focused on the root of the ergonomic problems at hand.

Qualitative Worksheets:
Ergonomic worksheets were used to prioritize problem areas. Three different types of worksheets were used to assist in the preparation of an ergonomic job analysis. These worksheets were variations on field-acceptable worksheets used by ergonomic consultants and industry. Factors such as job effort levels, priorities for change, stress, posture, force, repetitiveness, etc. were subjectively evaluated and given a number ranking or a yes/no response.

Videotaping Jobs for Analysis:
Videotaping of the problem areas in Cake Icing, Frozen Production Packaging, and Cake Packaging was performed over a two-week period. The workers at each workstation in these areas were filmed for approximately two minutes each, respectively. The film was viewed several times for accuracy and consistency of microanalyses and subsequent ergonomic assessments. Factors such as repetitive body motions, distance from worker to part, part height and movement, and apparent worker comfort were carefully evaluated.

Temperature and Humidity Characterization:
An indoor air quality monitor was used to measure the temperature and humidity in the areas of concern. Special attention was given to fluctuations during the course of the surveys. Temperature and humidity were measured continuously in each of the areas for approximately one hour. Also, employees were asked during this time period whether or not they believed that there was ever any significant temperature variability from shift-to-shift or from day-to-day.

Evaluation of Personal Protective Clothing (PPC):
The evaluation of PPC was focused on determining the type of hand and wrist protection that should be donned while performing specific jobs in the three problem areas. The technique used to make this evaluation was a qualitative survey sheet. Approximately six weeks into the assessment, five affected employees evaluated three types of protective gloves (the current porous cotton, cotton, and synthetic) for suitability. After wearing the three types of glove materials for one hour, the employees were asked to give a score of 1 to 5, with 1 being poor and 5 being excellent, on four merit criteria: thermal comfort, physical comfort, durability, and applicability. The one-hour sampling times were back-to-back in order to cut down on bias. A composite score was determined for the survey and then compared with cost for the final determination of the appropriate PPC.

RESULTS

The employee interviews brought out several key points. Most of the employee complaints were related to the soreness of the wrist and hand. A few complaints were

directed at soreness in the elbow and shoulder areas. In addition, several complained of palletizing and stacking, which seemed to either cause or complicate existing back pain. The employees in all three areas noted that the temperature of their work environment fluctuated, with most of the fluctuation being in Cake Icing and Cake Packaging. The workers pointed out that the main factors that caused the temperature fluctuations were seasonal variations and the opening/closing of doors. In addition, it was observed that the employees rotated jobs relatively often and usually after about one hour. However, many times this rotation involved the movement to a very comparable job with similar repetitive hand/wrist action. Of the twelve employees interviewed, only one mentioned of having any problems with the tools currently used.

The qualitative worksheets were used to help identify the major problem workstations within each of the three work areas. Careful evaluation of the completed worksheet resulted in the identification of the Bread Packaging and Cooking Packaging occupations in Frozen Packaging as the most ergonomically unsound. Other high-risk jobs identified included cake icing stations located in Cake Icing and the two packing positions in Cake Packaging. The distance and height of the work piece to the employee in these high-risk areas were within the guideline values for these jobs. However, there was evidence of excessive bending of the wrist(s). It should be noted that the workers observed were given the option of whether or not they wear gloves in Cake Icing while the observed employees in Cake Packaging and Frozen Packaging all wore some type of glove protection. All of these jobs have a repetitive sequence to complete in just a few seconds duration. No vibrating tools were observed and chairs/stools were provided at less than one-half of the workstations.

The viewing of the videotape of the high-risk jobs provided some useful information, primarily regarding the seriousness of each of the high-risk jobs. While viewing the cookie packing operation in Frozen Packaging, it became evident of the amount of up and down, upper-body flexing that was occurring during the course of just one cycle. Because of the complexity of the repetitive motion, coupled with a robust production rate and cold working conditions, it was determined that this workstation was the most ergonomically at-risk for repetitive trauma disorders (RTDs). The videotape viewing also provided other results as follows:

1. The production rate during the bread packaging operation was too fast.
2. There was too much distance between the operator and the conveyor at the cake packaging station.
3. In Cake Packaging and Cake Icing, the employees rotated back and forth between wearing gloves and not wearing gloves. In addition, they wore different configurations of PPC on their hands and wrists.
4. There were uncomfortable postures observed at the cake stacking position, resulting in leaning.
5. In Cake Icing the side scrape tool and the top scrape tool had design inadequacies. Also, there appeared to be a size factor problem with the cotton glove used to press the cakes together.

The result of the air quality study showed temperature fluctuations of up to six degrees over just a few hours as well as humidity levels as high as 82%. Interviews with employees revealed that fluctuations of up to ten degrees occur commonly over just a few hour time duration. Employees complained of the dampness of the areas, especially during certain times of the year.

The PPC/glove assessment provided information on the appropriateness and comfort of the different levels of hand/wrist protection in cold environments. The alternative Thermostat^{R} glove liner was given an average rating of "outstanding" (4.8 on a scale of 1 to 5) while the other alternative (cotton) and the current glove (porous cotton) were rated as "acceptable but not optimal" at approximately 3.0 on the same scale. The employees were impressed with the Thermostat^{R} glove primarily by its thermal comfort and apparent durability. As a note, several of the employees liked the glove so much that they would not give it up at the conclusion of the test. The only problem expressed about the Thermostat^{R} alternative was in Cake Packaging. Employees had a concern about the applicability of the gloves in the packing of the cakes. It was noted that the glove was "slick" on the surface of the box. However, upon observation, it did not appear that the employees were appreciably slowed down by this situation.

