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Ergonomic Interventions for the Prevention of Musculoskeletal Disorders

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Abstract

Nonfatal occupational injuries account for 95% of the total cases reported by private industry in 2015 with illness accounting for the remaining 5%. Employers recorded most illness cases as other illness which includes musculoskeletal disorders (MSD) and systemic disease. Musculoskeletal disorders (MSD) are a broad range of disorders involving damage to the muscles, tendons, ligaments, peripheral nerves, joints, cartilage, vertebral discs, bones, and supporting blood vessels. Work-related MSD is a subcategory of these disorders, which is caused or aggravated by working conditions. MSD occur slowly over time due to the repeated wear and tear or microtraumas to the body. Ergonomists seek to identify and rectify factors that negatively impact the physical health and efficiency of workers. Participatory ergonomic programs seek to maximize the involvement of the workers in this process based on the simple fact that the worker is the expert. The following interventions were possible through the practice of participatory ergonomics.

Keywords: work-related musculoskeletal disorders, ergonomic intervention, human performance, mission readiness

1. Watertight doors and accommodation ladders

An accommodation ladder is a portable flight of stairs that is attached to a ship. They are raised for protection while a ship is underway and then lowered when a ship reaches the port. Accommodation ladders have a high degree of articulation, each section is movable [1, 2].

The ladder has handrails on both sides for safety. Accommodation ladders are constructed in such a way that the steps are horizontal whatever the angle of inclination of the ladder because when a ship is in port, it raises and lowers with the tides. The lower end of the ladder is a platform on a roller to compensate for the motion of the ship in relation to the quay. Ladders are maintained by Navy personnel when used on Navy vessels.

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One group of Southwest Maintenance Center personnel repairs and maintains the accommodation (ACCOM) ladders, also known as anchored ladders, and other watertight fixtures such as doors, scuttles, and hatches for ships home-ported in San Diego, CA. Ladders and fixtures are serviced when a ship returns to the port; the time between services varies based on the mission (**Figure 1**).

During an industrial hygienist inspection, a possible overexposure to physical work place risk factors was documented due to the repair position of the ACCOM ladder, length of time for maintenance, types of tasks being performed and complaints of fatigue. Personnel placed the ACCOM ladders on sawhorses to perform maintenance work and repair. They had to bend over, reach forward, and squat during repairs. SWRMC personnel identified this arrangement as unsuitable and unstable with the potential of the ladder falling over (**Figure 2**).

Figure 1. ACCOM ladder on work stands before intervention. The ladders are being disassembled for repair.

Figure 2. Assembling accommodation ladder requires long duration of highly repetitive motions while exerting force. Pneumatic tools are not allowed and therefore the exposure is combined with high and somewhat awkward hand forces.

An initial ergonomics evaluation using the Navy's Safety Instruction evaluation tool (Physical Risk Factor Checklist [1]) found the task to rank a hazard. Navy guidance recommended immediate mitigation to reduce the risk of personnel injury. SWRMC shop personnel and the safety department practiced participatory ergonomics by working with the ergonomist and engineers to design and build a ladder turning fixture. The worker-based design was used as a foundation for the final holding device (**Figures 3** and **4**).

1.1. Pre-intervention

Pre-intervention: personnel were required to bend, stoop, twist, and kneel during the preventive maintenance (PM) process to access all sides of the ACCOM ladder. Short, infrequent exposure to awkward postures is typically tolerated by the workforce, while long exposures can cause injury. The fully assembled ladder was difficult to work on. It had to be manually

Figure 3. Assembling rails on an accommodation ladder.

Figure 4. A fully assembled accommodation ladder.

Figure 5. Watertight fitting.

turned to allow the personnel to work on its underside. Workers exerted unacceptably high forces while performing this heavy lifting task (**Figure 5**).

The combination of heavy lifting and sustained awkward postures placed those employees who were working on ACCOM ladders at an increased risk of developing work-related musculoskeletal disorders (WMSD) of the spine or shoulder. These disorders can be caused by exerting high forces which can contract muscles to their maximum capability; leading to fatigue and possible damage to the muscles and other soft tissues. Lifting outside of one's power zone (i.e., from knees to shoulders) increases stress on the spine. SWRMC personnel noted these postures when turning the heavy ACCOM ladders.