RECOMMENDATIONS AND CONCLUSIONS

The following was a list of the recommendations determined from the ergonomics assessment of this facility. The recommendations included:

1. Efforts needed to be focused on reducing the humidity levels in the climate-controlled areas. Humidity levels that exceed 60% are considered to be beyond the level of comfort for workers. These levels, coupled with the cold environment, can complicate RTD conditions and result in a synergistic effect. Further, the recommendation was to have an evaluation conducted on the existing HVAC and cooling systems. Also, the installation of dehumidification equipment can help to alleviate this problem.
2. Temperature fluctuations should be controlled. Workers have shown stress when temperature deviations exceed 4 degrees C during the course of their work shifts [18]. Slow acclimation to extreme temperatures that do not fluctuate much from the mean will help to minimize conditions resulting from repetitive motions. In essence, if the process temperature required is 45 degrees F, keep it within a degree or two of 45 degrees F during the course of the production shift as well as throughout the work year. The recommendation was also to keep the doors closed as often as possible, with minimal door opening. Further, it was recommended that, during seasonal changes in the temperature, evaluations should be made to eliminate major fluctuations in temperature. The possible installation of a modern environmental control system should be evaluated on cost and benefit merits.
3. A glove similar to the Thermostat^{R} synthetic liner should be adopted as required PPC for those high-risk operations in Cake Icing, Cake Packaging, and Frozen Packaging. At a minimum, these workstations should include the

bread and cookie packing occupations in Frozen Packaging, the cake icing and cake pressing jobs in Cake Icing, and the cake packing stations in Cake Packaging. The liner should be worn in combination with the current outer gloves in each of these areas, respectively.

4. The distance to the work piece should be kept at a minimum so that the arm movements or extensions of more than 15 inches are minimized [2]. While the workstations that violated this principle in these three areas of concern were only few in numbers, it was noticed that the distance from the operator to the work piece on the conveyor lines was causing some posture issues. Further, the recommendation was to place padding on the conveyor structure for the times when leaning was necessary. Another possible option presented was the availability of an adjustable stool at the various operations. Stool height issues were particularly noticed during the evaluation of the cake stacking operation.
5. An employee wellness program should be implemented that included finger/hand exercises aimed at alleviating conditions that lead to RTDs, and in particular, carpal tunnel syndrome. Simple stretching exercises should be performed before the shift begins (or during the first 5-10 minutes of each shift) and after the lunch break. This would help to improve the overall body circulation and aid in the warming up of the muscles. A regime recommended by the American Physical Therapy Association would be as follows:
    a. Resting one forearm on a table, grasp the fingertips of that hand and pull back gently. Hold this position for five seconds, and then repeat the exercise with the other hand.
    b. Press the palms flat on the table, as if doing a push-up. Lean forward to stretch the forearm muscles and the wrists.
    c. Move the hands around in a circle for about two minutes, thoroughly stretching the muscles of the hand. This helps to restore circulation and improve the posture of the wrist.
    d. Finish up by placing a rubber band around the fingers to provide resistance, and opening and closing the fingers. Do a set of ten repetitions with each hand. Repeat the ten repetitions again at lunchtime and at the end of the shift. In addition to performing the above wellness routine, it was recommended that the employee should shake out their hands periodically throughout the day during breaks in production, job rotation, etc.
6. For the conditions, it appeared that the production rate for bread packaging was too fast. It was recommended that a qualified industrial engineer or time study expert conduct a time motion study at this workstation.
7. The production boxes should be stacked one less high on the pallets. This was the only lifting-related concern in the evaluated areas.
8. While there were not major lifting concerns in the three areas evaluated, it was observed that several of the jobs in the main production area have lifting tasks. It was recommended that these jobs be quantitatively assessed with the application of the OSHA lift equation.

9. An ergonomics awareness program should be implemented plant-wide. This program would provide training on ergonomic-related issues and be the vehicle to move the wellness program in the right direction.
10. Employees should be given the option of whether or not to sit or stand at most of the evaluated workstations. Experts agree that, in most cases, a physically comfortable employee will exhibit less overall body stresses, with the outcome being normally the existence of less ergonomically-related complaints[[2]]. However, it was noted that in some situations the process dictates the need for the employee to stand in order to complete the job task.
11. During the rotation cycle, the supervisors should make every effort to move employees into positions that have very different body movements than those of the previous one or two rotations.

In conclusion, the synergistic effects associated with the repetitive motions in cold and humid work environments can lead to premature development of occupational disorders such as CTS. However, the implementation of appropriate engineering controls and personal protective equipment, coupled with additional minor process changes and an employee wellness program, can help to alleviate the seriousness of such work-related conditions.

As evidence of success, prior to the on-set of this study, this manufacturing facility had six individuals with some degree of disability attributed to repetitive trauma. Since the implementation of the program, only one additional individual has been diagnosed by an occupational physician with a disorder in this area. While the corrective action program initiated from the results of this project cannot be considered as the only reason for these improvements, one would tend to believe that, at a minimum, the impact has been beneficial.

Companies, such as the one in this study, are realizing productivity benefits in implementing effective ergonomics programs. It could be easily argued that an awareness of the ergonomic conditions of each workstation should become a part of the mindset of an operation from the top down. The existence of this mindset (and subsequent infrastructure) ultimately could provide the foundation for a successful ergonomics program and an optimal level of worker job satisfaction in many workplace settings.

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BIOGRAPHIES

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