1.2. Post-intervention

Navy' management fully supported a project to mitigate the risk factors found with ACCOM repair by allowing SWRMC personnel time and the use of recourses to fabricate a prototype holding fixture. The original idea was integrated into the final design through repeated design review meetings with SWRMC personnel, the ergonomist, and an engineer. Although heavy lifting and somewhat awkward postures are still inherent to ACCOM ladder repair, the use of the ladder fixture has greatly reduced the severity and frequency of the exposure to ergonomic stressors. The design was then exported across multiple Navy maintenance activities.

The ladder fixture was provided to the shop along with additional tooling to assist personnel with the removal of seized parts on the ACCOM ladders and watertight fixtures. Designing the tooling was no small task due to the numerous positions and sizes of these parts which included a variety of bolts, bushings, and pins, many of which were one-of-a-kind.

Successful completion of this project has saved a considerable amount of time and effort during the preventative maintenance of ACCOM ladders and watertight fixtures (**Figures 6** and **7**).

In 5 years, seven injuries were reported; in the 2 years following the intervention, no injuries were reported. Using the average total cost per claim by nature of the injury data as published

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Figure 6. Welder demonstrates awkward postures which were quite common during welding tasks on the ACCOM ladder.

Figure 7. After the intervention, rotating ladder fixture allows one worker to safety turn the ladder and locks into place. The ladder system saves time and effort and reduces the risk of injury and equipment damage.

Nature of injury	Cost per claim	# of injuries	Direct cost
Sprain/strain	$19,507.00	5	$97,535
Cut/laceration	$17,239.00	1	$17,239
contusion/bruise	$17,870.00	1	$17,870
Total direct cost			$132,644

Table 1. Estimation of direct cost incurred due to injuries.

by the National Safety Councils Injury Facts 2010.[1] **Table 1** summarizes the assumed direct costs incurred due to injuries.

Indirect costs are calculated using the index from Liberty Mutual[2] that estimates businesses are faced with between $2 and $5 of indirect costs for each $1 of direct costs. An amount of $3 of indirect to every direct dollar was used for this project.

Direct cost	$132,644
Indirect cost	$397,932
Total injury costs	$530,576

Injury cost averaged over 6 years = $530,576/6 = $88,429 per year.

Return on investment calculation

Pre-intervention annual injury cost = $88,429.

Post-intervention annual injury cost = $0.

Annual cost difference (savings if injuries are avoided) = $88,429.

Expected tool service life = 10 years.

Improvement investment = $377,000.

Ten-year cost savings: $507,290.

10 (annual cost of pre-intervention) – [improvement cost + {10 (annual cost of post-intervention}] = 10 ($88,429.) – [$377,000. + {10 ($0.}] = $507,290.

The improvement breaks even in 4.3 years.

Improvement cost/annual cost savings = 377,000/88,429 = 4.26 years.

The calculations do not take into account the time savings and product quality improvement from using the solutions.

2. Laundry facility streamlines process

The US Naval Academy (USNA) laundry facility is a massive operation processing 1.6 M pounds of laundry per year. The laundry facility sorts and washes bulk laundry and dry cleans and irons uniforms at a rate of approximately 6500 pounds per day. Other operations include alternations for the 4500 cadets who attend the four-year undergraduate college. Graduates earn a Bachelor of Science and commissions as ensigns in the Navy or second lieutenants in the Marine Corps (**Figure 8**).

[1]National Safety Council Injury Facts 2010 Edition, p. 58.
[2]Liberty Mutual Work Place Injury Data, April 2002 (http://www.ergoweb.com/news/detail.cfm?id=569)

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Figure 8. Emptying 40-lb. laundry bags which were pulled down from the conveyor.

2.1. Pre-intervention

Originally, bags were received and manually lifted out of a box truck, onto a transport cart and then once again manually transferred to a conveyor system in the check-in area. The 40-pound laundry bags traveled down the conveyor system and were manually removed when pulled from shoulder height and emptied onto a sorting table. The bulk bag, one per cadet, contains a mesh net bag of smaller items and loose larger items. These items were sorted by color and tagged. The contents of the bags were then verified against the laundry ticket submitted. Mesh nets were sometimes unpinned to replace smaller items; all bags and nets were then secured with a white wire lock-tie and placed on the lower conveyor. This process required repeated heavy pushing and pulling in awkward postures, repetitive motions, repeated gripping and postural stress (**Figure 9**).

The ergonomic hazards associated with the laundry production were lifting over shoulder height, high hand forces from using the large pins to secure the net bags and postural stress from leaning forward during the sorting. Individuals in the sorting area worked 8 h shifts

Figure 9. Loading laundry conveyor by throwing 40-lb. bags.

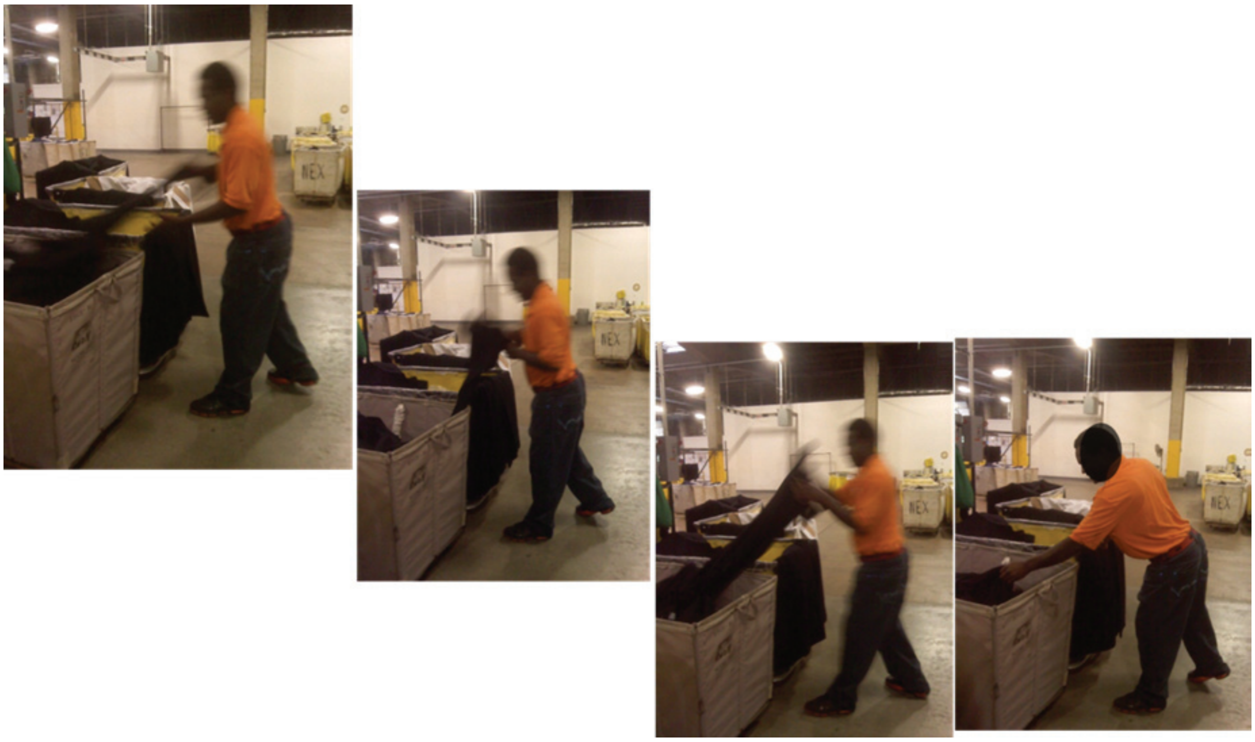

Figure 10. Highly repetitive dry cleaning laundry sorting.

pulling the 40-pound laundry bags from the top conveyor. Workers in the loading area worked the same duration but lifted the bags onto the transport system. The awkward posture and twisting while pulling or throwing the heavy bags exposed workers to a considerable physical stress (**Figure 10**).

2.2. Post-intervention

In 2013, the USNA facility redesign project began with the selection of equipment to reduce manual and repeated handling of the 40-lb. bags in the receiving and sorting area with an overhead monorail bag handling system. This $350,000 project improved working conditions for over 20 people and resulted in a tremendous drop-off in the number of injuries reported. The new system virtually eliminated manual moving of the bags and reduced complains of upper body fatigue. The monorail incoming bag system is a fast and efficient way to move material from the incoming truck to the sorting tables.

The overhead moving system was paired with dumping devices to eliminate pulling the cloths out of the bulk bags. Eliminating this step saved 3 min per bag. The cart dumpers provide exceptional emptying of laundry onto sorting tables eliminating the manual lift of the heavy bags from an over shoulder height position. With hands-free control, high-performance drive units and a 2000-pound capacity, the dumpers increase performance speeds over 30%. The adjustable height bag sorting table facilitates the initial break-up process and improves operator efficiency by reducing fatigue and excessive bending and twisting. In addition, the laundry bags were redesigned to include a loop/strap that allows each bag to be placed on a hook which conjoined to the overhead rail system (**Figure 11**).

The monorail overhead bag system provides a fast, efficient automated mechanism to move laundry bags from truck to the sorting table. Each sorting table or check-in station has a call button that allows the check-in worker to call a bag to the work station, and then release the contents of the bag onto the station. The worker uses another call button to send the empty bag back. The systems' debagger capability automatically releases empty bags from the overhead rail without operator intervention. A workstation level conveyor allows workers to send

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Figure 11. Cars full of laundry.

Figure 12. E-rail system.

checked-in and sorted items to the washroom department with minimal effort. These features help reduce the muscles loading and fatigue by eliminating the most stressful tasks (**Figure 12**).

3. Machine versus man power

Naval Air Weapons Station (NASW) China Lake is located in the California's Mojave Desert within the northwest section of San Bernardino County. NAWS China Lake is an airborne weapon testing and training range. Temperatures in China Lake rise over 100 degrees in the summer months.

NAWS China Lake is the Navy's largest single landholding, representing 34% of the Navy's total land worldwide. The 19,600 square miles of restricted airspace represents 12% of California's total airspace. NAWS China Lake provides an unprecedented venue for integrated testing and training for today's war fighters both on the ground and in the air. Because of the mission, like any research facility, NAWS China Lake generates hazardous waste (**Figure 13**).

3.1. Pre-intervention

NAWS environmental specialists retrieve, categorize, store, and dispose of various hazardous waste materials gathered from across the vast base. Different operations use different storage containers. NAWS follow strict hazardous waste protocols to prevent unauthorized waste from being disposed of illegally or accidentally (**Figure 14**).

When gathering the various waste streams, environmental protection specialists are exposed to a number of physical hazards, most notably heavy and awkward lifting, pulling/pushing, frequent standing, and temperature extremes. The physically demanding nature of the profession combined with the temperature extremes, placed the employees at an increased risk of developing additional or more severe WMSDs (**Figure 15**).

Figure 13. Before intervention, pulling super sacks (1 cu. yd.) of oil soaked rags onto lift gate.

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Figure 14. Before intervention, pushing plastic hopper onto rack truck.

Figure 15. Before intervention, off-loading truck at sorting area.

Environmental protection specialists repeatedly lifted, pulled, and pushed heavy items (e.g., batteries, oil rags, drums) as shown in the photos. The specialists lifted most items from ground level, and dragged or pushed them onto the lift gate. These items, such as solar and automotive batteries, drums, oil rags (over 2 million pounds a year), solvents, and cubic yard bulk bags (called super sacks), are handled multiple times throughout the disposal cycle.

The great expanse of the China Lake property means that items may be retrieved from various staging sites. Once back at the hazardous material processing/staging site, the items are removed from the truck. Some items are weighed while others are quickly categorized/staged for storage, and later moved again for disposal (**Figure 16**).

3.2. Post-intervention

Although the tasks of retrieving items from remote locations inherently requires the specialists to sit, climb, balance, stoop, kneel, crouch, crawl, lift 50 pounds and frequently walk and stand; the use of a crane installed on the back of the steak truck greatly reduced worker's exposure to

Figure 16. Totes of organized hazardous waste.

Figure 17. After intervention, truck mounted knuckle boom crane is sued in operations where other material handling equipment has not been capable of performing the waste removal.

physical work place risk factors. A crane now attached to the truck has eliminated much of the excessive materials handling and is capable of retrieving drums, super sacks or bulk bags (used for rags), and other heavy items from any storage surface (pavement or sand). The successful completion of this project has saved a considerable amount of time and effort during the movement of hazardous waste. The completed project replaces manual effort with machine power and improves the overall safety and health of the environmental specialists (**Figure 17**).

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through mishap prevention activities. The Navy Ergonomics program seeks initiatives to reduce exposure to injury risks and provides strategic direction to develop policies.

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